NON-INTERCONNECTED ISLANDS SYSTEM & MARKET OPERATOR

Project Implementation of the Athens Central Energy Control Center (ECC) and the Local ECC for the Electrical Power System in Rhodes

TECHNICAL AND FUNCTIONAL REQUIREMENTS

PART C:
MARKET MANAGEMENT SYSTEM

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List of Acronyms

AGC	Automatic Generation Control
AS	Ancillary Service
BP	Base Point
CA	Certificate Authority
CHP	Combined Heat and Power (Cogeneration - high performance)
DS	Dispatch Scheduling
DW	Data Warehouse
ECC	Energy Control Center
EMS	Energy Management System
HE	Hour-Ending
HEDNO	Hellenic Electricity Distribution Network Operator
LDAP	Lightweight Directory Access Protocol
MIP	Mixed Integer Programming
MMS	Market Management System
MP	Market Participant
MPS	Market Publishing System
MRS	Market Reporting System
MUI	MMS User Interface
NII	Non-Interconnected Islands
NII SMO	Non-Interconnected Islands System and Market Operator
PPC	Public Power Corporation
PSOs	Public Services Obligations
RAE	Regulatory Authority for Energy
RDAS	Rolling Day-Ahead Scheduling
RES	Renewable Energy Sources
RTD	Real-Time Dispatch
RTLS	Real-Time Data Recording and Logging System
SSO	Single Sign On
SW	Software

UI	User Interface
VS	Validation System

1 Introduction

In this document, the requirements of the Market Management System (MMS) of the project for the implementation of a Central Energy Control Center (ECC) in Athens, and of Local ECC for the Greek Non Interconnected Island (NII) of Rhodes are presented.

Section 2 presents an overview of the current market structure and relevant high-level market design requirements. These requirements are consistent with the current regulatory framework (NII Code, January 2014).

Section 3 presents a functional decomposition of the MMS and the general requirements for the MMS for the Central ECC in Athens and for the Local ECC in the Island of Rhodes.

Section 4 presents the requirements for the MMS Common Services, and Section 5 the requirements for the MMS Applications for the Central ECC in Athens and for the Local ECC in the Island of Rhodes.

Section 6 lists the requirements for the Load and RES Forecasting applications for for the Central ECC in Athens and for the Local ECC in the Island of Rhodes.

Finally, Section 7 presents the system external interfaces of the Central ECC in Athens and the Local ECC in the Island of Rhodes.

2 Market Structure Applicable to all Greek NII

In this section, the development trends of the electricity market in the Greek NII (Section 2.1) are summarized and an overview of the institutional and regulatory framework is presented (Section 2.2). The presented material refers to all Greek NII, and certainly applies to the Island of Rhodes.

This section is for information purposes.

2.1 Development Trends of the Electricity Market in the Greek NII

The autonomous electric power systems of the NII in Greece, due the their various significant differences compared to the mainland Interconnected System, are governed by a special legal and regulatory framework, which foresees special regulations regarding the operation of the market.

According to Law 4001/2011, the role of the Network Operator of the power systems of NII as well as the role of the their Market Operator has been assigned to HEDNO, while the publication of secondary institutional framework for the operation of this market is also foreseen. The basic legal text of this framework is the Code of the NII Power Systems Management (hereinafter NII Code), which effectively constitutes the basic regulatory framework for the participating producers and load representatives and the NII System and Market Operator (NII SMO).

In February 2014, the Regulatory Authority for Energy (RAE), completed the opening of the electricity market to the NII by establishing the secondary regulatory framework and, in particular, by:

- The establishment of the NII Code [RAE Decision 39/2014];
- The definition of the calculation methodology for covering the cost of Public Services Obligations (PSOs) to the NII consumers [RAE Decision 14/2014];
- The determination of the reasonable rate of return of the capital for the participation in the production of electric power in NII [RAE Decision 15/2014].

After the accomplishment of the regulatory framework, the direct and uninterrupted participation for the interested parties is permitted for the procurement of electricity in the NII power systems, separately per System (namely, for most cases, per island), in accordance with the terms and conditions applied in the wholesale market of the Interconnected System, albeit differentiated due to the significant differences of the NII Network Systems and Market, as well as the electricity generation from conventional generating units in an NII System.

The implementation of the NII Code is foreseen to take place gradually, through a transitional period spanning 5 years, for the gradual development and installation of the necessary infrastructure (ECCs, Information System, etc). In parallel, the development of this infrastructure will be accompanied with the appropriate and adequate management and staffing of the pertinent services of the NII SMO, in order to deal effectively with the rising and challenging responsibilities. At the same time, gradual adjustment of the existing installations and infrastructure of NII (power plants regardless of fuel category, network, etc.) to the new framework that is imposed by the Code is expected.

The electricity market structure in the NII includes the basic entities that trade with the NII SMO, namely the producers of all types of generating units, connected to the NII Network, including autoproducers, Load Representatives, such as the electricity suppliers to the NII consumers, the self-supplying customers and the Producers for any electric power withdrawal from the NII Network for addressing the energy needs of their Units, in particular the Hybrid. Due to the fact that the conditions for competitiveness in this market are scarce, specifically on the producers front, that the generation cost of electricity is higher in the islands compared to the mainland System, and that the penetration of Renewable Energy Sources (RES) of different technologies has grown significantly, the participation in this market is differentiated significantly from the more competitive markets, in order to restrain the total cost of the consumer, as well as to ensure the viability of the investments and therefore the incentives for attracting them.

The market operation is based on mechanisms of daily energy scheduling (Rolling Day-Ahead Scheduling-RDAS) for production and consumption, and on the mechanism for capacity assurance in the mid- and long-term, in every NII power system, as well as on the creation of appropriate market conditions in order to ensure that the terms and prices of electricity supplied to the island consumers are similar with the respective ones in the mainland Interconnected System.

Regarding the participation of producers with conventional generation units, a specific reward for the capacity availability and for the energy injection or other services (e.g., ancillary services) is provided, and the commitment order in daily dispatch is determined, based on their operating cost and not on priced energy offers.

The electricity generation cost in the NII is significantly higher than the generation cost in the mainland interconnected system. However, according to the pertinent provisions of the directive for the supply of PSOs, the legal framework provides that they can be imposed on the enterprises which participate in the electric power sector, namely on all suppliers, in order to provide uniform electricity prices to consumers throughout Greece. In this way, the island consumers will consume electricity at the same low prices as the consumers in the mainland, in spite of the increased generating cost on the islands. The extra cost that burdens the suppliers in the market due to the increased generating cost on islands is paid in exchange for this service.

The implementation of the NII Code, combined with the new calculation methodology of the remuneration to the providers of PSOs to NII (suppliers in NII), enables the direct participation of any interested supplier in any NII System, providing his customers with tariffs, per consumer category, that are uniform with the respective tariffs he provides his consumers in the Interconnected System, and receiving the respective remuneration for the provision of PSOs to NII that is seperately accrued to him for each system in which he participates, regardless of the generating cost of electricity in this System.

Respectively, the activity of electricity generation from conventional plants in the NII is thus rendered possible for any interested party, based on transparent and non-discriminatory rules. In this way, each interested producer has the ability to promptly commence the procedures for his participation on any NII System, receiving the reasonable rate of return of the regulated asset for his activity, as determined by RAE.

The Manuals and Decisions of RAE that are expected to follow according to the NII Code timetable with the passage to the new framework, will specify the relevant procedures and pricings. In detail, the NII Code foresees the publication of the following Manuals:

- Information Manual;
- RDAS and Dispatch Manual;
- NII Energy Control Centers Manual;
- NII Network Access Manual;
- NII Market Operation Manual;
- NII Development Program Manual;
- Capacity Assurance Mechanism Manual;
- RES/CHP and Hybrid Station Studies Manual;
- Meter and Producers Metering Data Management Manual.

IMPORTANT NOTE: In case of any inconsistency of the description provided in Section 2, the NII Code and Manuals prevail. The desciption provided in this Section is only for information purposes.

2.2 Overview of Institutional and Regulatory Framework for Greek NII Power Systems

In this section, the existing institutional and regulatory framework for the Greek NII Systems is presented, as it is depicted on the NII Code. It is necessary to stress that at many points of market and system operations, the implementation details of the Code provisions refer to the Implementation Manuals, which are to be prepared by the NII SMO and published by a RAE decision, and in which all the necessary regulations and calculation methodologies for the participants or the NII SMO shall be detailed, for the regulation of special technical and procedural issues that concern the implementation of the Code.

In the following sections, the functions listed below are described:

1. Rolling Day-Ahead Scheduling (RDAS)
2. Ancillary Services
3. Dispatch Procedure
4. Supply-Demand Deviations
5. Files and Registries
6. Generating Units Payment Calculation
7. Accounting
8. Settlement

The aforementrioned functions are not intended to be exhaustive but constitute a summary overview, for information purposes. **Not all the above will be implemented under the current Project. The detailed specifications of the MMS are listed in Sections 3-7.**

2.2.1 Rolling Day-Ahead Scheduling (RDAS)

The RDAS is defined as the generation scheduling of all the Generating Units that participate to cover the electric load for the 24 hours of the following day (Dispatch Day), which is executed and solved in two 12-hour subperiods of Dispatch Day (A and B RDAS Period).

The Dispatch Day is defined as the time period of 24 hours that coincide with one calendar day, has 24 Dispatch Periods and is used as a reference period (time horizon) for the scheduling of commitment and operation of NII Units.

RDAS Periods A and B include the time horizon of Dispatch Day which contains the 12 first Dispatch Hours or the 12 subsequent Dispatch Hours, respectively, of the Dispatch Day. However, the RDAS problem for Period A refers to the whole 24 hours even though, since it is re-solved for the Period B, the 12 remaining hours are calculated again when solving the Updated RDAS.

2.2.1.1 RDAS Scope

The scope of the RDAS is *the determination, on a daily basis, of the generating units commitment, for the security of supply of each NII Power System, in accordance with security constraints and operational rules of each NII System*.

For each NII power system, RDAS is executed separately and independently before the start of the Dispatch Day for the whole Dispatch Day (RDAS Periods A and B), and is updated once during the dispatch day of concern (B RDAS Period).

2.2.1.2 RDAS Timeline

The RDAS timeline for Dispatch Day D (starting at 00:00) is as follows:

D-6h: Deadline for submission of declarations.

D-3h: RDAS solution. Publication and notification of RDAS data.

D+8h: Deadline for updated generation declarations submission for RDAS Period B.

D+10h: Solution of RDAS Period B of current day D. Publication and notification of RDAS Period B data.

A brief overview of the aforementioned activities is presented.

Declarations of Participants in RDAS

The Declarations of the Participants in RDAS include:

- Load Declarations from Load Representatives for Customers that comsume electricity in the NII System, including the Self-Supplying Customers as well as the Producers with Storage facilities for the auxiliary loads of their Unit, when they are not covered by the generation of the Unit.
- Generation Declarations from Producers and Autoproducers for Dispatchable Units, separately for each Dispatcable Unit (maximum amount for the conventional units per hour, energy for the whole Dispatch Day or hourly program for RES/CHP and Hybrid Stations and energy that the Autoproducer will generate and inject).
- Declaration that are submitted by the NII SMO (for Dispatchable Units in commissioning status, for non-dispatchable RES/CHP and total load declaration).
- Availability and Non-Availability Declarations from Producers for the Generating Units.

Solution of RDAS, Publication and Notification of RDAS Data

For the solution of the RDAS, the NII SMO at first collects the following data:

- Accepted Generation Decalarations (all);
- Declarations submitted by the NII SMO;
- Unit Availability (as derived from the approved maintenance schedule and the Non-Availability Declarations);
- Technical Parameters of Dispatchable Units and Economic Parameters of Dispatchable Conventional Units;
- Expected Operating State of Units in Dispatch Hours that precede the first Hour of the Dispatch Day (initial conditions);
- The updated aforementioned data during the Dispatch Day.

The NII SMO then solves the RDAS Problem, whose objective is to minimize the generation cost of the conventional units, while achieving the maximum possible penetration of RES/CHP and Hybrid Stations, subject to the following constraints:

- Energy Balance;
- Requirements of Active Power Reserve;
- Technical Operating Constraints of Units;

- Full energy absorption from RES/CHP Units or Hybrid Stations, if this is technically feasible, and the operating commitment rules are respected;
- Power flow technical constraints between operating zones (if such zones exist) and determination of must-run units.

The solution of RDAS yields the Daily Schedule for each Dispatch Hour of the following Dispatch Day, that includes the synchronization, de-synchonization or operation of Dispatchable Units, the energy they are scheduled to produce and the total capability for the provision of active power reserve for each type of reserve.

The NII SMO publishes on its website the load and RES forecast, the results of the RDAS solution, and the total capability for the provision of active power reserves, and notifies to every participant that submitted accepted Generation Declarations the part of the the Daily Schedule of interest. In addition, the NII SMO publishes on its website preliminary reporting data of the actual operation of the NII System, for each Dispatch Hour of the previous Dispatch Day, which include the actual load and the production of the RES/CHP Units and Hybrid Stations, as well as for the Conventional Units, separately per Unit.

Submission of Updated Generation Declarations for RDAS B Period

The Updated Generation Declarations have similar content with the initial Generation Declarations, concern the time horizon of RDAS Period B, and are submitted by:

- RES or CHP or Hybrid Stations Producers, for each Dispatchable RES or CHP Unit with energy offer in the RDAS.
- RES or CHP Producers that can submit hourly generation schedule for each Unit or for the entire Station.
- Autoproducers for the Units of their facilities, for the aforementioned cases.

Solution of Updated Day-Ahead Scheduling for RDAS Period B. Publication and Notification of RDAS Period B Data

For the solution of the Updated Day-Ahead Program of RDAS Period B, the NII SMO takes into consideration the data of Period A, as they have been updated, as well as the Updated Generation Declarations, and solves the Updated Problem, publishing and notifying the Period B data as in Period A.

2.2.2 Ancillary Services

Ancillary services are the services that are required for the secure operation of the NII System and for ensuring the quality of electricity supply. The definition of each AS, the way it is measured and the quantitative and quality control procedure from the NII SMO shall be mentioned in the RDAS and Dispatch Manual as per the applicable international and European regulation, taking into consideration the operational particularities of each NII System.

The ASs include:

- The ASs of Frequency Regulation or Active Power Reserves (Primary, Secondary and Tertiarty Spinning and Non-Spinning Reserves).

- Other ASs (Voltage Regulation, Unit Startup and Cold Stand-by Reserve).

2.2.2.1 Frequency Regulation or Active Power Reserves Ancillary Services

Primary Regulation Reserve

Primary Regulation is defined as the automatic corrective operation of Generating Units and Loads, by active power regulators (speed governor or power electronics systems), for the frequency deviations of the Network from the reference frequency, through which the total production and the total consumption of energy are balanced and the stabilization of frequency within the Primary Regualtion Period is aimed, separately for each NII System, based on its size and characteristics, and in any case cannot exceed the period of fifteen (15) seconds from the moment that the frequency disturbance has occurred. This regulation may not restore the frequency back to its reference level and it is especially implemented through the generator droop of the load regulator of each Unit.

Unit Primary Regulation Reserve is defined as the change of Active Power produced within the Primary Regulation period, through automatic operation of the active power regulator, as described above, for the maximum allowed frequency deviaton within this period. The change of Unit Active Power must take place within the Primary Regulation Period and the Unit, depending on its technical characteristics, has to be able to maintain the Active Power production level, depending on the frequency deviation value, for at least fifteen (15) minutes since the frequency disturbance occurs.

NII System Primary Reserve is defined as the total contribution of Units and Loads of the NII System to the Primary Regulation Reserve.

Secondary Regulation Reserve

Secondary Regulation is defined as the Automatic Generation Regulation, through which the Unit production of Active Power is remotely regulated, by the Control Centers, in order to restore the frequency and to release the primary regulation. This regulation takes place within the Secondary Regulation Period, which is defined for each NII System separately, based on its size and characteristics and cannot exceed five (5) minutes since its activation. This regulation seeks to minimize the frequency deviation. The deviation tolerance threshold, as well as the activation criterion of Secondary Regulation for each NII System, is determined by the RDAS and Dispatch Manual.

Unit Secondary Regulation Reserve is defined as the variation margin of the produced Unit Active Power with fixed rate through remote regulation from the Automatic Generation Regulation, in order for the Secondary Regulation to take place, since this variation margin is fully available within the Secondary Regulation period and is maintained for a time period of at least twenty (20) minutes.

Unit Secondary Regulation Range is the period between minimum and maximum Unit Active Power level within which the generation of the Unit is possible to be determined by remote regulation.

Positive or Negative Secondary Regulation Reserve is the margin for increase or decrease, respectively, of the Unit Active Power, taking into consideration the current Unit Active Power level.

NII System Secondary Reserve and NII System Secondary Regulation Range are defined as the total Unit contribution for Reserve and Secondary Regulation Range, respectively.

The ASs of Primary and Secondary Regulation can also be provided by Units that absorb energy from the Network, as well as from Load Representatives/Consumers, if the provision of these services is feasible and verifiable by installing the appropriate equipment, as specified in the respective connection contracts; regarding the units that absorb energy (e.g. hybrid stations), based on their contracts for the Participation in the NII Market for the provision of ASs, or regarding Load Representatives, based on what is foreseen in the Contract for the Participation of the Load Representative in the Market.

Tertiary Regulation Reserve – Spinning and Non-Spinning

Tertiary Regulation is defined as the regulation (through Dispatch Instructions) that takes place periodically, in order to restore the NII System Secondary Reserve level as soon as possible, if it has changed as a result of the activation of Secondary Regulation, for the purpose of meeting the respective requirements of the NII System. This regulation concerns the change of Unit Active Power with a relevant Dispatch Instruction. The time period within which this regulation takes place is determined for each NII System by the RDAS and Dispatch Manual and cannot exceed seven (7) minutes. Unit Tertiary Regulation Reserve is defined as the margin of changing the generated Unit Active Power within a period of fifteen (15) minutes after the respective instruction, in order for the NII System Tertiary Regulation to take place, and it is determined by the ramp-up and ramp-down rates of each Unit. The Unit must be in place to maintain this change of generated Active Power for at least four (4) hours after receiving the Dispatch Instruction. NII System Tertiary Reserve is defined as the total contribution of all System Units to Tertiary Regulation Reserve so that the System Tertiary Regulation can take place. Unit Tertiary Spinning Reserve is defined as the Tertiary Regulation Reserve of a Unit which is synchronized with the System. Unit Tertiary Non-Spinning Reserve is defined as the Tertiary Regulation Reserve of a Unit which is not synchronized with the System.

During the calculations of the Unit Secondary and Tertiary Regulation, the power that the Unit provided for Regulation Reserve in the previous timeframes of regulation reserves is not taken into consideration [1].

2.2.2.2 Other Ancillary Services

Voltage Regulation

NII System Voltage Regulation aims at maintaining voltage within the normal operation range. For this purpose, it is required that adequate static and dynamic Reactive Power reserve exists. System Voltage Regulation is accomplished with responsibility of the Operator by applying:

- Use of equipment and Network components, and especially the tap changers of the transformers, break or activation of lines or cables, use of electronic devices or other systems of reactive power generation for compensation, activation or deactivation of self-inductance and capacitors.
- Use of Generating Units and their connection equipement to the Network, especially by tap changers of the transformers and regulation of their reactive power generation locally or centrally and manually or automatically.

The Voltage Control AS that is provided by the Producer is considered to be the sum of services that are provided according to the latter case.

NII System Black Start

The AS of NII System Black Start after operation interruption is defined as the service that is provided from Units with black start capability, without being supplied from the network, and the injection of energy in the Network within the period of one (1) hour maximum, or within thirty (30) minutes if it concerns Internal Combustion Engines with light fuel (diesel), or within fifteen (15) minutes if it concerns gas-fired or hydro Unit, or in general a Dispatchable Hybrid Station Unit.

Cold Reserve

It concerns Units that belong to the Cold Reserve State and are used exclusively for tackling special cases when there is very high load in the System, when the rest Units are not adequate to cover the System Load and the provision of the required ASs. In general, there are specific contracts for these Units.

[1] Generally, there is a different requirement for each type of reserve. The requirements must be fulfilled in their entirety. In the electricity markets context, during the ancillary service market-clearing procedure there is a possibility of “replacing” commodities of lower quality with products of higher value ("cascading market process").

2.2.3 Dispatch Schedule

2.2.3.1 Scope

The purpose of Dispatch Schedule is, *in real time, the scheduling of operation for the Dispatchable Units, the control of NII System for energy injection of Non-Dispatchable RES and CHP Units, as well as issuing relevant Dispatch Instructions (by the NII SMO), so that the total energy withdrawal from the NII System, according to the forecasts and measurements of the NII SMO, can be accomplished in a way that ensures the proper and reliable operation of the NII Network, the effective treatment of unexpected occurrences in the NII System, the quality of supply, the minimization of the total cost and the maximization of the energy to be absorbed by RES/CHP (RES/CHP and Hybrid Station Units).*

In order to execute this Dispatch Schedule, the NII SMO collects all the necessary data, updates the forecast for the NII System Load and the generation of Non-Dispatchable RES and CHP Units, solves the Dispatch Program and issues the Dispatch Instructions.

2.2.3.2 Timeframe of Dispatch Schedule

The Dispatch Program is solved periodically, every 15 minutes from the beginning of the Dispatch Day. The NII SMO timely informs the Producers for the scheduled operation of their Units. <u>In small and medium sized NII Systems</u> where Fully of Partially Controllable RES/CHP Units or Hybrid Stations are not operated, the Dispatch Program can be solved in longer time steps.

The time period of each time interval is determined at 15 minutes. The Dispatch Program solution period concerns the time horizon of 4 Dispatch Hours that follow its solution.

2.2.3.3 Unit Categories

Units that are connected to the NII System belong to the following categories, based on their capability to control their generation:

- Dispatchable Units with energy offer in the RDAS (Fully Controllable Units).
- Dispatchable RES or CHP Units with hourly generation scheduling offer in the RDAS (Partially Controllable RES or CHP Units).
- Non-Dispatchable RES or CHP Units (Non-Controllable RES or CHP Units).

Dispatchable Units with Energy Offer in the RDAS (Fully Controllable Units)

A Unit belongs to this category if its generation can be scheduled by the NII SMO, during the RDAS solution, based on an energy offer (maximum quantity for the conventional units per hour, and energy for the whole duration of the Dispatch Day for the RES/CHP and Hybrid), while respecting the operational technical constraints, especially the maximum and minimum power output, the constraint that concerns the ramp-up and ramp-down rates and the startup and shutdown times. For these Units, Dispatch Instructions can be issued for any generation level, within the operational technical constraints. These Units generally provide the sum of ASs. The Dispatchable Conventional Units are available for each Dispatch Hour for each operation level ranging from the technical minimum output to the maximum available output, while always respecting the technical constraints. The following two types are considered:

- Dispatchable Conventional Units
- Dispatchable RES or CHP or Hybrid Stations with energy offer in the RDAS (Fully Controllable RES/CHP Units and Hybrid Stations).

Dispatchable RES or CHP Units with Hourly Generation Scheduling Offer in the RDAS (Partially Controllable RES or CHP Units)

A Unit may belong to this category if it can submit an hourly generation schedule and follow it within the foreseen deviations. For these Units, Dispatch Instructions can be issued for generation, ranging from the technical minimum to the technical maximum power output submitted for each Dispatch Hour. These Units provide ASs.

Non-Dispatchable RES or CHP Units (Non-Controllable RES or CHP Units)

A Unit belongs to this category if it cannot be fully allocated in any of the two previous categories. For these Units, instructions of highest generation level are issued (setpoint), and there is no obligation for submitting a generation schedule. These Units can provide only some of the ASs.

A Unit can be considered Non-Dispatchable but still have the possibility to submit a hourly generation program in the RDAS, for part or sum of its generation output, as it submitted by the Partially Controllable Generating Units. A Unit is allocated in this category if at least 20% of its monthly generation has been submitted in the hourly schedules.

2.2.3.4 Dispatch Program and Dispatch Instructions

For the solution of the Dispatch Program, the data and constraints of the RDAS are taken into consideration, as they have been updated with the data collected by the NII SMO, the updated load forecast, the RES and CHP generation forecast, and the active power reserve requirements, the technical constraints and secure network operation constraints, and the requirements and constraints for the provision of other ASs (apart from the Active Power Reserves).

The results of the Dispatch Program for every Dispatch Hour of its time horizon are the synchronization or de-synchronization or operation of Dispatchable Units, the energy that the Dispatchable Units are scheduled to generate, the energy that can, at maximum, be injected from Non-Dispatchable RES or CHP Units, including the Hybrid Station RES Units, and the energy that the Hybrid Stations are scheduled to absorb for their storage facilities.

The notification of the Dispatch Program to the participants is made through the MMS and constitutes the initial Dispatch Instruction (4-hour dispatch program), while subsequently it is possible for new Dispatch Instructions to be issued, during the Real-Time Dispatch operation.

2.2.4 Supply - Demand Deviations

2.2.4.1 Purpose of the Deviations Calculation Procedure

The purpose of Deviation Calculation Procedure is *the calculation of energy quantitites of the Instructed and the Uninstructed Supply-Demand Deviations in MWh, and their matching to each Participant for each Dispatch Hour.* The implementation details and the Calculation Procedure shall be mentioned at the NII Market Operation Manual.

2.2.4.2 Definitions of Deviations

The **Supply-Demand Deviation** is defined, separately per Generation Declaration and Load Declaration and separately per Dispatch Hour, as the difference between the amount of electrical energy that is scheduled for injection or withdrawal from the NII System, in megawatt-hours (MWh) according to the RDAS Schedule or the Dispatch Schedule, and the quantity of electrical energy that is injected or withdrawn in real-time in the NII System, as it is measured for the same Dispatch Hour.

The deviations of active power generation from the Units are distinguished between instructed and uninstructed, as follows:

- The Instructed Generation Deviation in megawatt-hours (MWh) for one Dispatch Hour, is defined as the difference between the amount of energy that is scheduled for injection from the RDAS or the Dispatch Program and the amount of energy that is determined for injection by the Dispatch Instructions. Instructed Generation Deviations include also the deviations due to activation of Unit primary regulation.
- The Uninstructed Generation Deviation in megawatt-hours (MWh) for one Dispatch Hour, is defined as the difference between the amount of energy that is determined for injection by the Dispatch Instructions and the amount of energy that is injected from the Unit, as it is measured by the IT system based on the measurement data of the NII Control Centers (SCADA), or, in case such data do not exist, by the Unit Meter.

The Load Demand Deviation in megawatt-hours (MWh), for one Disparch Hour, of the Load Representatives, excluding the storage units of Hybrid Stations, is defined as the difference between the amount of energy that is included in the respective Load Declarations, and the amount of energy that is withdrawn from the network, as it is measured from the respective Meters, while taking also into consideration the demand curtailments.

The Hybrid Station storage units Withdrawal Deviations in megawatt-hours (MWh), for one Dispatch Hour, are distinguisted between instructed and uninstructed, as follows:

- The Instructed Withdrawal Deviation is defined as the difference between the amount of energy that is scheduled for withdrawal from the RDAS or the Dispatch Program and the amount of energy that is determined for withdrawal by the Dispatch Instructions.
- The Uninstructed Withdrawal Deviation is defined as the difference between the amount of energy that is determined for withdrawal by the Dispatch Instructions and the amount of energy that is withdrawn from the network, which is determined as the difference between the energy that is measured from the respective storage unit Meters and the RES energy of the Hybrid Station that is injected to the Network.

For the Non-Dispatchable RES and CHP Units, the Uninstructed Deviation is defined as the excess of the Dispatch Instruction for the maximum generation level (setpoint). In case that a Non-Dispatchable RES or CHP Unit submits an hourly generation schedule, apart from the aforementioned deviation, the Uninstructed Deviation also includes the injection of power that is lower than the one declared at the schedule, in case no lower setpoint has been set by the NII SMO.

In case that more than one Dispatch Orders are issued for a Dispatch Hour, the energy quantity that is determined from the Dispatch Orders is calculated as the sum of the product of the power that is determined by each order and the respective time steps of the order.

2.2.5 Records and Registries

In the context of the NII market operation, the NII SMO is obliged to keep the following records and registries.

- Records
  - RDAS and Dispatch Procedure
  - NII Market Settlement
  - Data of RES/CHP Units and Hybrid Stations
- Registries
  - Producers
  - Generation Stations
  - Units
  - Load Representatives
  - Meters

2.2.6 Generating Units Payments Calculation

During the calculation for the payment of the Generating Units, a distinction is made between conventional units, Hybrid Stations and RES/CHP Units and Units for meeting emergency requirements. In particular, payments are provided for energy injection, capacity availability and ASs. The determination of these payments is made based on prices (benchmarks) which are defined in a way to reflect the reasonable cost for the availability and operation of each Unit, per conventional Unit category based on their technology and a combination of other charecteristics, especially based on data from literature, standard methodologies and practices, as well as available data and certified measurements of Units and Stations manufacturers.

2.2.7 Accounting

The NII SMO can assign to a reliable Greek financial institution the execution of banking transactions that are required for the fulfillment of the obligations that result from the participation in the NII market and the covering of any Transactions Deficit, combined with exercising rights against Customers, in order to balance the transactions in the NII Market. In addition, the NII SMO determines the Financial Coverage Cost as well as the Fixed and Special Financial Coverage Cost Fee.

For the implementation of the accounting transactions and especially the participants debits, the Code foresees that the NII SMO keeps accounts, and defines the procedure for calculating charges and debits for each account of the participants, as well as the allocation of any deficit or surplus of each Account. In addition, each NII market participant keeps an account in a reliable banking institution, so that the payments or revenues collection is performed by banking transactions, following an order of the NII SMO.

2.2.8 Settlement

By the end of each calendar month, the NII SMO carries out a Monthly Settlement per NII System that includes the following separate settlements:

- Energy Transactions;
- Ancillary Services;
- Capacity Assurance Mechanism;
- Special Accounts of NII RES and Public Services Obligations;
- NII SMO Administrative Expenses Coverage and Asset Management;
- Third party Revenues/Use of Network Charges;
- Sanctions.

In addition, by the end of each calendar year, the NII SMO performs an Annual Final Settlement per NII System.

3 Market Management System General Requirements

3.1 General

This Section presents an overview of the general requirements for the MMS. The MMS-related infrastructure shall be installed in the Energy Control Centers (ECCs) as follows:

- Central ECC: The Central ECC in Athens will have a redundant MMS platform installed, with a capability to run the Rolling Day-Ahead Scheduling Application, as well as the DS and RTD. The system should be expandable to support running the RDAS, DS, RTD for the 32 NII. Forecasting applications will be included in this platform.
- Local ECC: The Local ECC in Rhodes shall host redundant MMS platforms of full capability, as described in the following sections.

Each of the two (2) MMS platforms (Athens, Rhodes) shall have a Main and a Backup System that should operate as complementary systems for the respective NII (only one should be active at a specific point in time while the other should be in monitor status). They should be always updated and synchronized to each other in order to be ready to change their operational status when needed.

The MMS installed in Rhodes shall communicate with its associated EMS.

Development systems shall be provided as follows:

For the Central ECC in Athens, the development system will have, apart from the RDAS capability and related forecasting, the capability to run DS and RTD, with the related forecasting applications. It will be a replica of the respective production system with the addition of the above functionalities.

The development system shall be non-redundant.

For the Local ECC in Rhodes, no development system shall be provided.

The Athens Central ECC shall be able to monitor the Island's market operation remotely via WebUI displays.

Specific requirements are as follows:

- MMS Minimum Architecture Implementation Requirements (Section 3.2);
- MMS Platform Main Requirements (Section 3.3);
- Data Storage General Requirements (Section 3.4);
- MMS Saved Case and Versioning Requirements (Section 3.5);
- Other General Technical Requirements (Section 3.6);

- Auditing Capabilities (Section 3.7).

3.2 MMS Minimum Architecture Implementation Requirements

The following Figure presents the expected minimum architecture for the implementation of the MMS.

This is rather a functional decomposition than a logical architecture of the system.

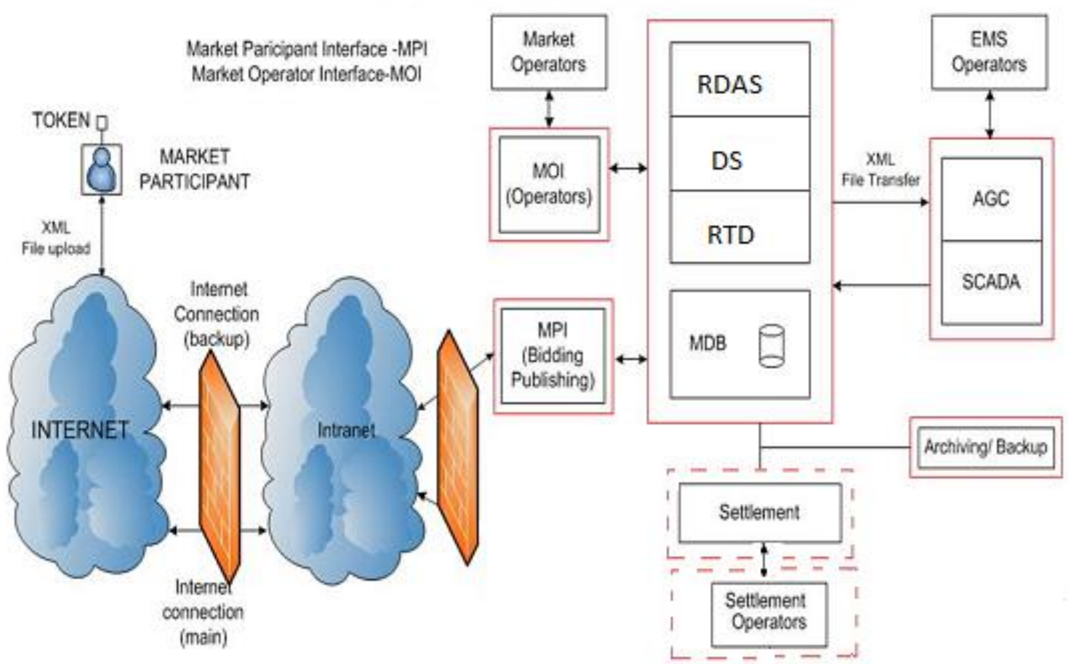

Figure 3-1. MMS Architecture

The expected architecture / infrastructure is presented in dedicated servers (external outline – red color) for hosting respective Applications, Databases and the MMS User Interface (MUI) subsystems (internal outline – black color) and the communication between subsystems. It also presents the interfaces of MMS to the existing EMS (this is applicable for the Rhodes MMS), the Settlement Application to be developed by HEDNO (not within this Project) in the Central ECC in Athens, and to the Internet.

The applications shown are the commonly known applications of Rolling Day-Ahead Scheduling (RDAS), Dispatch Scheduling (DS), and cost-based Real-Time Dispatch (RTD).

The MMS in Athens shall also have the DS and RTD capability.

The MMS of Rhodes communicates with active EMS, for the cost-based RTD-AGC data exchange. Market operators, internal and external users shall access the system through dedicated interfaces.

The MMS platform consists of two types of system components, namely:

- Common Services Systems (Section 4), and
- Application Systems (Section 5).

The Common Services Systems for the MMS platform include the following:

  - MMS User Interface (Section 4.1);
  - Validation System (Section 4.2);
  - Market Reporting System (Section 4.3);
  - Market Publishing System (Section 4.4);
  - Market Communications System (Section 4.5).

The Application Systems for the MMS platform include the following:

  - Master File (MF) (Section 5.1);
  - Rolling Day Ahead Scheduling (RDAS) (Section 5.2);
  - Dispatch Scheduling (DS) (Section 5.3);
  - Cost-based Real-Time Dispatch (RTD) (Section 5.4);
  - Real Time Data Recording and Logging System (RTLS) (Section 5.5).

It should be noted that the MMS platform functional design should be scalable, expandable and adaptable, in order to accommodate possible modifications (updates), in accordance with the regulatory framework in-force at each time period.

In addition to the above, load and RES forecasting applications shall be installed in Athens MMS, and in the Rhodes MMS, as specified in Section 6. The forecasting applications shall be fully integrated in the MMS platforms.

3.3 MMS Main Requirements

The MMS should meet the following main requrements:

- The MMS is considered as time critical application of high importance for the Market Operation and hence the Contractor should meet all requirements to meet MMS operation according to the NII Code.
- The MMS applications installed at the Rhodes Local ECC is running in one instance (for the island).
- The MMS applications installed at the Central ECC will have the capability to run at least three (3) instances in parallel, and for any type of island, i.e., small, medium or large, according to the NII Code.

- The MMS platform should be scalable, expandable and adaptable, in order to allow for new Market rules, new functions, users to be added to meet the market expansion as well as potential modifications in the regulatory framework. Tenderers should clearly demonstrate compliance with this requirement.
- Specifically for the MMS platform to be installed at the Central ECC, it should be expandable to 32 instances, to meet the needs for the 32 NII systems.
- All solver servers should be redundant (RDAS, DS, RTD), configured in clusters, and share common disk arrays for storing shared information (inputs and solutions).
- The mathematical formulation of the application solvers should be implemented to meet the MMS functional specifications.
- Data file replication to the Backup System should be provided and the respective database and data file replication should be synchronized using standard Disaster Recovery technology.
- Use of standard protocols is mandatory wherever they exist.
- Redundant traffic balancing authorization and authentication systems will be used in addition, where necessary, to warrant proper MMS performance and authorization requirements.
- User interface should be provided to configure main MMS parameters such as gate closure etc.
- Logical levels of the MUI as well as the corresponding servers (database servers, applications servers, web accessed servers, Authentication Authorization and Accounting servers etc.) should physically be separated in appropriate redundant firewall DMZs to warrant security requirements. The initial configuration of Firewalls shall be approved from NII SMO and the whole parameterization will be implemented in cooperation with the NII SMO.
- Backup/archiving infrastructure of MMS should be implemented.
- The Contractor should implement and deliver the MMS in full operation including any additional hardware/software, with the appropriate licenses so that the MMS meets the functional requirements and becomes fully operational.
- The system dimensions shall be enough to meet the NII development in the next 10 years and it will be finalized in the Detailed Design Phase of the Project. The system dimensions may be increased by the NII SMO due to business requirements changes. The system shall contain adequate spare computing resources to allow such increases. Additionally, the system shall be scalable to increased network size, number of resources, constraints, and users, without replacing the system through incremental additions of processing or database capacity.

- Appropriate Software Licenses for all Market Clearing applications and third party software should be delivered. The software licenses should be fully assigned to the NII SMO with the capability to independently modify and develop applications deployed on the system.
- In addition to the production System, a Development and Testing System that will be a Replica of the production system with its own infrastructure should be provided for Athens. This will provide the environments for developing / modifying and testing new market functions or modify existing ones to meet evolving market requirements. It will have capability to import and test saved cases from the production MMS. In this system, single servers are foreseen (non-redundant).
- All applications database software and Operating Systems (O/Ss) should fully support the Hellenic language.
- All modifications in the MMS should be done without affecting existing MMS functionalities and with a minimum downtime of the platform.
- All third party software will be the latest version of the third party vendors. The Contractor should provide all latest patches or upgrades, during the project development and implementation, and during warranty and maintenance period.
- The application should be fully compatible with J2EE latest version with latest version.
- Web enabled or User-friendly interface should be used for the administration, configuration and setup of applications.
- The Web servers that are exposed to external users should be properly configured and web cache and reverse proxy techniques should be used to minimize the risk to the critical MMS infrastructure.
- MMS should be separated and protected from the other NII SMO IT systems with a separate Firewall, provided by the Contractor.
- Load balancing techniques (hardware or software should be applied).
- MMS infrastructure should be compliant with NII SMO main Web servers.
- Identity Management and Security integration:

  The Identity Management services will be integrated for all applications running on server, including the Corporate Portal, will be in cluster Database form and will include:

  - SSO authentication;
  - LDAP authentication and users storage;

- The authentication mechanism should work with a variety of login and user registry solutions, including X.509 server and client certification and JAAS (Java Authentication Authorization Service) (or .NET equivalent);
- SSL support;
- User friendly management and monitoring.

3.4 Data Storage

The MMS must support the following data storage requirements:

- All inputs and outputs must be stored in defined database tables.
- All data structures must be defined in a data dictionary.
- All tables must have timestamps of when data was created, by whom, and when updated and by whom.
- Read only access to data must be configurable using security roles for online access via views, reports, or ad hoc queries.
- When data is stored in normalized form (e.g., predefined interval records), a conversion tool must be provided to translate these records to individual interval (date, time) records, so that the data can be easily exported to spreadsheets for settlement analysts and Market Participants.

Morever appropriate market data will be transferred to the NII Datawarehouse (DW). The data that will be transferred to DW represent all the market activities input data and results, in order to have an overview of the Market operation and relate market with system operation. The appropriate data that will be sent to DW will be defined during the Detailed Design Phase of the Project.

3.4.1 Effective Date Management

All data must be tagged with an effective date and time. This tag must be used to select the appropriate reference data for settlement purposes. In addition, all rules set up in the calculator engine must also be dated.

3.4.2 Data Integrity

Foreign keys should be used to ensure referential integrity. The MMS must implement and support declarative and procedural referential integrity to ensure that an entity cannot be inserted, updated, or deleted in such a way as to have invalid primary or foreign key references or orphans of any of its dependents. This referential integrity shall ensure that the databases are not corrupted and that audit capabilities are not compromised. Referential integrity checks must be performed to ensure that only clean data is passed into the Settlement Application (database). Foreign key constraints should be used to ensure referential integrity. Invalid records or records with discrepancies should be written to a log file for checking.

3.4.3 Automated Archiving

The MMS platform must support the following automated archiving requirements, subject to finalization during the Detailed Design Phase of the Project:

- Database monthly partitioning is required to manage archiving of market applications data;
- At a minimum 13 months of market applications data are to be kept on line;
- At the end of each month, new partitions should be created for the next month, and the 14th oldest month data should be automatically moved to secondary storage at the DW;
- Data past 13 months must be easily retrieved from the DW or offline storage, where data should be kept for at least the past 5 years.

3.5 MMS Saved Case and Versioning Requirements

Saved case solutions shall be stored immediately following the execution of each market. They shall be identified through a file numbering system that also records the version of market run in the event that RDAS/DS/RTD run multiple times for a specific market.

Saved cases shall be able to restore original inputs to RDAS, DS, RTD execution parameters, and RDAS, DS, RTD outputs. The supplier of the RDAS, DS, RTD application shall additionally provide for the ability to process a saved case from a restored RDAS/DS/RTD database.

Automatic and manual saved case capability shall be provided by the MMS Applications. The saved cases shall include all data from the Application execution and the interfaces (e.g., the EMS) for diagnostics for future reference purposes. The saved cases shall provide the ability to save and reuse study cases and associated data used to derive the solution set.

3.6 Other General Technical Requirements

Other general technical requirements that should apply to all MMS applications and systems include the following areas:

- User Interface for MMS Applications;
- Execution Control for MMS Applications;
- Display and Reporting;
- Open Interface;
- Data Entry;
- Image Capture;

- Report Control;
- Password Security;
- Function and Data Access Security;
- Reliability;
- Availability;
- Supportability Criteria.

3.6.1 User Interface for MMS Applications

The Applications User Interface (UI) will be built using J2EE/JSP based web SDK. The Applications UI will seamlessly integrate with the NII SMO portal. It will use the NII SMO's authentication system and LDAP infrastructure for authentication. The users will login through NII SMO's portal. The UI back end interface will connect to the LDAP server and get the users' roles and permissions and then grant the relevant permissions and access to the user.

UI displays will facilitate filtering based on page filters and advance filters. Standard edit, insert, cancel and sort functionality will be available in all Applications displays. It will allow users to view data for any version. UI displays will show all output data for a single resource for one hour at a time. UI will have the capability to export all 24 hours.

The Applications UI will provide user-friendly displays and tools to do manual corrections and bulk loading of market results data. UI displays will also facilitate copy forward and backward field/row to several rows within the same display.

The UI will facilitate exporting of data in MS Excel formats. An option will be available to export displayed or all rows.

The Applications will provide a full set of displays that will assist the user to navigate and review the data stored in the related databases.

Specifically, the Market Applications will provide the following capability:

- The Applications shall provide all the necessary user-friendly displays to inform the user about the market results, dispatch instructions, manual dispatch instructions, operating limits, energy prices, ASs schedules and ASs prices, unit commitment statuses, unit regulating statuses, unit telemetry, available reserves, regulating limits, ACE, etc. for each dispatch period, as applicable.
- Real-time information should be provided on the status of the submitted data or files (e.g., XML files with offers, nominations, etc.). For example, a notification should be displayed on the validity, matching of nominations, etc.
- User shall be able to easily search for or filter for a particular unit or entity in all displays. This shall include, but not be limited to, use of wildcard characters.

- For displays that do not require merit order listing, units or entities shall either be arranged in alphabetical order or in physical geographic order. Users shall be able to determine the geographic order of units or entities.
- The Applications input interfaces will be ODBC based configured through workflow controller.
- The Applications will use the workflow controller infrastructure to manage all executions and the data transactions.
- The Contractor may propose other solutions with the internal work flow controller to manage the executions and data transactions.

3.6.2 Execution Control for MMS Applications

The Applications engines shall provide on-screen and batch execution control capability to specify the following options, including:

- Location of input files;
- Location of output files;
- Change of default scheduling priorities;
- Convergence tolerances, such as objective function tolerance;
- Maximum number of iterations (if applicable);
- Other parameters as required, to be agreed upon during the Detailed Design Phase of the Project.

3.6.3 Display and Reporting

The Applications engines shall provide on-screen display and database query capability to report all the market outputs, including binding constraints.

3.6.4 Open Interface

The Applications should have an open interface. They shall be capable of accepting data and writing results to Oracle relational databases, or equivalent, using XML files. The Applications engines shall provide the capability for users to easily query the results and create reports at different resource and system levels.

3.6.5 Data Entry

Enterable data fields shall be defined when a display is generated. All enterable data fields shall be highlighted during the data entry process only. The user shall be able to enter the desired value anywhere within the data entry field. If only a portion of a data value needs to be changed, only that portion of the value shall need to be entered.

Data entry shall be initiated by the user selecting the value to be entered on a display. The value shall be highlighted and the value's identification shall be displayed. An authorization feature shall determine if proper authorization exists for the user to perform data entry. User entries shall also be verified. Invalid entries shall be detected and reported to the user as user guidance messages. The data entry function shall provide a means to view the acceptable limits of data entry, if an unacceptable entry is detected.

In order to distinguish mandatory enterable values from optional enterable values a different highlight or font will be required.

In the displays where enterable fields exist, a strong on-line help is required to inform at least about authorization features, mandatory enterable values, optional enterable values, alternative default values, limits acceptance, and required format for dates, and for decimal numbers.

Full-page data entry shall be provided which allows the user to make multiple data entries before requesting that the data be entered into the database. All valid entries shall be accepted unless a function/application requires all entries be correct before it accepts the input data. In that case, the user shall not be required to re-enter valid entries. When the user successfully completes a data entry, the previous value and new value shall be reported in an event message.

All data entry shall be subject to a time limit. If data entry is not completed within the specified time from the last keystroke performed in a console, the Application/System shall revert to the previous database value, generate an event message, and display a user guidance message. The timer shall be adjustable by the administrator for each user action.

The user shall be able to select another console without cancellation of an active data entry process. However, the user shall be able to end data entry at any time by selecting a cancel command or by requesting a different display in that console. These actions shall cause the process to be terminated and the data value shall remain unchanged. The ability to select data from one console and paste to another console shall be available.

3.6.6 Image Capture

The NII SMO shall be provided the capability to capture currently viewed displays or whole screen images. The image captured shall be stored as a file in an industry standard format, such as .jpg, .tif and .pmb. The Contractor shall provide image edit tools to allow the image to be modified or enhanced (including such features as sizing, cropping, color, conversion to black and white, conversion to a negative image, relocation of images, special effects). The modified image shall be stored as a file in the same format as the original file.

3.6.7 Report Control

The user shall be able to schedule periodic reports (including multi-year, yearly, monthly, weekly and daily reports), direct a report to a display, preview a report on a display, print a report, and archive a report using a report scheduling display. The report scheduling display shall enable entry of the following parameters, with default values provided where appropriate:

- Report name;
- Report destination (printer or archiving device);
- Time the Application/System should produce the report.

The user shall be able to examine and modify the contents of reports for the current period and for previous report periods using displays. Any calculation associated with the revision of data in a report shall be performed automatically after data entry has been completed.

3.6.8 Password Security

Password security shall be provided both for access to the Application/System and for access to the operating system, its layered products, and other applications. At a minimum, the Application/System shall use the password security features provided with the operating system. A password security feature shall be provided that permits only authorized users to access the Application/System through the consoles. Users shall logon by entering a user ID and a password. Each password shall be validated against the corresponding user information in the database. A successful log-on operation shall allow the user access. A means shall be provided for changing operating shifts without reassignment of authorized access at a console. A procedure shall be provided for users to log off.

Each log-on and log-off shall be reported as an event. The event message shall indicate the date and time the procedure was executed, the name of the console and the identification of the user. The log-on/log-off status of the user shall be unaffected by any failure recovery procedure in the Application.

A secure method shall be provided for the NII SMO-designated authority to establish and change passwords and user identifications. Application/System passwords shall be stored in encrypted form. Passwords shall meet similar criteria to those used by the operating system, such as length and no use of proper names or words. Users shall have the ability to change their own passwords. Changing a password shall require confirmation of the new password. The changing of a password shall be done via a single entry sequence and shall be propagated to all authorized applications and processors.

3.6.9 Function and Data Access Security

After a user has successfully logged on, access shall be restricted by assigning operating jurisdictions to applications, displays, reports, and database elements. These operating area assignments shall be made when the function, display, report, or database element is defined.

Similarly, each console shall be assigned one or more operating jurisdiction areas via access control displays. The access control displays shall be themselves assigned a unique operating jurisdiction.

Each time a user attempts a console action, the access security function shall compare the console's assigned operating jurisdiction against the operating jurisdictions assigned to the function, display, report, or database element. Console actions shall include at least the following actions:

- Calling a display;
- Viewing, editing, or printing a report;
- Operating on any value or its attributes;
- Managing any alarm.

If any of the console operating jurisdiction assignments match any of the function, display, report, or database element operating jurisdictions, the action shall be permitted. If no match is found, the action shall be terminated and the user shall be informed of the access violation.

The access security validation procedure shall follow a hierarchy of permissions:

- Displays and Reports – All Web applications and Web Reports will be assigned privileges for their components and resources as well as User authentication services (Encrypted User/Password or SW certificate Authentication, etc.). Applications and Reports do not need to rely on specific console jurisdictions.
- Functions – Access to the facilities of any function, such as completion of an administrative control action or an analysis function, shall be denied if the function's operating jurisdictions do not match the console operating jurisdictions, even though access was permitted to a display from which such facilities could be exercised. The means by which displays, reports, and databases are defined and modified shall be considered functions, as well as functions that manage the software configuration of the System. These functions shall be subject to the same access security validation as other functions.
- Database Elements – The Application/System internal database shall be in an industry standard format, such as Oracle or equivalent, accessible through standard applications such as SQLPLUS, Toad, or Access or equivalent. Access to view database elements shall be governed by the display and report permissions. Each database element shall also have its own operating jurisdiction assignments. Attempts to alter any acquired or calculated database element shall be denied if the element's operating jurisdictions do not match the console's operating jurisdictions. Database element alterations regulated by the access security shall include:

- Enabling and disabling data acquisition processing of a database element (including calculations);
- Enabling and inhibiting alarm processing for a database element;
- Manually entering a value or overriding a data value;
- Placing a data source into maintenance mode;
- Managing alarms, including alarm acknowledgment and deletion.

The access security function shall ensure that each operating jurisdiction is at all times assigned to at least one console. If a console failure or manual reassignment of console operating jurisdiction results in one or more operating jurisdictions not being assigned to at least one console, the unassigned operating jurisdictions shall be automatically assigned to a console and suitable alarms shall be generated.

3.6.10 Reliability

Every crucial and main function shall be supported by sufficient redundancy to ensure that any single failure will only briefly interrupt the availability of that function. Function processing on a failed processor shall be automatically restarted on another processor.

Each automatic transfer to backup resources of one or more functions interrupted by a failure shall be completed with no loss of data. Functions that were scheduled to execute during the time that a transfer is occurring shall automatically execute following completion of the transfer.

3.6.11 Availability

The Applications/Systems should be available to the users continuously without any interruption to the specified services. It should provide the appropriate redundancy to face any failure to equipment, software or networking.

All Web, Application and Authentication/ Authorization should be duplicated, and database systems should be in database clusters without failover downtime.

The Applications/Systems will be available for use 24 hours per day, every day.

The Applications/Systems shall have no single points of failure.

The Applications/Systems shall provide system security, monitoring and redundancy of all application tiers (e.g., web, rules, application, messaging, and database).

Every crucial and main function identified by the NII SMO during the Detailed Design Phase of the Project shall be supported sufficient redundancy to ensure that any failure will only briefly interrupt the availability of that function. Function processing on a failed processor shall be automatically restarted on another processor.

Each automatic transfer to backup resources of one or more functions interrupted by a failure shall be completed with no loss of data. Functions that were scheduled to execute during the time that a transfer is occurring shall automatically execute following completion of the transfer.

Users shall never be disconnected, put on hold or placed in a wait queue.

3.6.12 Supportability Criteria

The Contractor shall develop and deliver a comprehensive application, including all source code and other components necessary to allow the NII SMO to conduct enhancements, maintenance and real-time support of the application. The Contractor shall also be responsible for providing the necessary training and documentation to the NII SMO staff to ensure successful implementation of this goal.

The Contractor shall provide an open architecture structure that will easily accommodate system modifications and the delivered software should be flexible enough to be easiliy configurable and be able to support new rules and the evolution of the market architecture.

The Applications/Systems shall not use "hard-coding" for executing routines involving constraints and variables. Instead, constants and variable values shall be stored in tables, rules or other configurable and highly maintainable means. Rules shall use the same concept of extraction to reference variables rather than specific values. The variables and their values shall be stored outside the rule management repository and rules engine and made directly accessible for users to maintain.

Due to the continued natural evolution of power systems and related contractual agreements, the Contractor should be prepared to incorporate changes throughout system design, development and testing – up through delivery and acceptance.

Any programmatic interfaces must be fully defined and documented.

3.7 Requirements on Auditing Capabilities

The system shall provide the ability to store all input and output data to meet audit and rerun capabilities. The Contractor is responsible for any necessary implementation in order that all Applications are fully auditable. In particular, all configuration options, all data input, including input data and changes from the UI, and all data output must be recorded efficiently for auditing purposes and for historical information archiving.

Version control of all transaction inputs must be provided to simplify reruns and provide traceability of inputs used to generate specific outputs. Input transactions should also have effective and termination dates, which are updated each time a new input is supplied.

The system must provide the following information on all manually changed data:

- Creation Date/Time;
- Created by (user name);

- Modify Date/Time;
- Modified by (user name);
- Console ID.

4 MMS Common Services Requirements

The Common Services Systems for the MMS platform include the following:

1. MMS User Interface (Section 4.1)
2. Validation System (Section 4.2)
3. Market Reporting System (Section 4.3)
4. Market Publishing System (Section 4.4),
5. Market Communications System (Section 4.5)

In this section, the detailed requirements of the MMS platform common services and applications are presented.

4.1 MMS User Interface (MUI)

4.1.1 General

The MUI is a web-based uniform environment used by internal (NII SMO) and external users (market participants) with a complete set of displays for each application. The MUI system should be easily scalable so that the NII SMO staff can easily create new set of displays for new application modules as the market evolves.

The MUI system should follow the e-commerce standards, the market rules and proven practices regarding procedures, policies for user authorization, authentication and for data security and integrity (and business data confidentiality). Solutions with separate Market User Interfaces for Internal and External Users are acceptable.

All Applications (RDAS/DS/RTD) user interface should be implemented through MUI. The MUI system should support input/output of data in spreadsheet (Excel) and/or XML format. Also, the relevant converters from Excel to XML and inversely, for data entry and acquisition, should be facilitated by the MUI system.

The MUI should comply with specific requirements, as follows:

- MUI Main Functionalities (Section 4.1.2);
- MUI Technical Requirements (Section 4.1.3);
- MUI System Configuration (Section 4.1.4);
- MUI Subsystem Architecture (Section 4.1.5);
- MMS User Authentication, Authorization and Accounting (Section 4.1.6);
- Market Gates (Section 4.1.7);
- MUI Interface to Other Applications and Systems (Section 4.1.8);
- Exchange Data (Section 4.1.9);
- MUI Data Entry Additional Requirements (Section 4.1.10).

4.1.2 MUI Main Functionalities

The MUI system will consist of all necessary infrastructures (hardware-software) that facilitates the information exchange between MPs and NII SMO It should provide HMI interface for.

- Market Operator’s Interface
- Market Participant’s Interface
- Market Data Exchange Interface to EMS and "Settlement"[2]

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[2] The Settlement Application shall be implemented by a HEDNO-developed IT System (not part of this Project).

- RTD, EMS interface with validation logic
- RTD/RDAS/DS interface to "Settlement" with validation logic.

Registered and properly authorized users, including application operators, are connected to this system for submitting data, receiving validation and acceptance of the submitted data or data sent and results published in the Market Applications.

All the data exchanged are predefined for each Market Participant and Market Operator.

The MUI should be able to implement the data import as well data exports to other systems and applications that are not hosted in the Market Platform and especially with the EMS application AGC that operates based on the results of Market.

This infrastructure should permit the secure connection, over the public internet or intranet, of the Market Participants (MPs) to NII SMO systems and should ensure the security, the confidentiality and integrity of the exchanged data that they are allowed to submit or receive.

This infrastructure is also used for the internal NII SMO users such as the market/system operators, administrators, developers etc., responsible for submitting or overwriting technical data and for viewing information depending upon their responsibility inside the NII SMO. Solutions with separate Market User Interfaces for Internal Users and External Market Participants are acceptable.

The MUI system will manage the process of opening, closing, shifting and suspending Market Gates that activate the operations defined in the MMS applications. Further, the MUI system will manage the publishing and distribution of emergency announcements and notifications.

The users will submit registration requests to the NII SMO for accessing the data. The application and the registrations information should be processed and recorded to the MUI System.

All user requests internal or external should be propagated and processed through MUI.

The system should keep an appropriate market participant database with the registered participant Information and all related entity data (plants, capacity certificates etc.). This database should also keep all access information and any other data needed for each participant and it should be used as the reference for the comparison of all submitted or presented data.

4.1.3 MUI Technical Requirements

From a technology point of view, the Participant’s Interface and Market Data Exchange Interface should be implemented in a J2EE technology to meet as efficiently as possible with different Participant’s environments (browsers, etc.) and different operating systems and technologies as far as the data exchange is concerned.

For the Operator’s Interface, in order to achieve a rich client interface, 3-tier J2EE with Presentation layer JSPs, Servlets, HTML, etc or .NET or mixed environment with services should be used.

The Operator’s Portal and a Participant’s Portal will combine the above functionalities in suitable Web sites to provide specific users’ look and feel functionality according to their privileges. Special provision should be taken by the Contractor to select and provide a common architecture (from a minimum of 3rd party vendors) to satisfy all of the above requirements in an easily manageable manner. Prerequisite for accepting such solutions with this third party software is the respective 3rd party manufacturer’s support to NII SMO. The proposed architecture should be capable of integrating existing 3-tier MUI systems (Web / Application servers) to it.

Other 3-tier systems that are needed to be interfaced with the above MUI platform are:

- Specific Web applications that present EMS information relative to the Market Systems (either Real-Time or Historical) from the corresponding EMS / HIS systems (3-tier Web systems).
- NII SMO Public Web site.

4.1.4 MUI System Configuration

The MUI system architecture is presented in Figure 4-1. This configuration presents the minimum MUI implementation with a fully redundant 3-tier architecture. The MUI should use Portal technology to integrate all application respective user interfaces and it should also provide future integration of NII applications.

MUI should be deployed on the Application Server (latest version) with support of Reports, Forms utilities.

The system will offer MUI users authentication, authorization based on LDAP, and PKI infrastructure.

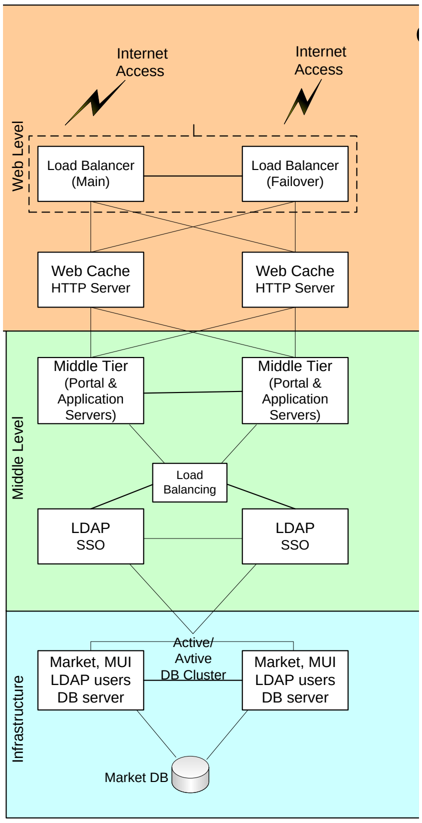


Figure 4-1. MUI Subsystem Architecture

4.1.5 MUI Subsystem Architecture

This MUI architecture should either serve both internal and external system users with single infrastructure or separated to two dedicated to internal and external users.

External Users (market participants) should access the MUI from public internet through NII SMO intranet while internal users should access MUI directly or indirectly though NII SMO intranet.

The Market Systems database will reside at each Control Center (Athens, Rhodes) using automatic replication and failover mechanisms. The databases should be configured in a cluster with high availability sharing and accessing the needed data continuously.

A Load Balancer equipment or software should be integrated to the MMS.

The MMS architecture should not exhibit a single point of failure.

The Contractor may propose for the implementation of MMS and MUI any equivalent solution with the same or better functionality and higher availability and redundancy.

4.1.6 MMS User Authentication, Authorization and Accounting

All users should be properly authenticated and authorized to use the MUI. MUI should support strong authentication and authorization with authentication tokens. LDAP, PKI, SSL standard technologies and capabilities interfacing with strong authentication systems (such as smart cards, HW tokens, etc.) should be used. Equivalent products, but with capability to map to the LDAP directory are also accepted.

Especially for external users who perform critical functions, hardware authentication tokens should be provided for at least 1000 users. These tokens should be compliant to current international standards.

In addition, a Certificate Authority (CA) architecture should be provided in the MUI platform so that the NII SMO, acting as the CA will have the capability to issue certificates for the Market Participants. The Contractor must also specify the technical characteristics (classes, etc.) and specific usages (sign-in, encryption, signing, etc.) for the use of X.509 certificates for the authentication of external participants of the system taking into consideration that NII SMO should not become an official CA.

The authentication of MUI system should permit authorized users to access application with the use of single user name and password in order to provide convenience and increased security to functions. The system should support data exchange and participant activity traceability (User access Accounting).

4.1.7 Market Gates

The MUI system will manage the process of opening, closing and suspending Market Gates that activate the operations defined in the MMS applications. Further, the MUI system will manage the publishing and distribution of emergency announcements and notifications.

The Market gates should be set according to the provisions of the Market Applications section.

The Contractor should provide appropriate user interface to reconfigure and to shift the gates.

4.1.8 MUI Interface to Other Applications and Systems

The MUI should implement all the data exchange, described in this document, between MUI and market applications (RDAS/DS/RTD) using standardized and open technology. The integration between different applications entails a set of technical requirements for data transformation (file adapters, db adapters), flow coordination, synchronous or asynchronous exchange message patterns and error-handling.

The Contractor should ensure that MUI handles all necessary Exchanges needed for proper Market Applications operation, as necessary.

4.1.9 Exchange Data

The MUI should serve MPs and internal users. In the next section (4.2) we present the requirements of the Validation System that is needed to validate submissions. The MUI will allow NII SMO Market Operators and Internal users to access the MUI according to their permission to access data. Market Operators should have additional rights to access, submit and modify data but not the submitted declarations from market participants.

The data exchanged, stored and presented by MUI will be either technical/ economical data that concern the electrical system and the electrical energy market or tables, curves and diagrams and will be retrieved upon user request through MUI from respective databases.

When necessary, MUI should exchange RDAS results needed for control purposes with other systems of the NII SMO IT systems by transferring respective data to the other systems databases, such as data needed for the EMS for control purposes.

4.1.10 MUI Data Entry Additional Requirements

In addition to the general data entry requirements set in Section 3.6.5, the MUI should support ad-hoc queries, reporting, analysis and Web-publishing tools (like J2EE-compliant BI beans for dynamic Web pages or equivalent) to enable users to access and analyze data from company's databases, without having to understand complex database concepts and to present them in a wide variety of crosstab and graph formats.

To face emergency situations, when users cannot communicate to MUI, the system should support manual data entry by authorized internal users with offers received by phone, e-mail attachments or with fax.

4.2 Validation System (VS)

4.2.1 General

The main objectives of the Validation System (VS) are to fully support each Market Application (RDAS, DS, cost-based RTD, etc.), as described in this document. To achieve these objectives, the VS should implement business rules to support these Application modules. Collectively, all of these rules (VS Rules) must be capable of being easily modifiable, traceable, auditable, achievable, and implementable within a rules engine-based environment or its equivalent.

The validation of the business rules will qualify the acceptance of all submitted data by the Market Operator and the Market Participants (MPs) into the NII SMO application.

The VS should comply with the following requirements:

- VS Main Requirements including scope and key capabilities (Section 4.2.2);
- VS Tasks Requirements (Section 4.2.3);
- VS User Interface Requirements (Section 4.2.4);
- VS Business Rules (Section 4.2.5);
- VS Additional Requirements (Section 4.2.6);
- VS Additional Supportability Criteria (Section 4.2.7).

4.2.2 VS Main Requirements

The validation of submitted data from the users should be based on validations rules that should be hosted in a Master File (MF) and will be defined during the Detailed Design Phase of the Project.

At a high level, the scope of the VS includes the following:

- VS will validate all submitted data by the market operator and the MPs. The VS vendor is expected to implement the rules of the markets in a standardized rules engine (or equivalent) format.
- Provide a short term data store for purposes of viewing validated submitted data.
- Auditing capability of all stored submitted data.
- Capability to control the flow of data ranging from submission of declarations by MPs' to VS, the publication of validated declaration by VS to each application and data flow from each application module to VS.
- Supporting capability for Operator requested reports on all stored submission data.

- Supporting capability for MP requested views on all stored MP specific sumbitted data.
- Provide a framework (preferably through a rules engine or equivalent framework) that will allow NII SMO personnel to assume complete maintenance, development, and implementation of all business rules after launch of VS.
- Support IT infrastructure principles including data security.
- Performance – the VS application must publish validated data for consumption by other applications within a stipulated time period after market closing.

The VS system should provide the NII SMO with the capability to change or add to any of the existing business functions or validation rules easily to accommodate future market rule changes. This system should allow the NII SMO the ability to change rules "on the fly" as business conditions dictate. VS will also make it easy for MPs to integrate their systems with the system. The successful completion of this project will provide flexible and cost-effective solutions for application enhancements, business-to-business integration, and system manageability.

The key capabilities of the VS with the respective explanation should be as follows:

- Correct implementation of RDAS/DS/RTD business rules: The VS implementation should contain up-to-date and accurate business rules. The VS implementation should ensure that accurate data is used for input into each application module. The VS implementation should coordinate processes to avoid process interference and inaccurate input data.
- N-tier architecture implementation: The VS implementation should allow flexible scaling of the new VS business layer in accordance with NII SMO business needs.
- Implementation of validation logic in a standardized rules engine: The VS implementation should allow "natural language" based updates to validation rules by NII SMO business staff.
- Implementation of XML based interfacing software:The VS implementation should allow other NII SMO business functions to maintain the modularity of their solutions so long as they comply with the published API interfaces of the VS business layer. The VS implementation will allow the NII SMO to create and maintain XML based templates in an easy manner. Such templates will be in conformance with NII SMO XML standards.
- Ability to use "off the shelf" and other vendor solutions: The modularization of the VS Business Rules implementation should allow the independent replacement of individual VS components.
- Audit trail implementation: The VS implementation will provide an audit trail for any modification or updates of business or process rules performed by the NII

SMO. This requirement will be satisfied in the short-term horizon by the "holding tank" database in the VS architecture. The longer-term requirement will be satisfied by the market database where all the data will he held.

- Archiving/Data Retention: VS data retention requirements will be determined at the time of the detailed design. However the vendor's proposal must include scope for such data retention.
- Monitoring: The VS implementation will support capability for monitoring transactional history in VS.
- Security: The VS implementation will adhere to 3-tier Web architecture.

4.2.3 VS Tasks

VS should perform the following tasks:

- Select an appropriate rules engine (or an equivalent) to implement the business rules.
- Determine detailed software architecture and design in collaboration with the NII SMO architecture team for the implementation of the business rules.
- Determine detailed architecture and design for data storage – also referred to as the "holding tank" database.
- Implement business rules in a rules engine or equivalent technology for validation of data input in the RDAS/DS/RTD applications.
- Implement the VS functionality in modular components.
- Integrate the VS UI, VS application and the "holding tank" as one VS product.
- Implement explicit messaging, auditing, tracking, and notification system.
- Implement the 3-tier architecture framework for VS's Web layer, application layer, and database layer.
- Factory and Site Acceptance (including performance) Testing of APIs.
- Factory and Site Acceptance (including performance) Testing of business rules.
- Documentation of validation rule engine architecture, event driven process architecture.
- Documentation of all APIs', and business rules.
- Documentation of testing procedures.

4.2.4 VS User Interface Requirements

An appropriate VS UI should be integrated to the VS application. The functions on the VS UI directly reflect the capabilities of the VS itself and other underlying applications, and describe how the user interacts with the system.

- The VS UI should meet the following:
- An intuitive, user friendly interface that will have the features needed to provide market participants the ability to participate in the market.
- Allow VS to send its generated “user friendly” messages to the user.
- Allow users to be “alarmed” on market issues and issues pertaining to submitted data.
- Allow a standardized user experience by following a common look and feel along with other NII SMO interfaces.
- Graphical controls are needed to capture and display submitted data information.
- The functions of the VS UI will be categorized and made available to the user through toolbars and menus.
- Iconography will be designed to be intuitive to the User. The templates and libraries available in the chosen technology will influence the design. Additional designs will be driven by the business Users to conform to specific industry standards, where needed.

The VS UI shall provide on-screen display and database query capability to report the following data related to the generation and load declarations, the unit technical and economic data (e.g. resource constraints, cost curves etc.).

4.2.5 VS Business Rules

The VS will only accept, hold and validate data based on predefined business rules. Market Participants should be allowed to submit declarations at multiple times while the market horizon for a specific Dispatch Day is open. The VS should time-stamp and validate the data instantly and inform of the MP about their status. MPs are also allowed to cancel their declarations if the market horizon is open. In principle, the following list contains the various statuses of the MP submitted declarations:

- Submitted (by the MP);
- Accepted (by the system);
- Conditionally valid (valid before the Master File update);
- Conditionally modified (modified before the Master File update);
- Valid (passed validation by the system);
- Modified (by the system);
- Generated (by the system);
- Cancelled (by the MP);
- Obsolete (because a re-submission has occurred);
- Clean (ready to be used by the market applications).

The Master File is the database tha holds all the data of Market Particpants that do not change very often (see Section 5.1). The basic rules to be implemented in the VS are described in the Applications section, where the requirements for the declarations and data submitted to be accepted are mentioned. The complete set of business rules will be developed during the Detailed Design Phase of the Project. The data submitted and the data actually used after validation shall be stored separately for auditing purpose. Modification or generation of new data by the VS is outside the scope of the VS.

4.2.6 VS Additional Requirements

The following are supporting requirements that the VS Contractor needs to comply with:

- Business users shall be able to change rules "on the fly" without having to bring in the Contractor for basic business rule changes
- Training shall be designed and delivered by the vendor such that a full day (8 hours) session will make users proficient in implementing new business rules through the VS application.
- VS screens shall display information in hour-ending (HE) format.
- In data validation screens, edit and manual override functions shall be achievable from all screen layers and for all data elements, with audit trails (including time, date, user who modified and reason for modification) and visual override indicators.
- Modified fields shall be displayed in a different color on the screen to draw attention to them.
- Allow multiple, simultaneous window viewing within the VS frame.
- No open window (especially data and textual entry windows) shall cause control of the other Applications or other VS screens/windows to "lock up" or otherwise become unusable.
- The system shall allow users to navigate between VS and multiple other applications easily and quickly.

4.2.7 VS Additional Supportability Criteria

In addition to the general supportability criteria, as mentioned in Section 3.6.12, the following Supportability criteria should encapsulate the requirements within the VS rule-based environment or its equivalent. This shall also apply to all implementation external rule engines or equivalent environment (may include processing engine, database, etc.)

- The system shall store rules in a centralized rule-based repository with a user-friendly interface to facilitate future enhancements, maintenance, versioning, viewing, and reporting. The rule management repository shall meet all requirements of the VS.

- The rule management repository shall be integrated with the rules engine to facilitate maintenance of the rules.
- The NII SMO user-friendly interface shall clearly expose the rule, its relationship to other rules/contracts and its formulas and calculations so that the Operators can understand, manage and maintain such rules.

4.3 Market Reporting System (MRS)

4.3.1 General

The Contractor as part of the MMS platform should implement a modular Market Reporting System (MRS) that will provide the NII SMO users the capability to develop new reports in order to address future market needs or modify the data of existing report modules that are produced by the current NII SMO reporting infrastructure. The MRS should be able to produce multi-year, Yearly, Monthly, Daily reports. The MRS should be modular, easy to use, and should contain an integrated report designer in order for the NII SMO staff to be able to manufacture on-demand reports.

The MRS should comply with the following requirements:

- MRS Main Requirements (Section 4.3.2);
- Data Manipulation (Section 4.3.3);
- Report Formats (Section 4.3.4);
- MRS IT Requirements (Section 4.3.5).

4.3.2 MRS Main Requirements

The MRS should provide the capability to develop new necessary Web-based reports, diagrams and charts or modify existing ones. The user shall be able to schedule periodic reports, direct a report to a display, preview a report on a display, print a report and archive a report using a report scheduling display. The report scheduling display shall enable entry of the following parameters, with default values provided where appropriate:

- Report name;
- Report destination (printer or archiving device);
- Time the application should produce the report.

The user shall be able to examine and modify the contents of reports for the current period and for previous report periods using displays. The data entry procedure specified above in the Data Entry section shall be used to enter and verify changes to data in reports. Any calculation associated with the revision of data in a report shall be performed automatically after data entry has been completed.

Specific MRS requirements also include:

- MRS users should have the final approval of all screens, reports, and functionality.
- The MRS shall include helpful error messages for the users.
- The MRS should make use of right click and hovering features to improve usability.

- The MRS should provide drop-down selection lists for all data entry fields that require the user to enter a selection from a known set of parameters.
- Consistent naming conventions shall be used throughout the MRS application.
- Data and text shall never be truncated in displays. It shall wrap or otherwise display the entire field of information.
- Provide automated spell checking for both English and Greek languages.
- For report creation and modification the edit and manual overrides functions shall be achievable from all screen layers and for all data elements, with audit trails (including time, date, user who modified and reason for modification) and visual override indicators.
- Modified fields shall be displayed in a different color on the screen to draw attention to them if necessary.
- The MRS UI should provide friendly and intuitive interfaces to allow ease of navigation.
- MRS functions shall be categorized and made available to users through toolbars and menus.
- All screen and application navigation shall be possible by mouse as well as by keyboard.
- Drill down screens and linkages shall be provided to assist in the ease of navigation.
- The development of new reports or the modification of existing ones that require opening of many windows (especially data and textual entry windows) shall not cause control of the applications or other MRS screens/windows to “lock up” or otherwise become unusable.
- The system shall allow users to navigate between MRS and multiple other applications easily and quickly.
- The MRS should offer easy user navigation through the data by drilling-down, pivoting, scrolling and formatting alert capability to spot importance aspects of these data.
- Report from Excel spreadsheet, and output formats to XML and PDF.
- Graph formatting capabilities, printing with zoom.
- Capability to publish the Enterprise Reports also as true Web pages, in a controllable presented format.
- Complex query results in attractive graphs, tables, and crosstabs.

4.3.3 Data Manipulation

The MRS should allow the NII SMO users to create new reports or modify existing report modules by providing a modular facility for easy data manipulation. In this section we present specific requirements for data manipulation.

- All data screens shall allow for data export to MS Excel and printing capabilities.
- All data (numerical as well as textual information such as notes) displays shall allow copy, cut and paste features.
- Manual entry and editing features shall be intuitive and robust while allowing manipulation of single and multiple values with efficiency.
- Data entry and modification screens shall be designed to minimize repetition.
- Sort, query and filter functionality shall be provided for all data components on each data screen and report (viewing or printing).

4.3.4 Report Formats

The MRS should allow users sufficient flexibility in developing various report modules. The following is a set of requirements regarding report formatting:

- Provide professional quality reports with formatting suitable for management style reporting.
- All reports shall include on all pages: a report title, operating date, a print date and time, “page X of Y” style page numbering, list any parameters used as filters, label all fields and display row and column name(s).
- All reports shall be printable and exportable in MS Excel.
- In screen, printed and exported file form, reports shall always include labels for the data (such as field names and headings).
- All screens and reports shall show hourly data horizontally across the screens and pages. All 24 (twenty-four) hours shall be visible at one time on the screen displays and on printed pages.
- Printed reports shall default to portrait layout when needed to show all 24 (twenty-four) hours of data.

In addition to stock reports, customizable reporting or fully flexible ad hoc reporting is desired.

4.3.5 MRS IT Requirements

The MRS should provide a Reporting Web architecture environment that will offer an Application server with formatting features as provided by products like Oracle Reports, JSP (Java Server Pages) with Presentation beans, JSF (Java Server

Faces), MS .NET products, Crystal Reports and others equivalent. All products used, will have export capabilities to XML, MS Excel, PDF with Greek encoding.

The MRS architecture should cover all MMS applications with Business Intelligence capabilities and should be deployed in 3-tier Web architecture, capable of allowing cross platform reporting development for all supplied and existing NII SMO Databases (i.e., Market, HIS, DW, etc.). The MRS 3-tier architecture should secure the structured Web reports, report engines and other resources accessed by users with privileges. It should also offer the capability of incorporating, Java-compliant Presentation beans in Web reports, JSPs or in portals and deployed on the application server for Web-based presentation. The MRS will provide data to the datawarehouse.

The MRS system should provide the reports with output formats also in Excel spreadsheet, XML, PDF and Greek encoding. Also Market application reports are required to be able to be specified for delivery on all applications (RTD, DS and RDAS) for the purpose of viewing and analyzing relative data and information.

4.4 Market Publishing System (MPS)

4.4.1 General

The Contractor should implement, as part of the MMS platform, a modular Market Publication System (MPS) to provide the NII SMO internal users the capability to develop new publication modules in order to address future market needs or modify the existing publication modules data of existing report modules. The MPS should provide a publication framework (in the form of parameterized views and respective presentations) for easy publication of NII SMO Market Data requirements.

The MPS should provide the capability to the users to publish phase dynamic Web pages related to RDAS/DS/RTD results that concern the specific participant only, as well as general information. More specific requirements for the publication data are mentioned in the relevant applications sections, and in any case will be finalized in the project detailed design phase.

Publishing of the application (RDAS/DS/RTD) results and related information from the power system operation will be provided to MPs both in the English and Greek language. This publishing should permit the user to select the information according to data type and the period of its interest.

The MPS should have as features the export of the presented data to other formats like Excel spreadsheet or PDF format upon user selection.

The MPS should comply with the following requirements:

- MPS IT Requirements (Section 4.4.2);
- General Publishing Requirements (Section 4.4.3).

4.4.2 MPS IT Requirements

The MPS should provide a Publishing Web architecture environment that will offer an Application server with formatting features as provided by products like Oracle Reports, JSP with Presentation beans, MS .NET products, Crystal Reports and others equivalent. All products used, will have export capabilities to XML, MS Excel, PDF with Greek encoding.

The MPS architecture should cover all MMS applications with Business Intelligence capabilities and should be deployed in 3-tier Web architecture, capable of allowing cross platform publishing module development based on existing NII SMO Databases (ie. Market, HIS, DW, etc.). The MPS 3-tier architecture should secure the structured Web reports, report engines and other resources accessed by users with privileges. It should also offer the capability of incorporating, Java-compliant Presentation beans in Web based publishing modules, JSPs or in portals and deployed on the application server for Web-based publication. The MPS will provide data to the DW.

The MPS should provide the publishing modules with output formats also in Excel spreadsheet, XML, PDF and Greek encoding. Also Market application publishing modules are required to be able to be specified for delivery on all applications (RTD, DS and DAS) for the purpose of viewing and analyzing relative data and information.

The MPS will publish specific MP information that is not available to other MPs, as well as general information available to all MPs. The main users of the MPS are the MPs, the Public and NII SMO operators and analysts.

4.4.3 General Publishing Requirements

The NII SMO is obliged to abide by the principle of transparency and to publish, in his website or any other appropriate way, the statistical data that he collects regarding the operation and development of NII Systems and the activites of the participants in the NII Market. In addition, the NII SMO keeps on his website the updated list of NII Market Participants per NII System, as well as an index with the Units for every NII System, with reference, for every Unit, of its registered capacity and ASs capability, per AS type.

The NII SMO, within two months after the end of the calendar year, prepares and publishes on his website the Annual NII System Operation Report, with the following content, per NII System:

- Monthly aggregate ex-post data regarding the produced energy quantities per Unit category, the energy that was withdrawn per Load Representative, the total cost (average variable, ancillary, capacity availability, emergencies etc.) per Unit category, the provision cost of NII Public Services Obligations, as well as the available capacity per Unit category.
- Summary Report that contains system critical incidents and aggregated Dispatch Instructions violation data, based on ex-post data regarding the Dispatch Procedure, as well as the violation of the registered techno-economic Unit data, and the relevant actions of the NII SMO.
- Summary Report that contains ex-post data regarding the provision of ASs and especially with incidents of inadequate ASs available. This report can contain suggestions for the improvement of the ASs scheduling and management procedures.

Implementation details will be determined during the Detailed Design Phase of the Project.

4.5 Market Communications System

The Contractor should implement, as part of the MMS platform, a complete and fully-automated inter-application module communication system, in order to transfer data/information between two “Market Operation” application modules.

The Market Communication system should allow transfer data/information between market and external applications (i.e., network applications, such as contingency analysis, AC-OPF, congestion management, state estimator, reserve requirements forecasting). This inter-application communication system should integrate all Market application with the rest of the NII SMO infrastructure.

5 MMS Application Systems Requirements

The Application Systems for the MMS platform include the following:

1. Master File (Section 5.1);
2. Rolling Day Ahead Scheduling (RDAS) (Section 5.2);
3. Dispatch Scheduling (DS) (Section 5.3);
4. Cost-based Real-Time Dispatch (RTD) (Section 5.4);
5. Real Time Data Recording and Logging System (Section 5.5).

This Chapter presents the requirements of the Application Systems. These requirements cover all types of NII, namely small, medium, and large.

- The Athens MMS (in the Central ECC), since it is expected to run RDAS market in all Islands, should comply with the requirements for all types of NII, i.e., small, medium, and large.
- The MMS in Rhodes should comply with the requirements for the large NII.

5.1 Master File

5.1.1 General

The Master File (MF) is the key data repository that contains all the static and semi-static data for all MPs. Most of the MMS applications will rely on the MF to retrieve information required to clear and settle the energy markets. The MF contains network and resource data for all MPs. It also contains cost information for all MPs and for all the registered resources. This includes static information (Unit Information, Constraints, Nodes, Resource Ownership, etc.), Aggregated Unit Definitions, Unit cost data such as Startup Costs, Minimum Load Costs, etc.

In this section specific tables that contain such data are presented. This list is not exhaustive but it is important to illustrate the level of complexity involved in designing and implementing this application. The Contractor may use these tables in its implementation proposal. However, the Tables are provided here for information purposes only.

In the next sections, the following are described:

- MF Main Requirements (Section 5.1.2);
- Requirements for Techno-Economic Declarations (Section 5.1.3);
- Table of Unit Registered Characteristics (Section 5.1.4);
- Maintenance Schedule (Section 5.1.5);
- Requirements for Economic and Administratively Set Data (Section 5.1.6).

5.1.2 MF Main Requirements

The MF main requirements are listed as follows:

- Main Functional Requirements (Section 5.1.2.1);
- Content Requirements (Section 5.1.2.2);
- Data Versioning Requirements (Section 5.1.2.3);
- Snapshot Replication Requirements (Section 5.1.2.4);
- Security Requirements (Section 5.1.2.5);
- Monitoring Requirements (Section 5.1.2.6).

5.1.2.1 Main Functional Requirements

The Contractor should provide a fully operational MF functionality that meets the needs of the NII IT Systems project.

The MF should meet the following requirements:

- MPs should be able to submit updates to the data related to their resources electronically from a Manual User Interface (UI). This should be a Web

Browser interface that provides MPs with access to view and maintain MF data.

- The MF should also provide a system level interface API (direct system to system interface) so that MPs can submit and obtain data.
- The MF should have some basic business validation rules to check incoming data.
- The MPs should be able to request for new Resources.
- The MF should provide the capability for a Comparison and Validation Report available in UI.
- MPs should be able to view and download approved MF data and expanded data reports in UI.
- The MF will also allow data exchange with email and Excel replace, not just electronic exchange of data with electronic notifications.
- The MF database must be updated to reflect changes necessary to accurately reflect the grid and the resources connected to the grid. The Technoeconomic Data Templates are used to update the Master File database for data that pertain to new or existing resources.
- The Manual UI of the MF function should have the following capabilities:
    - Upload/Download of Date in .CSV and XML format;
    - View Data;
    - Change Data;
    - Retrieve Data;
    - Add Data;
    - Reporting;
    - View History Data;
    - Delete Data;
    - Change Rights/Permissions;
    - Query the Status of Submittal;
    - Effective Date Change.

Note: In the NII Code, the following registries are foreseen to be kept by the NII SMO, <u>per NII System</u>:

- Producers Registry;
- Load Representatives Registry;
- Power Stations Registry;

- Units Registry;
- Meters Registry.

These registries shall be kept by the NII SMO at a HEDNO-developed IT System, which shall communicate with the IT Systems to be procured within this Project. Details shall be finalized during the Detailed Design Phase of the Project.

5.1.2.2 Content Requirements

The MF contains internal and external operating data for all resources within the NII SMO control area. The MPs can submit requests to initiate updates to specific operating parameters for generator resources.

Once the MP has submitted a request, the MF analyst reviews the request and determines if the updates comply with stated MF business rules. If the updates pass the initial review, the request is presented for further review and approval by affected NII SMO systems. The changes must be approved prior to them being made effective within the MF database. If there are questions regarding the requested updates, the NII SMO will contact the MP to coordinate modifications to the requested updates. The request will be treated as a new request upon resubmission, for example, if it fails business rules.

The MF should register and keep in an organized structure all the information of the Market Participants along with the respective generating resources registered technical data and capabilities and respective licences along with all related information and prerequisites to participate in the market.

Typical information in the MF for generating resources should be the type, fuel, limits, start up and shut down times and costs etc.

It is noted here that the MF should be in line with the respective resources modeled in EMS.

5.1.2.3 Data Versioning Requirements

The most critical function of the MF module is to manage, maintain, and control data updates. Once a day (usually at midnight) the MF will be updated to reflect authorized and approved changes effective for the next day’s market operation.

The Data versioning for the MF data is broken into two categories: meta data version and instance data version. The metadata version defines the version of the schema of the snapshot (not the internal MF database schema). Instance data version references the version of the actual data that conforms to the definition version. In this way, there is no ambiguity on the data contained within the schema. The instance data version must also be explicit so that there is no ambiguity as to what version of the data is being utilized by a system or process.

5.1.2.3.1 Versioning of Snapshot Meta Data

In the standard service definition process, metadata versions are managed via XML Schema namespaces. Versioning of the MF metadata definition is achieved via database schema name. This way of versioning makes it explicit as to what is contained within the snapshot. Using schema names also facilitates multiple versions of a MF snapshot to reside on a single database.

Other characteristics of the MF snapshot metadata version are:

- It should not be required that all systems (databases) replicate all version of the MF snapshot. Only the version or versions required for the application should be replicated.
- All MF snapshot metadata versions must be supported by the MF database until such time that the snapshot version is retired.
- Like standard service definitions, snapshot metadata changes should be subject to the service definition change process. This includes determining if the requested change can be versioned.

5.1.2.3.2 Versioning of Payload Instance Data

The version of actual instance data must propagate with each snapshot update. In the case of MF updates, there will be only one repository ID. These data resides in the receiving system schema for the snapshot being replicated. It is updated with every update.

5.1.2.4 Snapshot Replication Requirements

The MF function will deploy standard technologies for maintaing replica versions of the data. Snapshot is one of Oracle's tools for creating and maintaining replica versions of database objects (e.g. tables) in a distributed database system. Basic replication is implemented using standard CREATE SNAPSHOT or CREATE MATERIALIZED VIEW statements. Using Basic Replication we can only replicate data (not procedures, indexes, etc). Replication is always one-way, and snapshot copies are read only. Advanced replication supports various configurations of updateable-snapshot, multi-master and update anywhere replication. Advanced replication is complex to implement and maintain. The Contractor should not use advanced replication, since the MF function mechanism calls for updates ONLY to the master site or Master database.

All MF Tables should be installed under a master schema under the MF Database. Users will make manual updates to these tables using standard data entry tools. Each consumer application database should have a replica schema where the snapshots should be created. Applications will use their view of the MF Tables to create snapshots.

Every night at midnight a job should run to refresh each MF snapshot from the master database. This snapshot refresh interval and frequency should be configurable. Snapshots by default are created with COMPLETE replication option, meaning that the entire data set is replicated every night.

5.1.2.5 Security Requirements

Snapshot security levels should be similar to other database objects. Snapshot replication happens through direct database links from each snapshot database to the master database.

5.1.2.6 Monitoring Requirements

Oracle Enterprise Manager (or equivalent) in combination with tools such as IBM Tivoli, or equivalent, should be used for the monitoring of the databases.

5.1.3 Requirements for Techno-Economic Declarations

The MF should keep Unit Techno-Economic Declarations that will contain the Declared Characteristics for each Generation Unit in the Unit Registry.

5.1.3.1 Submission Obligation

Every Producer that owns a Generating Unit that is going to connect or has already connected to an NII System initially submits a Preliminary Declaration of Unit Techno-Economic Data with his application for a Unit Connection Contract and the Final Declaration of Unit Techno-Economic Data after the testing operation or the activation of the Unit. In case of a Generating Station that contains more than one (separable) Unit or contain Units of other type and other systems, such as Hybrid and Solar Stations, a separable declaration is submitted for these Units and systems. In addition, for Conventional Generating Units, an extra declaration for the infrastructure installations is submitted.

The Final Declaration of Unit Techno-Economic Data is binding and is valid if it is accepted by the NII SMO.

It is compulsory that the Declaration is updated after any change of the data that are included in it, on the responsibility of the Producer.

A newer Declaration replaces the previous if it has been legally submitted and approved.

The submission process of the Techno-Economic Declarations will be implemented by a HEDNO-developed IT System. The data shall be passed to the MF.

5.1.3.2 Techno-Economic Declaration Content

Standardized Tables are provided that are used for the declaration of data and characteristics of the Units and Stations, which in summary include:

- Unit Technical Parameters;
- Hybrid and Solar-Thermal Station Technical Parameters;
- Conventional Units Variable Cost Parameters;

- Cost Parameters following a Dispatch Instruction;
- Conventional Generating Unit Fixed Cost Parameters;
- Conventional Station Fixed Cost Parameters.

Table 5-1. Techno-Economic Parameter Declaration Table

A. Unit Technical Parameters			
Description		Numerical Value	Unit of Measurement
A.1 Unit Technical Characteristics			
Additional time for synchronization in case of revocation from non-availability state			Hours
A.2 Unit Technical Characteristis for Ancillary Services (in case they are different per Unit state, e.g. synchronized, soak, warm etc., the table is submitted per state)			
Automatic Generation Control (AGC)			
Maximum power output under AGC			MW
Minimum power output under AGC			MW
Secondary Regulation Range			MW
Black Start Capability			YES/NO
Primary Regulation Reserve			MW
Tertiary Regulation Reserve			MW
Standing Reserve			MW
B. Additional technical parameters of Hybrid and Solar-thermal Stations			
B1. Technical Characteristics of Hybrid Station storage units			
		Type	Description
Number and Type of Autonomous Station Storage System	Stor. Syst. 1		
	Stor. Syst. 2		
		Numerical Value	Unit of Measurement
Capacity of Storage Systems for Energy Storage	Stor. Syst. 1		MWh
	Stor. Syst. 2		MWh
Maximum Power Output of Station Storage Units	Stor. Unit 1		MW
	Stor. Unit 2		MW
	Stor. Unit 3		MW
	Unit Type 1		MW
	Unit Type 2		MW
B2. Other Station Characteristics			
Installed Capacity of Station RES Units			MW
Maximum net capacity of Station RES Units			MW

Station Auxiliary Generating Units Power Rating				MW
Station Auxiliary Boiler Rating				MWh
C. Variable Cost Parameters for Conventional Units				
Fuel Type		Fuel A		
		Fuel B		
		Fuel C		
Fuel Lower Heating Value per fuel type		Fuel A		GJ/measurement unit
		Fuel B		
		Fuel C		
Specific fuel consumption curve	Net Production Level (MW)	Fuel A (kg or lt/MWh)	Fuel B (kg or lt/MWh)	Fuel C (kg or lt/MWh)
Specific emissions curve	Net Production Level (MW)	Fuel A (kg CO_2/MWh)	Fuel B (kg CO_2/MWh)	Fuel C (kg CO_2/MWh)
Percentage fuel mixing at every point of the Specific Fuel Consumption function	Net Production Level (MW)	Fuel A (%)	Fuel B (%)	Fuel C (%)

Average Cost of Specific Consumption of raw materials other than fuel (for all the steps of the Specific Fuel Consumption function)			Cost (€/MWh)	
Average Special cost of additional maintenance expenses due to operation, except for fixed maintenance costs (for all the steps of the Specific Fuel Consumption function)			Cost (€/MWh)	
Average Special Cost fo additonal workforce expenses due to operation, except for the fixed expenses for the workforce (for all the steps of the Specific Fuel Consumption function)			Cost (€/MWh)	

D. Cost Parameters After Dispatch Order

Description	Numerical Value		Unit of measurement
Special Startup Cost, determined as the total variable startup cost of the Unit up to the technical minimum output, separately for each startup from a non synchronized cold, warm or hot state.	From cold		Kg or lt of fuel (per fuel type /startup)
	From warm		
	From hot		
Fuel consumption for standby operation for Unit fast start.	To warm		Kg or lt of fuel (per fuel type) per hour
	To hot		
Operating and maintenance cost, except for the fuel cost, for standby operation for Unit startup.			€/MW-h

E. Fixed Cost Parameters of Conventional Generation Unit

Description	Numerical Value	Unit of Measurement
Total Cost of Unit Installation, including the cost for		€/MW

necessary equipment for the unit operation, except for the equipments included in the Power Station installation, per MW of the Unit Nomical Capacity.			
Annual Maintenance and Operation Cost of the Unit, except for the fuel cost for maintaining the unit in standby.			
F. Fixed Cost Parameters of Conventional Station			
Description		Numerical Value	Unit of Measurement
Fuel tanks capacity per fuel type	Type A		kLit
	Type B		
	Type C		
Installation Cost of the Power Station, which includes all equipment and infrastructure of the Power Station for the operation of itsUnits, other than the Unit Installation Cost.			€
Annual Fixed Cost for Power Station Functionality and Standby.			€/MW-year

CHP Units with conventional fuel submit the techno-economic data of the respective type of conventional unit.

The technical data of the final Techno-economic Unit Data Declaration need to correspond to the ***actual technical data*** *of the unit operation. The* ***economic data*** *of the Declaration need to be* ***cost-reflective,*** *namely they must reflect the costs incurred by the Producer, as they are calculated in accordance with the NII Code.*

In the MF, the total number of Dispatch Days of the current calendar year is kept, for which a non legal Techno-economic Data Declaration has been observed for the same Producer.

Details will be determined during the Detailed Design Phase of the Project.

5.1.3.3 Requirements for Unit Techno-economic Characteristics

Basic Technical and Operational Requirements

According to the applicable regulatory framework, basic technical requirements are determined for Fully or Partially Controllable Units that connect to the NII System, which are presented below for informational purposes.

Table 5-2. Steam Units with Oil, Natural Gas or other Primary Fuel Source

Technical Minimum	Not greater than 40% of Nominal Capacity
Ramp-up Rate	Not less than 1.5% of Nominal Capacity per minute when Unit is in Normal Dispatch Status

Ramp-down Rate	Not less than 1.5% of Nominal Capacity per minute when Unit is in Normal Dispatch Status
Minimum up time after Minimum Generation Level	Not greater than 8 hours
Minimum down time	Not greater than 4 hours
Forbidden Zones	Up to two, each with power range less than 10% of Nominal Capacity
Load Under Synchronization	Not greater than 10% of rated Capacity
Time off-load before going into longer standby state	Maintain hot state for at least 12 hours. Maintain warm state for at least 60 hours.
Synchronization time (following an instruction)	From hot status: not greater than 3 hours From warm status: not greater than 8 hours From cold status: not greater than 12 hours.
Time period from Synchronization status to Technical Minimum	From hot status: not greater than 40 minutes From warm status: not greater than 90 minutes From cold status: not greater than 180 minutes.

Table 5-3. Internal Combustion Engine Units with Oil, Natural Gas or Other Primary Fuel Source

Technical Minimum	Not greater than 40% of rated Capacity
Ramp-up Rate	Such that within 20 minutes for the 4-stroke and within 25 minutes for the 2-stroke from the Unit synchronization, the full capacity can be reached.
Rampe-down Rate	Such that within 20 minutes the unit output can be reduced from its technical maximum to the technical minimum.
Minimum up time after Synchronization	Not greater than 2 hours
Minimum down time	Not greater than 1 hour
Forbidden Zones	Not permitted
Load under Synchronization	Not greater than 10% of Nominal Capacity
Synchronization time (after order)	From warm status: not greater than 20 minutes From cold status: not greater than 1 hour για 4-stroke and not greater than 2 hours for the 2-stroke.
Time Period from Synchronization to Technical Minimum	10 minutes

Table 5-4. Oil or Natural Gas Combined Cycle Units

Technical Minimum	Not greater than 35% of rated Capacity
Ramp-up Rate	Not less than 1.5% of rated Capacity per minute when the Unit is at Normal Dispatch Status
Ramp-down Rate	Not less than 1,5% of rated Capacity per minute when

	the Unit is at Normal Dispatch Status
Minimum up time after Synchronization	Not greater than 8 hours
Minimum down time	Not greater than 4 hours
Forbidden Zones	Up to two, each with power range of less than 10% of rated Capacity
Load under Synchronization	Not greater than 10% of rated Capacity
Time off-load before going into longer standby state	Maintain hot state for at least 12 hours. Maintain warm state for at least 60 hours.
Synchronization time (following an instruction)	From hot state: not greater than 3 hours From warm state: not greater than 8 hours From cold state: not greater than 12 hours.
Time from a Synchronization state to a minimum generation output state	From hot state: not greater than 40 minutes From warm state: not greater than 90 minutes From cold state: not greater than 180 minutes.

Table 5-5. Open Cycle Gas Units with Oil, Natural Gas or Other Primary Fuel Source or Other Units that are not Specifically Mentioned

Technical Minimum Output	Not greater than 20% of Nominal Capacity
Ramp-up Rate	Must allow for the Unit to reach its maximum Capacity from the Synchronization state within 20 minutes
Ramp-down Rate	Must allow for the Unit to lower its Capacity from maximum level to technical minimum level within 10 minutes
Minimum up time after Synchronization	Not greater than 1 hour
Minimum down time	Not greater than 1 hour
Forbidden Zones	Not permitted
Load under Synchronization	Not greater than 10% of the rated Capacity
Synchronization time (after order)	15 minutes
Time Period between Synchronization and Minimum Output Level (soak time)	5 minutes
Special Constraints	Restart or within two hours or after four hours

Each Unit must have the following reactive power supply capability, as measured at the generator terminal buses:

Table 5-6. Reactive Power Supply Capability Table

Voltage Range	Network	Range at Maximum Continuous Rating	Range at 40% of Maximum Continuous Rating
-10% to +10%	MV	Power factor from 0.93 capacitive to 0.85 inductive	Power Factor from 0.7 capacitive to 0.4 inductive
-15% to -		Power Factor from 1.00 to 0.85	PowerFactor from 0.7 capacitive to

10%		inductive	0.4 inductive
-5% to +13%	HV	Power Factor from 0.93 capacitive to 0.85 inductive	Power Factor from 0.capacitive to 0.inductive
-10% to -5%		Power Factor from 1.00 to 0.85 inductive	Power Factor from 0.7 capacitive to 0.4 inductive

In each Fully Controllable or Partially Controllable generation Unit an analog speed governor and load control unit, or relevant load device, are adjusted, in order to allow frequency response under normal operating conditions. The design and operation of the speed governor with usual regulation ranges between 3% and 5%, and is subject to the relevant European specifications which are applicable by the time of the installation design, or if such do not exist, to the relevant specifications that are generally implemented in the European Union.

The Fully Controllable or Partially Controllable Generating Units must have the capability to participate in the NII System voltage regulation with continuous regulation of the unit voltage, through a suitable automatic voltage regulator of continuous regulation, according to the specifications that are determined by the NII SMO based on the NII Code and defined in detail in the Connection Contact. The NII SMO can reject, with a proper justification, the characteristics that are proposed by the Producer.

For Fully or Partially Controllable Generating Units, the following specifications of operating reserves are required:

- Each Unit must have primary frequency regulation capability. The controller droop must comply with the specifications set by the NII SMO. Units must have primary reserve provision capability in MW of Unit output not less than than ZZ% of the registered capacity, at least for a range of more than 50% of the registered capacity. The provided reserve is determined linearly from ZZ% to 100% and from 50% to the technical minimum of the Unit in order to respect the technical minimum and maximum generation limits of the Unit. The ZZ% percentage is set to 10% for all Units.
- This percentage can differ per Unit technology or by NII System up to 20%. The primary reserve must be provided according the definitions described in section 2.2.2.
- Each Unit must provide secondary operating reserve in MW of Unit output not less than XX% percentage of registered capacity at least for a value range between 50% and (100-XX)% of the registered capacity. The provided reserve is linearly determined from (100-XX)% to 100% percentage and from 50% to the technical minimum of the Unit in order to respect the technical minimum and the maximum output of the Unit. The XX% percentage is set at 15% for the combined-cycle Units, at 5% for the steam Units, and at 20% for other Units.

- Each Unit must provide spinning reserve according to the definitions described in section 2.2.2.
- Each Unit must provide non-spinning reserve according to its technical characteristics.

The specifications of design and operation for the Non Controllable RES/CHP that connect to the NII System concern at a minumum the following:

- Operating frequency and voltage limits;
- Uninterrupted operation capability under low voltage;
- Voltage, reactive power and power factor regulation requirements;
- Contribution to Load-Frequency regulation;
- Communication with the NII Energy Control Center.

Partially Controllable RES/ CHP Units must comply with the design and operation requirements that apply to the Fully or Partially Controllable Generating Units of similar technology.

Maximum power output and tertiary reserve provision limits for the Units taken into consideration in the solution of the RDAS and Dispatch Program are constrained by the hourly generation of the Unit.

For Partially Controllable Generating Units that include battery storage systems, that connect to the NII Network though direct/alternative current converters, the following are taken into consideration:

The basic technical design requirements for the storage systems and the converters are as follows:

Table 5-7. Table of Basic Technical Design Requirements for Storage Systems and Converters

Technical Minimum Output	Not greater than 10% of converter’s registered net power
Ramp-up Rate	Must allow for the Unit to increase its capacity from synchronization state to maximum output within 1 minute.
Ramp-down Rate	Must allow for the Unit to lower its capacity from maximum level to technical minimum level within 1 minute.
Minimum up time after Unit startup	Not greater than 20 minutes
Minimum down time	Not greater than 20 minutes
Forbidden Zones	Not permitted
Load under Synchronization	Not greater than 10% of converter’s registered capacity
Synchronization time (after order)	Not greater than 3 minutes
Time period between Synchronization	Not greater than 1 minute

and Minimum Output Level (soak time)	

The basic operational requirements of storage systems and converters are determined in the Connection Contact at the same level as for the respective requirements of the Gas Turbine Units.

Partially Controllable RES/CHP Generating Units must comply with the minimum design and operation requirements that apply to Fully or Partially Controllable Generating Units of similar technology.

The Dispatchable Hybrid Station Units with battery storage systems and direct/alternative current converters, comply with the minimum design and operation requirements that are determined for the Partially Controllable Units with the same storage system technology.

Fully Controllable Generating Units of other RES/CHP Units comply with the minimum design and operation requirements that are determined for Units of similar technology.

Generating Units Variable Cost Requirement

The efficiency of the Conventional Unit, which is calculated for every operating point (net power generation in MW) based on the specific consumption curve of the Unit while taking into consideration the Lower Heating Value of the respective fuel, cannot take any value, at any operating point ranging from the technical minimum to the maximum output, that is lower than 20% for the gas-fired Units, 40% for the Combined Cycle Units, 35% for the Internal Combustion Engines and 30% for the steam Units.

The fuel that is declared for the Unit must be the fuel that is mentioned at the generation licence terms.

5.1.3.4 Declaration Approval/Rejection

The Declaration is evaluated regarding its compliance with the technical requirements and in case that a non-compliance is found a procedure for the declination approval is followed (as it is foreseen by he regulatory framework).

In particular for the techno-economic data of the Unit, as declared, and concern: a) the specific fuel consumption curve, b) the CO2 emission curve, c) the additional variable maintainance and operational cost, and d) the fuel consumption per Unit startup, separately from cold, warm or hot state, it is evaluated if they range within a margin of up to 5% with respect to the prices of the respective Specific Fuel Consumption and CO2 Emission Benchmark Curves, as well as the per Unit Additional Variable Maintenance and Operational and Fuel Consumption per Unit Startup Benchmark Cost, which correspond to the category and the characteristics of the specific Unit, whereupon they are considered accepted.

5.1.4 Table of Unit Registered Characteristics

This Table is filled by the NII SMO, during the registration procedure of a Unit to the Unit Registry.

It is kept in the MF, and contains the following data:

- Final Declaration of Techno-economic Data, as in effect, including the Producers' Declaration (it concerns the modification of techno-economic data due to force majeure).
- Approved Deviations of Techno-economic Data;
- Declaration of Non Availability (Total or Partial);
- Data and information that the NII SMO obtains during the stage of commissioning and electrification of the Unit.

More details be determined during the Detailed Design Phase of the Project.

5.1.5 Maintainance Schedule

The Maintainance Schedule refers to a calendar year, and lists the downtime periods due to scheduled maintainance, for the NII System and each Unit that connects to the network. It is prepared by the NII SMO in collaboration with the Producers.

The Unit Maintainance Schedule and its updates are notified to RAE, published at the NII SMO website, and are binding for all Producers.

In case a Producer cannot adhere to the Unit Maintainance Schedule, he is obliged to declare the non availability of the Unit for the respective time period and to promptly inform the NII SMO, with the submission of a Non Availability Declaration.

5.1.6 Requirements for Economic and Administratively Set Data

All economic and administratively set data, e.g. offer caps, penalty values, other administratively defined prices, etc., should be kept in the MF, and be available for use by all other MMS Applications. At the very least, all data mentioned in this document should be kept, and be updated as required.

Detailed information on these data will be provided at the Detailed Design Phase of the Project.

In the next sections, a brief description is provided for the following:

- Benchmark Curve of Conventional Unit Variable Generation Cost;
- Benchmark per Unit Cost of Conventional Unit Startup;
- Variable Generation Cost Curve and Startup Cost of Conventional Unit;
- Ancillary Services Price.

5.1.6.1 Benchmark Curve of Conventional Unit Variable Generation Costs

The Benchmark Curve of the Conventional Unit Variable Generation Cost consists of pairs of power generation level (MW) for the time period of one hour and total variable cost (€/MWh) taking into consideration:

- The Benchmark Curve of Fuel Cost, which is determined based on the Benchmark Curve of Specific Fuel Consumption.
- The Benchmark Curve of CO2 Emission Cost.
- The Benchmark of the per Unit Additional Variable Maintainance and Operational Cost.

The Benchmark Curves of the Variable Generation Cost are determined so that each category of Conventional Unit and standard combination of characteristics corresponds to only one Variable Generation Cost Curve.

The values of each Benchmark Curve of Variable Generation Cost must adequately cover the generation of the Unit ranging from the Technical Minumum output to the 100% of its registered capacity, so that for all intermediate generation points (between two consecutive values of power in the curve) the respective values can be calculated by linear interpolation.

In particular, for each Conventional Unit category and standard combination of characteristics, the following are determined:

- The Benchmark Curve of the Specific Fuel Consumption;
- the Benchmarket Curve of the CO2 Emissions;
- the methodology parameters, which are determined based on international literature data, standard methodologies and practices, as well as available data and standard measurements from Unit manufacturers;
- The methodology parameters, which are exogenously determined on a monthly basis, based on internationally approved prices and indices, such as the fuel and CO2 emission market prices, as well as their calculation method;
- The methodology parameters, whose values are determined by the Regulatory Period Parameter Determination Desicion.

The calculations of the above will be performed by a HEDNO-developed IT System. The values of the data will be passed to the MMS.

5.1.6.2 Benchmark per Unit Cost of Conventional Unit Startup

The Benchmark per Unit Cost of Conventional Unit Startup is defined based on the Unit fuel consumption for startup from cold, warm or hot state and the fuel prices, and is valued at €/startup for each state.

The Benchmark per Unit Cost of Conventional Unit Startup is defined as the fuel consumption cost for Unit startup, separately for cold, warm and hot stand-by state, until the stabilization of the generation at an operating point that corresponds to the technical minimum output.

The Benchmark per Unit Cost of Unit Startup is determined based on the fuel consumption of the Unit for startup (in kg or lt / startup), from cold, warm or hot state (benchmark of Fuel Consumption per Startup) and the fuel prices (€/kg or lt of fuel), as they are determined, per fuel type, on a monthly basis according to internationally approved fuel price indices, which are transparent and verifiable. The reasonable fuel transportation cost to the NII System where the Conventional Unit is installed is included in these prices, as well as taxes and fees as per the applicable legislation.

The Benchmark per Unit Cost of Conventional Unit Startup is determined per startup (in €/startup from cold, warm of hot state), based on the methodology, per Conventional Unit category, and standard combination of technical and other characteristics similar to those being used for the calculation of Unit variable generation cost.

The Benchmark will be uniquely determined per Unit Cost of Unit Startup per stand-by state, for all Conventional Unit categories, and standard combination of technical and other characteristics.

In particular, for each Conventional Unit category and standard combination of characteristics, the following are determined:

- The benchmark of fuel consumption per startup (in kg or lt / startup), from cold, warm or hot state.
- The methodology parameters which are determined based on international literature data, standard methodologies and practices, as well as available data and certified measurements from Unit manufacturers.
- The methodology parameters, which are determined exogenously per month, based on internationally approved prices and indices, such as the fuel price and CO2 emission market prices, as well as their calculation method.
- The methodology parameters, whose values are determined based on the Regulatory Period Parameter Determination Decision.

The calculations of the above will be performed by a HEDNO-developed IT System. The values of the data will be passed to the MMS.

5.1.6.3 Variable Generation Cost Curve and Startup Cost of Conventional Units

Variable Generation Cost is defined as the per MWh generation cost of electricity from a Conventional Unit for each operating point (€/MWh), and includes the fuel cost, the CO2 emission cost, as well as the additional variable maintainance and operational cost of the Unit.

Fuel cost is determined based on the specific fuel consumption curve (kg or lt of fuel/MWh) for each operating point and the fuel prices (€/kg or lt of fuel), as they are determined, per fuel type, on a monthly basis, according to internationally approved fuel price indices, which are transparent and verifiable. Fuel prices also include the reasonable fuel transportation cost to the NII System on which the Conventional Units are installed, as well as any applicable taxes or fees.

CO_2 emission cost is determined based on the CO_2 emission curve of the Unit (kg CO_2/MWh) for each operating point and the CO_2 emission prices (€/tn CO_2), as they are determined on a monthly basis, according to internationally approved CO_2 emission price indices, which are transparent and verifiable.

The Additional Variable Maintainance and Operational Cost of the Unit is determined by the Regulatory Period Parameter Determination Desicion, in Euro per generating energy unit (€/MWh), and includes the operational cost of the Unit, excluding the fuel cost and CO_2 emission cost, the part of the maintainance cost of the Unit that relates to its operation, as well as the cost margin for the operation of the Unit. The cost margin is uniform per NII Conventional Unit category (e.g. technology and power size) and does not exceed the threshold of 2% of the minimum total variable cost of the most cost-effective Unit of all NII System Units.

During the registration of any Conventional Unit to the NII System Unit Registry, the NII SMO checks if the techno-economic data of the Unit, as they are declared and concern: a) the specific fuel consumption curve, b) the CO_2 emission curve, c) the additional variable maintainance and operational cost, and d) the fuel consumption per Unit startup, separately from cold, warm or hot state, vary within a 5% range compared to the values of the respective Benchmarks for the Specific Fuel Consumption and CO_2 Emission, the per Unit Additional Variable Cost, Maintenance and Operational and Fuel Consumption per Startup, that correspond to the category and combination of characteristics of the specific Unit, whereupon they are considered accepted.

In case that the declared techno-economic Unit data are accepted, the NII SMO determines the Variable Generation Cost Curve and the Startup Cost Curve based on these data for the RDAS and Dispatch Program formulation.

In case that the declared techno-economic data are not accepted, the NII SMO determines the Variable Generation Cost Curve and the Startup Cost Curve of the Unit, for the payments that will be used in the RDAS and Dispatch Program formulation, based on the benchmarks for the Specific Fuel Consumption and CO_2 Emission Curves, as well as the per Unit Additional Variable Maintainance and Operational Cost and Fuel Consumption per Startup, that correspond to the category and standard combination of characteristics of the Unit.

The NII SMO informs in writing the Producer and RAE regarding the Variable Generation Cost Curve and the Unit Startup Cost that will be used for the formulation of RDAS and Dispatch Programs.

The calculations of the above will be performed by a HEDNO-developed IT System. The values of the data will be passed to the MMS.

5.1.6.4 Ancillary Services Price

The price for the provision of ASs for Primary Regulation Reserve and Secondary Regulation Reserve is determined for the NII System by the NII SMO and approved by the Regulatory Authority of Energy in €/MW of capability for the provision of the Unit's relevant registered technical characteristics.

The price for the provision of the Tertiary Regulation Reserve AS refers solely to the provision of Non Spinning Reserve from Units to which an instruction is sent for remaining in stand-by state for a fast start, provided the Producer incurs a cost mainly related to fuel consumption. This price is determined in €/hour and per state (warm and hot), per Conventional Unit category to which the Unit belongs or any other category of RES/CHP and Hybrid Station Unit, and combination of technical and other characteristics.

The calculations of the above will be performed by a HEDNO-developed IT System. The values of the data will be passed to the MMS.

5.2 Rolling Day-Ahead Scheduling

5.2.1 General

The Rolling Day-Ahead Scheduling (RDAS) aims at determining, on a daily basis, the commitment and dispatch of the Dispatchable Units, to safely satisfy the demand of the NII System, subject to security and operational constraints of the NII System as foreseen by the NII Code.

The RDAS is carried out, before the beginning of each Dispatch Day for the entire Dispatch Day (A and B Period of RDAS), and is updated once during the Dispatch Day to which it refers (B Period of RDAS). RDAS is implemented separately and independently for the NII Power System.

The participation in the RDAS shall mean for the NII power System:

- The submission of Load Declarations from Load Representatives for customers that consume energy in the NII System, including Self-Supplying Customers, as well as, producers with storage units and for the loads of the auxiliary systems of their units, when they are not covered by the Unit production.
- The submission of Generation Declarations by production license holders and Autoproducers for Dispatchable Units.
- The submission of Declarations by the NII SMO.
- The submission of Availability and Non-Availability Declarations by Producers for their Units.

5.2.2 RDAS Timeline

The RDAS timeline for Dispatch Day D (starting at 00:00) is as follows:

D-6h: Deadline for submission of declarations.

D-3h: RDAS solution. Publication and notification of RDAS data.

D+8h: Deadline for updated generation declarations submission for RDAS Period B.

D+10h: Solution of RDAS Period B of current day D. Publication and notification of RDAS Period B data.

The timeline is indicative and may be subject to changes.

5.2.3 Collection and Validation of the Declarations submitted in the context of RDAS

For the RDAS clearing purposes, the following declarations are submitted:

1. Load Declarations;

2. Generation Declarations;
3. NII SMO Declarations;
4. Availability and Non-Availability Declarations.

5.2.3.1 Load Declarations

Submission Obligation:

- The Load Representatives for the consumption of their customers and the Self-Supplying Customers (non-binding).
- The Producers whose Power Stations absorb energy from the network for serving their needs, except for the self-consumption, and the producers of the Hybrid Plants for absorption of energy from the network for the needs of their storage systems (binding).

The submissions are performed through the MUI and are considered legal (from the VS) if the following requirements are met:

- The Suppliers Load Declaration concerns the energy absorption in MWh, for each Dispatch Hour of the Dispatch Day, for all the customers represented by the Supplier.
- The Self-Supplying Customers Load Declaration concerns the energy absorption in MWh of the Self-Supplying Customer for each Dispatch Hour of the Dispatch Day.
- The Producers Load Declaration, whose Power Stations absorb energy from the network for serving their needs, except for their self-consumption, concerns the absorption of energy in MWh for each Dispatch Hour of the Dispatch Day.
- The quantity of energy which is included in the Load Declaration is defined with a half MWh precision for large (Rhodes) and medium sized NII Systems and with a ten kWh precision for small sized NII Systems.
- The Load Declaration shall concern either only the upcoming Dispatch Day or more consecutive Dispatch Days within the current month.
- The hourly dispatch and the total declared energy shall not exceed the respective amounts based on which the applicable guarantees have been calculated and paid, as listed in the MF.
- Especially for the Hybrid Plants the following requirements hold:
    - If the energy to be injected, as stated in the Generation Declaration for energy injection from the Hybrid Station, is less than the energy quantity in MWh, which is equivalent to the guaranteed power multiplied by the number of guaranteed power supply hours, according to the production license terms of each Station, hereinafter designated as Guaranteed Energy, a Preliminary Energy Absorption Declaration is submitted by the

Producer for the needs of the storage systems of the Station, in order to allocate, for the time horizon of the Dispatch Day, this energy in total, if this is required by the NII SMO.

- The energy stated in the Preliminary Energy Absorption Declaration shall be reasonable, based on the efficiency of the energy operation cycle of the storage system (absorption-storage-production) of the Station.
- The Preliminary Energy Absorption Declaration includes the necessary energy in MWh which needs to be absorbed in total during the Dispatch Day by the NII Network, so that the Guaranteed Power requirements are met, according to the production license terms of each Station, if this is required by the NII SMO.
- This declaration includes also binding declaration for capability of energy absorption from the NII System per Dispatch Period, which incorporates any schedule for the absorption units of the Hybrid Stations for energy storage from its RES Units.

A submitted declaration can be replaced up to 2 times, until the submission deadline.

The NII SMO accepts or rejects the Declarations and imposes the applicable sanctions if required.

Implementation details will be determined during the Detailed Design Phase of the Project.

5.2.3.2 Generation Declarations

Submission Obligation:

- The Producers of conventional fuel Dispatchable Units, separately for each Dispatchable Unit.
- The RES/CHP Producers and Hybrid Stations for each Dispatchable Unit with energy offer in the RDAS.
- The RES/CHP Producers that can submit hourly production schedule for each Unit or for the entire Station.
- The Autoproducers for the Units of their facilities, for the above cases respectively.

The above obligation shall be suspended for the time in which the Unit is under Scheduled Maintenance and during the period of validity of a Non-Availability Declaration.

All the above, except for the Producers of conventional fuel Dispatchable Units, are entitled to submit an updated Generation Declaration for the RDAS B Period.

Other RES or CHP Producers and Autoproducers of Non Dispatchable Units do not submit Generation Declaration.

The submission is performed through the MUI and the declarations are considered legal (by the VS), if the following requirements are met:

- The Generation Declaration of conventional fuel Dispatchable Units concerns the maximum quantity of energy in MWh which the Unit is capable to inject in the network for each Dispatch Period of the Dispatch Day (maximum net hourly power).
- The Generation Declaration of RES/CHP and Hybrid Station Dispatchable Units with energy offer in the RDAS concerns the quantity of energy in MWh which each Unit will inject in the network, in total for the time horizon of the Dispatch Day.
- The Generation Declaration of RES or CHP from Stations with hourly generation schedule concerns the quantity of energy in MWh that the Station will inject in the network for each Dispatch Period of the Dispatch Day.
- The Generation Declaration of Autoproducers concerns the quantity of energy in MWh which will be produced and separately the quantity of energy in MWh which the Station will inject in the NII Network for the relevant Unit categories.
- The updated Generation Declaration of RES or CHP or Hybrid Station Dispatchable Units with energy offers in the RDAS or from Stations with hourly generation schedule or Autoproducer Units of these categories, has a similar content to the Generation Declaration and concerns the time horizon of the RDAS B Period.
- The quantities of energy which are included in the above declarations are defined with a half MWh precision for large and medium sized NII Systems and with a ten kWh precision for small sized NII Systems.
- The Generation Declaration of Dispatchable Units may concern either only the upcoming Dispatch Day or more consecutive Dispatch Days within the current month.

Especially for the Generation Declaration of Hybrid Stations, the following requirements apply in addition:

- The Hybrid Station Producer submits a Generation Declaration for energy injection in the NII Network for the energy which intends to supply to the NII network, until the deadline for the submission of Load and Generation Declarations.
- The Generation Declaration can be distinguished by the Producer in the offered energy separately for each RDAS Period (A and B). The energy that is offered for the first RDAS Period shall not exceed 50% of the total offered energy in the Generation Declaration. The NII SMO shall make any effort for the absorption of the offered energy in each RDAS Period if this is compatible with the goal accomplishments of the RDAS clearing and the Dispatch Schedules.

- The Generation Declaration shall take into account the technical characteristics of the Controllable Units of the Hybrid Station and correspond to a sufficient energy size for the operation of a Dispatchable Unit of the Station, which is declared available for the Dispatch Day for at least two (2) hours in its maximum power, otherwise a Generation Declaration with zero offered energy is submitted.

A submitted declaration can be replaced up to 2 times, until the submission deadline.

The NII SMO accepts or rejects the Declarations and imposes applicable sanctions if required.

Implementation details will be determined during the Detailed Design Phase of the Project.

5.2.3.3 Declarations submitted by the NII SMO

The NII SMO has an obligation to submit the following Declarations:

- Declaration for the Units which are in commissioning/testing operation.
- Declaration of maximum expected injection based on the Non Dispatchable RES and CHP Units forecast.
- Total Load Declaration based on load forecast.
- Active Power Reserve Requirements.

Declaration for the Units in Commissioning/Testing Operation

The Declaration concerns the energy quantity in MWh which the Dispatchable Units in commissioning/testing operation are scheduled to inject in the NII Network for each Dispatch Period of the Dispatch Day.

Declaration of maximum expected injection based on Non Dispatchable RES and CHP Units forecast

The Declaration concerns the energy quantity in MWh which is estimated that the Non Dispatchable RES and CHP Units will inject at maximum (maximum expected based on forecast) in the NII Network for each Dispatch Period of the Dispatch Day, according to the relevant RES generation forecast performed by the NII SMO.

The NII SMO, in the context of RDAS, performs the RES and CHP generation forecast for the Non Dispatchable RES and CHP Units for which Generation Declarations are not submitted, taking into account the following:

- Non Availability Declarations of the Non Dispatchable RES and CHP Units.
- Historical production data of RES/CHP and Hybrid Stations per technology and statistics resulting from their processing.
- Weather forecasts and relevant statistical data correlating RES/CHP and Hybrid Station generation with weather parameters.

- The Technical Characteristics of RES and CHP and Hybrid Stations Units, which are connected to the Network, mainly the energy efficiency with respect to the RES type and the potential categorization of them.
- Other data which are collected and/or reported to the NII SMO about the availability and the operating status of the Units, as well as the NII System operating status. In particular, each Producer with Non Dispatchable Units must immediately inform the NII SMO in case of important damage of the Units or sustained outage for any reason.

The result of the above process is the estimate of the average hourly energy production in MWh, for each Dispatch Period of the Dispatch Day, either per operational zone (if such is defined) or in total.

Total Load Declaration

The declaration concerns the amount of energy in MWh that is estimated to be absorbed in total by the NII Network for each Dispatch Period of the Dispatch Day, according to the relevant load forecast performed by the NII SMO.

The NII SMO, in the context of RDAS, performs the load forecast for each Dispatch Period of the Dispatch Day, taking into account the following:

- Accepted Load Declarations of the Load Representatives.
- Energy injection forecast from RES/CHP which are exempted from the dispatch and operation instructions of the Units, either having obtained an exemption from the Code obligations or because they fall into one of the following categories:
    - Non Dispatchable RES/CHP Units with installed capacity less than or equal to 100 kW regardless of the category they belong to or the RES or CHP technology, which are installed in large sized power systems.
    - Non Dispatchable RES/CHP Units with installed capacity less than or equal to 50 kW regardless of the category they belong to or the RES or CHP technology, which are installed in medium and small sized power systems (not applicable for Rhodes).
    - RES/CHP Units and Hybrid Stations which are in commissioning/testing operation period.
    - Power Plants which are not connected to the NII Network.
- Historical load data and statistics resulting from their processing.
- Weather forecasts and relevant statistical data correlating load with weather parameters.
- Network operations which will affect the load to a certain Connection Point in the NII System.

- Other data which are collected and/or are reported to the NII SMO, such as e.g., change in the content of the Load Declaration which exceeds the deviation tolerance, as well as any other information which shall affect the Meter energy quantities of the Load Representative.

The result of the above process is the estimate of the NII System Load in MWh, for each Dispatch Period of the Dispatch Day, either per operational zone (if such is defined) or in total.

Active Power Reserve Requirements

The requirements of ASs (Active Power Reserves) are determined separately for Primary, Secondary and Tertiary System Control, for each dispatch Period of the Dispatch Day, or by operational area (if such is defined) or in total.

5.2.3.4 Availability and Non-Availability Declarations

They are submitted by Producers for their Generation Units. The Non-Availability Declaration is distinguished between Total or Partial Non Availability.

Total Non-Availability Declaration: In case of a Unit outage, which was declared available in the RDAS, and which prohibits the electricity generation from that Unit at least until the end of the deadline for submission of declarations (regular or updated), the Producer is obliged to submit a Declaration of Total Non-Availability of the Unit, in which an estimated time of non availability should also be mentioned.

Partial Non-Availability Declaration: In case of a Unit outage, which was declared available in the RDAS, and which prohibits the electricity generation up to the Unit Net Power or which imposes a change to the Unit Registered Technical Characteristics, for at least until the end of the deadline for submission of declarations (regular or updated), the Producer is obliged to submit a Declaration of Partial Non-Availability of the Unit, in which the new characteristics of the unit and an estimated time of the partial non availability should also be mentioned.

The Non-Availability Declaration includes the description of the technical reasons, for the Unit non availability. During the commissioning and testing operation of the Unit, the Producer can submit a Partial Non-Availability Declaration without reference to a particular reason.

The declaration is valid until the end of its declared period, unless it is earlier withdrawn by the Producer.

The validity period of a Non-Availability Declaration cannot refer to a time period prior to the time of submission.

The NII SMO can reject a submitted Non-Availability Declaration, if he realizes that this is not true and does not comply with the NII Code provisions; in this case he applies the foreseen sanctions.

5.2.4 RDAS Solution

The following general description of the RDAS problem corresponds to an optimization problem whose objective function aims at the maximization of the social welfare, for all Dispatch Periods of the Dispatch Day, subject to the units and the system technical constraints.

The Contractor will present to the NII SMO a final mathematical formulation of the RDAS problem, in which the input data, the decision variables, the objective function, and the constraints will be fully defined. The user should be able to enable or disable each one of the constraints.

Details of the algorithms used for the RDAS solution will be determined during the Detailed Design Phase of the Project. The Contractor is responsible for the selection of the algorithms required to adhere to the specifications contained in the Tender.

5.2.4.1 Input Data

For the RDAS formulation, for the following Dispatch Day, the following data are taking into account:

- The accepted Generation Declarations (submitted in the RDAS)
- The Declarations submitted by the NII SMO (submitted in the RDAS).
- The availability of the Units, according to the approved maintenance schedule, which is kept in the Master File, and the Non-Availability Declarations of the Units (submitted in the RDAS).
- Technical parameters of the Dispatchable Units from the Table of the Unit Registered Characteristics and especially:
    - Technical minimum;
    - Ramp rates;
    - Minimum times in a certain state or transition between states.
- Economic parameters of the Dispatchable Conventional Units (obtained from the Master File) and especially:
    - The Variable Generation Cost curve of each Unit.
    - The startup cost from any stand-by state until the load corresponding to the technical minimum.
    - The cost of ASs.
- Status of the Units as they are scheduled to operate during the Dispatch Periods preceding the first Dispatch Period of the Dispatch Day. It is obtained either from the last RDAS or from the last Dispatch Schedule (if it covers that time period).

The update of the Day-Ahead Schedule is performed with the above data, as they have been updated during the Dispatch Day and the updated Generation Declarations, which refer to the RDAS B’ Period.

5.2.4.2 Decision Variables

The RDAS results include:

- The synchronization, de-synchronization or operation of Dispatchable Units for each Dispatch Period.
- The energy scheduled to be produced by the conventional fuel Dispatchable Units, for each Dispatch Period of the Dispatch Day.
- The energy scheduled to be produced by RES/CHP or Hybrid Station Dispatchable Units with energy offer in RDAS, for each Dispatch Period of the Dispatch Day.
- The energy scheduled to be produced by the Dispatchable RES or CHP Units with hourly schedule, for each Dispatch Period of the Dispatch Day.
- The energy expected to be injected by the Non-Dispatchable Units for each Dispatch Period of the Dispatch Day.
- The energy planned to be absorbed by the Hybrid Stations for the needs of their storage systems.
- The ASs planned per Unit with such a capability.

Implementation details will be determined during the Detailed Design Phase of the Project.

5.2.4.3 Objective Function

The methodology of the Day Ahead Schedule Clearing Mechanism (and of the Updated one) includes the formulation and solution of the problem, simultaneously for all the Dispatch Periods of the Dispatch Day and/or the RDAS B’ Period, aiming at the maximum possible penetration of RES and CHP and Hybrid Stations, while minimizing the total operational cost of the Conventional Generation Units.

The Day Ahead Schedule problem, as well as the Updated Day Ahead Schedule are cleared simultaneously for all the Dispatch Periods, of the Dispatch Day, and for the RDAS B’ Period respectively.

The energy absorption from the network is allocated in such a way that the optimal technical and economic result for the NII System operation is achieved, i.e., it is applied by priority during the low load hours.

5.2.4.4 Constraints

For the RDAS formulation, the following constraints are taken into account:

- Energy Balance for each Dispatch Hour of the Dispatch Day

- Meeting Active Power Reserve Requirements for each Dispatch Hour of the Dispatch Day.
- Technical constraints for each conventional fuel Dispatchable Unit and RES/CHP and Hybrid Station Dispatchable Unit, for each Dispatch Period of a Dispatch Day:
  - Maximum Generation Capability
  - Technical Minimum Generation
  - Ramp rates
  - Minimum time in a certain state or transition between states
- Full absorption of the energy offered by RES/CHP or Hybrid Stations Units according to the Generation Declarations, if this is technically feasible.
- Satisfying operating rules for RES or CHP Units or Hybrid Stations.
- Technical constraints for the energy flow between operational zones, while meeting the requirements for the safe operation of the NII Network.
- Ability to determine must-run units.

5.2.4.4.1 Operating Rules for RES or CHP or Hybrid Station Units.

The RES Units of a Producer or Autoproducer, as well as the RES Units and the Controllable Units of the Hybrid Stations have priority over the CHP Units.

The NII SMO is obliged to absorb at priority the energy generated by the RES Units of all categories including the Units of Hybrid Stations as well as by the CHP Units, compared to the conventional Units, with the reservation of the safe operation of the NII System. In this context, the above priority is not applicable for the technical minimum generation of the must-run Conventional units, as they have been defined for each NII System, as well as for any generation of Conventional Units which are necessary to provide the ASs, which cannot be provided by the RES/CHP Units and the Hybrid Stations.

In what follows, specific rules are listed, which are implemented in case of infeasibility of the market-clearing problem, due to failure of satisfying the constraint of absorbing all energy offered according to the Generation Declarations by the RES or CHP or Hybrid Station Units.

5.2.4.4.2 Dealing with Problem Infeasibility

<u>In case of problem infeasibility, due to failure of satisfying the constraint of absorbing all energy offered according to the Generation Declarations by the RES or CHP or Hybrid Station Units,</u> the NII SMO solves again the problem removing this constraint and following the specific rules of dispatch and operation of the RES/CHP and Hybrid Plants.

The following rules are applicable in all market-clearing processes, both in the RDAS and the DS Process and the Real Time Operation. For this reason and to avoid text repetition, although this section concerns RDAS, the rules are listed for all processes.

<u>In case that in a specific Dispatch Period the energy offered by RES/CHP and Hybrid Station Units cannot be fully absorbed,</u> for the RDAS or DS resolution or during the real time dispatch, a restriction is applied in the generation of these Units, based on the following specific rules and principles, so that the solution is feasible:

- The RES/CHP and Hybrid Station Units generation restriction takes place only if it is not feasible to further restrict the generation of conventional Units which are necessary to be dispatched for the secure operation of the NII System (e.g. the provision of the necessary Active Power Reserves) taking into account their technical minimum.
- The RES Units and the Hybrid Station RES Units have priority over the CHP Units, so the restriction of the generation of these Units takes place only if it is not feasible to further restrict the CHP which have been dispatched in the Dispatch Period at their technical minimum.
- The Hybrid Station Controllable Units have priority in the commitment over the Conventional and CHP Units.
- Especially for the Units that offer Energy in the RDAS, such as the Hybrid Stations, the initial scheduling of the hourly generation of these Units is of priority, in the RDAS solution, without considering the active power balance constraint (supply-demand).
- The restriction of the power output of the RES or CHP or Hybrid Station Units is performed proportionally up to the point that the technical minimum output of any Unit of this category is about to be violated. The proportional restriction for all the Fully Controllable and Partially Controllable Units is performed based on the scheduled power for that Dispatch Hour. For the non Dispatchable RES and CHP Units, this restriction is performed for the RDAS and the DS based on the foreseen power output, whereas for the real-time dispatch, based on the maximum declared available capacity.
- If the restriction of the RES/CHP and Hybrid Station generation allows the de-commitment of a Conventional Unit, based on the rules for the secure operation of the NII System, and if this de-commitment is allowable, it is performed and the load is re-allocated proportionally firstly to RES Units, followed by the Hybrid Station Controllable Units, followed by the CHP Units.
- If a RES/CHP or Hybrid Station Unit de-commitment is required, the first to be de-committed are the CHP Units.

- If the Conventional Unit or the CHP Unit cannot be de-committed, and a RES and Hybrid Station Controllable Unit de-commitment is required, then the following are taken into account:
    - The RES Hybrid Station Controllable Units that provide the necessary ASs (such as the Active Power Reserves) are considered in a uniform way and are the last to be de-committed.
    - RES Hybrid Station Controllable Units that do not provide the necessary ASs (such as the Active Power Reserves) are the first to be de-committed. The de-commitment is performed progressively in Unit by Unit basis, until the RDAS and DS constraints are satisfied. The NII SMO manages the rotation in the Unit de-commitment per category and technology, so that a balanced outcome is achieved for all these Units on a yearly basis.
- The generation of the Non-Dispatchable RES Units, beyond that included in the daily binding generation schedules, and which can be absorbed by the NII System, according to the Dispatch Program, is primarily allocated per technology according to the RES generation forecast, and secondarily to the Stations of same technology based on the available capacity according to their Capacity Availability Declarations. In cases of Stations that submit binding daily generation schedule, this allocation is performed based on the Capacity Availability Declaration, except for the power that is considered guaranteed according to the relevant Declaration of the Producer.
- For RES or CHP Unit for which the capability for energy generation from conventional fuel is foreseen in their generaiton licence and relevant provisions, this generation is of the same priority with the respective one of RES or CHP Unit.

<u>In case of problem infeasibility, because of not meeting the energy balance or the Active Power Reserve Requirements</u>, the NII SMO repeats the RDAS clearing, taking into account the Guaranteed Energy and the relevant Energy Absorption Declaration from these Hybrid Stations whose Generation Declaration falls short of the Guaranteed Energy.

<u>If during the RDAS clearing process the need for energy absorption from the network appears for some Hybrid Stations and Declarations for energy absorption of these Stations exceed the technical capabilities of the available Units of the NII System</u>, the NII SMO curtails the energy to be absorbed, proportionally based on the guaranteed energy of each Hybrid Station Producer.

<u>In the case that the problem is infeasible</u>, the NII SMO applies the appropriate procedures for the Load Curtailment.

Implementation details will be determined during the Detailed Design Phase of the Project.

5.2.5 RDAS Record Keeping

The NII SMO is obligated to keep full data about the RDAS operation, including of the RDAS update, in an organized database, per NII System, aggregated and per participant, which includes at least:

- The data, parameters and constraints that are taken into account in the RDAS solution (including Load Forecasting, RES generation and Active Power reserve requirements).
- The RDAS solution results.
- Record with the receipts of the RDAS results notified to the participants.
- Record with the information collected from the notifications to the NII SMO (changes).
- Record with the violations due to a non legal Load Declaration, non legal Generation Declaration, non legal Non-Availability Declaration, for each Load representative and Producer.

The above data are kept by the NII SMO for a period at least five (5) years and the RDAS participants can have access to them.

5.2.6 Notification of the Participants and Data Disclosure

The NII SMO shall publish in its website or disclose the following information:

- Load and RES Forecast.
- RDAS clearing Results.
- Total availability for providing active power reserves, for each reserve type.
- Preliminary data of the actual operation of the NII System, for each Dispatch Period of the previous Dispatch Day, comprising:
  - The actual load
  - The generation of RES/CHP and Hybrid Station Units, as well as the conventional Units, separately per Unit.
- The part of the Day-Ahead Schedule that concerns those who submitted valid Generation Declarations.

5.3 Dispatch Scheduling

5.3.1 General

Dispatch Scheduling (DS) aims at the scheduling, in real time, of the Dispatchable Units operation, the management of the NII System for energy injection by the Non-Dispatchable RES and CHP Units, as well as the issuing by the NII SMO of the relative Dispatch Instructions, so that the total energy absorption from the NII System, according to the NII SMO forecasts and measurements, is implemented, ensuring the proper and reliable NII System operation, the effective response to NII System unforeseen events, the quality of supply, the minimization of the total expenses and the maximization of the energy absorption from RES/CHP (RES/CHP Units and Hybrid Stations).

In the context of DS, the NII SMO collects all necessary data, updates the forecasts for the NII System load and the Non-Dispatchable RES and CHP Units generation, prepares the DS Program and issues the Dispatch Instructions.

The main operation regarding the DS are summarized as follows:

- Data collection and control which are reported in the DS context.
- DS Program preparation.
- Issuing and sending Dispatch Instructions.

5.3.2 DS reported Data Collection and Control

In the DS context, the NII SMO collects information about the availability and the operation status of the Units, as well as the NII System operation status. Briefly, the reported data include the following:

- From the Dispatchable Unit Producer, changes with respect to:
  - The new content of the Generation Declaration when its content is expected to be changed or has been changed due to force majeure, for one or more Dispatch Periods of the Dispatch Day, beyond the tolerance deviation.
  - The Non-Availability of the Unit.
  - The new generation capability of his Unit for each Dispatch Period of the Dispatch Day, when the Unit was declared as non-available and the reasons for the non-availability reasons no longer hold.
  - Any information included in the Techno-Economic Declaration of the Unit that has been modified or is expected to be modified, due to force majeure, for one or more Dispatch Periods of the Dispatch Day with special documentation.

- Every transition of the Unit thermal status between the states cold, hot and warm, in case of a Unit with multiple states.

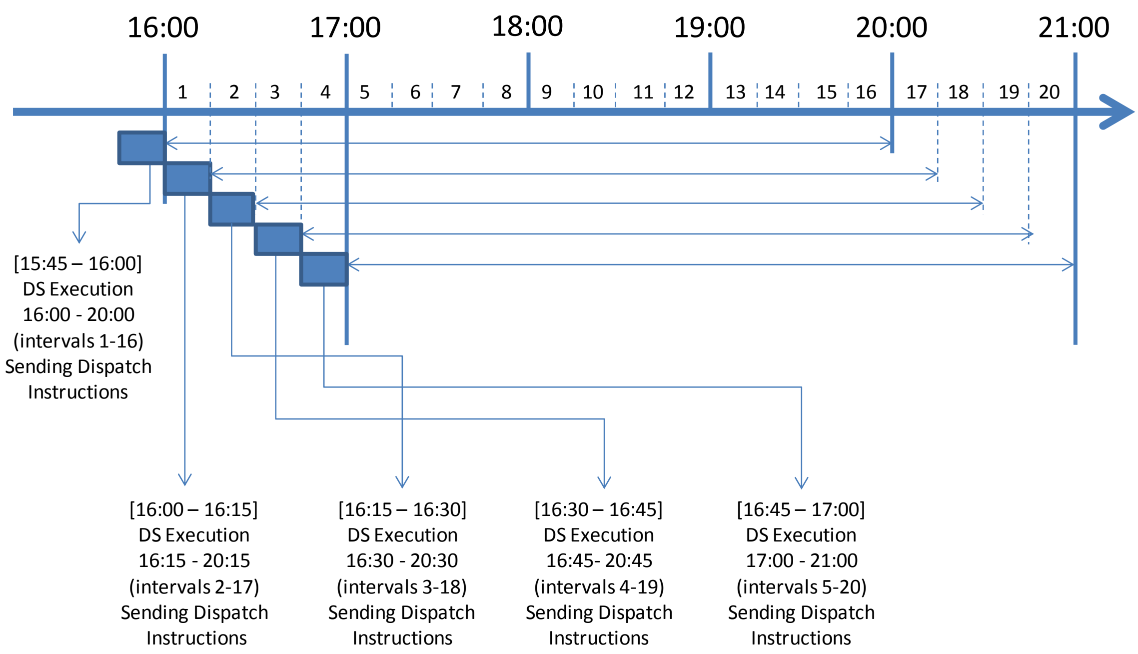
- From Non Dispatchable Unit Producer in case of a major damage of the Units or sustained outage for any reason.
- From Load Representative who has submitted Load Declaration, any change in the content of the declaration which exceeds the deviation tolerance, as well as any other information which may affect energy quantities of Meters he represents.

The data submissions are performed through the User Interface of the Market Management System (MMS).

Implementation details will be determined during the Detailed Design Phase of the Project.

5.3.3 Preparation of Dispatch Schedules

The NII SMO prepares the Dispatch Schedule periodically every 15 minutes for the following 4 hours from the beginning of the Dispatch Day with a time interval of 15 minutes. Commitment instructions issued in previous intervals are respected in the relevant subsequent optimization cycles. After the Dispatch Schedule preparation, the NII SMO promptly informs the Producers for the scheduled operation of their Units according to the current Dispatch Schedule.



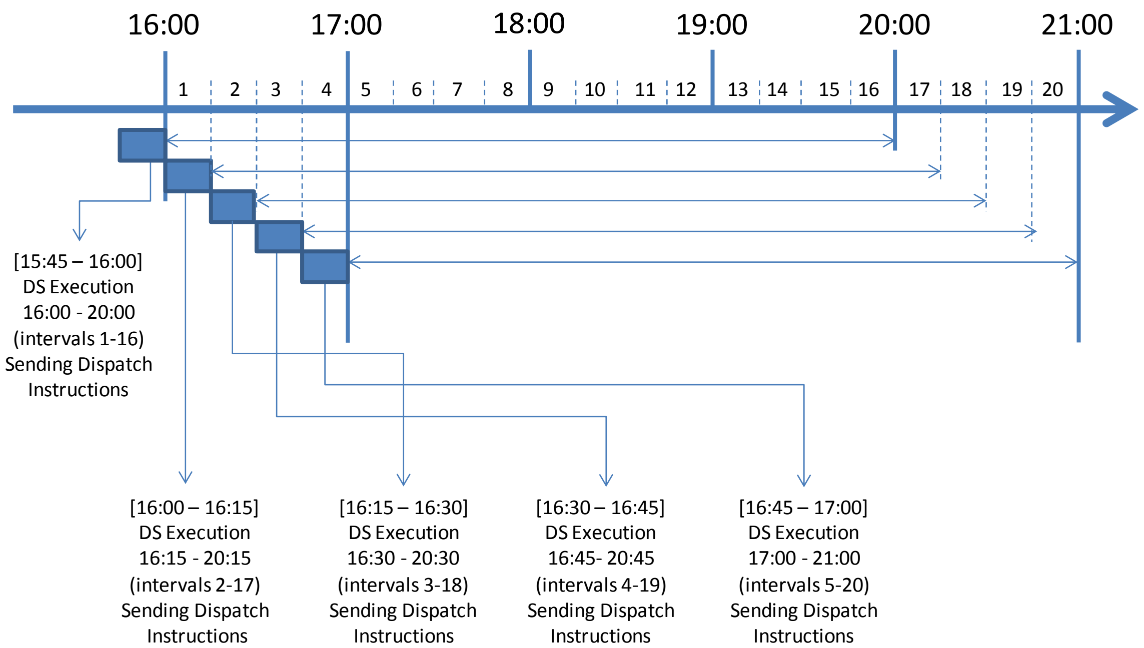


Figure 5-1. Indicative Dispatch Schedule Preparation

In small and medium sized NII Systems (not applicable for Rhodes), in which no Fully or Partially Controllable RES/CHP Units or Hybrid Stations operate, the Dispatch Schedule can be prepared by the NII SMO at longer time intervals.

The Dispatch Schedule preparation includes the data and the constraints for the formulation of the problem, the results and the methodology.

Implementation details will be determined during the Detailed Design Phase of the Project. Details of the algorithms used for the RDAS solution will also be determined during the Detailed Design Phase of the Project.

5.3.3.1 Data and Constraints

For the DS formulation and the issuing of the Dispatch Instructions, the following are taken into account:

- The RDAS data and the constraints, as they may have been modified based on:
  - The data collected by the NII SMO about the availability and the operating status of the Units, as well as the NII System operating status.
  - The updated load, RES and CHP generation, and active power reserve requirements forecasts.
- The technical constraints and limitations for safe operation of the network.
- The requirements and the constraints for the provision of other ASs (except for Active Power Reserves).

Implementation details will be determined during the Detailed Design Phase of the Project.

5.3.3.2 Decision Variables

The Dispatch Schedule results for each Period of its time horizon are the following:

- The startup (synchronization) or the shutdown (de-synchronization) or the operation of the Dispatchable Units.
- The energy which is scheduled to be generated by the Conventional Dispatchable Units.
- The energy which is scheduled to be generated by the Dispatchable RES or CHP Units or Hybrid Stations with energy offer in the RDAS.
- The energy which is scheduled to be generated by the Dispatchable RES or CHP Units with hourly energy schedule offer.
- The energy which at maximum can be injected by the Non Dispatchable RES or CHP Units, including the RES Units of Hybrid Stations.
- The energy which is scheduled to be absorbed by the Hybrid Stations for the needs of their storage systems.
- The ASs, as they are allocated to Units, to meet the respective requirements.

Implementation details will be determined during the Detailed Design Phase of the Project.

5.3.3.3 Methodology

The methodology for the Dispatch Schedule consists of formulating and solving the problem, simultaneously for all the Dispatch Periods of problem horizon (time horizon of 4 Dispatch Hours following the beginning of the DS problem), aiming at the maximum possible RES and CHP penetration (RES/CHP Units and Hybrid Stations) while minimizing the total operational cost of the Conventional Units. Furthermore, the Dispatch Schedule should aim at:

- Restoring or preserving the active power reserve margins within the required limits.
- The minimum deviation from the Day Ahead Schedule, with respect to the Dispatchable Units commitment and dispatch.

In case of problem infeasibility, due to failure of satisfying the constraint for fully absorbing the energy offered by the Generation Declarations of the RES or CHP or Hybrid Station Units, the NII SMO re-solves the problem removing this constraint and following the specific rules of dispatch and operation of the RES/CHP Plants and Hybrid Stations, as in the RDAS process.

In case of problem infeasibility, due to failure of satisfying the constraints of the energy balance or the Active Power Reserve Requirements, the NII SMO proceeds with a Load Curtailment program.

In case that the DS solution violates any of the network constraints or other ASs, the NII SMO shall manually modify the program, until the constraints are satisfied.

Implementation details will be determined during the Detailed Design Phase of the Project.

5.3.3.4 Elements of Problem Formulation

The Contractor shall present to the NII SMO a final mathematical formulation of the DS problem, in which the input data, the decision variables, the objective function and the constraints will be fully defined. The formulation is similar to the RDAS problem formulation.

The time horizon of 4 hours and the discretization of 15 minutes will be parameterized.

5.3.4 Issuing and Sending of Dispatch Instructions

The NII SMO issues and sends Dispatch Instructions to the participants, starting from the notification of the part of the Dispatch Schedule which refers to them, and may re-send new Instructions, if necessary, depending on the deviation of the power system operating conditions, during the Real Time Dispatch.

Briefly, the NII SMO issues Dispatch Instructions:

- For the operation of Dispatchable Conventional Units and Dispatchable RES/CHP and Hybrid Stations Units with energy offer in the RDAS, separately for each Unit.
- For the RES and CHP Units with an hourly schedule, and the non Dispatchable RES and CHP Units, exclusively for the restriction of their generation, in relation to the Generation Declaration or their technical maximum capacity. The Dispatch Instructions for RES and CHP Units of Non-Controllable Generation refer to the total generation of each Station. Issuing a Dispatch Instruction is possible for parts of the Station that are connected to a different point of the network, if this is justified by network limitations.
- Dispatch Instructions, according to the Code, are also considered the instructions through automated control systems, such as the Automatic Generation Control system, the system for sending setpoints to limit Non Dispatchable RES and CHP Units etc.
- Units Synchronization and De-synchronization Dispatch Instructions.
- Dispatch Instructions about the adjustment of the Dispatchable Units Reactive Power (capacitive or inductive).

Any subsequent Dispatch Instruction replaces the respective previous one (on the same subject).

In cases where the Dispatch Instructions include numerical values for the Active or Reactive Power or the voltage level of the Dispatchable Unit, these values refer to the Connection Point of the Unit to the Network.

5.3.4.1 Active Power Dispatch Instructions

For each Unit the Active Power production level determined by Dispatch Instructions cannot be lower than the technical minimum generation of the Unit.

5.3.4.2 Unit Synchronization and De-synchronization Dispatch Instructions

With respect to the Unit Synchronization and De-synchronization Dispatch Instructions the following shall apply:

- The Dispatch Instructions about the Synchronization and De-synchronization of the Units are issued following the preparation of the RDAS or DS and in the appropriate time, taking into account the technical characteristics for the synchronization and de-synchronization of the Units and the transition between the thermal states.
- The NII SMO, before issuing a Unit synchronization Dispatch Instruction or after issuing of Unit de-synchronization Dispatch Instruction, can issue Dispatch Instructions concerning the thermal state of the Unit, among the categories cold, warm and hot. The Producers are obliged to inform the NII SMO about the thermal state status of the Unit.
- In case a Dispatch synchronization Instruction does not include a specific numerical value for active power generation, it is presumed that the Instruction concerns the increase of the production after the synchronization to the Unit technical minimum, whereas when the Dispatch Instruction does not include specific numerical value for reactive power production, it is presumed that the Instruction concerns the Reactive Power production of zero (0) MVAr following the synchronization.
- In case a de-synchronization Dispatch Instruction does not include a specific numerical value for Reactive Power production, it is presumed that the Instruction concerns the decrease of the Reactive Power production to zero (0) MVAr at the synchronization point, during the de-synchronization time.

5.3.4.3 Reactive Power Dispatch Instructions

The NII SMO issues Dispatch Instructions regarding the adjustment of the Reactive Power (capacitive or inductive) by the Dispatchable Units as follows:

- A Dispatch Instruction that refers to the Reactive Power production can determine the numerical value for the voltage that needs to be achieved at the Unit Connection Point.
- In issuing an Active Power Dispatch Instructions, the impact of the Instruction on the Unit Reactive Power production capability is taken into account, and vice versa.
- The Dispatch Instructions for the Autoproducers Units refer to the aggregate generation of these Units.
- The Dispatch Instructions for Hybrid Station storage units can refer to ASs.

Implementation details will be determined during the Detailed Design Phase of the Project.

5.3.5 DS Record Keeping

The NII SMO is obligated to keep full data DS operation, in an organized database, for the NII System, aggregated and per participant, which includes at least:

- The data, the parameters and the constraints that are taken into account for the DS solution (including Load, RES generation, and Active Power reserve requirements forecasting).
- The content of the Dispatch Instructions and the receipts of the Dispatch Instructions.
- Record with the information, which have been collected from notifications to the SMO (changes).

The above data are kept by the NII SMO for a period of at least five (5) years and the participants can have access to them.

5.4 Cost-Based Real-Time Dispatch (RTD)

5.4.1 General

In this project, the RTD will be executed by deploying cost-based data of units, and not priced offers by MPs as is the case in real-time markets. As such, we call this application cost-based RTD. In the remaining of the Section, when there is a reference to RTD, it is meant to be for the cost-based RTD.

The RTD calculates, periodically or upon AGC trigger, base-points for all units (re-dispatches generation) by minimizing cost objective based on the techno-economic generator cost data, and prioritizing RES absorption as per Code Requirements. The RTD optimizes the generation dispatch considering the actual data and conditions (measured production, actual capacity limits, synchronization and control status of the units and the ramping capabilities of the on-line units, etc.) as well as the very short term load and RES generation forecasts within the next 5 minutes.

Typically the RTD executes automatically every five (5) minutes but under certain conditions AGC or a system operator's request can trigger its execution. The AGC should trigger the RTD to run (for an “out of sequence” execution) upon the occurrence of a specific system conditions, such as a significant change in power system load, a change in any generating unit’s operational status, a system emergency or a change in the control mode, etc. The RTD re-optimizes the energy production while meeting primary and secondary reserves, according to the current system conditions. The operator will also be able to specify manual dispatch instructions or constrain the dispatch of any unit. These manual instructions and constraints must be classified and recorded for auditing purposes and for settlements.

The RTD provides the base-points for the units/plants to the AGC RTD module. Then the base-points are processed by the AGC by considering respective regulation component of the units and dispatch instructions are calculated and issued to all dispatchable units/plants. For the units that are not automatically controlled by the AGC but participate in the market, the RTD notifies each unit, through the SCADA subsystem of EMS, the respective base-point as a manual instruction. These manual instructions (unfiltered base-points) are communicated and presented to the station Operators in appropriate displays in the control rooms of the power plants and the operators should execute even manually these dispatch instructions. There are 3 control rooms for the power plants in Rhodes.

The RTD considers the problem as a constrained linear optimization problem, consisting of an objective function (operational cost minimization with maximum possible RES absorption), a set of decision variables (quantity to be allocated for each unit), and a set of linear constraints (equality or inequality constraints). It uses a Linear Programming model that allows the inclusion of linear energy and security type constraints directly into the problem formulation. It includes in the solution the units that are detected actually as on-line and it acquires upward and downward secondary reserves from the units that are at that time in AGC mode.

The RTD re-optimizes the dispatchable unit’s base-points to minimize the objective function while meets the secondary reserve requirements provided by the units that actually participate in AGC regulation in real time. These units are automatically recognized by RTD through the information coming from EMS. The RTD can dispatch base-points to a unit in its secondary reserve range and it has constraints related to the total system secondary reserve requirements. In case reserve requirements are not met appropriate alarms are issued to alert dispatchers to take necessary actions.

The RTD requires a load and RES forecast for the next 5-min intervals in its time horizon. This forecast will be derived from the Very Short Term (5 minutes) Forecasting Application.

5.4.2 RTD Functional Requirements

The RTD shall execute regularly at a dispatch time before each dispatch interval. There shall be a fixed time delay between each dispatch time and the following dispatch interval. The time delay shall account for the RTD execution time, the dispatch approval time, and the communication time for dispatch instructions (a configurable parameter). The first dispatch interval of an hour shall start at the start of that hour and the last dispatch interval shall end at the end of that hour. The duration of the dispatch interval and the time delay shall be configurable parameters in RTD in multiples of 5 minutes, both initially set to 5 minutes. However, the duration of the dispatch interval shall not be less than the time delay, to prevent multiple RTD runs before any real dispatch.

The Base Point (BP) is the optimal dispatch calculated by RTD.

RTD shall perform the following functions:

- Calculate the Dispatch BP for each participating resource as the optimal dispatch for the next dispatch target;
- Procure secondary reserve as needed to meet the reserve requirement at least cost subject to resource constraints;

The RTD shall employ a constrained optimization methodology to perform an optimal energy and reserve dispatch for the next 14 5-min dispatch intervals. The duration of the interval (5-min interval) and the horizon (14 5-min intervals) shall be configurable.

Figure 5-2 below provides an example of the cost-based RTD execution.

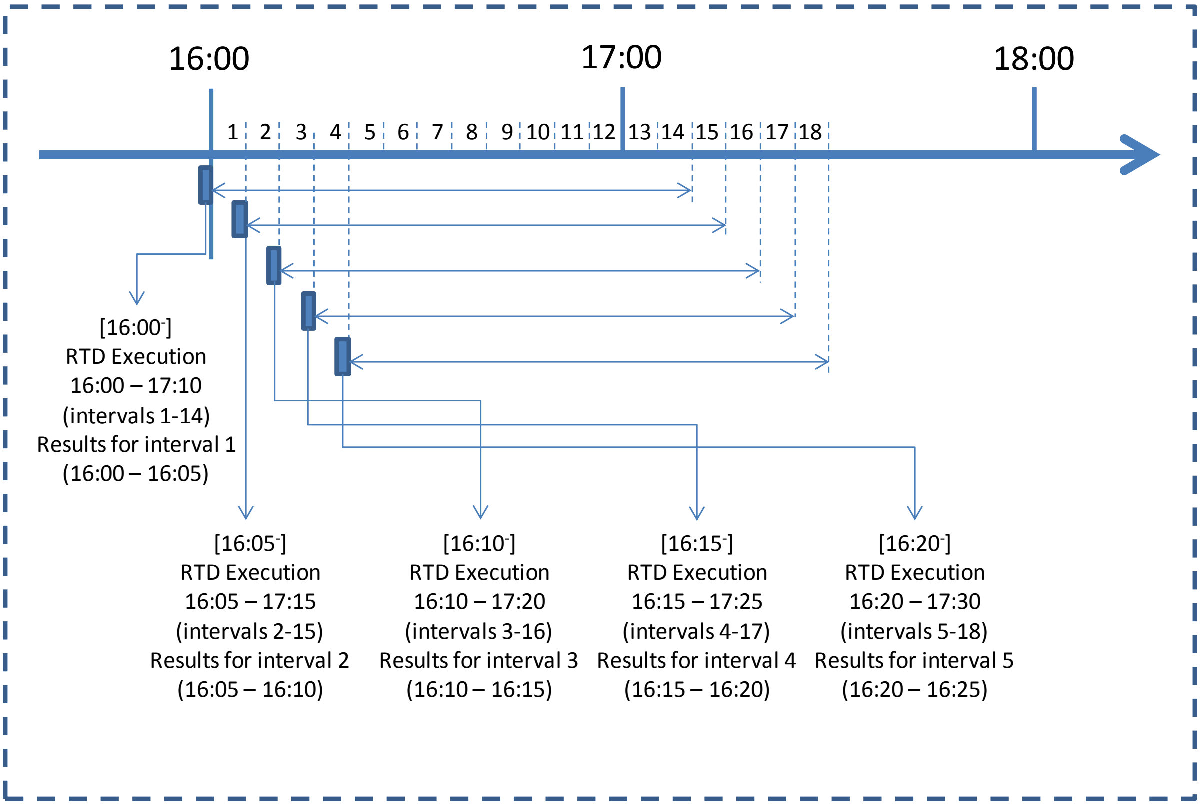


Figure 5-2. Cost-Based RTD Execution

The RTD shall dispatch dispatchable resources, indicated by a flag, optimally over the dispatch time horizon to meet forecasted load minimizing the cost over the entire time horizon, subject to resource constraints. The RTD shall execute automatically at a specified time delay (configurable parameter) before the start of each dispatch interval, and also manually by the user, providing the following functions:

- Procure energy at least cost (based on cost-based data) subject to resource constraints;
- Procure secondary reserve at least cost subject to resource constraints.
- Dispatch dispatchable resources optimally subject to resource constraints and specific provisions for managing the RES as stated in the RDAS section;
- Calculate available Tertiary Reserve from resources that provide it.

Quick-Start resource commitment decisions shall be taken optimally in the DS process before the RTD interval dispatch. Nevertheless, the RTD shall allow the user to manually start up offline resources if needed to meet demand. After offline resources are started up, they shall remain online unless they are dispatched at their minimum operating limit for an entire time horizon, in which case the RTD shall suggest that they should be shut down, if that is feasible. The RTD should not dispatch resources within any of their forbidden operating regions, unless they are ramp-constrained. Resources dispatched within a forbidden operating region, but constrained at maximum ramp rate, shall continue to be dispatched in the same direction in following intervals until they clear the forbidden region.

The RTD shall update the start-up history log with actual times of start-ups and shut-downs. RTD shall use a status flag from EMS to determine whether the unit is online or not. During each run, RTD shall check the current status of each dispatchable unit against the status during the last run. If the status changes, RTD shall update the history log with the startup or shutdown time equal to the time that RTD read the EMS data. The NII SMO understands that this methodology will lead to logged startup and shutdown times being several minutes off the actual startup or shutdown time.

Resource specific dispatch flags shall be provided to switch in and out the resource's data for the RTD dispatch.

5.4.3 RTD Additional Requirements

5.4.3.1 User modifications to the RTD dispatch

Via a display, the user shall be able to easily remove an instruction from the list of instructions generated by the RTD run, or modify an instructed BP to a new value between the previous BP and the instructed BP. When this happens, the system shall do the following:

- Log the time and operator who performed the action
- Change the resource's BP to account for the change.
- System shall NOT recalculate a new set of dispatch instructions.
- RTD shall use the new BP for the next automatic run.

5.4.3.2 Dispatch Instructions

The RTD shall issue a startup instruction when a resource is either scheduled to startup, is manually committed by the operator, or is returning from an outage and has any combination of non-zero DS schedule, secondary reserve, or tertiary reserve. The RTD shall issue a shut down instruction when a resource is either scheduled to shutdown, is manually de-committed by the operator, or has an outage.

After a shutdown instruction is issued, the RTD shall consider the resource off line.

The RTD shall calculate dispatch instructions for each dispatch interval within the time horizon. A dispatch instruction shall specify the following:

- The dispatch time, i.e., the time when the dispatch instruction is calculated.
- The relevant dispatch targets within the time horizon. The first dispatch target is the end of the next dispatch interval after the dispatch time. The remaining dispatch targets follow every 5 minutes (configurable dispatch interval duration, which is a multiple of 5 minutes) until the end of the next hour.
- The BP at each dispatch target within the time horizon.

- A start time indicating when the resource should start moving their unit.

The BP for the first dispatch target is a binding dispatch instruction; the rest are advisory, as they will be recalculated by RTD later. Similarly, a startup or shutdown instruction time before or at the first dispatch target is binding; other startup or shutdown instructions are advisory, as they may be revised by RTD or DS later, except for startups that require early notification due to their startup time. After binding startup or shutdown instructions have been issued, they may not be revised by RTD unless the relevant resource temporal constraints permit that. Provisions must be made to always allow operator override of any RTD instruction including a corresponding log including an operator comment text message field.

5.4.3.3 Out-Of-Sequence (OOS) Dispatch

The RTD shall provide the capability to manually constrain, start up, or shut down resources. These manual constraints shall be logged as out-of-sequence (OOS) dispatch instructions.

This feature shall be available to the operator through an interface table. RTD shall retrieve resources to be constrained at regular intervals, when RTD runs.

The RTD shall implement OOS dispatch instructions as temporary lower, upper, or fixed operating limits, as appropriate, and they may be different across hours. A fixed limit is essentially a simultaneous temporary lower and upper limit set to the same value.

The OOS instructions are entered by the NII SMO into the RTD software in order to satisfy certain constraints for reliability purposes that cannot be modeled in the MMS engine. Usually they are determined by analysts and engineers in the Operations department using off-line network tools, such as power flow, security analysis, etc. RTD treats these instructions as fixed constraints.

Specifically, the NII SMO may constrain a resource for several reasons. Some of these reasons are:

- Dispatch a resource to handle transmission constraints;
- Dispatch to mitigate unscheduled loop flow;
- Test a unit for delivery performance of ASs;
- Dispatch a unit under a Must Run contract with the NII SMO.

An OOS instruction has the following properties:

- Resource ID of the resource being constrained;
- Start time of the constraint – this is the time that the resource should be inside of the limit;
- End time of the constraint – this is the time that the limit expires. This time may be beyond the time horizon of the RTD;

- Constraint type – min, max, or fixed limit;
- Constraint operating level – the value of the limit;
- An energy code indicating how to settle the constraint and how to resolve conflicts with another constraint;
- Constraint reason – if operator entered, reason given for the constraint.

5.4.3.4 Dispatch log

All binding dispatches produced by RTD shall be recorded in a Dispatch Log, no matter if they are automatic or manual. This data may be stored in a table or in a comma delimited text file. The information provided in the Dispatch Log shall include for each participating resource:

- Resource ID;
- Flag to indicate binding or advisory dispatch;
- Dispatch Time;
- Telemetry at Dispatch Time;
- Commitment Status (On/Off) at Dispatch Time;
- Any Startup or Shutdown binding instruction at Dispatch Target;
- BP for each resource;
- Operating Mode (auto or manual);
- Block flag to indicate if the dispatch was blocked by the user;
- Compliance Flag to indicate compliance;
- User ID who made the dispatch;
- Breakdown of energy (e.g. min load);
- Maximum ramp rate used in dispatch.

5.4.3.5 Visual Interface

The RTD shall provide all the necessary user-friendly displays to inform the user about startup, shutdown, and dispatch instructions, BP of any given participating resource and aggregate by zone (if applicable), calculated and telemetered inter-zonal interface power flows (if applicable), etc., and to allow modifying RTD options.

The RTD screens shall display information in hour-ending (HE) format on selected displays to be agreed upon.

User shall easily be able to identify from RTD screens whether they are in manual or automatic mode. Vendor shall make use of text titles and screen coloring to achieve this requirement.

User shall be able to easily search for or filter for a particular unit in all displays. This shall include, but not be limited to, use of wildcard characters.

For displays that do not require merit order listing, units shall either be arranged in alphabetical order or in physical geographic order. Users shall be able to determine the geographic order of units.

5.4.3.6 Dispatch Screens

In addition to the requirements above, the following are additional requirements for dispatch screens:

- RTD shall display the total dispatch for each interval in the current hour for a unit on applicable dispatch screens.
- For RTD dispatch screens, units shall be color-coded so that the operator can easily identify a unit's characteristics. RTD shall assign a different color for the following unit properties:
  - Unit on AGC;
  - Unit with a minimum run time of longer than 10 minutes (a configurable number);
  - Unit already been constrained / dispatched.
- A timer shall be placed on appropriate screens to indicate the time remaining until instructions are automatically sent to market participants.

5.4.3.7 Ancillary Service Dispatch

In addition to the requirements in the above sections, the following are additional requirements for AS dispatch screens:

- For ASs dispatch screens, RTD shall display the type of ancilliary service awarded;
- Operator shall be able to use similar procedure to activate or de-activate an AS;
- User shall have the ability to change dispatch MW per unit when activating or de-activating units.

5.4.3.8 Other Display Requirements

The RTD shall include a set of screen(s) with the following information:

- Screen to display the dispatch log. By default, the form shows the dispatches for the last 8 hours. Users shall be able to query for other periods of time.
- Screen to display data obtained from EMS. From this screen, RTD shall also allow the user to override obsolete or bad quality data with manually entered values.

- Screen to display units with planned and active constraints (OOS, min run time, etc.)
- Screen to display units that are unavailable due to start-up restrictions.
- For previous, current and next hours:
  - Hourly generation schedule – both quantity and change between hours
  - Hourly load schedules – both quantity and change between hours.
  - Actual hourly load – both quantity and the change between hours.
- For intervals within the study horizon:
  - An interval-by-interval look at the above quantities (deltas between interval values)
  - Actual values for the previous six intervals for the above data.
  - Estimated values for the next six intervals for the above data.

5.4.3.9 Visual Alerts

RTD application shall provide a means to publish and store alert messages. The alert and event actions shall include clearly marked visual messages. Each alert shall contain text that clearly identifies the issue at hand.

5.5 Real-Time Data Recording and Logging System (RTLS)

5.5.1 General

The Contractor should develop a software module for recording and logging information about the operation of the cost-based RTD. The system will be called Real-Time Data Recording and Logging System (henceforth "RTLS"). The RTLS should collect this information from the RTD market application, and from the Energy Management System (EMS). The information that pertains to a given Dispatch Period (operational hour) would be recorded in a dedicated database after the end of that Dispatch Period. The RTLS will subsequently publish this information so that it can be accessed by other applications and systems, particularly the Settlement, which will be performed by a HEDNO-developed IT System (not part of this Project).

RTD and EMS results will be transferred to the RTLS system after the completion of the RTD for the current day.

Specific requirements for the RTLS are as follows:

- RTLS Interface Requirements (Section 5.5.2);
- RTLS Calculations Requirements (Section 5.5.3);
- RTLS User Interface Requirements (Section 5.5.4);
- RTLS Database and Data Maintenance Requirements (Section 5.5.5).

5.5.2 RTLS Interfaces Requirements

In what follows the key interfaces of the RTLS function are listed.

5.5.2.1 EMS

The EMS shall provide information to the RTLS system regarding the commitment status of the units, telemetry information, etc.

The detailed and specific information that will be recorded and logged in the RTLS system from the EMS is the following; the list is not exhaustive, and will be finalized during the Detailed Design Phase of the Project:

- The commitment status and the actual output in MW for each generating unit as it is obtained from the State Estimator (SE), which would be running every five minutes automatically, and also manually triggered after a major event. The associated timestamp and a flag indicating normal operation or major event would also be recorded. Note that the SE timestamps should match the RTD execution timestamps that are at the midpoints of five-minute clock intervals, i.e., at 2½, 7½, 12½, and so on, minutes into each hour.

  The telemetry in MW for each generating unit as it is obtained from SCADA along with an associated timestamp and a quality code that would indicate whether the telemetry is good or bad. Note that the telemetry timestamps should match the SE and RTD execution timestamps.

- The available spinning reserve for each generating unit and in aggregate for the Control Area in each Dispatch Interval (five-minute period).
- The regulating status (on or off) for each generating unit and for each Dispatch Interval that indicates whether the unit was on or off Automatic Generation Control (AGC) in that interval.
- For generating units on AGC, the set-points in MW sent to the units, normally every four seconds, for Load Frequency Control (LFC).
- For generating units on AGC, the high and low regulating limits used in AGC for each Dispatch Interval.

5.5.2.2 Cost-based RTD

The RTD will provide to RTLS system information related to dispatch instructions, operating limits, manual instructions.

The RTLS shall record the following information from the RTD:

- The dispatch instruction in MW for each generating unit. The associated timestamp (when the dispatch instruction was issued) and the dispatch instruction time (when the dispatch instruction is valid for) would also be recorded.
- The upper and lower operating limits for each generating unit used in RTD for each Dispatch Interval. These limits are the unit maximum capacity and the technical minimum generation, respectively, but modified appropriately for any applicable non-availability declaration.
- Manual dispatch instructions (constraints) in MW entered by the Operator in RTD. The manual dispatch timestamp (when the dispatch instruction was logged or modified) and the manual dispatch instruction time horizon (start time and end time) would also be recorded.
- The ASs schedules.

5.5.2.3 RDAS and DS

RDAS and DS application will provide the data required (e.g., synchronization and de-synchronization instructions), so that the RTLS calculations as listed in the following section can be performed.

5.5.3 RTLS Calculations Requirements

This section presents the indicative calculation requirements for the settlement purposes, with respect to the compliance with market rules and specified tolerances. This information will be determined as part of this project and passed to the settlements application; settlement will be performed by a HEDNO-developed IT system, which is not part of this project. Note that the definitions of the deviations were listed in section 2.2.4.

The Producer is considered to comply with Dispatch Instructions in the following cases:

- For the synchronization or de-synchronization of his Unit, when he executes it with a maximum deviation of ten (10) minutes from the time defined in the Instruction.
- For the active power production if he executes it with a maximum deviation of ±3% from the value defined in the Instruction, and the time defined in the Instruction.
- With respect to Voltage Control:
    - For the Reactive Power production from his Unit, if he executes it at maximum within one (1) minute from the time defined in the Instruction and with deviation which does not exceed ±5% of the value defined in the Instruction.
    - For maintaining a specific value of the power factor, if he executes it within one (1) minute after the time specified in the Instruction (if the coupling/decoupling of the capacitor is not required), with maximum deviation of ±1% from the value specified in the Instruction.
    - For achieving a voltage value in the Connection Point of the Unit if he executes it at maximum within one (1) minute after the time specified in the Instruction (if the coupling/decoupling of the capacitor is not required), with maximum deviation of ±1% of the value specified in the Instruction or if the technical capability of the Unit has run out based on its declared technical characteristics.

For RES/CHP Units and Hybrid Stations, special provisions for the deviations and for the deviation tolerances apply.

The design of the storage system - Hybrid Station RES Units is performed in such a way that the deviation of the power output of RES plants for storage and the absorption of this energy in its storage system shall not exceed ± 5% in minute average power value, and cumulatively per month ± 3% of the total stored energy. The calculation of the deviations takes into account the potential simultaneous power supply of Hybrid Station RES Units directly to the NII Network or the scheduled power. Alternatively, with the obligation of respecting the minute deviation upper limit (±5%), the Producer is allowed to operate the Hybrid Station storage units in a frequency control state (e.g. primary), while monitoring the fluctuation of the wind generation level (two control cycles). In this case the upper monthly limit of ±3% is increased to ±5%. In any case, for the calculation of the energy absorbed from the NII Network, only the quantities which are measured by the energy meters are taken into account, and the previously mentioned allowed deviations do not affect the calculations.

For each Unit deviation, which is calculated based on the Deviation Calculation Process, which exceeds the limits of the corresponding tolerance deviation, sanctions are imposed, except for the Units which are in commissioning/testing operation.

Also sanctions are imposed for each load demand deviation of the Load Representatives (excluding the Hybrid Station storage units) and for any uninstructed deviation of the Hybrid Station storage units absorption, which exceeds ±10% of the declared energy in each Dispatch Period.

As a general requirement, any calculations that are possible to be implemented with EMS and MMS available data, and which are required for settlement purposes, should be performed by the RTLS Application. The calculated data will be passed to the HEDNO-developed IT System. It is clarified that the RTLS does not have access to metering data, and meters' database (registry). Certified metering data will be passed from the metering system directly to the HEDNO-developed IT System. That System will perform any calculations required for settlement purposes, and which involve metering data. RTLS should only provide EMS and MMS derived data.

Implementation details will be determined during the Detailed Design Phase of the Project.

Finally, indicative data are listed below, which are required to be kept in the RLTS application for the purposes of sanctions.

- The total time within the Dispatch Day during which the Producer does not comply with the synchronization Instructions, calculated starting from the end of the applicable tolerance until the compliance or the issuing of a new de-synchronization Instruction.
- The total number of the Dispatch Days during the current calendar year for which a non-compliance with a synchronization Instruction has been observed for the same Unit of the same Producer.
- The total number of the Dispatch Days in the current calendar year for which a deviation from a Dispatch Instruction for Active Power production has been observed for the same Unit of the same Producer.
- The total percentage deviation from the relevant voltage control Instructions for each Dispatch Day, calculated as the sum of the percentage deviations absolute values per Dispatch Period, beyond their respective tolerance limits for each type of instruction.
- The total number of the Dispatch Days in the current calendar year for which a deviation from Dispatch Instructions for voltage control has been observed for the same Unit of the same Producer.

- The total number of months in the current calendar year in which non provision of an AS has been observed for the same Unit of the same Producer.
- Ex post data regarding the provision of ASs.
- The total number of months in the current calendar year in which an inconsistency of the declared quantitative techno-economic data has been observed for the same Unit of the Same Producer as well as the percentage deviation from the declared quantitative techno-economic data.

5.5.4 RTLS User Interfaces

The RTLS User Interface (UI) will be built using J2EE/JSP based web SDK. UI will be based on the same functional design as the RTD application. RTLS UI will seamlessly integrate with the NII SMO portal. It will use NII SMO's authentication system and LDAP infrastructure for authentication. The users will login through NII SMO's portal. The UI back end interface will connect to the LDAP server and get the users' roles and permissions and then grant the relevant permissions and access to the user.

User interface displays will facilitate filtering based on page filters and advance filters. Standard edit, insert, cancel and sort functionality will be available in all RTLS displays. It will allow users to view data for any version. User interface displays will show all output data for a single resource for one hour at a time. User interface will have the capability to export all 24 hours.

RTLS UI will provide user-friendly displays and tools to do manual corrections and bulk loading of market results data. UI will also facilitate copy forward and backward field/row to several rows within the same display.

RTLS UI will facilitate exporting of data in MS Excel formats. An option will be available to export displayed or all rows.

RTLS will provide a full set of displays that will assist the user to navigate and review the data stored in the RTLS database. Specifically RTLS will provide the following capability:

- RTLS will support all input and output interfaces. RTLS will interface seamlessly with the RTD and EMS systems.
- RTLS shall provide all the necessary user-friendly displays to inform the user about dispatch instructions, manual dispatch instructions, operating limits, energy prices, ASs schedules and ASs prices, unit commitment statuses, unit regulating statuses, unit telemetry, available spinning reserves, regulating limits, ACE, etc. for each dispatch period.
- User shall be able to easily search for or filter for a particular unit in all displays. This shall include, but not be limited to, use of wildcard characters.

- For displays that do not require merit order listing, units shall either be arranged in alphabetical order or in physical geographic order. Users shall be able to determine the geographic order of units.
- The RTLS input interfaces will be ODBC based configured through workflow controller. RTLS will log count of data retrieved from RTD/EMS and data stored in RTLS.
- RTLS will publish RTD and EMS data. The Contractor will develop necessary services to support publishing of the data. The Contractor will work with the NII SMO to define service definitions. Output interfaces will be available for configuration as part of the run configuration.
- RTLS will use the current RTD workflow controller infrastructure to manage the data transactions.

5.5.5 RTLS Database and Data Maintenance Requirements

RTLS will use the same Oracle database server and storage as the RTD application. It will have a separate independent schema from the RTD. All necessary and required data from the RTD and the EMS will be extracted and transferred into the RTLS database. The RTLS data-model will be designed to be very close to the RTD schema for consistency. RTLS database will be partitioned for higher query performance. It will store data for 18 months before it gets to off line storage. The RTLS database will support data versioning and audit logs. RTLS will keep track of reason of change, who did the change and when was the change done. An audit log table will keep track of all changes and reference it to the actual corrected market results. The RTLS application will facilitate users to see all audit log information and navigate to the corresponding display to see the updated results.

Email notification will be sent to Market Participants for any confirmed/approved changes of data. Email notification will not contain any details of the change. Email addresses of the Market Participants will be stored in the RTLS database. An administrative display will be provided to insert or edit email information.

RTLS will maintain data for 18 months. Data older than 18 months will be stored off-line. Archival of data older than 18 months will be designed and implemented as part of this project. The current data model design will take into account design consideration for archiving and reloading of RTLS data.

6 Load and RES Forecasting

Load and RES Forecasting are two vitally important functions for the short-term and very short-term operations of the NII power systems that are daily performed by the NII SMO.

Both Applications should be able to integrate tools from other vendors as well. The Contractor should provide the capability for the user to enter load/RES forecasting values from third-party software.

Since the Load and RES Forecasting Application shall be integrated with the MMS, located in Athens and Rhodes, the following apply in general:

- Load and RES forecasting application in the Athens MMS should comply with the requirements for all types of NII, i.e., small, medium, and large.
- Load and RES forecasting applications in the Rhodes MMS should comply with the requirements for large NII.

The requirements for the forecasting applications are listed as follows:

- Load Forecasting in Section 6.1;
- RES Forecasting in Section 6.2.

6.1 Load Forecasting

The Contractor should provide a complete Load Forecasting (LF) solution that supports, in general, the following modes of LF:

- *Short-Term Load Forecasting (STLF),* which, in general, is used to predict loads from a few hours up to 36 hours ahead. The forecasting step ranges from a few minutes (e.g., 15 minutes) to one hour.
- *Very Short-Term Load Prediction (VSTLP),* which, in general, is used to predict loads from a few minutes up to a couple of hours ahead. The forecasting step is in the order of few minutes (e.g. 5-10 minutes).

Both modes of LF provide valuable assistance in terms of the optimal short-term and very short-term operation of the NII systems. The STLF is mostly used for the short-term scheduling of the generating units (conventional and RES), while the VSTLF is mostly used for the real-time dispatching and generation control.

The LF software packages to be implemented by the Contractor can be based on advanced Artificial Neural Network (ANN) techniques, since these techniques are considered to provide accurate results under most system conditions. However, other methodologies (e.g., regression models, expert systems, support vector machines, etc.) are also acceptable, if they are deemed to provide more accurate predictions.

In case that ANN techniques are adopted, the functionality of the ANN models should be divided into three areas, as follows:

1. Offline ANN training;
2. Online ANN training and adaptation
3. Online ANN operation.

During the offline training, the ANN is presented with a sequence of historical input - desired output pairs for a specified time period. The ANN internal parameters (weights) are computed so that the training error is minimized. Afterwards the model is loaded online to make predictions for the requested time period. Then, the offline training of the ANN model is skipped for some future time periods and existing ANN model parameters from previous training is employed so as to avoid unnecessary CPU time consumption.

The desired prediction accuracy is pre-specified in root-mean-square (RMS) percentage. If the offline training does not provide satisfactory prediction accuracy, the user can refine the selection of data sources for retraining to achieve the required prediction accuracy. Furthermore, when the actual real-time load exhibits behaviours significantly different than what the ANN model has been trained for, online training and adaptation of the model is needed.

The minimum requirements for the specific LF applications, namely STLF and VSTLP are detailed in the following Sections.

6.1.1 Short-Term Load Forecasting Application

The purpose of the STLF function is to predict loads up to 36 hours ahead for use by the market or other functions. To comply with the provisions of the NII Code, two different STLF models shall be developed, namely as follows:

a) An STLF Model that is used to predict loads up to 36 hours ahead, in hourly intervals.
b) An STLF Model that is used to predict loads up to 4 hours ahead, in 15-minute intervals (16 steps).

The hourly predictions produced by Model (a) are used by the NII SMO as key input to the RDAS function that is typically solved twice for each dispatch day (day D): once prior to the beginning of the dispatch day (e.g., at 21:00 of day D-1), covering the entire day-ahead scheduling period (24 hours of day D, Periods A&B), and once few hours prior to noon of day D (e.g. at 10:00 a.m.) covering the 12 hours of the second half of day D (i.e., hours 13-24, Period B).

The 15-min predictions produced by Model (b) are used by the NII SMO as key input to the Dispatch Scheduling (DS) function that is typically solved iteratively every fifteen (15) minutes for the next four (4) hours with a 15-min time resolution and covering the entire time range of the dispatch day D.

6.1.1.1 STLF Input Data

The accuracy of the STLF applications depends not only on the load forecasting techniques employed, but also on the accuracy of the selected input data. For STLF applications, the main input data comprise of historical load time series and several exogenous factors, such as time factors, network conditions and weather data.

Historical load time series comprise of past actual load values in time resolution that shall be consistent with the respective STLF model time intervals. A detailed description of how the historical load time series is exported is given in the following paragraphs.

Time factors include the time of the day, the day of the week, the day of the year, holidays, social events, strikes, etc.

Weather parameters are critical factors in the short-term load forecasting. Temperature and humidity are the most commonly used weather variables, while additional variables, such as wind speed, cloud cover, precipitation, etc., could also be used as inputs, provided that relevant datasets are available. Additional input data may also be considered by the Contractor to improve the forecast accuracy.

The Contractor has to consider all these factors and include them as inputs into the developed STLF models. The specific STLF input data are summarized in Table 6-1.

Table 6-1. STLF Input Data

Category	Relevant Data
Historical load data	Historical time series of actual load values up to *n* past time intervals (minutes, hours, days)
Time/Calendar data	Time of Day, Day of Week, Day of Year, Special Day (holiday, daylight time saving, etc.)
Historical weather and climate data	Past values of weather data (temperature, humidity, etc.) up to *m* past time intervals (minutes, hours, days)
Forecasted weather data	Forecasted values of relevant weather data up to *f* future time intervals (minutes, hours, days)
Special events	Strikes / Social events/ incidents to the network

The above selection of input data is given for illustration purposes only. The final selection of input data is the responsibility of the Contractor. According to the provisions of the NII Code, the NII SMO must also consider the accepted load declarations submitted by the respective load representatives as well as other relevant data that are collected by the NII SMO and that are deemed to improve the performance of the forecasting procedures.

6.1.1.2 STLF Output Data

Based on the requirements of the RDAS and DS systems, for the NII system, the STLF system shall deliver:

(a) The mean hourly forecasted load for the 24 hours of the next day (Periods A&B, 24 values) using Model (a). In case that an updated forecast is required the mean hourly forecasted load for the second half of the current dispatch day (Period B, 12 values) shall also be delivered.

(b) The 15-minute average forecasted load for the next 4 hours (16 values) using Model (b).

The delivery time (lead forecast time) for all outputs shall be specified during the Detailed Design Phase of the Project.

On demand by the NII SMO operators, the STLF models shall be able to deliver probabilistic forecasts instead of single-valued (point) forecasts. Even though non-parametric probabilistic predictions may take the form of quantile, interval or density forecasts, the basic quantity to be considered is the quantile forecast, since the other two forms may be expressed in terms of two or more quantile forecasts. The *q*-quantile selection shall be customizable. However, quantile representation does not exclude the prediction interval approach. For the prediction interval approach, instead of one interval specification, the STLF system shall provide the capability of multiple prediction intervals (i.e., beginning with a 10% interval and progressively extend the interval by 10%, until reaching the 90% interval forecast). Intervals selection shall be customizable. Finally, whatever the approach, the quality of probabilistic forecasts shall be evaluated.

In addition, the STLF system should allow the analyst to replace the forecasts, if necessary, by an alternate source using a file-based interface. The alternative sources could be:

a. *Similar Day forecast:* The load forecast is obtained by searching through the database for historical days with similar features (weather, time and seasonal characteristics) to the forecasted period. The “similar day” approach should retrieve a set of days considered best matches to the day for which the forecast is desired. Then, the analyst should be able to choose one of these to be applied as a load forecast.

b. *Load Shape forecast:* The load forecast is obtained by selecting a load shape (either manually entered or the load shape from a historical day) and scaling it.

c. *External forecast:* The load forecast is obtained from an outside source using a file-based interface.

Descriptive statistics should be provided to enable the analyst to compare the forecasted with the actual load in each STLF model. The statistics allow the analyst to acquire further insight to the performance of the forecast model.

Both graphical and numerical methods should be provided. Numerical methods typically refer to summary statistics, such as standard deviation, mean, max, min, median as well as estimation of confidence intervals. Graphical methods shall include line plots, box plots, scatter plots and load forecast error distributions.

Therefore, the NII SMO will have the ability to review load forecasts and draw intuitive conclusions regarding load forecast performance. All statistics and charts should be exportable for further processing or inclusion in business reports.

Also the STLF results (output data) should be stored in the LF database in order to be available for retrieval and be queried by external systems in order to be used, for example, by market applications, etc.

Figure 6-1 illustrates the ANN-based STLF architecture.

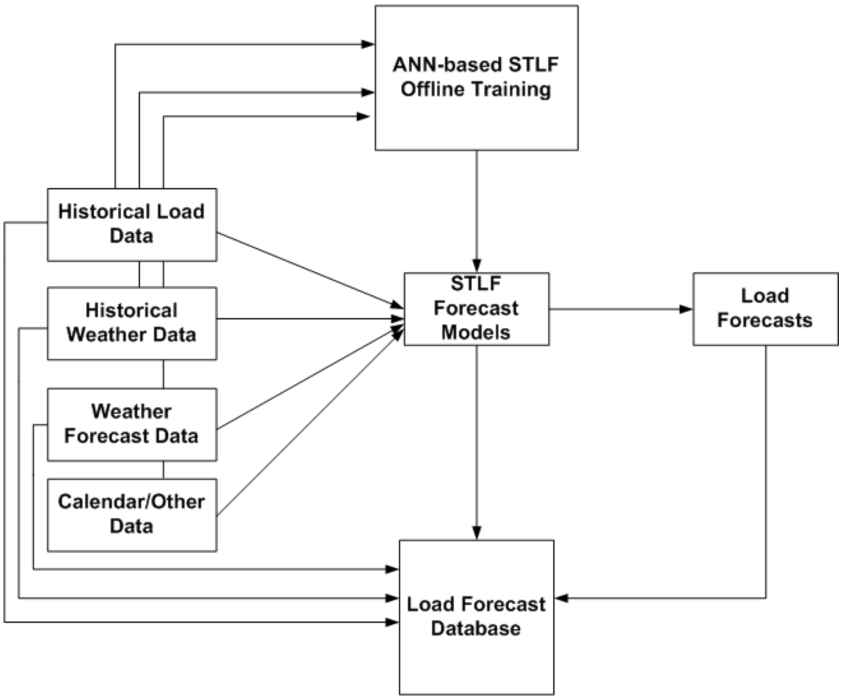


Figure 6-1. ANN-based STLF application architecture

6.1.1.3 STLF Performance

The performance of an STLF model depends largely on the forecasting lead time, the forecasting horizon, the load behavior and the time discretization of the respective forecasting model.

The error measure most frequently used to assess STLF performance is the Mean Absolute Percentage Error (MAPE), defined as follows:

$$MAPE = \frac{100}{T} \cdot \sum_{t=1}^{T} \left| \frac{y_t - \hat{y}_t}{y_t} \right| \ (\%)$$

where

y_t is the actual load value;

$\hat{y}_t$ the respective forecasted value and t is the discrete time step;

T is defined according to the forecasting time horizon of the LF model (e.g. T= 24 for day-ahead forecasting evaluation with hourly time-discretization).

The individual hourly forecast errors along with the 24 hour and 4 hour-ahead MAPE values shall be calculated and displayed in appropriate screens of the STLF system.

The delivered forecasts shall meet prespecified targets that are defined based on the aforementioned performance indices.

Figure 6-2 shows such performance targets for the 24 hour-ahead STLF with hourly time discretization and the 4 hour-ahead STLF with 15-min time intervals, according to the size of the NII system.

Table 6-2. STLF MAPE Requirements for NII Systems

NII System[3]	Maximum 24h-ahead MAPE (%)	Maximum 4h-ahead MAPE (%)
Small	3.0	-
Medium	2.5	-
Large	2.0	1.5

Error residuals caused from poor weather forecast prediction will not be taken into account when calculating the MAPE.

Error analysis data for the last 24 hours shall also be generated and be available to the NII SMO. These data shall also be stored in the LF database and the analyst should be able to perform queries and retrieve specific error analysis information.

The Contractor should also ensure that prediction errors that exceed 10% of the forecasted load should occur for less than 50 times per year.

6.1.2 Very Short-Term Load Prediction Application

The Very Short Term Load Prediction (VSTLP) function is designed to provide much shorter-term load predictions for real-time use than conventional STLF does.

[3] According to the provisions of the NII Code, small NII systems are those whose average peak load demand of the last 5 years does not exceed 2 MW. Medium NII systems are those whose average peak load demand of the last 5 years lies between 2 and 100 MW, and large NII systems are those whose average peak load demand of the last 5 years exceeds 100 MW.

To comply with the provisions of the NII Code, an VSTLP model that is used to predict loads up to 70 minutes ahead, in 5-minute intervals (14 steps) shall be developed. The time horizon and the duration of each time interval can be configurable.

The 5-min predictions produced by the VSTLP model are used by the NII SMO as key input to the cost-based Real-Time Dispatch (RTD) function that is typically solved iteratively every five (5) minutes comprising the next seventy (70) minutes with a 5-min time resolution.

6.1.2.1 VSTLP Input Data

The VSTLP function is designed such that it has the capability to:

- Distinguish between different seasons (for instance, summer and winter);
- Distinguish between weekends, holidays and weekdays;
- Distinguish between off-peak times and on-peak times;
- Predict the next several 5-minute load values, which conform to the dynamics that it has displayed for the most recent time period, for instance, the past 30 minutes up to two hours;
- Conform to the 15-min average values of load that are forecasted by the 4 hours ahead STLF function.

The weather change is a relatively slow process compared to the 5-min load forecast for the VSTLP time horizon, and weather information is already used in the 15-min forecasts produced by the 4 hours ahead STLF model. Therefore, weather variation information will not be directly used in the VSTLP function, but the 15-min forecasted load values are to be used to adjust the 5-min forecasted load values by the VSTLP. On the other hand, the manual training data source specification (or automatic selection according to a designated selection criteria) allows the Operator's intervention that may introduce weather relevance into the selection process – this implies indirect use of weather information. Furthermore, VSTLP online training provides yet another opportunity to make adjustments to the already trained NN and improves the likelihood of reducing the gap between the forecasted load dynamics based on the load dynamics present in the selected load data source and that of the current load.

Therefore, the input data for the VSTLP application vary significantly with respect to the input data used for the STLF application. In fact, the input data are restricted to the historical load time series (mainly the most recent available SCADA measurements are used), the 15-min forecasted load data produced by the 4 hours ahead STLF model and the time/calendar data to account for seasons, weekdays/weekends/holidays, etc. The proposed selection of input data is given for illustration purposes only. The final selection of input data is the responsibility of the Contractor.

The specific VSTLP input data are summarized in Table 6-3.

Table 6-3. VSTLP Input Data

Category	Relevant Data
Historical load data	Historical time series of actual load values up to *n* past time intervals (minutes, hours)
Time/Calendar data	Time of Day, Day of Week, Day of Year, Special Day (holiday, daylight time saving, etc.)
Forecasted load data	15-min average forecasted load values (output from the 4 hours ahead STLF function) up to *f* future time intervals (minutes, hours)

6.1.2.2 VSTLP Output Data

Based on the requirements of the RTD system, for the NII system, the VSTLP system shall deliver the 5-minute average forecasted load for the next 70 minutes (14 values).

The delivery time (lead forecast time) for all outputs shall be specified during the Detailed Design Phase of the Project.

Descriptive statistics should be provided to enable the analyst to compare the forecasted with the actual load. The statistics allow the analyst to acquire further insight to the performance of the forecast model.

Both graphical and numerical methods should be provided. Numerical methods typically refer to summary statistics, such as standard deviation, mean, max, min, median as well as estimation of confidence intervals. Graphical methods shall include line plots, box plots, scatter plots and load forecast error distributions.

Therefore, the NII SMO will have the ability to review load forecasts and draw intuitive conclusions regarding load forecast performance. All statistics and charts should be exportable for further processing or inclusion in business reports.

Also, the VSTLP results (output data) should be stored in the LF database in order to be available for retrieval and be queried by external systems in order to be used, for example, by market applications, etc.

Figure 6-2 illustrates the ANN-based VSTLP application architecture.

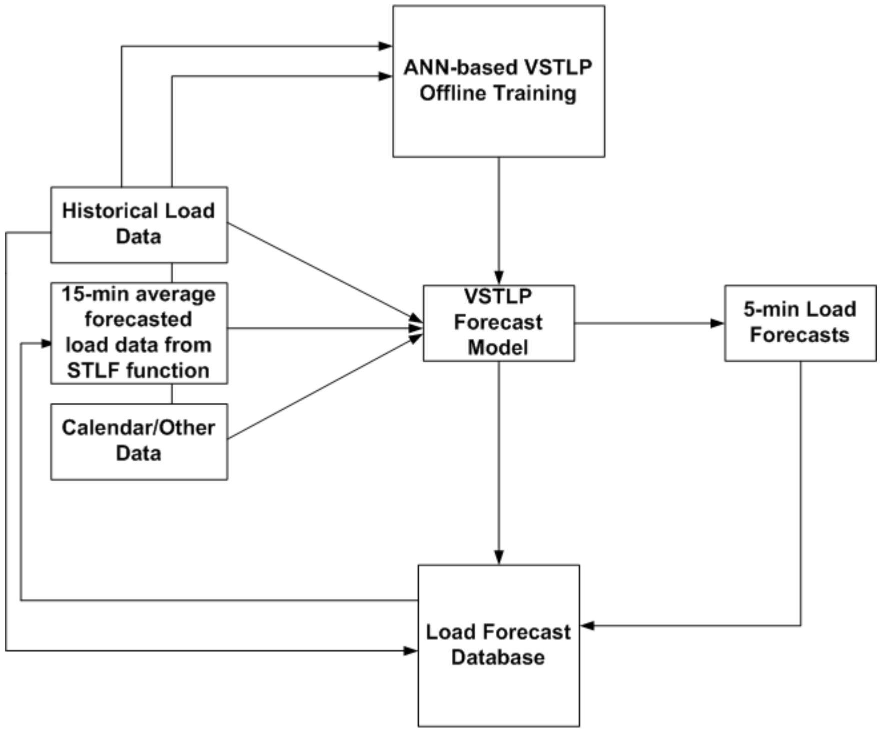


Figure 6-2. ANN-based VSTLP application architecture

6.1.2.3 VSTLP Performance

Similarly to the STLF functions, the performance of the VSTLP model shall be assessed using the Mean Absolute Percentage Error (MAPE) index, already defined in section 6.1.1.3.

The 5-min individual forecast errors along with the respective MAPE values for each 70 min ahead period shall be calculated and displayed in appropriate screens of the VSTLP system.

The delivered forecasts shall meet prespecified targets that are defined based on the MAPE index. Table 6-4 shows such performance targets for a 70 min-ahead VSTLP with 5-min time discretization, according to the size of the NII system.

Table 6-4. VSTLP MAPE Requirements for NII systems

NII System	Maximum 70-min ahead MAPE (%)
Small	2.0
Medium	1.5
Large	1.0

Error analysis data for the last 24 hours shall also be generated and be available to the NII SMO. These data shall also be stored in the VSTLP database and the analyst should be able to perform queries and retrieve specific error analysis information.

The Contractor should also ensure that the number of individual errors exceeding a specific threshold (to be defined during the Contract development) should be less than a specific value (also to be defined during the Detailed Design Phase of the Project).

6.1.3 Load Forecasting Operation Modes

The STLF and VSTLP models will be built offline and then the analyst will be able to bring the model online (activation). The activation of a model shall be defined by an activation period (where the activation period could be defined, for instance, by a start time and an end time or by a more complex scheduler configuration file). This will enable the analyst to create an execution sequence in order for the forecast to automatically cope with anticipated changes in seasonal patterns.

All LF models should provide the NII SMO with two modes of execution:

- automatic and
- manual.

The automatic mode of execution should apply only to models deemed active. For models that are active, the automatic execution, on cycle basis, shall be the default mode. The execution cycle time for each online LF model shall be specified during the Detailed Design Phase of the Project and may be modified by the analyst. The software should also provide the capability of an ad-hoc execution of an online model (upon operator's request) to refine forecast with respect to more recent data.

The Contractor should provide detailed documentation regarding the availability of the models and algorithms offered in the STLF and the VSTLP applications and in case third party software is used, the licensing and supporting material should also be provided.

6.1.4 Load Forecasting Data Manipulation

All data from SCADA (load and weather variables measurements) shall be made available to both STLF and VSTLP applications automatically. This means that the LF system shall have its own database, in which all SCADA data, processed data, prediction results, configuration data and parameter data shall be stored. An appropriate graphical user interface (GUI) for the easy management of the database shall also be developed.

Since different time resolution (time intervals) is used for the two distinct STLF models and the VSTLP model, it is recommended that all raw SCADA data be stored in the finest available time resolution (e.g., one-minute data) in the database. In this case, the Contractor should build appropriate procedures to produce 5-minute, 15-

minute and one-hour average load values that will then feed (automatically or manually) the respective STLF and VSTLP models.

It must be clarified that the SCADA load data match the total NII system load that is telemetered at the production side, i.e., it is equal to the sum of the real-time power output of all conventional generating units, wind plants and other plants that are monitored by the SCADA system and which are usually connected to the high-voltage (HV) system and/or medium-voltage (MV) network. However, the large penetration of renewable energy sources units (mainly PV plants) connected to the distribution (MV & LV) network results in large deviations between the load measured at the production side and the actual consumers load. In other words, the actual consumers load is underestimated by the energy injected by the distribution-level RES plants.

For this purpose, in order to calculate the actual real-time consumers load with satisfactory accuracy, two different approaches are proposed:

- In case that all RES plants (installed both in the HV system and the MV&LV network) are telemetered (as formally required by the provisions of the NII Code), these measurements shall be used to calculate the total NII system load, which will be equal to the sum of the real-time power output of all generating units (conventional and RES plants installed in all voltage levels).
- In case that the RES plants connected to the MV&LV network are not telemetered (which is the current status in all NII), an appropriate procedure shall be followed to estimate their power output in real-time.[4]

The Contractor shall acquire and use such real-time production data in order to calculate the actual consumers load data, which will then be used as main input data in the STLF and VSTLP models for the NII system, as already described.

The Contractor shall also provide an automated procedure to feed the weather forecast data to the models. In addition, manual override of input data in the GUI shall be allowed.

The LF database shall contain load and weather information for each day of the year, for up to three (3) years. The software shall include an automatic raw data validation and invalid data manipulation process. The Contractor should provide the following pre-processing techniques to make the data more manageable: rescaling, normalization and handling of missing data. Extrapolation or other mathematical approaches for missing and invalid data shall be performed and the NII SMO should

[4] Such an approach is currently implemented in Crete, according to which 20 PV parks spanning the entire island and connected to the distribution network have been equipped with telemonitoring devices, which allow the control center to monitor their power output in real-time. Based on these PV park telemeasurements, the total real-time power output of all distribution-level PVs is estimated using an advanced upscaling procedure and is then used to calculate the total actual consumers load in real-time.

be aware of the raw data manipulation process by an appropriate warning. In addition, the software must provide the necessary tools to the analyst to monitor input data and be able to modify or exclude invalid data from the model.

The Operators shall review the forecast suggested and shall use their judgment, if necessary, to appropriately modify the predictions prior to their implementation in the real-life NII system operations.

6.1.5 Load Forecasting Model Qualities

The STLF and VSTLP models should possess the following qualities:

- Each model should adapt automatically to new measurements. As the forecast period elapses, the model should automatically update its data window and re-compute a new forecast, according to schedule.
- The algorithm should constantly apply corrections to the load forecast, as new data and weather measurements become available.
- The algorithm should be robust and fault-tolerant. Reasonable forecasts should be produced, even when input data consist outliers or erroneous data.

6.2 RES Forecasting

The NII SMO asserts that RES units require special treatment in the short-term, since their output depends largely on prevailing environmental or weather conditions, resulting in a limited ability to respond to dispatch instructions at the present time. Therefore, short-term RES production forecasting is very important for the efficient RES integration in NII systems.

The Contractor shall develop a short-term RES forecasting infrastructure, mainly for wind and solar PV forecasting, able to provide the NII SMO with appropriate energy/power production forecasts for the non-dispatchable RES units that are not obliged to submit declarations for energy production in the framework of the RDAS operations.

The Contractor should provide a complete RES Forecasting solution for each available RES technology that supports, in general, the following modes of RES Forecasting:

- Short-Term RES Forecasting, which, in general, is used to predict RES production from a few hours up to 36 hours ahead. The forecasting step ranges from a few minutes (e.g. 15 minutes) to one hour.
- Very Short-Term RES Prediction, which, in general, is used to predict RES production from a few minutes up to a couple of hours ahead. The forecasting step is in the order of few minutes (e.g. 5-10 minutes).

Both modes of RES forecasting provide valuable assistance in terms of the optimal short-term and very short-term operation of the NII systems. The Short-Term RES

Forecasting is mostly used for the short-term scheduling, while the Very Short-Term RES Prediction is mostly used for the real-time dispatching and generation control.

Based on the NII Code requirements, RES forecasting shall be performed for either the entire NII system as a whole or for separate operational zones, specified by the NII SMO according to the NII system size and conditions. For instance, the operational zones could be either zones where multiple RES units are considered aggregated into a virtual unit or even a single RES unit.

ANN tools are commonly used for RES production forecasting/prediction at RES unit-wise or system-wide level. However, other methodologies are also acceptable, if they are deemed to provide more accurate predictions.

The Contractor is also encouraged to experiment with other technologies such as support vector machines, multiple linear regression, etc. The various models have different requirements for the amount of data to produce a reliable forecast and the length of time needed to run. The Contractor should select the most appropriate model or models to implement the RES forecasting function with the objective to achieve an acceptable performance. In case that ANN-based models are adopted, their main functionalities should follow the ones described in Section 6.1.

The minimum requirements for both RES forecasting applications, namely Short-Term RES Forecasting and Very Short-Term RES Prediction, according to the provisions of the NII Code, are discussed in the following Sections. It is clarified that the following description refers specifically to wind and PV production forecasting. However, it should be easily extendable to other non-dispatchable or partially dispatchable RES categories, such as solar thermal, small hydro, biomass, geothermal, etc.

6.2.1 Short-Term RES Forecasting Application

The purpose of the Short-Term RES Forecasting function is to predict RES production up to 36 hours ahead for use by the market or other functions.

To comply with the provisions of the NII Code, two different Short-Term RES Forecasting models shall be developed, namely as follows:

a. A Short-Term RES Forecasting Model that is used to predict RES (wind and PV) production up to 36 hours ahead, in hourly intervals.

b. A Short-Term RES Forecasting Model that is used to predict RES (wind and PV) production up to 4 hours ahead, in 15-minute intervals (16 steps).

The hourly predictions produced by Model (a) are used by the NII SMO as key input to the Rolling Day-Ahead Scheduling (RDAS) function that is typically solved twice for each dispatch day (day D): once prior to the beginning of the dispatch day (e.g. at 21:00 of day D-1), covering the entire day-ahead scheduling period (24 hours of day D, Periods A&B), and once few hours prior to noon of day D (e.g. at 10:00 a.m.) covering the 12 hours of the second half of day D (i.e., hours 13-24, Period B). According to the provisions of the NII Code, for small NII systems where no fully or partially controllable RES units operate, the execution of RDAS for Period B is not required. However, the Contractor should provide the capability to execute the STLF twice even for the small Islands.

The 15-min predictions produced by Model (b) are used by the NII SMO as key input to the Dispatch Scheduling (DS) function that is typically solved iteratively every fifteen (15) minutes comprising the next four (4) hours with a 15-min time resolution and covering the entire time range of the dispatch day D.

6.2.1.1 Short-Term RES Forecasting Input Data

In general, RES production depends on multiple exogenous factors and exhibit several levels of seasonality. The accuracy of RES forecasting applications depends not only on the RES forecasting techniques employed, but also on the accuracy of the selected input data.

For Short-Term RES Forecasting applications, main input data comprise historical RES production time series and several exogenous factors, such as time factors and weather and climate data.

Historical RES production time series comprise past actual RES production values in time resolution that shall be consistent with the respective RES forecasting model time intervals (see above).

Time factors include, in general, the time of the day and the day of the year.

Weather parameters can affect substantially the short-term RES forecasting. The Contractor is expected to use regional physics-based models to create sets of forecast atmospheric data for the region around the resources to be forecasted. These data are used as input to the ANN/statistical models. The physics-based model should be used by the Contractor to significantly improve the forecasting accuracy. The input data to the model should comprise regional weather data (i.e., surface observations, Doppler radar wind data, etc.) collected by Weather Forecast Stations and data from larger-scale physics-based models that may run by other agencies (or a third-party sub-contractor). The output variables of the physics-based models are forecasted meteorological variables that are needed as inputs to the ANN/statistical models. Specifically, various meteorological variables, such as wind speed, wind direction, solar irradiation, temperature, air density, etc, shall be used as inputs, depending on the RES category treated. Additional meteorological variables/input data, if available, may also be considered to improve the forecast accuracy.

The Contractor has to consider all these factors and include them as inputs into the developed short-term RES forecasting models.

For easy reference, the appropriate inputs for RES forecasting are separated for wind and PV generation. In the case that other non-dispatchable or partially dispatchable RES technologies operate in the NII systems, similar datasets with those adopted for wind and PV forecasting shall be adopted.

Table 6-5 and Table 6-6 summarize the specific input data for Wind and PV forecasting, respectively. The proposed selection of input data is given for illustration purposes only. The final selection of input data is the responsibility of the Contractor.

Table 6-5. Short-Term Wind Forecasting Input Data

Category	**Relevant Data**
Historical wind production data	Historical time series of actual wind production values up to *n* past time intervals (minutes, hours, days)
Time/Calendar data	Time of Day, Day of Year
Historical weather and climate data	Past values of weather data (e.g. wind speed, wind direction, temperature, humidity, precipitation, etc.) up to *m* past time intervals (minutes, hours, days)
Forecasted weather data	Forecasted values of relevant weather data up to *f* future time intervals (minutes, hours, days)

Table 6-6. Short-Term PV Forecasting Input Data

Category	**Relevant Data**
Historical wind production data	Historical time series of actual PV production values up to *n* past time intervals (minutes, hours, days)
Time/Calendar data	Time of Day, Day of Year
Historical weather and climate data	Past values of weather data (e.g. solar irradiation, sunlight, cloud cover, temperature, etc.) up to *m* past time intervals (minutes, hours, days)
Forecasted weather data	Forecasted values of relevant weather data up to *f* future time intervals (minutes, hours, days)

According to the provisions of the NII Code, the NII SMO must also consider the non-availability declarations submitted by non-dispatchable RES (Wind and PV) units in the framework of RDAS as well as other relevant data that are collected by the NII SMO and that are deemed to improve the performance of the forecasting procedures.

6.2.1.2 Short-Term RES Forecasting Output Data

Based on the requirements of the RDAS and DS systems, for each RES category of the NII system, the Short-Term RES Forecasting function shall deliver:

(a) The mean hourly forecasted RES production (Wind and PV production) for the 24 hours of the next day (Periods A&B, 24 values) using Model (a). In case that an updated forecast is required for medium- or large-size NII systems, the mean hourly forecasted RES production for the second half of the current dispatch day (Period B, 12 values) shall also be delivered.

(b) The 15-minute average forecasted RES production (Wind and PV production) for the next 4 hours (16 values) using Model (b).

The delivery time (lead forecast time) for all outputs shall be during the Detailed Design Phase of the Project.

On demand by the NII SMO, the Short-Term RES Forecasting models shall be able to deliver probabilistic forecasts instead of single-valued (point) forecasts. Even though non-parametric probabilistic predictions may take the form of quantile, interval or density forecasts, the basic quantity to be considered is the quantile forecast, since the other two forms may be expressed in terms of two or more quantile forecasts. The q-quantile selection shall be customizable. However, quantile representation does not exclude prediction interval approach. For the prediction interval approach, instead of one interval specification, the RES forecasting system shall provide the capability of multiple prediction intervals (i.e., beginning with a 10% interval and progressively extend the interval by 10%, until reaching the 90% interval forecast). Intervals selection shall be customizable. Finally, whatever the approach, the quality of probabilistic forecasts shall be evaluated.

In addition, the Short-Term RES forecasting function should allow the analyst to replace the forecasts, if necessary, by an alternate source using a file-based interface. The alternative sources could be:

a. *Similar Day forecast:* The RES forecast is obtained by searching through the database for historical days with similar features (weather, time and seasonal characteristics) to the forecasted period. The “similar day” approach should retrieve a set of days considered best matches to the day for which the forecast is desired. Then, the analyst should be able to choose one of these to be applied as a RES forecast.

b. *RES Production Shape forecast:* The RES forecast is obtained by selecting a load shape (either manually entered or the RES production shape from a historical day) and scaling it.

c. *External forecast:* The RES forecast is obtained from an outside source using a file-based interface.

Descriptive statistics should be provided to enable the analyst to compare the forecasted with the actual values in each Short-Term RES Forecasting model. The statistics allow the analyst to acquire further insight to the performance of the forecast model.

Both graphical and numerical methods should be provided. Numerical methods typically refer to summary statistics, such as standard deviation, mean, max, min, median as well as estimation of confidence intervals. Graphical methods shall include line plots, box plots, scatter plots and load forecast error distributions.

Therefore, the NII SMO will have the ability to review RES production forecasts and draw intuitive conclusions regarding RES forecasting performance. All statistics and charts should be exportable for further processing or inclusion in business reports.

Also the RES forecasting results (output data) should be stored in the RES forecast database in order to be available for retrieval and be queried by external systems in order to be used, for example, by market applications, etc.

Figure 6-3 illustrates the ANN-based Short-Term RES Forecasting application architecture.

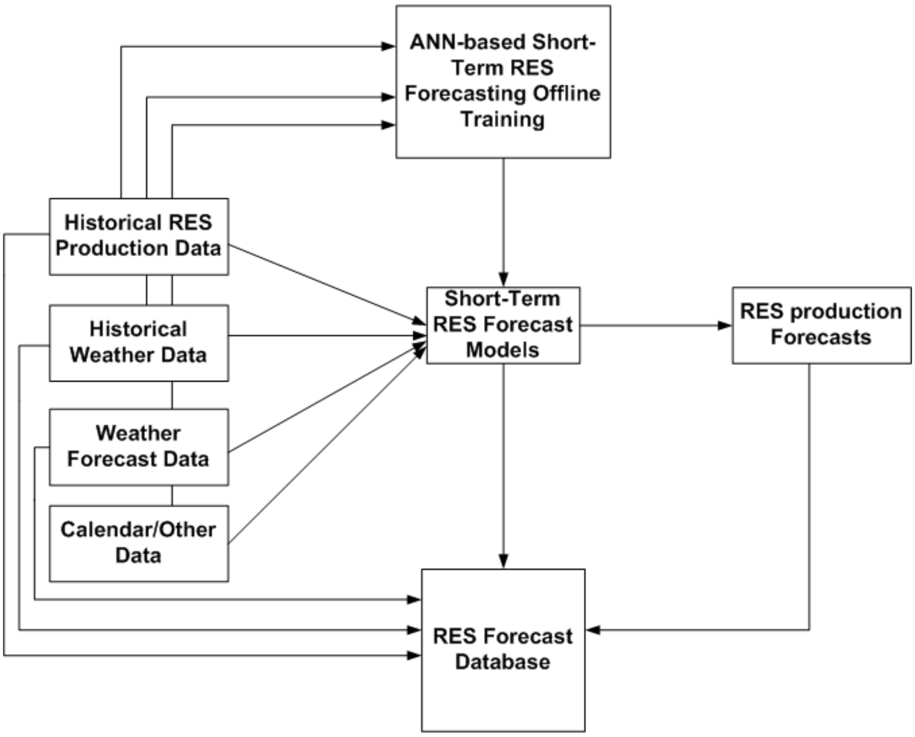


Figure 6-3. ANN-based Short-Term RES Forecasting application architecture

6.2.1.3 Short-Term RES Forecasting Performance

The performance of a Short-term RES Forecasting model depends largely on the forecasting lead time, the forecasting horizon, the specific RES techology and specific geographical conditions and the time discretization of the forecasting model.

Two suitable indices for assessing the RES forecasting accuracy are: the Normalized Mean Absolute Error (NMAE) and the Normalized Root Mean Square Error (NRMSE), which are defined as:

where,

y_i is the forecasted value per time interval;

$\hat{y}_i$ is the actual (measured) value per time interval;

T is defined according to the respective forecasting time horizon (e.g. T= 24 for day-ahead forecasting evaluation with hourly time-discretization);

P_{inst} is the respective installed RES capacity for the examined RES technology.

The performance indices for the two Short-Term RES Forecasting functions can be defined according to the forecasting horizon and time discretization of the specific model, where, in general, a stricter requirement is defined for shorter forecasting horizons.

The delivered forecasts shall meet prespecified targets that are defined based on the aforementioned performance indices. Both errors, NMAE and NRMSE, shall be calculated by the software on a daily basis, both for the entire NII system as a whole and for each operational zone (if applicable).

The individual hourly forecast errors along with the 24-hour ahead and 4-hour ahead NMAE and NRMSE values shall be calculated and displayed in appropriate screens of the RES forecasting system.

Table 6-7 shows such performance targets (as a percentage, in %) for the 24 hour-ahead RES forecast with hourly time discretization and the 4 hour-ahead RES forecast with 15-min time intervals for the entire NII system, according to the size of the NII system.

Table 6-7. Short-Term RES Forecasting Error Requirements for NII Systems

NII System	Maximum 24-hour ahead NMAE (%)	Maximum 24-hour ahead NRMSE (%)	Maximum 4-hour ahead NMAE (%)	Maximum 4-hour ahead NRMSE (%)
Small	16.0	20.0	9.0	12.0
Medium	14.0	17.0	7.0	9.0
Large	12.0	15.0	6.0	8.0

Error residuals caused from poor weather forecast prediction will not be taken into account when calculating the NMAE and NRMSE.

Error analysis data for the last 24 hours shall also be generated and be available to the NII SMO. These data shall also be stored in the RES forecasting database and the analyst should be able to perform queries and retrieve the following error analysis information.

The Contractor should also ensure that wind prediction errors that exceed 40% of the installed wind capacity should occur for less than 5% of the time, calculated in an annual period.

6.2.2 Very Short-Term RES Prediction Application

The Very Short-Term RES Prediction function is designed to provide much shorter-term RES production predictions for real-time use than conventional Short-Term RES Forecasting does. To comply with the provisions of the NII Code, a Very Short-Term RES Prediction model that is used to predict RES production up to 70 minutes ahead, in 5-minute intervals (14 steps) shall be developed. In any case, the time horizon and the duration of each time interval can be configurable.

The 5-min predictions produced by the Very Short-Term RES Prediction model are used by the NII SMO as key input to the cost-based Real-Time Dispatch (RTD) function that is typically solved iteratively every five (5) minutes comprising the next seventy (70) minutes with a 5-min time resolution.

6.2.2.1 Very Short-Term RES Prediction Input Data

The Very Short-Term RES Prediction function is designed such that it has the capability to:

- Predict the next several 5-minute RES production values which conform to the dynamics that it has displayed for the most recent time period, for instance, the past 30 minutes up to two hours;
- Conform to the 15-min average values of RES production that are forecasted by the 4 hours ahead Short-Term RES Forecasting function.

The weather change is a relatively slow process compared to the 5-min RES forecast for the Very Short-Term RES Prediction time horizon, and weather information is already used in the 15-min forecasts produced by the 4 hour ahead Short-Term RES Forecasting model. Therefore, weather variation information will not be directly used in the Very Short-Term RES Prediction function, but the 15-min forecasted RES production values are to be used to adjust the 5-min forecasted RES production values produced by the Very Short-Term RES Forecasting. On the other hand, the manual training data source specification (or automatic selection according to a designated selection criteria) allows the operator's intervention that may introduce weather relevance into the selection process – this implies indirect use of weather information. Furthermore, Very Short-Term RES Prediction online training provides yet another opportunity to make adjustments to the already trained NN and improves the likelihood of reducing the gap between the forecasted RES generation dynamics based on the RES generation dynamics present in the selected RES generation data source and that of the current RES generation.

Therefore, the input data for the Very Short-Term RES Prediction application vary significantly with respect to the input data used for the Short-Term RES Forecasting models. In fact, the input data are restricted to the historical RES production time series (mainly the most recent available SCADA measurements are used), the 15-min forecasted RES production data produced by the 4 hours ahead Short-Term RES Forecasting model and the time/calendar data to account for the time of day, seasonal effect, etc. The specific Very Short-Term RES Prediction input data for

Wind and PV are summarized in Table 6-8 and Table 6-9, respectively. The proposed selection of input data is given for illustration purposes only. The final selection of input data is the responsibility of the Contractor.

Table 6-8. Very Short-Term Wind Prediction Input Data

Category	**Relevant Data**
Historical wind production data	Historical time series of actual wind production values up to *n* past time intervals (minutes, hours)
Time/Calendar data	Time of Day, Day of Year
Forecasted load data	15-min average forecasted wind production values (output from the 4 hours ahead short-term wind forecasting function) up to *f* future time intervals (minutes, hours)

Table 6-9. Very-Short-Term PV Prediction Input Data

Category	**Relevant Data**
Historical wind production data	Historical time series of actual PV production values up to *n* past time intervals (minutes, hours)
Time/Calendar data	Time of Day, Day of Year
Forecasted load data	15-min average forecasted PV production values (output from the 4 hours ahead short-term PV forecasting function) up to *f* future time intervals (minutes, hours)

6.2.2.2 Very Short-Term RES Prediction Output Data

Based on the requirements of the RTD system, for the NII system, the Very Short-Term RES Prediction application shall deliver the 5-minute average forecasted RES (Wind and PV) production for the next 70 minutes (14 values).

The delivery time (lead forecast time) for all outputs shall be specified during the Detailed Design Phase of the Project.

Descriptive statistics should be provided to enable the analyst to compare the forecasted with the actual RES production. The statistics allow the analyst to acquire further insight to the performance of the forecast model.

Both graphical and numerical methods should be provided. Numerical methods typically refer to summary statistics, such as standard deviation, mean, max, min, median as well as estimation of confidence intervals. Graphical methods shall include line plots, box plots, scatter plots and load forecast error distributions.

Therefore, the NII SMO will have the ability to review RES production forecasts and draw intuitive conclusions regarding load forecast performance. All statistics and charts should be exportable for further processing or inclusion in business reports.

Also the RES forecast results (output data) should be stored in the RES forecast database in order to be available for retrieval and be queried by external systems in order to be used, for example, by market applications, etc.

Figure 6-4 illustrates the ANN-based Very Short-Term RES Prediction application architecture.

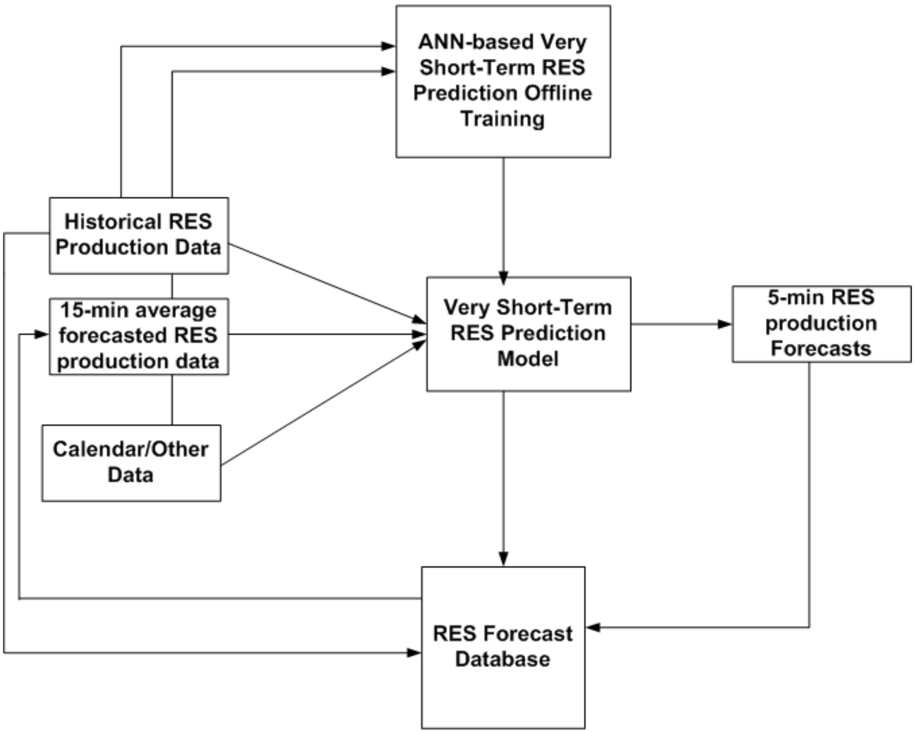


Figure 6-4. ANN-based Very Short-Term RES Prediction application architecture

6.2.2.3 Very Short-Term RES Prediction Performance

Similarly to the Short-Term RES Forecasting functions, the performance of the Very Short-Term RES Prediction model shall be assessed using the Normalized Mean Absolute Error (NMAE) and the Normalized Root Mean Square Error (NRMSE) indices, already defined in section 6.2.1.3.

The 5-min individual forecast errors along with the respective NMAE values for each 70 min ahead period shall be calculated and displayed in appropriate screens of the Very Short-Term RES Prediction system.

The delivered forecasts shall meet prespecified targets that are defined based on the NMAE and NRMSE index. Table 6-10 shows such performance targets (as a percentage, in %) for a 70 min-ahead Very Short-Term RES Prediction with 5-min time discretization, according to the size of the NII system.

Table 6-10. Very Short-Term RES Forecasting Error Requirements for NII systems

NII System	Maximum 70-min ahead NMAE (%)	Maximum 70-min ahead NRMSE (%)
Small	7.0	9.0
Medium	5.0	7.0
Large	4.0	6.0

Error analysis data for the last 24 hours shall also be generated and be available to the NII SMO. These data shall also be stored in the VSTLP database and the analyst should be able to perform queries and retrieve specific error analysis information.

The Contractor should also ensure that the number of individual errors exceeding a specific threshold (to be defined during the Contract development) should be less than a specific value (also to be defined during the Contract development).

6.2.3 RES Forecasting Operation Modes

The RES forecasting/prediction models will be built offline and then the analyst will be able to bring the model online (activation). The activation of a model shall be defined by an activation period (where the activation period could be defined, for instance, by a start time and an end time or by a more complex scheduler configuration file). This will enable the analyst to create an execution sequence in order for the forecast to automatically cope with anticipated changes in seasonal patterns.

The RES forecasting/prediction models should provide the NII SMO with two modes of execution:

- automatic and
- manual.

The automatic mode of execution should apply only to models deemed active. For models that are active, the automatic execution, on cycle basis, shall be the default mode. The execution cycle time for each online RES forecasting/prediction model shall be specified during the Detailed Design Phase of the Project and may be modified by the analyst. Apart from the automatic operation, the NII SMO should have uninterrupted access to the RES forecasting/prediction system to provide ad-hoc manual execution of any model in order to refine forecasts with respect to more recent data (e.g. in case of non-expected large-scale microclimate changes). For the above purposes, the uninterrupted and reliable operation (both automatic and manual execution) of the RES forecasting infrastructure is crucial.

RES forecasts/predictions shall be made on a RES unit basis, if requested from the NII SMO and given that the necessary data are available, and shall be aggregated on a regional (operational zones) and/or system basis. This method will provide more accurate predictions, while at the same time it shall provide consistency across all

NII systems RES resources. The model provided by the Contractor shall be validated using operational data from RES units in a range of terrain types and RES regimes.

The Contractor should provide detailed documentation regarding the availability of the models and algorithms offered in the RES forecasting/prediction system and in case third party software is used, the licensing and supporting material should also be provided.

6.2.4 RES Forecasting Data Manipulation

All data from SCADA (RES production and weather variables measurements) shall be made available to the RES forecasting/prediction system automatically. This means that the RES forecasting/prediction system shall have its own database, in which all SCADA data, processed data, prediction results, configuration data and parameter data shall be stored. An appropriate graphical user interface (GUI) for the easy management of the database shall also be developed.

Since different time resolution (time intervals) is used for the three distinct RES forecasting/prediction models, it is recommended that all raw SCADA data be stored in the finest available time resolution (e.g., one-minute data) in the database. In this case, the Contractor shall build appropriate procedures to produce 5-minute, 15-minute and one-hour average RES production values that will then feed (automatically or manually) the respective RES forecasting/prediction models.

Unavailability of SCADA measurements for numerous RES units may occur due to either lack of communication or the fact that several RES units are connected to the distribution network, and, therefore, get not visible from the SCADA system (this is the current status for some wind plants as well as all PV parks in many NII medium and small systems; this is not the current status for the wind plants in Rhodes). In any case, this inefficiency shall be overcome to allow for the real-time monitoring and accurate forecasting of the RES units power output. For these RES units, a RES Estimation Function shall be activated to estimate the real-time RES production, and therefore, allow for reliable RTD operations and RES curtailment decisions. The RES Estimation Function uses available RES measurements (either SCADA measurements or real-time telemeasurements) in conjunction with an advanced upscaling procedure and estimates the real-time production of RES units for which no real-time production data are available otherwise. The different characteristics of the various RES technologies may call for customized upscaling and estimation procedures to be developed for each technology.

The Contractor shall also provide an automated procedure to feed the weather forecast data to the models. In addition, manual override of input data in the GUI shall be allowed.

The RES forecasting database shall contain RES and weather information for each day of the year, for up to three (3) years. The software shall include an automatic raw data validation and invalid data manipulation process. The Contractor should provide the following pre-processing techniques to make the data more manageable:

rescaling, normalization and handling of missing data. Extrapolation of other mathematical approaches for missing and invalid data shall be performed and the NII SMO should be aware of the raw data manipulation process by an appropriate warning. In addition the software must provide the necessary tools to the analyst to monitor input data and be able to modify or exclude invalid data from the model.

The operators shall review the forecast suggested and shall use their judgment, if necessary, to appropriately modify the predictions prior to their implementation in the real-life NII system operations.

6.2.5 RES Forecasting Model Qualities

Each distinct RES forecasting/prediction model should possess the following qualities:

- Each model should adapt automatically to new measurements. As the forecast period elapses, the model should automatically update its data window and re-compute a new forecast, according to schedule.
- The algorithm should constantly apply corrections to the RES production forecast, as new data and weather measurements become available.
- The algorithm should be robust and fault-tolerant. Reasonable forecasts should be produced, even if input data consist outliers or erroneous data.

7 System External Interfaces

In the context of this Project, the overall design and successful implementation of the various interfaces shall be the responsibility of the Contractor. The NII SMO shall provide any available documentation and assistance for the successful system integration of the Project with the external systems as presented below.

7.1 Interface to the HEDNO-Developed IT System (including the Settlement)

The NII SMO is in the process of developing a separate system for implementing the Settlement. This System is referred to as "HEDNO-Developed IT System". This system shall perform the following:

- Market Settlement, including any applicable transactions for the Capacity Assurance Mechanism.
- Keeping the Market Registries, as they are foreseen in the NII Code. The master data with respect to the market registries shall be kept in this system. The Master File of the MMS shall be updated in case that any change is made at the master data of the registries.
- Support the submission of the Technoeconomic Declaration, as they are foreseen in the NII Code. The master data shall be kept in this system. The Master File of the MMS shall be updated in case that any change is made at the master data of the technoeconomic declarations.
- Detailed specifications of the master data will be provided to the Contractor during the Detailed Design Phase of the Project.
- The HEDNO-developed IT System shall interface to the Metering System, and specifically the Metering Data Management System, to derive data required for settlement purposes. The interface with the Metering System is not within the scope of this project.
- The HEDNO-developed IT System shall also interface to HEDNO's ERP for accounting purposes. The interface with the ERP is not within the scope of this project.
- Market results and RTLS data will be communicated to the HEDNO-developed IT System.

7.2 Interface with HEDNO's Website

For the needs of this project, HEDNO's corporate portal shall be used. The actions to be implemented include, but are not limited to the following:

- Submission of declarations by the Market Participants;
- Publication of forecasts, market results, reports, etc.;
- Communication with the Market Participants.

