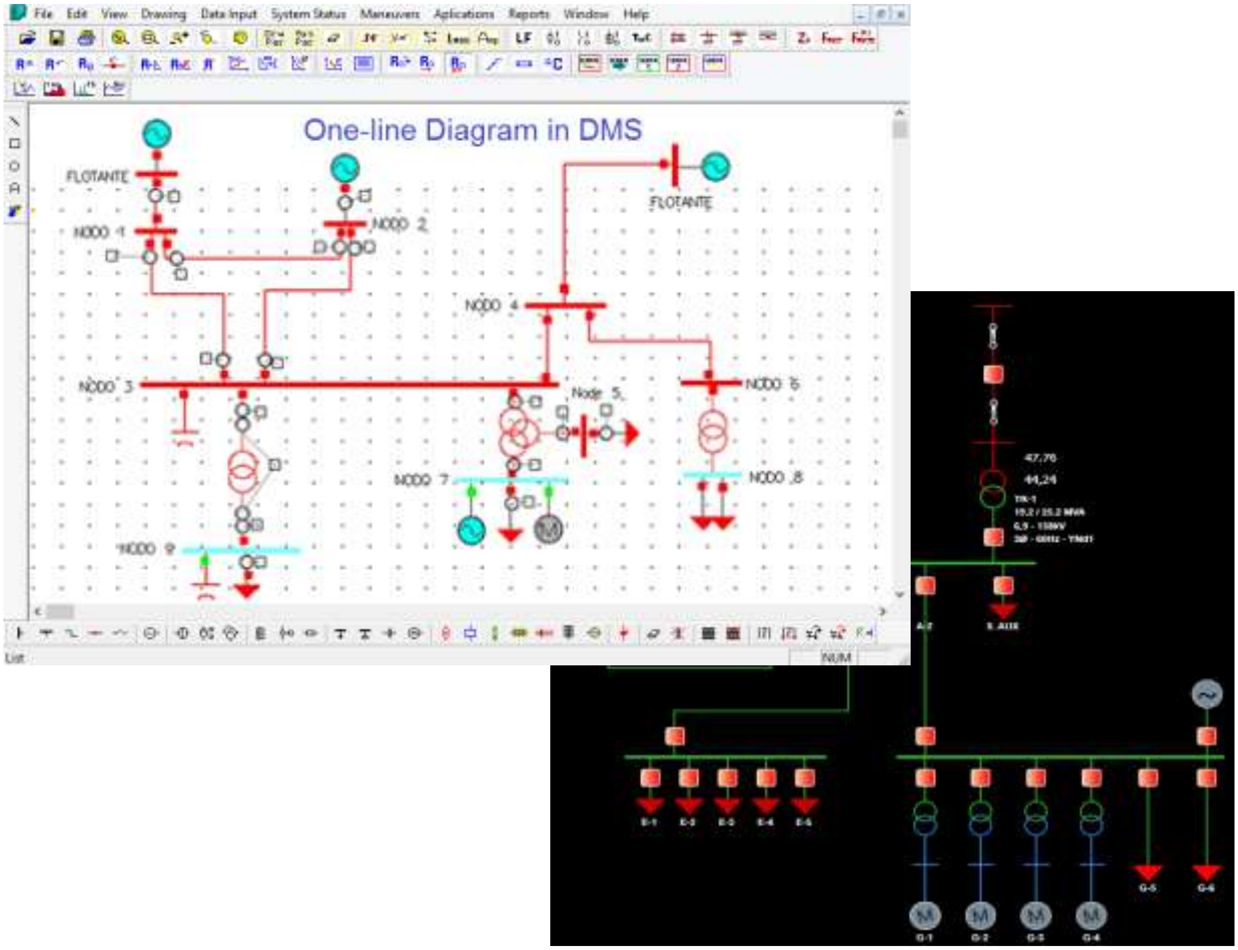
SPARD® EMS / DMS

DISTRIBUTION MANAGEMENT SYSTEM-Functional Description



ENERGY MANAGEMENT SYSTEM (DMS)

USER MANUAL

Code: M-DMS-ESP-01
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Energy Computer Systems have a continue process of research and development of new applications, thus permanently optimizes the program. Although this document is updated regularly, at times the information contained in it, not necessarily describe the operation of the SPARD® version that is delivered to the customer.

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1. INTRODUCTION

Operators manage the electric power systems with the purpose of a safe and optimal state of operation, taking into account varying system conditions throughout the day of operation.

To achieve this goal, a continuous monitoring of the power system is necessary by a SCADA system, which allows the acquisition of measurements along the network. The variables measured can be the power flows on the lines, the level of voltage on the nodes, the current on the lines, the outputs of generators, the states of breakers, the position of the tap changers of the transformers, etc.

The variables mentioned above are used by DMS Systems (Distribution Management), to carry out different functions such as contingency analysis, load prediction, optimum power flows, control of reactive power, voltage control, state estimation, etc.

SPARD® DMS is an advanced power system modeler and simulator, which links to SCADA systems in real time and to SPARD® OMS (Outage Management System) allowing the execution of the aforementioned functions.

Energy Computer Systems offers the entire integrated ADMS (Advanced Distribution Management System) platform, which includes integrated SCADA, DMS, OMS and additionally, GIS.

2. MODES OF INTERACTION WITH THE SCADA SYSTEM

2.1 Simulation Mode

In simulation mode, DMS only receives data from the SCADA and does not return any data. It receives SCADA data at user request, with which it can make variations to the modeling or to data received in real time to make simulations, focused on operational planning.

The received variables in this mode are:

- Active and Reactive Power of Loads.
- Breakers Position.
- Position of Transformers Tap.
- Voltage of Float Nodes.
- Generated Power by Generators
- Active and Reactive Power consumed by Motors
- Generated Reactives by Capacitors

2.2 State Estimation Mode (See functional description in 3.9)

Receives data periodically from SCADA. The state estimation of the unread variables by SCADA is performed by the algorithm of state estimation, load flow (where applicable, to have pseudo - readings), neural networks and other auxiliary algorithms. The results of the simulations are sent back to the SCADA.

The received variables in this mode are:

- Active and Reactive Power of the loads.
- Breakers Position.
- Position of the Transformers Tap.
- Voltage on the Controlled Voltage and Float Nodes.
- Generated Power by Generators
- Active and Reactive Power consumed by Motors
- Generated Reactives by Capacitors

The variables sent in this mode are:

- Voltages (value and y angle) on the PQ Nodes.
- Currents and Powers on Lines.

- Currents and Powers on Transformers
- Generated Active and Reactive Power by Float Nodes
- Estimated Active and Reactive Power on the Loads without Telemetering.

The state estimation also analyzes the measurements received from SCADA and performs an evaluation of the data quality.

2.3 Training Mode (See also numeral 3.10)

DMS has two ways to use the training mode.

In the first way, a previously constructed sequence of events is simulated, where the results of the simulations are sent to SCADA. In this case, DMS is a replacement of the real network, where situations that can occur in reality can be simulated, with the security of not doing operations on the electrical infrastructure.

The second way to use the training mode is to allow the instructor to make improvised changes during the training, by operating and setting elements in the DMS one-line diagram.

The variables sent in this mode are:

- Active and Reactive Power of the loads.
- Breakers Position.
- Position of Transformer Taps.
- Voltage on the Controlled Voltage and Float Nodes.
- Generated Power by Generators.
- Active and Reactive Power consumed by Motors.
- Reactives Generated by Capacitors
- Voltages (value and angle) on the PQ Nodes.
- Currents and Powers on Lines.
- Currents and Powers on Transformers.
- Generated Active and Reactive Power by Float Nodes.
- Fault Currents and Voltages.

In both ways, the operator can send commands from SCADA, which affect the DMS simulation and feedback the SCADA system.

The commands that can be sent from SCADA to DMS are:

- Breakers Operation
- Change of transformers taps.
- Change of dispatches in generators
- Data of Simulations of operation of the protection coordination system (Relay data)

3. FUNCTIONS

3.1 Topological Processor

The topological processor travels along the power grid, starting from the power supply points, to the load points. In its path, it can propagate topological data such as the state of energization (energized, de-energized, parallel, undefined, grounded etc.), voltage level, color (by state, voltage level or supply point), etc.

The topological processor is used internally in all the analysis and optimization applications.

DMS uses an extremely fast tree path algorithm with instant response (more than 100,000 nodes are processed in less than 0.9 seconds). This is because in the network modeling used, each element knows to which other elements it is connected, thus avoiding expensive and unnecessary searches.

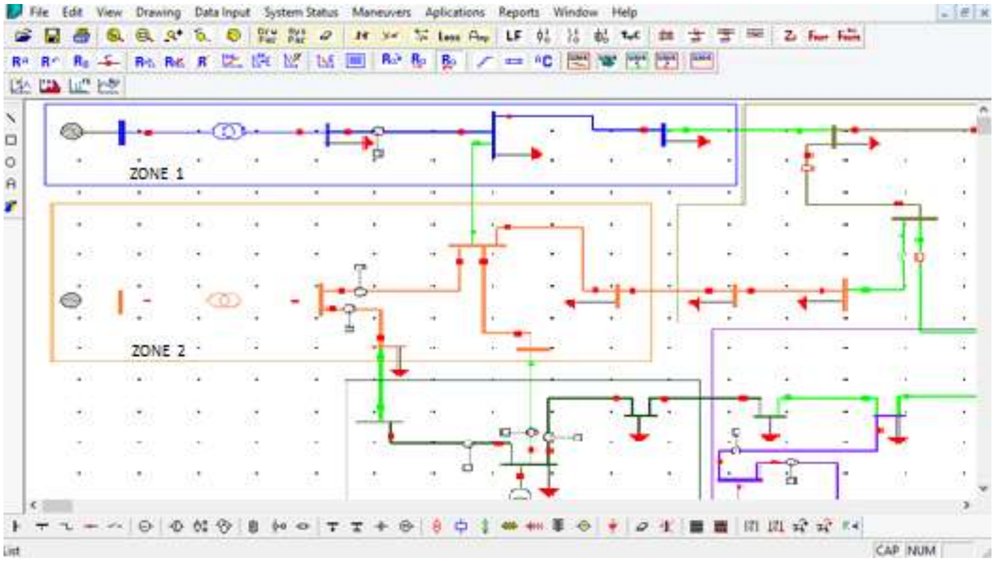


Figure 1. Example of an Electric network differentiating the voltage levels by colors

3.2 Power Flow

The Power Floe calculates the node voltages, power and current flows in lines and transformers, knowing the load data and injections into the system. This is done with the data obtained by meters in field that report to the SCADA System, so that the operator can know the state of the system at any time, and make simulations for short-term planning.

As for usage, if the user wants to know a voltage in a node, she must click on it and the program will show the corresponding value on the screen (see Figure 2); likewise for transmission lines and / or transformers to show power and currents flows.

If the user carries out operations such as opening or closing a breaker, raising or lowering a tap of a transformer or the excitation of a generator (changing data of loads, lines etc.), the displayed values change immediately according to the electrical impact of the operation. It is also possible to retain voltage data of the power system, using a specific option of the program to compare new voltage data after some maneuver has been performed.

In addition, DMS allows to carry out comparisons through the use of several windows. With this option the user is able to observe two states of the power system simultaneously.

DMS has three methods of load flow: ZBus Load Flow, Newton-Raphson Complete and Newton-Raphson decoupled. The user can select the one that fits better with his working way. It also allows to have different models of load: Constant Power, Constant Impedance, Exponential Model and ZIEP Model. In the ZIEP model, each load can have individual modeling.

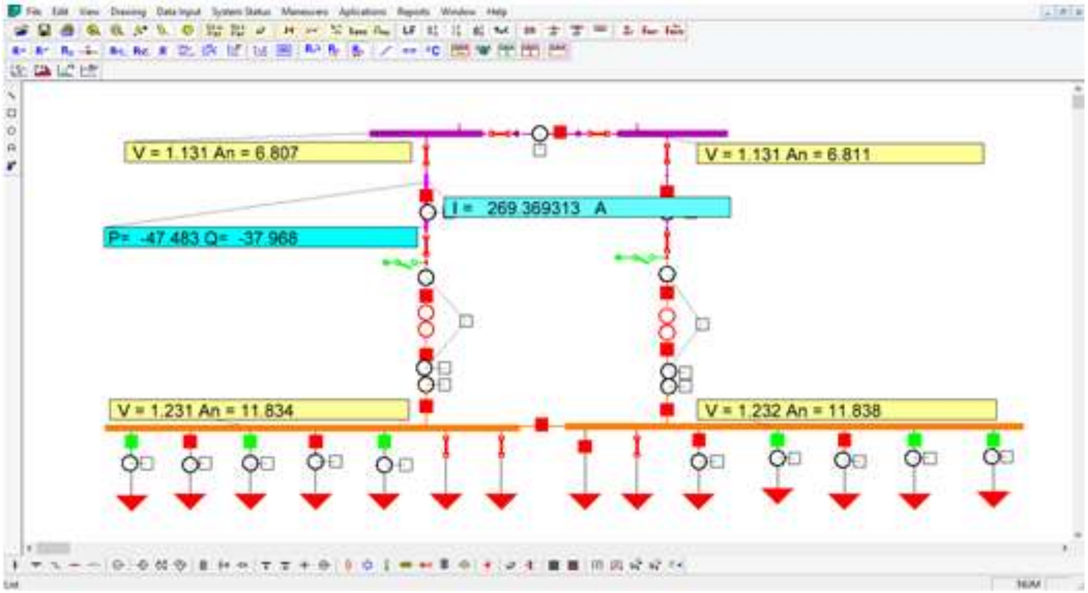


Figure 2. Example of visualization of node voltages, currents and powers in an electric network.

3.3 Short Circuit Analysis

It allows to know the levels of short circuit in specific points and the contributions of the elements to the short. The different types of fault can be simulated (three-phase, single-phase, two-phase, and between phases). The short circuit analysis is used to adjust the protections of the system.

When carrying out fault simulation at any point in the network, selected by the user, immediately all the electrical variables of the different elements of the system are calculated. The user can view, by clicking on any item, their data in the fault state, such as short circuit inputs, fault currents and fault voltages.

In addition, it is possible to simulate all the fault cases assuming a fault impedance.

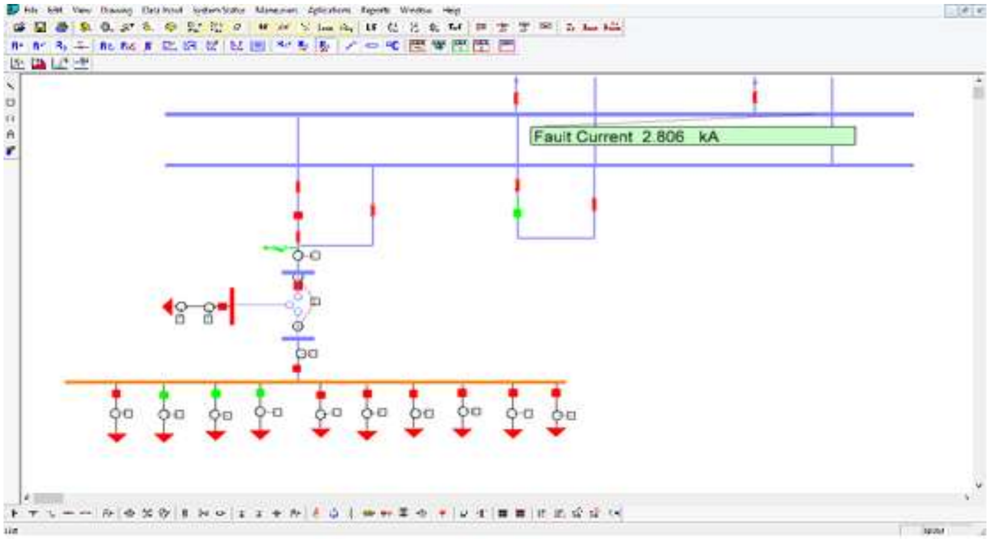


Figure 3. Example of the display of the fault in a bus

3.4 Protection Coordination

The coordination of protections module allows to use the results of the short circuit analysis to simulate the operation of the system relays, and thus adjust and coordinate the protection system.

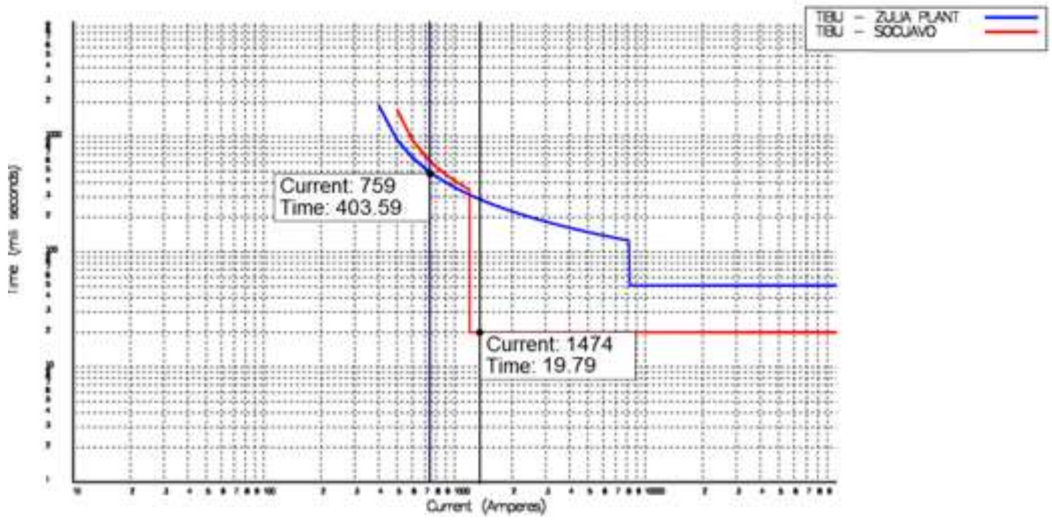


Figure 4. Example of the coordination of protection in a branch of an electric network

DMS includes libraries where a collection of protection relays with their respective technical and operative characteristics are found, these characteristics can be visualized and modified to adapt to the requirements of the power system.

DMS presents a window for visualization and manipulation of operation curves of relays. This tool supports the optimum coordination, since the made adjustments will be reflected in the relay settings in the power system.

Another way to achieve the adjustment and coordination of protections, is to use the Automatic Coordination option in which DMS automatically adjusts the relays and their different parameters (tap, time dial, etc.) to achieve optimum coordination of protections in the system.

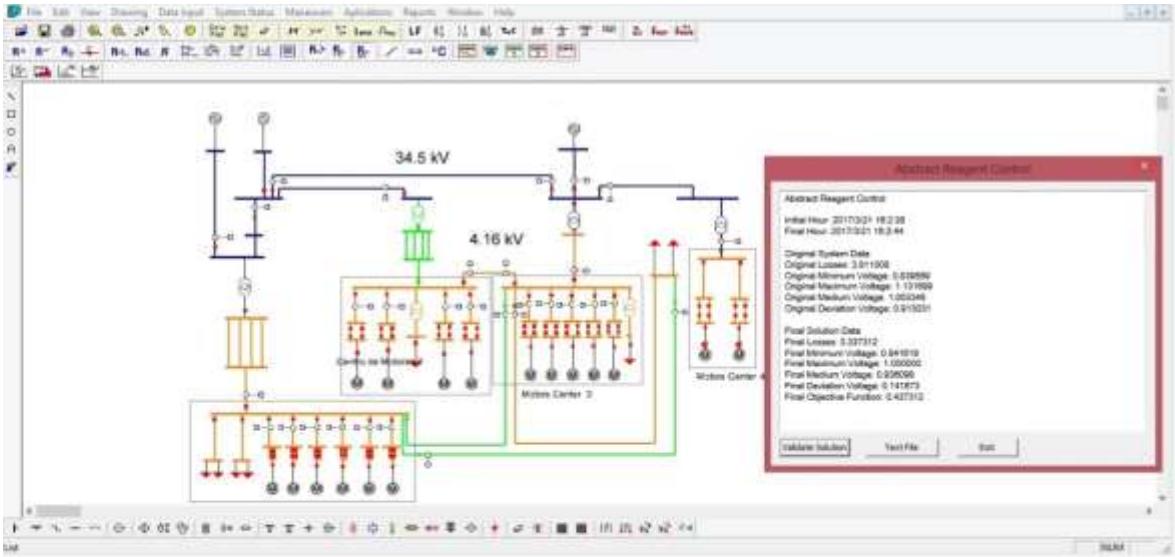
To do this, the coordination criteria are introduced, such as backup time between consecutive relays, percentage of load flow at which the relays would operate, percentage of the fault at which instantaneous relays would operate, and so on. The program autonomously simulates faults throughout the system and adjusts the parameters of the relays by an optimization algorithm.

Once the automatic module has finished, the user can verify, through simulations, the achieved coordination and customize it with specific changes, in order to get as close as possible to an ideal coordination.

3.5 Reactive Control

The aim of reactive control is to maintain the voltages of the power system nodes within acceptable levels, so that there are no over-voltages or under-voltages while the losses are minimized. Reactive control is carried out by adjusting optimum operating points, by moving tap changers from the power transformers, and by connecting or disconnecting capacitor banks.

DMS uses a parameterizable genetic algorithm to determine the positions of the taps and the capacitors to be connected or disconnected. The number of generations and the size of the population can be parameterized, as well as the lower and upper limits of voltage. The solutions are tested using the load flow, as well as the calculation of the objective function.



Abstract Reagent Control

Initial Hour: 2017/3/21 18:2:38
Final Hour: 2017/3/21 18:3:44

Original System Data
Original Losses: 3.011908
Original Minimum Voltage: 0.839889
Original Maximum Voltage: 1.131899
Original Medium Voltage: 1.003346
Original Deviation Voltage: 0.913031

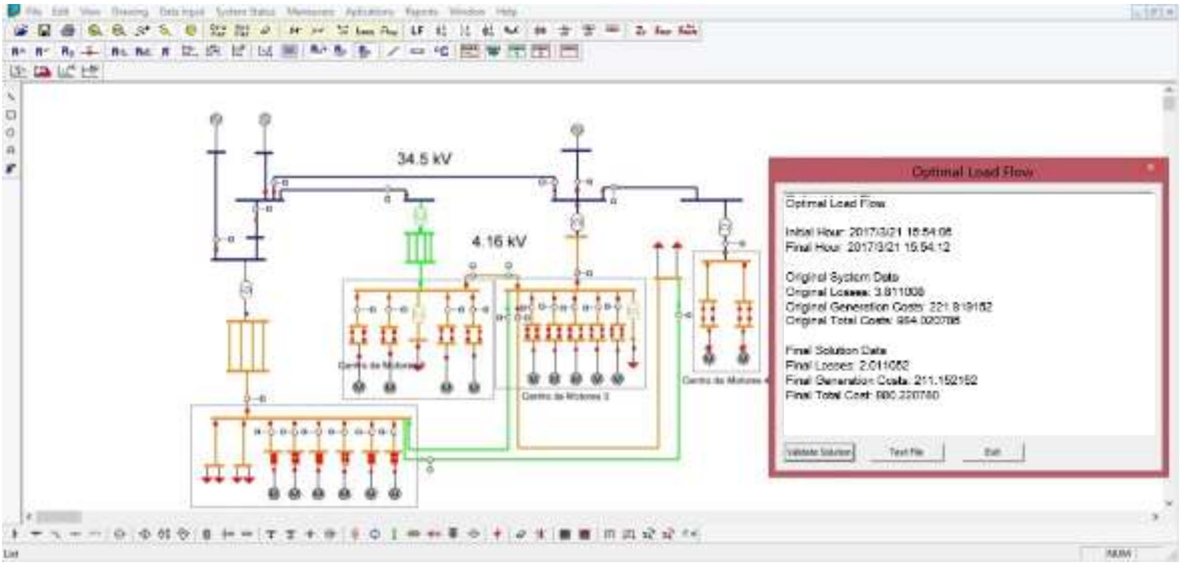
Final Solution Data
Final Losses: 3.337312
Final Minimum Voltage: 0.941019
Final Maximum Voltage: 1.000000
Final Medium Voltage: 0.938096
Final Deviation Voltage: 0.141873
Final Objective Function: 0.427312

Figure 5. Example of the reactive control

3.6 Optimal Load Flow

The optimal load flow is a variation of the traditional load flow, where the objective is to find the operating conditions that allow a minimum operation cost, taking into account the cost of generation and the cost of energy losses. In the optimal flow of DMS, the lower and upper voltage limits are also taken into account. A parameterizable genetic algorithm is used, where the user can establish the cost of losses, the number of generations, the size of the population and the voltage limits.

To use the optimal flow, a cost of function is assigned to each generator, and its operational limits are parameterized (minimum active power generated, maximum active power generated, minimum reactive power generated, maximum reactive power generated). The final result of the optimization are the power dispatches of each generator.



Optimal Load Flow

Initial Hour: 2017/3/21 15:54:06
Final Hour: 2017/3/21 15:54:12

Original System Data
Original Losses: 3.811008
Original Generation Costs: 221.819152
Original Total Costs: 984.020786

Final Solution Data
Final Losses: 2.011062
Final Generation Costs: 211.152152
Final Total Cost: 980.220780

Figure 6. Example of Optimal Load Flow

3.7 Contingency Analysis

The power systems are operated in such a way that no overload or any statistically possible contingency occurs in real time. A contingency is a situation where one or more elements of the network are lost, for example the opening of a line or transformer. These contingencies are analyzed to determine the operating solutions that generate the least impact on the system (avoiding overloads and loss of stability).

Using fault probabilities per element, DMS simulates the output of an element (line, transformer or generator) through a generator of random numbers, taking the necessary measures so that the load flow converges with the voltage within the limits allowed in contingency and without overloading the elements of the network.

Among the remedial measures taken by the contingency analysis module are load shedding, load transfers and connection of backup elements if there are any available.

3.8 Load Forecast

It consists of the prediction of the hourly load of energy demand of the system in the short term. It is based on the load history, weather conditions, day of the week and seasonal data.

DMS uses neural networks, which are trained with historical readings data. The reading information is classified on typical days (Ordinary, Festive, Saturday, etc.) in such a way that there is a neural network for each typical day. The neural network returns a projected power value receiving as input the hour data.

3.9 State estimation

The state estimation provides an optimal estimate of the state of the system based on available measurements and the assumed network model. Usually, the state estimation is composed of the following functions:

- Data Acquisition: The different measurements are obtained through the SCADA system.
- Processing of the network topology: Gets the state of the breakers and sets up the system diagram.
- Observability analysis: Determines if a state estimation can be obtained for the whole system using the set of available measurements.
- State Estimation Solution: Determines an optimal state estimation of the system, which corresponds to the complex voltages at the nodes of the whole system. This estimate is based on the network model and available measures.
- Processing of erroneous data: Detects the existence of errors in the systems measurements.
- Identification of the network model: Estimates the parameters of the network and detects errors in the configuration of the network identifying erroneous states of the breakers.

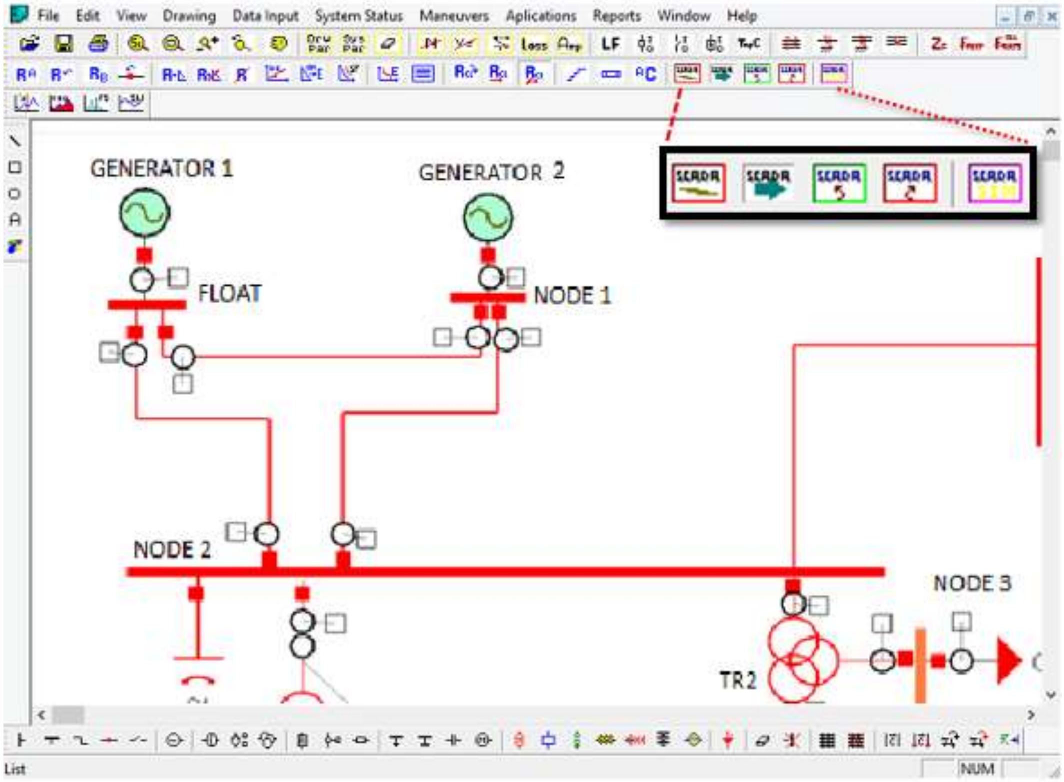


Figure 7. Example of the state estimation and options of the connection of SCADA to DMS

3.10 FLISR - Fault Location, Isolation and Service Restoration

Reducing the interruption time to customers in the distribution network has always been a goal for the power distributors. The integrated SCADA–EMS/DMS–OMS (also recently named ADMS-Advanced Distribution Management Systems) systems automate the network to achieve it. These are the systems responsible for minimizing the interruption time identifying precisely the fault localization and re-energizing areas that are not in fault condition. For this reason, the algorithms of localization, isolation and restoration of the service are an important part of ADMS. FLISR is operated and visualized on the OMS.

In SPARD®, a centralized algorithm that works in the control center is used, which works with the opening (interruptions) information that arrives from SCADA. When opening of a circuit or of a recloser happens, the FLISR algorithm is activated, which triggers the following steps:

Fault Location

Obtaining the Fault Data: Fault current data is captured for all three phases. The last read voltage is used as the pre-fault voltage. If no data is available on the SCADA (not all protection devices have this functionality), the operator can enter the estimated current data.

Identification of the Fault Type: The currents are analyzed using fuzzy logic to classify the fault into one of four types: three-phase fault, single-phase fault, biphasic fault and between phases. Depending on the type of the fault, the current fault data is converted into fault impedance.

Network route: The network is traversed from the opening point until the fault impedance is found. There can be the case to find multiple possible points.

Fault Grouping in Clusters: In the case that several possible fault points are identified, historical faults are grouped into clusters. To each cluster a fault probability is given. The user must confirm the point of failure.

Fault Isolation

Detection of Power Points: To detect the power supply points of the fault, the network is traversed from the fault location until protection devices are found. Ideally, the system should have devices with remote control. You can restrict the protection devices available in the parameterization of the algorithm.

Fault Isolation: Consists of sending opening commands to all the protection devices that supply, or could supply, into the fault. It can be parameterized to be performed automatically or manually with the authorization of the operator, or just as a suggestion.

Service Restoration

Detection of Possible Connection Points: Once the fault is isolated, the disconnected load is broken up into islands. For each island, the possible connection points are identified by going over the network from the opened points, when the fault is isolated.

Detection of the Optimum Connection Point: For each possible connection point, of each island, an optimum connection point is determined. To do this, the load flows are simulated, connecting the island to the connection point. The load flow determines: possible overloads, power losses, and maximum voltage drop (voltage). The optimal point depends on what is desired to optimize (losses, voltage, overloads). The optimization criterion is parameterizable.

Restore of the Normal Condition of Operation

Once the fault is repaired, the system can be operated under normal conditions. To do this, all the operations carried out are saved and executed in the reverse order of their original execution.

3.11 Operator Training System OTS

OTS or Operator Training System is the DMS function that allows to train SCADA personal in an operative environment with real conditions, but in a simulated way. In OTS the real network is replaced, where situations that happen in reality are reproduced, with the security that the student is not going to make operations over the real electrical infrastructure.

OTS is a tool that allows the instructor to design scenarios with programmed event sequences, which can be executed automatically. The instructor also can generate improvised incidences manually. The types of occurrence that are included are: opening / closing a breaker, tap change, load input / output, motor input / output, generation input / output, capacitor bank input / output, and fault occurrence.

OTS has a two-way communication with the SCADA. All the variables of operable elements (such as breakers) in SCADA must reach OTS. Equally, OTS feeds back SCADA with data of electrical type, simulating the operation of the real network.

The variables sent in this mode are:

- Active and Reactive Power of the loads.
- Breakers Position.
- Position of Transformer Taps.
- Voltage on the Controlled Voltage and Float Nodes.
- Generated Power by Generators.
- Active and Reactive Power consumed by Motors.
- Reactives Generated by Capacitors
- Voltages (value and angle) on the PQ Nodes.
- Currents and Powers on Lines.
- Currents and Powers on Transformers.
- Generated Active and Reactive Power by Float Nodes.
- Fault Currents and Voltages.

In both ways, the operator can send commands from SCADA, which affect the DMS simulation and feed back the SCADA system.

The commands that can be sent from SCADA to DMS are:

- Breakers Operation
- Change of transformers taps.
- Change of dispatches in generators
- Data of Simulations of operation of the protection coordination system (Relay data)