Technical Description

PROCUREMENT OF SOFTWARE FOR DISTRIBUTION NETWORK PLANNING STUDIES
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A. General Terms

A.1 GENERAL PROJECT DESCRIPTION

The project consists of the following parts which are described in detail in the following paragraphs:

- Software Package
- Customization – Parameterization Tasks
- Personnel Training
- Network Data Entry and Data Migration
- Technical Support
- Technical Documentation

The Contractor shall provide all of these parts in the offer.

A.1.1 The Software Package

The Software package may comprise a number of modules and must be expandable by adding new modules if necessary to cover the needs of HEDNO as described in Part B. All proposed solutions must fully comply with functional requirements as described in Part B. The software package comprises commercial off the shelf solutions while custom made applications shall be avoided if possible. All custom made applications shall be listed together with their functional features.

A.1.1.1 Interoperability

All subsystems, modules and applications of the software package must communicate and integrate with each other where required.

A.1.1.2 Optional components

A number of optional components of the Software Package, not required by HEDNO, may be offered by the tenderers. These components must be included in a separate Table of Optional Components. The cost, if any, of these components is not going to be calculated to the evaluation of the tender. It is at the discretion of HEDNO to evaluate, negotiate and acquire as many of the optional components as necessary at a price no higher than the price offered in the Table of Optional Components.
A.1.2 Customization

Customization includes all tasks required so that the system can serve the needs of HEDNO in accordance with the functional specifications, including transformations and/or development of modules that are absent from the offered package.

Custom made components shall be minimal and can only be offered if the functional requirements are not met by parameterization, in order to achieve the following objectives.

- Maintain the advantages supported by the package itself.
- Minimize future maintenance costs and complexity of the project.
- Maximize the quality of the applications.

The percentage of functionality covered by Custom made components cannot be greater than 10% of the total functionality as described in Part B.

The following issues must be addressed in the offer:

- Which are the customization tools that accompany the package?
- How custom made applications integrate with the software package.
- How new versions of the package are acquired without repeating customization procedures.
- How the effort of customization can be continued after the package is brought into productive operation.

A.1.3 Training of HEDNO Personnel.

The Contractor will be responsible to provide a training program to the personnel of HEDNO, covering the issues of use, operation, maintenance, and administration of the Software Package. Ten employees of HEDNO will attend seminars with the option of a 40% increase. The exact number of trainees per seminar will be determined by agreement with the contractor. These employees will be trained to become software trainers for other employees of HEDNO.

Training shall take place in an appropriate Test/Training environment that the Contractor will provide with the appropriate data. Any action taken within the training does not affect the other environments of HEDNO information system nor threaten the integrity of the data.

The minimum duration of the training program is 1 month, and is not necessarily a consecutive period but will be arranged according to the
availability of HEDNOs personnel. The detailed content of the training program shall be submitted for approval to HEDNO and shall include the following information:

- Description of the seminar.
- Duration in days.
- Objectives.
- Language of Teaching.
- Place.
- Required knowledge and experience (prerequisites) of trainees.
- Possible visits to similar existing worksites that use the same software package. Any travel expenses of HEDNOs employees will be covered by HEDNO in that case.

Trainees shall have received educational material and a demo version of the program prior to the beginning of the seminars.

Seminar trainers must have the following qualifications:

- Understanding and a high level of knowledge of software equipment and experience in the field of power systems simulation.
- Very good knowledge of the language of the seminar.

In addition, training shall take place when new versions and features of the program are available.

The contractor is required to prepare the necessary training material for the seminars, written in a comprehensible way. After the end of each seminar, the various books and printed material, CDs, DVDs, etc., will remain the property of HEDNO. HEDNO reserves the right to reproduce educational material for the use of its personnel only, within its workplaces.

If the contractor believes that training requirements will be met in a different way, he may alternatively modify the design of proposed training. It is in the absolute discretion of HEDNO to accept or not the proposed amendments.

It is the Contractor's obligation to find the venues for the seminars to be held in Greece (apart from technical visits). It is desirable that training be done at the premises of HEDNO. In this case, the requirements shall be described by the Contractor. After completing each seminar, HENDO will assess the results to evaluate if the objective has been achieved.

Seminars evaluated as unsatisfactory will be resumed as soon as possible at the contractor's expense. In this case, HEDNO shall determine the changes to be made to the above seminars and notify the contractor.
within 30 days of the end of the unsatisfactory seminar. The language of the seminars, books and material may be either Greek or English.

A.1.4 Network Data Entry and Migration.

The Software package must have the ability to import all network data already available in HEDNOs databases in various formats (such as GIS data, DMS data, PSS/ ADEPT files, PSS/U dat files, pss/e files). All relevant tasks to interconnect these data sources of the various information systems must be completed according to the functional requirements described in Part B.

A.1.5 Technical Support – Maintenance and Upgrade of all Components of the Software

The Contractor undertakes the maintenance of all the offered hardware and software for a period of five (5) years. During the maintenance period, the Contractor will upgrade or replace the software offered. HEDNO will be able to discontinue maintenance with three (3) months written notice. Maintenance services also include the following tasks:

- Acquiring new releases.
- Upgrades and installation of upgrades to the software products offered.
- Installation and implementation of patches / fixes.
- Phone support for troubleshooting.
- Remote monitoring of installed software when required by HEDNO.

A.1.6 TECHNICAL DOCUMENTATION

This includes the analytical technical description of the system offered and comprises the following parts:

- User Manuals. These include detailed guidelines with regard to user navigation, graphical user interface, usage scenarios, system operations, etc.
- Technical References. This includes the analytical description of modeling system components and algorithms that are implemented
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with citations to the relevant literature. All parameters of network components are described in detail.

- User Administration Guidelines (user roles, password administration, access rights, etc).
- Security Guidelines.
- Description of interconnection to third party solutions.
- Scripting tutorial with examples and study cases.
- API references.

The tenderer will provide HEDNO with all new releases of the above documentation during the maintenance period. Technical documentation will be written in English or Greek language.

A.2 System Architecture

The Contractor’s Software will be incorporated in a system that is built according to the following architecture.

- **Data Server**
  
  All data necessary for the operation of the software are stored and well organized in the data server. A backup server is also used to restore data under the event of any failure on the data server. These data include:
  
  - **Network Data**
  - **Time Series Data Base**
    
    Historical data such as load time series and switches status are included in this database.
  - **Project Repository**
    
    All projects created by the users are stored in a repository in the data server.
  - **Script Repository**
    
    Scripts created by the users or the contractor are maintained here.
  - **Equipment Libraries**
    
    A general purpose library as well as user defined libraries are stored in the data server.

- **License Server**
  
  License allocation is coordinated by one or more servers. The total number of licenses purchased by HEDNO can be divided in separate license pools. Each pool may be associated to specific departments of HEDNO, or selected groups of workstations. Flexibility must be provided with regard to the number and size of license pools that can be created as well as the number of license servers that can be
utilized, so long as the constraint of the number of licenses purchased is not violated.

The above servers do not necessarily correspond to discrete computing systems and can be merged into one server.

- **Data transcription interfaces (where required)**

The transcription of primary data from the data sources of GIS / SCADA / Time Series DB Loads to the Data Server is implemented by interfaces, provided by the contractor. These interfaces are part of the contractor's offer and their cost is included in the offer. Transcription interfaces are used where DB-links are not possible or not suitable. It is recommended that interfaces use generally accepted communication standards to the extent that they are also supported by implemented systems of HEDNO.

- **WorkStations**

These are Personal Computers (Desktops or Laptop) where the Software Package is installed. These PCs are connected to the intranet of HEDNO either directly or via a virtual network connection. Each workstation can receive a license from the corresponding license server both through intranet and virtual network, in order to launch and operate the Software Package. Thus the number of workstations executing concurrently the software package is limited by the number of licenses purchased by HEDNO. The number of workstations however, that will have potential access to the software is unlimited and includes all workstations connected to the intranet or virtual network of HENDO. Each workstation can also download or upload data from the data server according to its access rights. In addition, all workstations will be able to locally store data, including all type of data stored in the data server.

Licenses can be detached from the license server for a predefined period, i.e. a user can schedule to work under circumstances with no access to HEDNOs intranet or virtual internet. A small number (7) of critical workstations will be able to work, performing basic operations and using locally stored data, even under an unexpected failure of the network. These workstations will use the same version of the software package which will be updated when updated versions are purchased.

Any additional software required for the operation of the Software Package will be provided by the contractor and its cost is included.
in Contractor’s offer. An exception is office application software and Operating System which is already installed in the workstations.

Figure 1. Architecture of the proposed solution

A.2.1 Access and Administration Rules

The secure operation of the Software is related to the protection of the integrity of the data stored in the server from malicious third party intervention.

To protect application data, the access rights of the users involved will be hierarchically assigned and based on the responsibilities of each user. The assignment of rights will be governed by the principle of least privilege (i.e. assigning the minimum rights required for the user to perform its
tasks). In the frame of this hierarchical approach, the following user authorization roles are defined:

- **General Application Coordinator**
  Will have general access to all levels of data.

- **Administrator:**
  They are users with increased access rights to application's resources. We distinguish the following subcategories:
  1) **User Administrator:**
  They will provide access rights to the user of the Software Package.
  2) **Library Administrator:**
  They will have access rights to modify the libraries of the software.
  3) **Scripting Administrator**
  They will have the access right to create or modify scripts.
  4) **Network Data Administrator**
  They will have access rights to modify network data. These access rights may cover the full network or may be related only to a subset of the network (e.g. a region for which the administrator is responsible).
  5) **Users**
  They will have the right to read and download all information from the data server and store data in their workstations. They can upload their projects on the data server, at a special dedicated section.
  6) **Technical Support Personnel:**
  They are responsible to perform routine maintenance / upgrading and backup operations, as well as to restore them in case of disaster recovery. Technical Support Personnel will be trained by the contractor for any specialized functions performed through the backup environment.

**The above roles may be merged into fewer persons.**

**Activities Logging (Logging):**
In order to monitor the processes, especially those related to downloading and updating data, it is advisable to record the actions of the users in a log file or in a special database. These records can be used for auditing work when necessary.

Also the following issues shall be addressed in the offer:

- Communication protocols
- Encryption
- Authentication

A.3 HEDNO Contribution.

HEDNO is responsible to provide the following components:

- Communication Network (WAN)
- Hardware: HEDNO will provide the required servers and workstations, according to the Software Package requirements, which the Contractor will disclose to HEDNO.
- Software: HEDNO will provide:
  - Operating Systems for the Server and the Workstations.
  - Relational Database Software.

The Contractor will disclose to HEDNO the minimum requirements of its software in terms of hardware, operating systems and relational databases. Any software requirement other than the above provided components will be provided by the contractor and its cost is included in the offer.

The contractor will work with the personnel of HEDNO to harmonize the software provided with the company’s practices on computer security and to ensure confidentiality in the use of corporate data.

A.4 Project Scheduling

The project is divided in the following Phases:

- Phase A: Initial Actions.
- Phase B: Requirements Analysis, System Design, Process and Operation Development.
- Phase C: Main Project.
Phase D: Staff training.

Phase E: Acceptance tests and preparation for full deployment.

Phase F: Production Operation - Gradual integration of all users.

**Phase A: Initial Actions.**

- Agreement on procedures, standards and implementation methods
- Project groups, and role assignment
- Workplaces and equipment preparation
- Demo versions of the software together with a user tutorial, will be provided until its final installation.
- Detailed content of the training program submitted for approval to HEDNO
- Analytical timetable and work plan so that it is simple and objective to monitor project implementation and any deviations. The criteria should and the details of the Deliverables of each Phase of the Project are defined.

Deliverables:

- Project Gantt Chart.
- Detailed description of phases and deliverables as well as the sequence of actions of the project.

**Phase B: Requirements Analysis, System Design, Process and Operation Development.**

The main objective of this Phase is to provide the contractor with a comprehensive and accurate picture of system requirements, data, and business processes (existing and new). At this stage the following are implemented:

- Installation and commissioning of the necessary Servers
- Software package installation ready for personalization and development tasks. It includes the installation of customization, personalization, development tools and other tools.
- Identification and detailed description of functions and procedures of HEDNOs studies.

**Phase C: Main Project**

In this phase the system is customized and the necessary programs are developed to meet all the requirements:
- Parameterization, personalization and system development according to specifications and requirements.
- Development implementation and installation of interfaces with third-party systems as well as with HEDNO databases and archives.
- Developing access rights and developing end-user procedures.
- Preparing study cases for testing.
- Importing necessary network data from existing digital sources.
- Importing available libraries.
- Development of end-user training program and material that will be delivered to the trainees.

Deliverable:

- Customization Procedures.
- All source and executable code in electronic format for all custom tasks.
- A test plan that includes the entire system test cycle at the various stages of the implementation.
- Disaster Recovery Plan, including the necessary actions to be taken to rescue data, restore the system and generally continue operation in the event of a natural or other disaster.
- Emergency Operation Plan (e. g loss of communication network).
- Architecture of the entire System in its full form.

Phase D: Staff Training

Staff training is carried out in accordance with paragraph A.1.3. This phase can be carried out in parallel with phases B and C and must have been concluded before beginning of phase E.

Phase E: Acceptance tests and preparation for full deployment

This aims to control good operation by future end-users. A prerequisite for starting Phase E is to complete the introduction of necessary network and library components into the software database.

Phase E includes:

- Test of all the features of functional requirements.
- Acceptance Test of interfaces.
- Acceptance test of imported network data from other sources.
- Acceptance test of imported libraries.
- Acceptance test of management procedures (backup/restore, database management).
Phase F: Production Operation - Gradual integration of all users

During this phase, the software has been installed in all necessary workstations. The daily operation of the system is executed, and problems that arise are solved.

A.5 System Expandability

HEDNO must be able to:

- Add functions to the system.
- Alter the initial Customization of the Software.
- Install new releases by transferring the above work from its previous release without resuming customizations, and deployments.

Tenderers must include in their tender a detailed description of how the above can be implemented.

A.6 Test Environment

The system shall include a test environment platform (testbed) for the purpose of running special applications, which will include special designed representative examples and study cases.

A.7 References.

Tenderers shall be experienced in software solutions for distribution system operators and the software provided must be currently used from at least 4 Distribution System Operators each of which serve more than 1,000,000 consumers. At least two of them belong to countries of Europe and North America. The minimum required experience listed above shall be evidenced by Acceptance Certificates.

Tenderers must mention in their tender for every project for which they have not submitted an Acceptance Certificate at least the following details:
• The trade name of the Company which is the owner of the project and the number of consumers it serves.
• Detailed characteristics of the project.
• The name(s) of the person(s) responsible for the project’s acceptance and operation from the Company that is the owner of the project.
• Phone number(s), fax number(s) and email of the aforementioned persons.
B. Functional Requirements

B.1 Introduction

A compliance table, containing all necessary requirements, will be provided and filled by all tenderers. For each functional requirement the tenderer must answer if it is supported by its already developed solution, will be developed by a custom made application, or not supported at all. In case a functional requirement is supported by a custom made application the tenderer must provide information regarding the time needed to develop the application as well as details of the implementation. In the paragraphs below a description of the functional requirements is provided.

B.2 User Friendly Interface

The software package and all its application shall be user-friendly according to the following guidelines:

- WIMP (Widows, Icons, Menus, Pointers) Based Graphical User Interface (GUI).
- Uniform look and feel among subsystems and modules.
- Menu driven options that include all modules licensed to a user. The options must be grouped in different levels so that it is easy for the user to find and access.
- Ease of navigation and access between the various screens, tasks and modules.
- Shortcut keys must be provided in order to facilitate the user to navigate through the applications.
- Data entry facilities shall be provided to ensure correct and quick data entry and significantly reduce the chances of error. Indicatively the system shall:
  - Provide default values for the required fields.
  - Check the validity of values entered by the user and provides warnings in case of not valid values.
  - Provide short help messages at each field in order to inform the user about the required data.
- The user shall be able to have multiple sessions to the application simultaneously from the same workstation (subject to license availability).
• Online help for the user must be fully implemented and provided in all levels, easy to use and access.
• A single line diagram can easily be generated through a user friendly CAD system, by simply clicking and dragging equipment symbols onto the drawing pane with automatic snap and align into position.
• Equipment symbols are organized in a pane next to the drawing space.
• There is no restriction on drawing sizes and number of nodes and elements.
• All equipment can be entered graphically.
• Editing functions like undo, redo, delete, copy, paste, move and zoom for processing the network diagram are available.
• An element can be dragged and moved from one node to another node without deleting the element.
• Data and graphic can be moved to and from third party software (like MS-Excel, MS-Word).
• The equipment data are entered in dialogs. Grouping is provided to show which data is needed for which analysis.
• Annotation graphics such as lines, rectangles, ellipses, arcs, ellipse sections, polygons, polylines, any kind of bitmap graphics, can be used for documenting the diagram.
• Input of user text with selectable font and size.
• Colors and line types can be freely selected.
• Elements overloaded after a load flow or short-circuit current analysis can be color-highlighted.
• Isolated elements can be highlighted.
• Coloring options to distinguish user-selectable network areas, zones, feeders, voltage levels, earthed or unsupplied networks and galvanic separated networks.
• Differences from a base case network can be colored.
• Coloring according to ranges. Many calculated variables can be colored according to their values (e.g. according to element losses or according to voltage drops)
• Results can be presented in tables and graphic charts.
• Load flow animation is provided.
• The user can create and define his own symbols and composite graphics for each element type and node.
• Any number of different symbols per element type or node can be defined.
• On the diagram the symbols can be flipped, rotated and resized.
• Representation of nested networks is supported.
• Properties and commands are appropriately grouped.
• Abnormal conditions/violations flagging is supported.
• On-line editing and zooming (buses or nodes, branches, shunts).
• Power flow display (arrows indicating direction) for active, reactive and apparent power as well as currents. This includes short circuit flow display on the single line diagram.
• Background and graphic files can be inserted by the user.
• Grids and rulers on the diagram.
• ‘Move’ and ‘Delete’ function for result boxes.
• Geographic Diagrams (GPS-based) with background maps.
• Diagram export and printing functionality with print area definition and print previewing with page layout to print the network on any paper size.
• One line diagram can be exported to AutoCAD.

Graphical representation of the network can be omitted by the user and calculations can be as well performed without it (e.g. the user will provide data in a tabular format or ASCII file format). Electrical data shall be enough to run all modules. A graphical representation may be added subsequently and a tool that assists the user to draw existing elements or creates automatically the single line diagram will be provided.

B.3 Data Management

Data management tools and facilities shall provide the user with all the features required to manage, overview and maintain all the data from a project. Editing and overview of data (both inputs and analysis results) must be easy and self-descriptive

• Each element of the network can be individually edited by double clicking on its graphical representation to open the corresponding dialog box.
• The dialog box comprises the required fields, organized in groups, each of which corresponds to a calculation module.
• Elements of the same type (e.g. all lines of the network) can be edited simultaneously in a tabular manner.
• Sorting and filtering elements according to various criteria such as element type, name or the value of a specified parameter must be possible. Sorting of elements together with their input parameters and analysis results in alphabetic order is also supported.
• Searching of elements by name or property or parameter value. The user can edit simultaneously the values of parameters of the elements of the listing provided (e.g. the user can search for all nodes with name containing the letter “A” and then modify the parameter Nominal Voltage of these nodes at the same time).
Advanced querying of parameter values can be supported (e.g. presenting all lines with length above a limit and rated current below a ceiling value).

- The user has the option to provide time series, or table or vector data for parameters instead of giving explicitly a unique value. This time series, vectors or tables express the variation of the parameter with time or an external variable. For example instead of assigning a unique value to the active power of a load of a node, the user has the ability to provide a time series of loads.
- All elements are listed in a tabular manner. Each element selected on the table can be marked and highlighted in the network graphic diagram.
- Timestamps of creation and modification of each element are provided.
- User defined data can be assigned for each element.

**B.4 Project Management**

The studies performed by a user are well organized in projects, which may be either folders containing files or database files. Each project incorporates all necessary data, libraries, graphical representations and calculations for the respective study. The project comprises variations which are differentiated configurations of the network that all derive from a root case. Changes in the root case can be inherited by the variations.

For each variation a number of snapshots can be defined each of which represents a different operating state of the network (i.e., different loading and generation profiles)

The following features shall be supported:

- Versioning of projects. Using versions, the historic development of a project can be controlled. Also, the previous state of a project can be recovered by rolling back a version.
- Root Case Definition. The user can define a base case of a project which is the reference to all other cases created representing e.g. the initial configuration of a network. Changes in the root case can be inherited to the derived cases.
- Children Cases (Variations). These cases derive from the root case and inherit all modifications from the root case. A children case represents a modification of the network and may be associated with a chronology that declares the date that this modification takes place.
Snapshots Definition. For each case a number of snapshots can be defined, i.e. operating states of the same network that differ in loading, switching status, generation, etc.

Each project can be shared among users so that it is possible to work on it in a collaborative manner. The owner of the project defines the list of users and their access right to the shared projects.

Comparing Cases or snapshots. Two Cases or Snapshots can be compared to one another and differences are highlighted. This includes the results of analyses, with the facility to create comparative result tables.

Update a Project. (Update a derived project from base and vice versa).

Exporting/Importing a Project. A project can be imported and exported to other workstations using the same software (including workstations not belonging to HEDNO)

Networks merging and splitting
  o Merge two or more separate pieces of network together to create one larger model.
  o Split one large model into two or more individual models

B.5 Models of Network Components

The software shall provide appropriate modeling of the electrical components of a distribution network. Each of these components shall have a graphical representation and can be inserted in the network diagram by dragging it from a group of symbols and dropping it onto the diagram pane. The user shall have the option to omit the network representation of components, simply by providing network data in a tabular manner.

The components of a network can be organized in groups of several types (i.e. Zones, Areas, feeders).

Each component is associated with information such as its operator and owner/owners together with ownership shares, date of installation and date of decommissioning.

The following categories of components are supported:

- Nodes
- Branches
- Feeders
- Switches
• Machines
• Wind Turbines
• PV Systems
• Batteries
• Virtual Power Plants
• Loads
• External Grids
• Power Electronics
• Compensation Devices
• Sources
• Controllers
• Protection Devices

An unlimited number of components can be included in the projects.

The requirements of each of the above components are explained in more detail below:

**B.5.1 Nodes**
- One–Phase Nodes (AC and DC)
- Three-Phase Nodes

**B.5.2 Branches**

**B.5.2.1 Transformers**

All possible connection types can be modeled such as:

- 2 Winding Transformer
  - Y-Y. (1, 2,3phase)
  - Y-Y (180°) (1, 2,3phase)
  - Y-delta (±30°).(1, 2,3phase)
  - Delta-wye (±30°).(1, 2,3phase)
  - Delta-delta. (1, 2, 3phase)
  - Delta-Delta (+180) (1, 2,3phase)
  - Center-tapped delta. (1- phase)
  - Center-tapped wye (±30°).(1-phase)
  - Y-wye with phase shift. (1, 2,3phase)
  - Z -Y (±30°). (3 phase)
  - Z -Y (±150°).(3 phase)

- 3 Winding Transformer
  - D-d-d connection (Delta-delta-delta)
  - YN-d-d connection (Grounded wye-delta-delta)
- YN-YN-d connection (Grounded wye-grounded wye-delta)
- YN-YN-yn connection (Grounded wye-grounded wye-grounded wye)
- YN-YN-d auto-transformer (Grounded wye-grounded wye-delta auto transformer)
- YN-d-zn (Grounded wye-delta-grounded Z)
- YN-d-y (Grounded wye-delta-wye)

- Autotransformers
  - 2 and 3 winding autotransformers
  - 1, 2 and 3 phases
  - Y-connected autoregulator (1, 2,3phase)
  - Delta-connected autoregulator (1, 2,3phase)

**B.5.2.2  Tap Changer Modelling**

A Tap Changer of a transformer is also modelled in detail. The basic data and functionalities required to model the tap changer are:

- At which side of the transformer is the tap changer installed
- Additional Voltage per tap
- Phase change per tap
- Controlled Node
- Setpoint of the controlled variable
- Lower bound of the controlled variable
- Upper Bound of the controlled variable
- Neutral Position. At this position Winding ratio equals the ratio of rated voltages
- Maximum tap position
- Minimum tap position
- Short circuit voltage per tap position
- Copper Losses per tap position
- Controller time Constant
- Option for Continuous or Discrete operation
- Remote Control Operation. There is the option to control a node different than the transformer terminals
- Control Mode Selection. The following options shall be provided :
  - Voltage Control
  - Reactive Power Control
  - Power Factor Control
- Line drop compensation function is supported. This function controls the voltage at a remote node without measuring the voltage at that node. Instead, the actual value is estimated by measuring the voltage at the HV or LV side of the transformer and calculating the voltage drop across the line. The user provides R and X settings as inputs.
B.5.2.3 Overhead Lines and Cables

The software provides modelling for both DC and AC lines, including all phase technologies (3-phase, 2-phase and single phase), with and without neutral conductor and ground wires, for both single circuit and mutually coupled parallel circuits. The user can configure all relevant parameters such as line length, reactance, resistance, susceptance, conductance per phase as well as in positive, negative and zero sequence.

B.5.3 Feeder

The user can define a feeder by simply defining its starting point and orientation. Then an algorithm will search for all components connected to the feeder and assign them into the feeder entity. The feeder is terminated when an open point is encountered. Also there is the option to terminate the feeder when a different voltage level is encountered.

The user can scale load of the feeder, select a color for it, mark all of its elements, view, edit and modify parameters of its components in a tabular manner.

B.5.4 Switches

One and three phase switches are provided. Switching time (i.e. time required to perform a switching operation) is a parameter defined by the user. Modelling includes the following type of switches for all voltage levels, (one phase and three phase):

- Load switches
- Disconnect switches (one phase and three phase)
- Busbar couplers
- Circuit breakers
- Grounding switches
- Remote controlled switches
- Reclosers
- Autoreclosers
B.5.5 Machines

Asynchronous, Synchronous, DC Machines and Doubly Fed induction Generators are modeled in detail. Short circuit models for machines are also provided and their contribution to the short circuits is calculated and presented.

B.5.5.1 Asynchronous Machine

Three-phase induction machines are modeled using a full two-circuit representation of the machine’s rotor. This model describes the steady-state equivalent characteristics of an induction machine. The model is fully configurable by the user (i.e. the user can define values for $r_a, X_a, X_m, r_1, X_1, r_2, X_2$).

B.5.5.2 Doubly Fed Induction Machine (DFIG)

The user provides active and reactive power of the DFIG. The rotor can be either single or double cage. Short circuit model is provided for the DFIG. The user also has the option to provide a slip-torque current. Modelling supports Wye, Delta and Wye-Neutral Connection.

B.5.5.3 Synchronous Machine

The model is adequate enough to provide the following options

- Active Power Control and Balancing.
- Reactive Power/Voltage Control.
- Short Circuit Model of Synchronous Machine.
  - Sub-transient equivalent.
  - Transient equivalent.
  - Synchronous equivalent.
• RMS- and EMT-Simulation.
• Mechanics.
• Saturation modelling.
• Controls (AVR and Governors).

B.5.5.4 DC Machine

A dc machine model is provided suitable for load flow and short circuit analyses as well as RMS and EMT simulation.

B.5.6 Wind Turbines

Wind turbines can be modeled according to the “WECC Wind Plant Dynamic Modeling Guidelines”\(^1\) or IEC 61400-27-1\(^2\). The software package is able to model all types referred to those guidelines, i.e.:

- Type 1 – Fixed-speed, induction generator
- Type 2 – Variable slip, induction generators with variable rotor resistance
- Type 3 – Variable speed, doubly-fed asynchronous generators with rotor-side converter
- Type 4 – Variable speed generators with full converter interface

All considerations as well as control models referred to the WECC or IEC 61400-27-1 guidelines shall be integrated in the software package. Short-circuit current contribution for all types of wind turbines shall be calculated, to be taken into consideration for system protection studies. Minor differentiation to these guidelines can be accepted as long as it is adequately explained by the Contractor that they lead to equivalent modelling.

Modeling of turbine dynamics including aerodynamics is provided. A wind model is also incorporated to wind turbines, i.e. the user can provide a time series of wind speed, or statistical properties of wind speed and the wind model returns the MW produced. Transient wind conditions with ramp, gust, & noise disturbances can be simulated. Such disturbances can be defined and simulated for a wind turbine separately or for a group of turbines.

\(^2\) https://webstore.iec.ch/publication/21811
B.5.7 PV Plants

Modeling and simulation of a PV plant incorporates the modelling of arrays of PV panels together with the inverter and DC link capacitor.

The electric characteristics of a PV array, such as the V-I characteristics of a PV cell, are incorporated in the model.

A PV array can be modeled as a current source. The power output of the PV array can be modelled as a function of irradiation, temperature, etc.

A PV plant can be a part of a virtual power plant in a time series steady state analysis (i.e. combination of a PV plant with a Battery Energy Storage System).

The short circuit contribution of PVs can be calculated to be taken into consideration for system protection studies.

The PV panel can operate in Voltage control, power factor control and droop control mode.

B.5.8 Batteries

A DC battery is based on a DC Voltage Source and provides modelling for short circuit analysis (Short circuit contribution of batteries can be calculated). Charging and discharging control can be implemented both in RMS simulations (B.6.12) and to time series steady state analysis (B.6.2). State of Charge of the battery must be taken into account in the analysis.

B.5.9 Virtual Power Plants

The user shall have the option to define and model a virtual power plant, i.e. to select a number of generators of the network as well as storage facilities and provide a target total power production for it. The target production can be scaled up and down and is dispatched among the components according to user defined rules.

B.5.10 Loads

Modelling of Loads shall include the following aspects:
- ZIP modelling (constant impedance, constant current, constant power).
- Balanced and Unbalanced Loads.
- Single Phase (Line to Ground) Loads.
- Single Phase (Line to Line) Loads.
- Three phase load Y connection.
- Three phase Load Delta connection.
- Low Voltage Load.
- Scaling Factor.
- Annual Increase.
- Number of Customers Connected.
- Load Profiles (e.g. daily summer and winter load curve).
- Load Groups (e.g. loads in a specific area can be grouped).
- Load Categories (e.g. residential, commercial, industrial load).

Load Groups and Load Categories can share the same properties such as Scaling Factor, Annual Increase, etc.

The can use one of the following options as inputs for a load:

- Active and Reactive Power.
- Active Power and Power Factor.
- Apparent Power and Power Factor.
- Current and Power Factor.
- Current and Active Power.
- Apparent Power and Active Power.

Loads are also associated with charges (tariffs) which reflect the following costs.

- Load interruption Cost.
- Energy Cost.
- Active Power Cost.
- Reactive Power Cost.

These tariffs may be defined as non-linear function or in a tabular form and may be time dependent (i.e. dependent on time of year or on duration of the interruption event).

Short circuit contribution of Loads can be calculated.

**B.5.11 Grid Equivalent**

External Grids can be represented by a Thevenin equivalent of a voltage source with an impedance.
B.5.12 Power Electronics

A variety of models for power electronic devices is provided, such as

- PWM AC/DC Converter.
- Rectifier/Inverter.
- Soft Starter.
- DC/DC Converter.
- FACTS and HVDC Systems.

B.5.13 Reactive Compensation

The software package provides modeling of reactive power compensation devices such as:

- R-L-C Shunt with all possible connection configuration
  - 3 phase Delta-Delta.
  - 3 phase YN-YN.
  - 2 phase YN-YN.
  - 1 phase.
  - 1 phase to earth.
  - 1 phase to neutral.
  - 2Phase Y-Y.
- Switched Shunt.
- Series RLC-Filter.
- Static Var System.
  - Reactive power control.
  - Voltage control.
  - Power Factor Control.

R-L-C shunts are controllable. The basic data and functionalities required to model shunt adjustment are:

- Additional Mvar per step.
- Controlled Node.
- Setpoint of the controlled variable.
- Lower bound of the controlled variable.
- Upper Bound of the controlled variable.
- Maximum step.
- Minimum step.
- Controller time Constant.
• Remote Control Operation. There is the option to control a node different than the transformer terminals.
• Control Mode- The following Options are provided:
  o Voltage Control.
  o Reactive Power Control.
  o Power Factor Control.

B.5.14 Sources

A source is generally used to supply (or remove) power to a network or to provide a reference voltage. In some cases it serves as an idealized equivalent for an upstream or adjacent network. The following types of sources are modelled:

B.5.14.1 AC Voltage and Current Source

• Three-phase and single-phase sources.
• Swing source.
• Voltage-Behind-Impedance.
• Zero/positive/negative sequence model.
• ABC phase model.
• The source can have grounding impedance.

B.5.14.2 DC Voltage and Current Source

B.5.14.3 Controllers

The software shall provide a library with a variety of controllers and is capable of modelling new specific controllers for real-time dynamic simulations (RMS and EMT). In case third party software is involved in modelling simulation, this will be provided by the tenderer together with all related installation guides, technical documentation and users training at no additional cost. The following types of controllers are provided

• Generators, motors, transformers, compensation, HVDC, VSC or any other component could be controlled.
• Automatic Voltage regulators, Turbines, Governors, PSS.
• Secondary control for frequency or balancing control.
B.5.15 Protection devices

A variety of protection devices must be included in the package

- Over current relay with i/t characteristic
- LV- and MV-circuit breaker, fuses, recloser
- Distance protection with any R/X-characteristic
- Voltage, frequency and power swing relay
- Pole slip relay
- Differential relay
- User-defined modelling of any protection device with function blocks
- Reclosers and autoreclosers
- Surge arresters

B.6 Computational Modules

The following Computational modules shall be provided by the Software Package

- Load Flow Analysis.
- Load Flow with Load Profiles.
- Time Series Steady State Analysis
- Short Circuits Analysis.
- Motor Starting.
- Network Reduction.
- Power Quality -Harmonic Analysis.
- Tie Open Point Optimization (TOPO).
- Phase Balance Optimization.
- Optimal Capacitor Placement.
- Optimal Power Flow.
- Optimal Power Restoration.
- Optimal Remote Control Switch (RCS) Placement.
- Optimal Recloser Placement.
- Optimal Feeder Reinforcement (cable/line dimensioning).
- Contingency Analysis.
- Reliability Studies.
- Protection Functions.
- Techno-Economic Studies.
- RMS Analysis.
- Element Connection Studies.
The above calculation modules can be executed with no restriction on the number of network components (i.e. nodes, branches e.t.c.). These modules are described in detail in the following paragraphs.

**B.6.1 Load Flow Analysis**

This module performs load flow analysis of a network (i.e. a steady-state representation of node voltages, currents and power flows). The analysis can be performed for networks that may fall in one of the following categories:

- Symmetrical and Unsymmetrical Network.
- Radial Networks.
- Meshed Networks.
- High, Medium and Low Voltage Networks.
- DC Networks.
- Mixed DC and AC Networks.
- Multiple isolated networks.
- Single-, bi- and three-phase AC networks with and without the neutral conductor.

The following node types are supported: slack, PQ, PV. More than one slack node is possible. Appropriate automatic conversion of the node type is a feature that can be enabled by the user.

The user can specify the initial state, number of iterations, convergence requirements, solution precision, operation of controlled transformers and switchable shunts (by enabling and disabling tap control) as well as Limiting/releasing synchronous machines to/from max/min reactive power limits.

The load flow is calculated by using well established algorithms such as Newton-Raphson or voltage drop method. At least two alternative algorithms are provided to the user to select.

The algorithm performs also the following analysis options:

- Voltage sensitivities and branch flow sensitivities
- Modal analysis for identifying strong and weak parts of the network

Tabular output of results is provided: for the whole network or individually for each area / zone. Listing of power flows between area/zones, overloaded elements, sorting function, selective output.

**B.6.1.1 Load Flow with Load Profiles**
The software package performs load flow analysis not only for specific snapshots of the system but also for load and generation profiles provided by the user (through SCADA – DMS historical data or telemetry data).

**Input Data**

- User-defined load and generation profiles (day, week, month and year factors)
- Unlimited number of profile types for consumers and generators (e.g. household, industry.)
- Import of measurement data and load/generation profiles

**Calculations**

- Single load flow calculation and time simulation
- User-defined time increment
- Combination of time intervals

**B.6.2 Time Series Steady State Analysis**

This computational module performs a time series simulation in order to evaluate the impacts of time dependent variations such as load and RES production, battery charging/discharging and state of charge variation as well as planned outages and changes in network configurations over a user defined study period (which may extend from one some hours to many years). This simulation is a series of steady state load flow calculations, with a user defined step size (hourly or even less). The analysis takes into account load growth when performed for a period extending one year and allows for the definition of special days and holiday adjustment of load. The user can define maintenance schedules for each component of the network as well as putting in service new installations during the study period.

The analysis is based on the load flow module defined above and can support all features required.

The results summarize all the results of a load flow calculation together with customizable reports that include:

- Plots for Time Series results
  - All results derived from a load flow analysis as well as composite results defined by the user
• Statistical Data per variable such as:
  o Maximum, Minimum, Average Values
  o Variance, Standard Deviation
  o User defined data based on raw results.
• Energy Quantities such as:
  o Energy Losses
  o Demand
  o RES Production
• Time of maximum, Minimum
• Tabular Reports
• Loading Ranges
• Voltage Ranges
• Non Convergence (instances where load flow couldn’t converge)

**B.6.3 Short Circuit Analysis**

A short circuit calculation determines the effect of a fault on the network. This module shall provide two options:

In the first option the user places the desired faults at single or multiple nodes or on line locations, and specifies the fault details (e.g., three-phase, phase-to-ground, fault impedance, etc). The module calculates all node voltages, branch currents, fault currents and contribution from all sources (generators and loads).

In the second option a series of faults (three phase to ground, phase to ground, phase to ground through impedance, phase to phase, phase to phase to ground, ungrounded three phase) including all nodes of the network is sequentially and individually applied. The module calculates the current magnitudes in each of the faults,

The calculation is performed according (but not limited) to the following methods

- IEC 60909 (VDE 0102)
- Superposition method with consideration of pre-fault voltages from a load flow.

The contribution of all type of generation and loads can be calculated.

The results include at least the following:
➢ Initial symmetrical short-circuit current power peak, Transient short circuit current, breaking current, steady state current, thermal and asymmetrical breaking current, plus DC component.
➢ Minimum/maximum short-circuit current.

This module integrates with protective device coordination.

The module provides accurate model for transformer earthing connection (i.e. Petersen coil modelling) and calculates machine short-circuit contributions. Load grounding is also modelled for short circuit calculation analysis.

The module also provides the following calculations:

➢ Estimates the location of a fault, given its type and value.
➢ Equipment rating verification.

Result viewing

Different reporting tools are available to facilitate the visualization of results:

➢ Detailed reports in tabular format that can be exported to Microsoft Excel.
➢ Customizable Reports.
➢ One-line diagram customizable display and report.
➢ Color-coding to illustrate abnormal conditions according to user-defined criteria. Color coding according to user defined levels of short circuit power and current is supported (e.g. user defined color in cases that short circuit power exceeds the limit of 250MVA).
➢ Customizable tags at user-defined locations on the one-line diagram.

B.6.4  Motor Starting

Motor starting analysis is a calculation of voltages and currents in the network when one or more motors are being started. The motor starting module allows the user to choose the motor(s) to be started and to compare the network conditions before and after the motor(s) has been started. The following options are provided:

➢ Single or multiple motor starting
➢ Steady-state motor starting
➢ Various motor starting methods such as:
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- reactor
- auto transformer
- variable rotor resistance
- star delta

- Transient motor starting (synchronous /asynchronous motors), simulating the operation of controller models.
- Thermal limit check of cables and transformers.
- Automatic tap changing transformers can be locked for a user-defined time-delay.
- It is possible for the user to define initial bus voltage of the connected bus.

B.6.5 Network Reduction

This module is designed to reduce the size of a network model by replacing sets of buses and the network elements (lines, transformers,...) that connect them with a smaller but exact, numerically equivalent network.

For a properly chosen set of buses, this equivalent network will have fewer buses and branches than the original, yet still provide the correct response to faults or load flow calculations in the unreduced portion.

The network can be reduced for

- symmetrical or asymmetrical short circuit calculations according to IEC909, IEC60909, ANSI/IEEE or superposition method and
- load flow calculation.

The reduced network gives the same short circuit or load flow results as the original network.

B.6.6 Power Quality -Harmonic Analysis

One of the main aspects of power quality is the harmonic analysis.

Harmonic Analysis will be performed in 3-phase, 2-phase, 1-phase AC systems. The module will be used to compute the network impedance and harmonic level for each frequency and for each node as well as the frequency response of networks.

This module also performs the following calculations:
- Harmonic voltage and current indices calculation.
- Various harmonic distortion indices such as Total Harmonic Distortion (THD), Harmonic Distortion (HD), Harmonic Factor (HF), Total Harmonic Factor (THF), Total Arithmetic Distortion (TAD), total RMS currents and voltages.
- Non-characteristic harmonics and inter-harmonics.
- Calculation of K-Factors and Loss Factors for 2-winding transformers.

It considers the following harmonic sources

- Balanced and Unbalanced harmonic sources.
- Multiple harmonic injections:
  - Current sources
  - Voltage sources
  - Thyristor rectifiers
  - PWM-converters
  - Static Var systems (SVS)
  - Non-linear loads

The analysis may use both balanced (positive sequence) and unbalanced (multiphase) network model. Frequency dependence of element parameters is taken into account.

The results are exported in harmonic distortion plot with pre-defined distortion limits according to international standards.

The results are also presented in the time domain.

The results can be entered in the single line diagram.

Also the following analysis are performed

- Filter sizing and analysis
- Flicker Analysis
- Frequency Sweep
- Ripple control

The sum of harmonics is calculated according to ANSI or IEC standards (such as IEC 1000-2-6 or IEC 1000-3-6)

**B.6.7 Optimization Functions**

**B.6.7.1 Tie Open Point Optimization (TOPO)**
The scope of this module is to find the optimal radial configuration of a grid, providing as objective function the following options for the user to select:

- Power Losses minimization.
- Reliability indices optimization.
- Cost optimization. This may be a user defined cost function that combines both losses, reliability indices and energy interruption cost.
- Minimization of voltage exceptions to reduce the number of voltage violations.
- Minimization of overload exceptions to reduce the number of overloaded equipment.

The above optimization shall be subjected to certain constraints, defined by the user including the following:

- Maximum/minimum limits for each type of equipment
- Voltage constraint. The user sets maximum and minimum voltage level as well as maximum voltage drop

The user shall have the option to optimize a subset of switches or the full set of switches. In addition the module supports the option to consider all branches (i.e. lines, transformers etc) as being switchable on both connection sides in the optimization procedure.

TOPO can work with one or multiple load snapshots.

TOPO provides all possible solutions (or at least an adequate number of solutions) in ascending order according to the objective function defined.

Results are presented both graphically and in reports to help evaluate the proposed solution.

The comprehensive report provides:

- Detailed listing of the switching operations recommended
- Network summary on loading, kW losses for both before and after the recommended switching operations
- Overloaded equipment listing for the initial and final network configurations
- Number of voltage violations for the initial and final network configurations
- Evaluation of the annual cost of system losses

**B.6.7.2 Phase Balance Optimization**

This tool will facilitate the user to alleviate asymmetric load allocation among the three phases. The algorithm reallocates single phase load and generations in a way to minimize unbalances either on the feeding point, or the average unbalances over the feeder. The user can define a list of
elements that cannot change phase connection. The report includes a list of elements that change phase and their phase reallocation as well as the metrics of phase unbalance before and after phase balance optimization. The single line diagram of the proposed solution can also be automatically created.

**B.6.7.3 Optimal Capacitor Placement**

This module places capacitors on the network in order either to resolve technical issues (voltage profiles) and/or to reduce operating costs (e.g. due to losses).

In the first case, where only technical considerations are taken into account, the user provides the available number of capacitors together with their characteristics (number of banks and bank size) as well as the potential installation locations. The analysis will define the optimal position or positions for capacitor placement, taking voltage profiles as a criterion.

In the second case capacitors are installed as long as they are economic (i.e., as long as the value of the monetary savings from the placement is greater than the cost of the capacitor itself). The optimization is subjected to constraints set by the user:

- Thermal Constraints.
- Voltage Minimum and Maximum

The user has the option to set a number of load snapshots to provide modeling of the load variations, which occur with time, temperature, or other factors. When switched capacitors are placed, the capacitor switching increment for each snapshot is also calculated. User provides the energy cost for losses as well as capacitor costs (both capital and annual operation and maintenance cost).

The following parameters are taken into consideration

- The cost of electrical energy \( c_P \) in €/kWh.
- The cost of electric active power \( d_P \) in €/kW, i.e. is the cost of generation or capacity that would have to be purchased to replace the system’s active power losses.
- The discount rate, \( r \), used to bring future savings and costs back to the present time.
- The evaluation period, \( N \)
- The installation cost for capacitors, \( c_Q \), is specified in €/kvar of capacitor size
- The maintenance rate for capacitors, \( m_Q \), i.e. the yearly cost of keeping them in service. The rate is expressed in €/kvar-yr.
- **Connection type**
• **Load snapshots to consider.** Evaluation of the operation of Capacitor Placement will take into account representative load states defined by the user.

• **Number of banks available.** Number of banks which are available for placement.

• **Eligible nodes.** A set of nodes which are eligible to install the capacitors.

The objective function to be optimized is defined as:

\[
(Total\ Cost) = \text{Cost} - \text{Savings} + \text{ViolationPenalty}
\]

Where Cost represents the Net Present Value (NPV) of installation and maintenance cost over the examined period plus a penalty factor when violations occur (i.e., Thermal and Voltage limits constraints).

\[
\text{Cost} = \text{Installation Cost} + \text{Maintenance Cost}
\]

While savings represents the NPV of active and reactive energy savings

\[
\text{Savings} = (\text{Active Energy Savings}) \times cP + (\text{Active Power Savings}) \times dP
\]

The user provides the number of available capacitors, their type and eligible connection nodes and the algorithm calculates the proposed connection nodes for all or some of the available capacitors that minimize the value of the objective function defined above. Report includes comparison of the network before and after the installation of capacitors in terms of voltage profiles, Energy losses, Active power losses and costs.

New capacitors indicated by the calculations can be displayed automatically highlighted on the single line diagram of the network.

### B.6.7.4 Optimal Power Flow

The Optimal Power Flow (OPF) module optimizes a certain objective function in a network subject to the load flow equation constraints and equipment limits (Maximum and Minimum Voltage levels, Thermal limits, generator active and reactive power limits). The objective function to be optimized may be a cost function related to the production cost or to active power losses or to a user defined objective function

### B.6.7.5 Optimal Power Restoration
The Optimal Power Restoration module determines the optimal sequence for operating switching when searching for location of a fault in a distribution network and defines the locations of switches which are to be opened/closed and the corresponding sequential order that a service team shall open/close these switches in order to restore power with the minimum interruption cost, taking into account first-priority consumers with critical loads.

**B.6.7.6 Optimal Remote Control Switch (RCS) Placement**

This module optimizes placement of a fixed number or optimal number of switches per feeder. The objective function of the Optimal RCS Placement command can be set to either:

- Minimize ENS by installing a specified number of RCS per feeder / backbone to minimize the Energy Not Supplied.
- Balance ENS by installing an optimal or fixed number of RCS per feeder / backbone to balance the Energy Not Supplied. This option may be used in some circumstances to plan the network in a way that considers connections with many (or large) customers and connections with few (or small) customers in a nondiscriminatory way.
- Minimize EIC by installing an optimal or fixed number of RCS per feeder / backbone to minimize the Expected Interruption Cost.

**B.6.7.7 Optimal Recloser Placement**

The analysis finds the optimal location of reclosers in order to optimize certain reliability indices, under user-defined constraints such as loading limits, distance between reclosers, etc. The user defines the number of reclosers to be installed in the network and has the option to exclude specific locations. The module summarizes the reliability indices before and after the optimal recloser placement. The proposed reclosers to be installed can be automatically inserted and highlighted in the network diagram.

**B.6.7.8 Optimal Feeder Reinforcement (cable=line dimensioning)**

This module includes the following features:
- Automatic cable sizing based on international standards such as VDE, IEC, NEC.
- Cable reinforcement optimization.
- Selection between a list of cables.
- Verification of thermal and short-circuit constraints.
- Verification of user-defined voltage constraints.
- Cable Ampacity calculation.

**B.6.8 Contingency Analysis**

Contingency analysis is defined as the analysis of load flows before and after an outage of one or more components (such as transformers, busbars, transmission lines, etc.) of the system. Contingencies may take place either in a single time step (N-1, N-2,...,N-p contingencies) or in multiple time steps (N-1-1 contingency).

The module has the ability to create automatically a list of all possible contingencies of the system, or a list of contingencies of selected type of elements (i.e. only lines, or only transformers). The option of a fast screening method to scan outage list and identify higher risk contingencies for further evaluation is provided.

Each contingency is checked against the following constraints:

- Max thermal loading of components (%).
- Lower limit of allowed voltage (p.u.).
- Upper limit of allowed voltage (p.u.).
- Maximum voltage step change (p.u.).

A list of violation is reported for each component and for each contingency. The non-convergent cases of the contingency analysis are displayed in a list.

**Contingency Ranking also is provided in order to** identify the most severe contingencies.

**B.6.9 Reliability Studies**

A Reliability analysis module is provided to evaluate a set of reliability indices for a power system. The results are used in order to:

- Determine the reliability of existing systems.
- Identify poor areas of system reliability.
- Quantify the impact on reliability of proposed system upgrades, expansions and reconfigurations.
The reliability characteristics of each component are modelled and the relevant parameters are defined by the user. Component reliability parameter libraries can be created by the user. The inputs provided by the user for each component include the following:

**Failure Rate:** The number of failures per time of a network item. The failure rate is normally expressed in terms of the number of failures per year. For lines and cables the failure rate can be expressed in number of failures per km per year.

**Failure Duration** – The time period from the initiation of a failure until the network item is restored (either repaired or replaced) so that it is able to perform its intended function.

The above parameters can be defined for each component separately or for a group of components.

With regard to the feeders of the Hellenic Distribution Network in many cases the only available historical data are the failures (rates and duration) of each feeder at its starting point, while detailed data of the failure rate of each component are missing. Thus it is necessary that the reliability studies module is accompanied with a tool that can approximate the failure rates and duration of components according to the historical data of the failures of the feeder.

The following data are provided for switches:

**Switch Time** – The time period from the time a switching operation is required due to a forced system outage until the actual switching operation occurs.

**Probability of Successful Switching:** a value between 0 and 1 indicating the probability that the switching will be successful.

The module performs reliability analysis according to the state of the art practices and calculates the following indices (at least):

**System Average Interruption Frequency Index (SAIFI)** – The average frequency (number) of sustained interruptions per customer over a predefined area. The definition is:

\[
SAIFI = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}}
\]
**System Average Interruption Duration Index (SAIDI)** – The average time the customers are interrupted. Also referred to as the customer minutes of interruptions or customer hours. The definition is:

\[
SAIDI = \frac{\sum \text{Customer interruptions duration}}{\text{Total number of customers served}}
\]

**Customer Average Interruption Frequency Index (CAIFI)** – The average frequency (number) of sustained interruptions for those customers experiencing sustained interruptions. The customer is counted once regardless of the number of times they are interrupted. The definition is:

\[
CAIFI = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers interrupted}}
\]

**Customer Average Interruption Duration Index (CAIDI)** – The average time required to restore service to the average customer per sustained interruption. The definition is:

\[
CAIDI = \frac{\sum \text{Customer interruptions duration}}{\text{Total number of customers interrupted}}
\]

Additionally, customer information such as the number of customers served (CS) and the total number of customers interrupted (CI) shall be also provided.

**Energy Not Supplied (ENS)**: Energy on average not delivered to the system loads.

Interruption cost can also be calculated by the above indices. Expected Interruption Cost can be defined as:

\[
EIC = \sum_{i=1}^{N} ENS_i \cdot G_i(ENS_i)
\]
Where $N$ is the number of customers, $ENS_i$ is the Energy not supplied for customer $i$, $C_i$ is the cost of energy not supplied for customer $i$ per MWh. Each customer has a different interruption cost which may be a non linear function of interruption time and can be defined by the user. An interruption cost library can be created by the user, in a way that can be reusable for multiple studies.

The user can create similar cost functions by using the above reliability indices. User defined reliability indices can be also formulated using the raw calculation results of the module.

The contribution of component outages to the reliability indices and associated costs is also calculated and the order of most contributing components can be provided.

The results are presented in customizable reports as well as on the single line diagram.

Comparative results for different network snapshots can also be presented in the reports.

Results can be exported to MS excel and to ASCII format.

**B.6.10 Protection Functions**

**B.6.10.1 General Requirements**

- Effective modeling of protection devices, supporting various protection functions such as overcurrent, distance, over-voltage/under-voltage, under-frequency, differential and voltage restrained/controlled overcurrent.
- Several protection devices can be inserted at each point of the simulated network.
- Simulate different types of faults as described in B.6.2 (three phase, three phase to ground, phase to phase, phase to phase to ground, single phase to ground, single phase to ground through impedance), as well as simultaneous faults (arbitrary collections of classical faults, plus phase-open faults) while permitting the user to insert specific fault impedance value if desired.
- Take into account different phasing values in order to calculate device operating times. The user-defined phasing values are: phase A, B, C, positive sequence, negative sequence, zero sequence, maximum of all phases, maximum over all sequences and neutral to ground.
- Ability to inherit full protection device characteristics and selected configuration parameters from PSS/Adept (.adp) or PSS/Engine Hub (.dmp) file formats (for example, selected pick-up value, selected
time-dial value, etc). Sample files will be provided to verify this ability.

- Ability to change configuration parameters of every protection device, such as time dial and pick up, according to the available values provided by the manufacturer. This can be done either through a dialog box that appears when the user selects the protective device from the one-line diagram, or by entering data in a tabular form.

- Ability to insert user-defined current and voltage transformer ratios.

- Directionality support with different polarizing methods for phase and ground faults (e.g. self-polarization, cross polarization, positive and negative sequence polarization, memory voltage polarization).

- Support inverse and definite time characteristics for current, voltage and frequency protection functions taking into consideration the user-selected phasing.

- Support rate of change of frequency (RoCoF) characteristics.

- Advanced analysis tools: sequence-of-operation (or step-event analysis), voltage sag analysis, fault location, arc flash analysis etc.

- Ability to generate relay test files in COMTRADE and other formats. Support inter-tripping, permissive and inter-blocking schemes through communication links or via programmable logic among relays.

- Modelling of line differential protection schemes.

### B.6.10.2 Protection devices Database requirements

- Comprehensive relay library with relay models suitable for steady-state and quasi-dynamic calculations.

- Incorporation of the entire HEDNO’s relay database into the available database.

- Updates of device library upon request of HEDNO with inclusion of new protective device models.

- Any type of protection device modeling by numerical equation input or by providing the needed protective curve points.

- Ability to import relay settings data from relay vendors software (e.g. ABB, SIEMENS, GE, SCHNEIDER, SEL) if applicable.

- Available protection library comprised of comprehensive models for fuses and reclosers and equipment damage curves for transformers, sectionalizers and conductors/cables. Ability to store files as binary objects within the database tables for storing in the database manufacturer’s relay and test files, as well as drawing files.

### B.6.10.3 Overcurrent Protection

- Study the proper protection coordination for various fault cases, as well as for motor starting and transformer energization, also taking into account inrush currents.
➢ Coordination between relays at different voltage levels (and additional axis for voltage levels) and provisions for line-to-line and line-to-ground through-faults on delta-wye transformers.
➢ Automated detection of protection zones.
➢ Automatic relay time dial selection based on user defined operating time to achieve coordination at selected fault current level.
➢ Facility to import one-line diagram graphics and external graphic files to the curve plot.
➢ Verification of protection scheme and coordination based on user defined criteria/rules and industry standards/guidelines.
➢ Ability to detect possible violations and concerns of equipment protection and device coordination (e.g. by providing violation descriptions with each violation detection).

**B.6.10.4 Distance Protection**
➢ Generic as well as detailed modeling of distance relays using model specific parameters and operating logic.
➢ Display different zones of reach for every fault direction according to protection settings for distance protection function.
➢ Support different R/X characteristics, such as MHO, Circle, Polygone among others or user-defined functions.
➢ Assistance to the user in order to achieve distance protection coordination.
➢ Out of step detection.

**B.6.10.5 Diagrams, Reporting and Output**
➢ Current type and time type selectivity diagrams.
➢ Automatic display of tripping times for calculated currents in time-overcurrent diagrams.
➢ Ability to calculate short-circuit currents corresponding to certain types of faults at every node of a network (fault all) and display the results on the one-line diagram of the network.
➢ Ability to calculate precisely the time and current margins between curves.
➢ Ability to show unlimited number of protection devices curves on the same diagram.
➢ Ability to change the color and width of every protection curve in order to distinguish different curves from each other.
➢ Ability to modify overcurrent protection device settings by double-clicking on curves and by dragging curves.
➢ Ability to show the short circuit current in lines/arrows intersecting with the curve plots along with a label highlighting the fault type and fault location.
➢ Labels of overcurrent protective devices in the curve plots shall at least include:
o Device tag name
o Current transformer ratios; and tap/pickup, time dial, and instantaneous settings
o Manufacturer name and model type
o Fuse current rating and type User defined labels, allowing the user to select the device characteristics to be displayed, is also a desired feature.

➢ For any type of fault, all protection devices that are installed at points of the network that are parts of contributing paths to the fault have to be detected and displayed at the same protection selectivity diagram. Contributing network paths to the fault have to be automatically traced and displayed on the network diagram. The tripping times, according to the corresponding fault current and the curves of the protection devices, have to be clearly displayed as well as the time difference among successive tripping times.

➢ Display parts of the network that are not effectively protected for all fault cases through automatic detection of protection miscoordination.

➢ Export protection study reports in text-processing platform suites formats, in which data corresponding to the examined type of fault, the protective devices of interest, the tripping times and the time difference among successive tripping times have to be included.

➢ Export the curve plot to PDF, JPG, AutoCAD® (XML), and other formats.

➢ High-quality printed outputs on a large variety of printers and plotters.

➢ Support R-X diagrams for distance protection schemes and display of the impedance trace.

➢ Graphical display of post-fault solution and relay operating time on the one-line diagram and the phasor diagram.

B.6.11 Techno-Economic Studies

This module facilitates the user to evaluate investments on networks and substations upgrade. This module is capable of investigating a number of network expansion planning strategies defined by the user. Each expansion strategy is divided into expansion steps which may be defined on a monthly basis (or less if possible). Each expansion step represents a modification in the configuration of the network (which may be for example a new installation) and is associated with its relevant investment cost.

The module takes into account the following inputs
The annual load factor \( f \) of each feeder under study which is defined as the ratio of average load over a year to the peak load of the year.

A coincidence factor \( m \) of each feeder under study which is the ratio of demand of the feeder at the time of System’s peak to the peak demand of the feeder.

Statistical Properties of Failures which may be derived from historical data. (as in module Reliability Studies)

Costs of Losses (both energy and power cost). This include both copper losses and iron losses of transformers

Investment Cost.

Annual Maintenance Cost of new installations. Negative Maintenance Cost may be inserted when components of the network are uninstalled.

Additional Costs

User defined Costs.

Expected Life Span of new installations

Scrap Value of installations (value after expected life span)

Reliability Costs (i.e. ENS cost, Energy Interruption Cost), calculated according to the specifications of Reliability Cost Requirements Section (B.6.9) and Load modelling features (B.5.10)

Interest Rate (%)

Calculation Period

Load Growth Scenarios. The user can define load growth scenarios either by providing a mathematical formula or giving explicitly the annual load growth. The load growth may be uniform for all loads of the network under study, or defined separately for each group of loads.

At each expansion step the following network constraints are evaluated at each expansion step

- Voltage Maximum and Minimum Constraints
- Maximum Loading Constraints of equipment(line, cables, HV/MV transformers)

A well-established method for the estimation of annual energy losses during the study period will be employed. The method will be checked against its validity by HEDNO and modifications may be asked. Usually the annual copper losses are expressed as a function of copper losses during peak load and load factor while iron losses are steady during the year. Thus iron losses and Copper Losses shall be distinguished in the calculations. For feeders with large distributed generation the method of approximating annual losses as a function of peak load losses and load...
factor is not always accurate. Alternatives of this method (such as calculating the losses for representative load states) shall be also examined for more reliable results.

There is also the option to employ the tie-open optimization module in order to optimize tie-open points on an annual basis, or at each expansion step.

The module performs automatically all the above calculations for each expansion strategy and evaluates a set of indexes such as:

- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Estimated payback period
- Estimated discounted payback period.
- Cost- Benefit
- Average Annual Rate of Return
- Return over Investment

It is also possible for the user to define indexes via scripting.

The reports of the module are presented in a tabular form that includes the following elements at each row of the table:

- Calendar Year
- Strategy Year
- Investment Cost
- Copper Losses and Cost
- Iron Losses and Cost
- Energy not Supplied Cost
- Total Cost

All costs are discounted to their present value. Investment cost include maintenance costs

Alternative forms of reports may be accepted upon discussion with HEDNO.

The user has the option to create custom-made reports based on the results of the analysis

**B.6.12 RMS Analysis**
This module simulates the dynamic behavior of a power system in the domain of time under the event of certain disturbances such as:

- LLL, L-G, LL and LL-G fault application and removal
- Line switching and line re-closing
- Single pole switching including line charging effects
- Load shedding, load adding and load ramp event.
- Generation loss
- Disconnection of system elements
- Tripping and reclosing of protective devices
- Setpoint change of a controller
- Wind disturbances (ramp, gust, noise)

The machine speed of a generator can be also defined explicitly by the user in a tabular or data file format, in a time domain simulation. In that case the governor model would see this machine speed (frequency) as its input signal and will respond according to its dynamics. This facilitates the user to evaluate the performance of a governor model according to the grid code specifications.

The module will provide a control model library of dynamic models of equipment and their controls. This includes default data values of the parameters, their description and block diagrams. The following control models are included:

- Round poles and salient poles generators
- Modeling of excitation systems taking saturation into account, based on IEEE standards
- Power system stabilizers
- Governor models comprising hydraulic, thermal, diesel, and gas turbines
- Detailed modeling of static-VAR compensators
- Under-voltage, under-frequency and frequency droop relays
- Impedance relay with typical circular trip characteristics including single reset time reclosing
- Induction motor models with frequency dependent modeling
- Dynamic modeling of distributed generation such as Wind Energy Conversion Systems (WECS), photovoltaic (PV cells), fuel cells and micro turbines
- Tap controller models

The user also is facilitated to model any desired control system using user-defined modeling.
**B.6.13 Element Connection Studies**

This module assists the user to perform studies that evaluate the impacts of connection of a new element (which may be either load or generation) at a specific point of the network (hereafter called Point of Common Coupling –PCC). The evaluation is based on the D-A-CH-CZ standard but is modified in order to suit the Greek code requirements.

In order to perform such a study, five operating scenarios which represent the extreme cases of an annual operation are automatically created as following:

1. Maximum Load Demand – No RES production.
3. Minimum Load Demand – No RES production.
4. Minimum Load Demand – Maximum RES production apart from PV which have no production (i.e. night minimum)
5. Average Load Demand- Maximum RES production

The evaluation procedure includes the following criteria:

1. **Thermal Limits of network elements.** Thermal Limits constraints can be evaluated by performing load flow analysis for the 5 operating scenarios defined above, according to the methods and procedures defined in the load flow requirements section. Thermal limit constraints are also evaluated for a no-load – maximum RES production scenario.

2. **Short Circuit.** Short circuit calculation (according the methods and procedures defined in the short circuit analysis requirements section) is performed for all nodes of the grid under study and short-circuit current limit violations are reported. The user provides the short circuit limit constraints for each type of short circuit.

3. **Slow Voltage Change.** These are steady state voltage variation which are expressed by 10-minutes mean values according to EN50160. The five operating scenarios are used in order to assess the impact of the new installation to the slow voltage variation.

   For these scenarios, Minimum ($U_{min}$), Maximum ($U_{max}$), and Mean Voltage ($U_{mean}$) levels of each node as well as its Deviation around the median value ($U_d$), and Median Voltage Deviation ($\Delta U/U_n$) are computed and checked against user defined constraints.
Voltage deviation around the median value of a node i, represents the annual variation of the nodes voltage and is defined as:

\[ U_\delta = \frac{U_{\text{max}} - U_{\text{min}}}{2U_n} \]

Where \( U_n \) is the nominal voltage of the node.

Median Voltage Deviation is defined as

\[ \Delta U = \frac{U_{\text{max}} + U_{\text{min}} - U_n}{2U_n} \]

4. **Rapid Voltage changes.** These are variations of the rms value of voltage during a period which may be between 1 cycle to some seconds (maximum 10 minutes) according to EN50160. This is related to the voltage fluctuation during connection and disconnection of the element. The computation of the maximum voltage fluctuation \( d_{\text{max}} \) is performed using the following simplified relation

\[ d_{\text{max}}(\%) \approx 100 \cdot k \frac{S_{nE}}{S_k} \]

where

- \( S_k \) Short circuit power at PCC (computed by the module)
- \( S_{nE} \) Nominal power of the element to be connected (input by the user)
- \( k \) is the coefficient of voltage deviation, which is either the Voltage Step factor \( K_u(\psi_K) \) for wind turbines according to IEC 61400, or maximum current spike factor \( (k_{i,\text{max}}) \), ratio between the highest current occurring during the switching operation and the rated current of the generating unit, for other technologies.

5. **Flicker.** According to D-A-CH-CZ standard
6. **Harmonics.** According to D-A-CH-CZ standard
7. **Voltage unbalance.** According to D-A-CH-CZ standard
8. **Reactive power compensation.** According to D-A-CH-CZ standard
9. **Commutation.** According to D-A-CH-CZ standard

**Input by the user**

The user can select a combination of the above criteria (all of them or some of them). The module is fully parameterized by the user and can be
easily reconfigured in order to take into account changes of the connection regulation. Default values are given for constraints to avoid repeating data entry each time a study is performed. The user provides the input the details of the element to be connected together with the PCC. The user defines the following parameters of the element to be connected:

- Parameters related to the short circuit level (subtransient reactance, impedance and time
- Voltage Step factor, or maximum current spike factor.
- Maximum Connection Current coefficient
- Reactive Power Control. The element to be connected may have the ability to control Reactive Power by a variety of methods ( (Reactive Power, Voltage), (Reactive Power, Active Power), (Active Power, Power Factor) ) or by introducing the suitable curve so that it is possible to create scenarios with varying PF

**Reporting**

- A table with all assessment criteria accompanying with a pass/fail indication for each criterion
- Next to each pass/fail indication there is a link to the results of the respective study
- The user has an insight of the procedure and is able to examine further its results (i.e. this is not a black box model)
- The results of the 5 scenarios under study are presented in a tabular report that includes:
  - Minimum, Maximum, Mean Voltage at each node
  - Median Voltage Deviation to the nominal value ($\Delta U/U_n$) (%).
  - Voltage Deviation (%).
- Color coding is used for violations
- Voltage results are presented in a top down tree structure.
- In case of non-compliance to the criteria, the module may propose possible corrective actions (such as installation of reactor/capacitor, or feeder reinforcement)

**B.7 Libraries**

Libraries comprising characteristic types of all components of the network are integrated in the software package. A library manager assists the user to edit and deploy libraries. A library can be central for all users in which case it will be stored in the data server or personalized for each user in which case it can be stored either on the data server or in the local storage of the user.
B.8 Reporting
Solution results from any analysis may be displayed in the form of result boxes on the network diagram or in a tabular report. These result boxes are fully editable by the user and all computable variables can be displayed. Fonts, Size and styles, units, precision, placement are also editable by the user. The format of results are fully customizable (variables monitored, units used, selection between Line-Line or Line–Ground measurements). Several predefined tabular reports are available. Customized reports can also be designed. Reports can be automatically exported as csv, xlsx and docx files.

B.8.1 Charts

- Results can be displayed in charts (lines, bars, pies)
- Sub charts can also be created.
- Results from different variants can be compared and displayed in the same chart.
- Charts can be exported as JPG, or to word / excel files

B.8.2 Feeder Voltage Tree Based Diagrams
The voltage profile of a radial network based on the networks load-flow results can be displayed on a plot with a y-axis indicating the voltage of nodes while the x-axis represents the length from the feeder's starting point. Each branch of the feeder is displayed as a separate line on the same plot (i.e. the total number of lines on the plot equals the number of branches of the feeder).

B.8.3 Comparison between calculations
There is the option to present results of two variations of a project on the same report.

The differences between cases are colored according to the severity of the deviation, making it possible to recognize the differences between calculation cases very easily.

B.9 Geographic Representation of the Network

The elements of the network can be represented in a geographic diagram so long as geographic coordinates of these elements are provided. The geographical coordinates of system elements can be either imported via the interface with the GIS system of HEDNO (see B.10.2) or inserted manually or with a script by a text file or database. The software is compatible with GGRS-87 coordinate system, i.e. the user can insert coordinates in this system. The geographic diagram has a map background. A variety of maps shall be provided (such as Google Maps,
Bing Maps). OpenStreetMap (OSM) must be included in the options for a map background.

**B.10 Interfaces**

**B.10.1 Other Power System Analysis Software**

The software package is able to import data from various similar software packages which includes the following:

- PSS/U (dat files) (two sample .dat files will be provided)
- PSS / Adept (.adp files sample files will be provided) or alternatively PSS/Engine HUB-File (two sample .dmp files will be provided). All network elements (including protection devices and settings) of the sample files must be automatically imported in the software package. The conversion of files will take into account also adept protection database. Full conversion of all parameters included in the input files shall be supported. The single diagram representation of the network will be maintained as in the source file.
- Adept protection databases. A sample data file containing protection setting and parameters is provided. This file will be imported in the software. A manual regarding protection database properties is also provided.
- PSS/E (raw and dyr files). Sample files will be provided.

**B.10.2 Geographical Information System**

HEDNO is developing a GIS system based on Smallworld Electric Office version 4.3.4 on a VMDS database. The software package must provide a plugin to import network data from the GIS. In case of future updates of Smallworld Electric Office, the plug-in must also be updated by the Contractor at no additional cost. Incremental update is possible for detecting differences between Smallworld data and data already inserted in the database of the software package. Users also can select to load the full network or only a part of it (via a map or a list).

When importing GIS data from the Smallworld Electric Office System of HEDNO, geographic diagrams are automatically created as well as automatic single line diagrams of the network.
B.10.3 Time Series Data

Time series data are retrieved by various databases of HEDNO, including SCADA DMS systems and telemetry data. These time series will be imported in the software database and assigned to the relevant network components either through db-links or offline through custom made interfaces. HEDNO will provide the tender with the database structure as well as the format of archives available and the tenderer will create the necessary interfaces for its software.

B.10.4 CIM

CIM (Common Information Model) is defined in IEC-61970 and IEC-61968, and its purpose is to allow the exchange of information related to the configuration and status of an electrical system. Both export and import of CIM is supported. The contractor is bound to support future modifications of CIM during the maintenance period of the project.

B.11 Scripting

The user has the option to execute a predefined list of analyses in an automated manner, i.e. the user provides a list of computations to be performed and the system runs these computations as a batch without any further intervention of the user.

Scripting facilities also are provided, that enable the user:

- To develop custom-made computational modules, based on the modules provided by the software
- To process the results of an analysis.
- To automate tasks in a more sophisticated way than the one provided in the standard task automation module
- To configure network in an automated fashion
- To integrate the software package with other applications
- To develop new control algorithms

B.11.1 APIs

The software package provides an Application Programming Interface (API), which offers third party applications the possibility to use its functionality into their own program.

B.12 User Licenses

Το λογισμικό αναδόχου θα διαθέτει πλατφόρμα διαχείρισης δικαιωμάτων εκτέλεσης, μέσω της οποίας ο διαχειριστής αδειών θα αναθέτει ρόλους
B.12.1 Full User

A full user has access to all computational modules described in paragraph B.6. A total number of 40 full user licenses will be required.

B.12.2 Simple User

A simple user has access to the following computational modules.

- Load Flow Analysis (B.6.1)
- Short Circuit Analysis (B.6.3)
- Techno-Economic Studies (B.6.11)
- Element Connection Studies (B.6.13)

There is no restriction in the number of nodes or elements of the networks to perform the above studies.

B.12.3 Critical WorkStations

Critical Workstations can execute the software even under the event of an unexpected failure of the network that provides access to the license server. A total number of 7 licenses is required. A critical workstation has access to the following computational modules:

- Load Flow Analysis (B.6.1)
- Short Circuit Analysis (B.6.3)
- Techno-Economic Studies (B.6.11)
- Element Connection Studies (B.6.13)
- Protection Studies (B.6.10)