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Implementation of DMS Calculations in the Distribution Network Control Centers of Elektra Zagreb and Elektroslavonija Osijek

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SUMMARY

The DMS system functionality is enhanced by an upgrade of the Network Manager SCADA/DMS system from version 2.3 to version 6.4. All DMS calculations are improved with new functionalities. The load calibration function was extended with a WLS state estimator that is a standard feature in transmission networks. The load flow function was extended with advanced generator modelling capabilities and its handling and reporting were improved. A save case functionality with a very intuitive interface was added. A dynamic network colouring function was connected with DMS calculations enabling colouring of observable areas, loads and end branches. A new dynamic contour colouring function was added enabling colouring of high and low voltage areas regarding their nominal values.

KEYWORDS

SCADA, DMS, estimator, power flow, short circuit.

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1. INTRODUCTION

The upgrading of SCADA/DMS System in distribution control centre of electric power providers Elektra Zagreb and Elektroslavonija Osijek from Network Manager (NM), version 2.3 to version 6.4, in addition to upgrading of SCADA system and functions, have resulted in an upgrade and extension of DMS system functionalities used for calculations and power analyses of the distribution power network in real time and study time. The NM System upgrading process included a migration of the existing SCADA/DMS network model from the existing to the new NM system. The migrated network model comprising all the data of distribution network elements of each individual distribution area is used correctly for operation of advanced DMS calculations of the new NM system. The new NM DMS 6.4 system includes the DMS calculation functionality of the old NM 2.3 system with enhanced functionalities and new DMS calculation functionalities of NM 6.4 system that are listed and described in this Paper.

2. NEW CALCULATION FUNCTIONALITIES

2.1. Load Calibration / State Estimation Function

The DMS load calibration function is a base for all the other energy analyses in the NM system. In the essence of its operation, the DMS load calibration function is in charge of the power balance of the distribution power system and for setting it realistically for the needs of other DMS calculations. A static network model comprising power data on all the network elements and the shot of instantaneous measuring and indication conditions from the SCADA system are used as input data for DMS load calibration function. Using the stated input data set, the load calibration function performs network condition calculation (state estimation), corrects incorrect measuring and replaces data that have not been entered or that have been wrongly entered by the user. The function result is the most probable state of the network including the voltage magnitudes and angles for all network nodes, i.e. power flows of network branches.

In addition to standard sub-functions from the NM, version 2.3, the load calibration function of NM DMS, version 6.4, has a new sub-function for WLS state estimation determining the voltage magnitude and angle for each network node using the input set of measured power flows of branches, loads of consumers, production of generators or external injection of neighbouring networks and voltage magnitudes measured on busbars. That sub-function is applicable to both radial and mashed networks and it gives solutions for observable and non-observable network parts. It does not have limits regarding the network topology and size or voltage levels. State estimation sub-function comprises the functionality of detection of incorrect measuring and their elimination from calculations when they deviate significantly from estimated values, i.e. their replacement with pseudo calculated measuring.

Load calibration function is performed following the sequence of these sub-functions:

1. Statistic load calibration.

That sub-function calculates the base value of the active and reactive load for subsequent usage by the topological load calibration sub-function. The sub-function uses statistic information such as load profiles, number of consumers of each individual load, typical load values per seasons and load type values.

2. Electric network topology calculation.

That sub-function builds the network electric topology on the basis of circuit breaker statuses and the calculation results in the network node-branch model that is used subsequently for iterative calculations.

3. Identification of gross mistakes or Plausability Check.

That sub-function identifies abnormal measuring. Measured values entering one electric node are examined using the Kirchoff Law; unnatural losses are detected on branches when measuring is performed at both branch ends. Voltage measuring is examined regarding the voltage status of the network (under voltage status or no voltage status), and regarding the voltage level (its range per unit).

4. Calculation of network observable part and identification of incorrect measurements.

The state estimation of the observable part of the network is calculated in this step. The observability calculation and WLS state estimation calculation are used. The state estimation calculation prepares a list of incorrect (suppressed) measurements.

5. Topological load calibration.

That sub-function calculates pseudo measurements for the active and reactive power of not measured loads in non-observable networks. It takes into consideration the current topology (which loads are energized), static load calibration results, results at border nodes of observable network part, and also measurements of the active and reactive power if there are any. It also uses measurements of current and line injections, as well as entered power factor.

6. Complete solution.

The latest step calculates the common solution of the observable and non-observable network part. Results of the load topological calibration and the observable network part are united and the complete solution for the whole model is generated. The WLS algorithm for error minimization is also used in the solution uniting procedure.

7. Presentation of results on single pole diagrams and DMS reports.

The load calibration function submits data on the observable network part to the dynamic network colouring function. The observable part of the network is the part for which there are sufficient number of measurements of SCADA system that enable calculation of the voltage magnitude and angle in a node and where observable branches have observable nodes at both end. Final results of the load calibration calculation are shown on single line and network diagrams on NM system displays and in DMS reports. Additionally, results of that load calibration are used as input data for other DMS functions.

2.2. Power Flow Functions

That DMS function uses the output results of the load calibration function described in the previous chapter as input values and it is performed exclusively on results of that function. Results of power flow calculation can be reviewed through DMS report, in single line and network screen displays of electric power network or in the tool tip on the hovered network element. The power flow calculation function is performed in real time or in the study mode.

It is possible to load the complete status of the network with all the parameter values and calculated adjusted loads into a special memory space in the study mode. A change of topology triggers load calibration and power flow calculation in the real time mode to adjust power values with the newly appeared status. Loads defined in the real time are used in the study mode as fixed values and any change of switch-on status or measurement triggers power flow calculations resulting with an insight into possible conditions of the network and current and voltage conditions. Short circuit calculations are based on results of load calibration.

Results of the power flow calculation function are compared to the predefined limit values of elements. If any overload is found, an alarm will be generated. All overloaded branches and all network nodes for which voltage limits are exceeded are emphasised and marked with a special colour on the display of the selected network single line diagram. The operator has a possibility to store a certain group of calculation results for subsequent study on the basis of his/her own decision.

A power flow calculation can be performed for:

- One feeding line, a group of feeding lines or an arbitrarily determined insulated network;

- Radial or mashed part or a complete distribution network.

Prior the initiation of the calculation, the operator determines the initial situation in the network. The initial situation in the network can be an instantaneous state of the network or a previous stored state of the network. Unless the operator is completely satisfied with the initial situation, he/she can enter a new situation of change existing data (e.g. the condition of individual elements in the network) and perform a power flow calculation afterwards.

Generator operational curves are implemented into the DMS system to observe limits of the active and reactive power. If the calculated value exceeds the limits, the node with a constant voltage becomes a node with a constant load with the adjusted reactive power at the limit.

An enhanced LFC algorithm with an external power flow calculation loop is used for calculation of the position of the tap changer of transformers with automatic voltage regulation, a reactor and switched capacitor banks. New tap changer and new switch position of reactors and capacitor banks are being calculated iteratively. The external loop stops when the adjusted voltages are reached or when the maximum iteration number is reached. The LFC algorithm enhancement consists of the fact that the regulation point in which the set value of the regulated voltage is being observed is always treated as a remote point and there is no need for manual differentiation between the local and the remote busbar.

The power flow calculation sends loading of the elements to the dynamic network colouring function to colour the load in accordance with the ratio of the calculated load and the maximum loading.

2.3. Saving of Cases

After each automatic or manual triggering of DMS functions a save case is stored which includes all input and output of DMS functions that can be used later for analyses of the distribution network in the study data base. The user can configure the saving of cases on the user interface. E.g. data can be stored every 5, 15 or more minutes and they can be stored on predefined places on SCADA/DMS servers. The user can also restore a required group of data in a study data base on the same interface and make any further analysis and calculation of power flows or short circuits.

2.4. Short Circuit Function

The short circuit calculation function in the cyclic operation mode makes the calculation of three phase short circuit on the whole network model according to IEC 60909 Standard. In addition to the cyclic operation, the function can be invoked by a manual request on selected elements (busbars or lines) on which the short circuit calculation will be made. In this case, the following short circuit calculation types can be selected:

- Three phase short circuit calculation (symmetric fault);
- Two phase short circuit calculation (line to line fault);
- Two phase with ground short circuit calculation (double line to ground fault);
- Phase to ground short circuit calculation (line to ground fault).

Short circuit calculation results are visible on all displays in the form of short circuit current value at the short circuit point and surrounding influences. Besides, results of calculations of all the kinds of short circuits are visible in the table form of DMS reports.

2.5. Dynamic Network Colouring

The dynamic network colouring function was present also in previous NM system versions, but the new version, NM 6.4 SCADA/DMS, gained a few new modes of colouring and some modes connected to DMS functions: colouring of observability, load, graph profile of results along the line, and colouring of the open lines.

A different type of dynamic network colouring can be selected for each window on the display. Dynamic network colouring modes in the system are divided into the global and the local modes.

Global dynamic network colouring modes are shown with the same colours on all operating stations. The following dynamic network colouring modes are available:

- Colouring on the basis of the voltage state of elements: energized, un-energized, earthed, unknown;
- Colouring on the basis of power sources: elements are coloured with same colour if they have power supplied by same source;
- Colouring belonging to a certain part of the network: the user determines parts of the network on the basis of his/her own criteria when preparing data and they can be coloured differently on the display;
- Colouring of nodes: an individual node represents a group of all equipment interconnected electrically and separated by lines, transformer or open switching devices;
- Colouring on the basis of feeding source: a part of the network is coloured according to a switch designated as feeding source;
- Colouring on the basis of the voltage level: a voltage level has the same colour;
- Colouring of parts of the network on the basis of tags set in the network;
- Colouring on the basis of a subsystem: when data are being entered elements belonging to each particular system are identified, e.g. the subsystem of busbars of the same voltage level in the transformer substation determining the dispatcher’s authority.

Local dynamic network colouring mode identifies a part of the network selected by the operator with a separate colour. The following local dynamic colouring options are available:

- Colouring of path between elements;
- Colouring of path from element to nearest source;
- Colouring of all connected loads;
- Colouring of path from element to a main source.

2.5.1. Colouring of Observable Network

The observable part of the network is the part of the network for which there are sufficient measurements in the system that the voltage magnitude and angle of a node can be calculated, and for which branches of both node ends are observable. Data determining which part of the network is observable can be retrieved from the load calibration calculation function. Observable colouring shows the observable parts of the network with one colour and non-observable network with some other colour. An example of colouring of observable and non-observable network is shown in the Figure below. Red colour identifies the observable area, white colour non-observable area and blue colour identifies the equipment that is not energized.

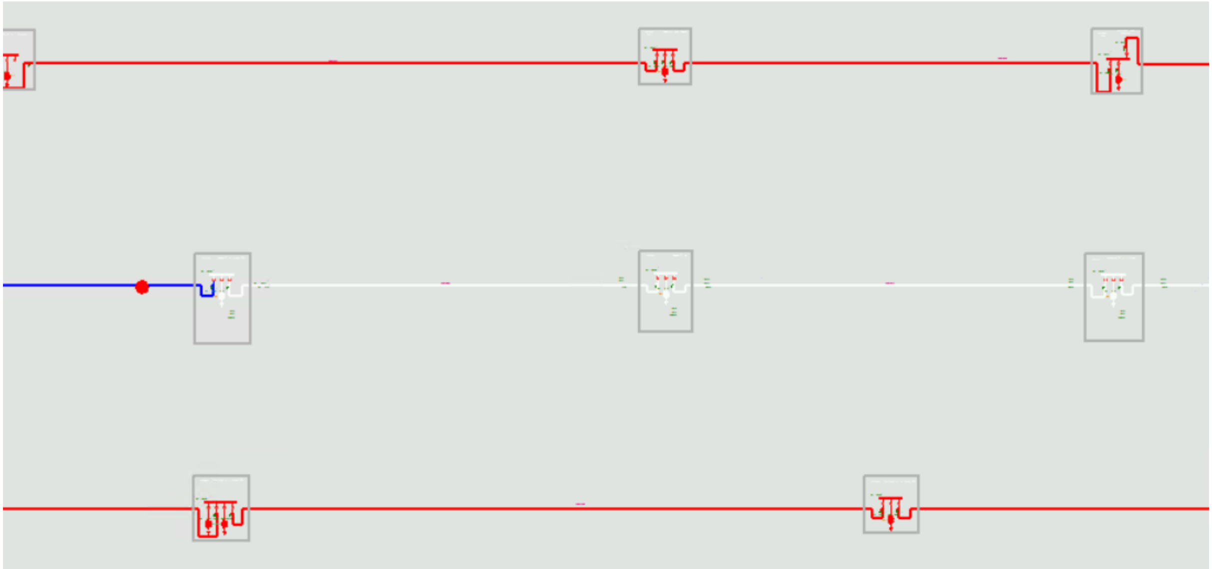

Figure 1 Observable network colouring

2.5.2. Loading Colouring

Colouring on the basis of the loading retrieves the data from the power flow calculation function. The percentage of the loading of each individual element is calculated on the basis of the calculated loading and the rated value for that element. Elements are coloured on the basis of the scale determined for the percentage of the load. An example of loading colouring is shown in the figure below.

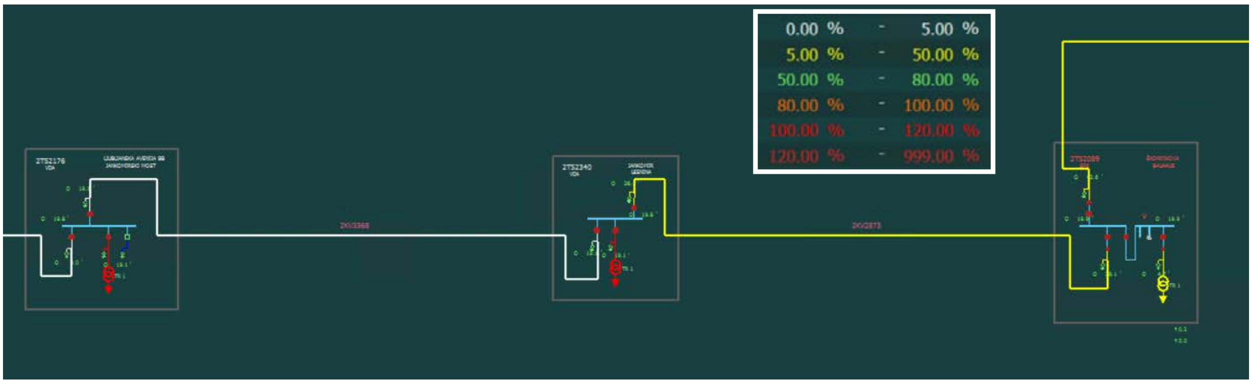

Figure 2 Loading colouring with the legend

2.5.3. Profile monitoring

Profile monitoring is a graph where lengths of lines on a selected route are placed on the x axis and calculated values from the power flow calculation function on the y axis. Points are marked on the x axis showing busbars alongside the selected route together with their names. A display of calculated voltage levels, currents, active and reactive power per unit or real values on the selected route can be set on the y axis. An example of the profile monitoring for the display of the voltage on the radial part of the line among six 20 kV voltage substations is shown in the Figure below.

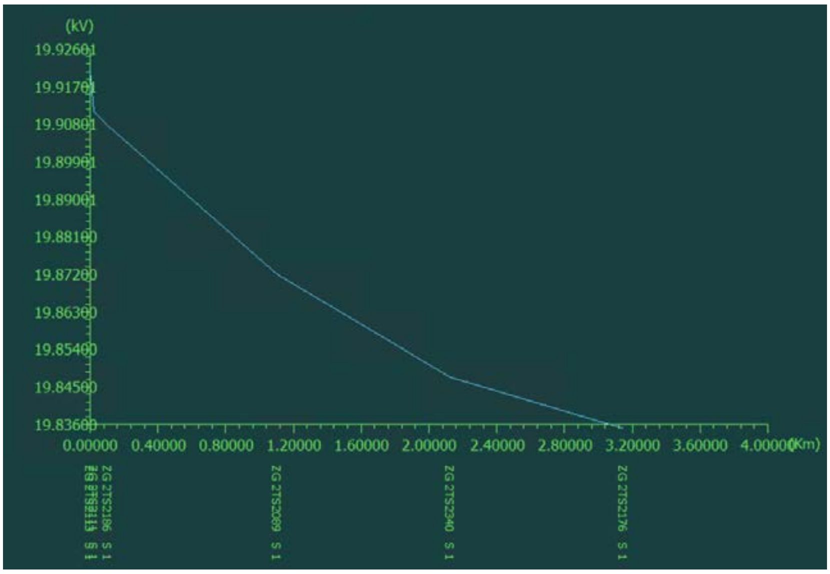

Figure 3 Voltage profile monitoring

2.5.4. Open End Colouring

Open end colouring can be used to show lines where one end is not connected to any other equipment (except busbar). In such case one half of the line is shown as dotted line. An example of colouring of open end branches is shown on the figure below.

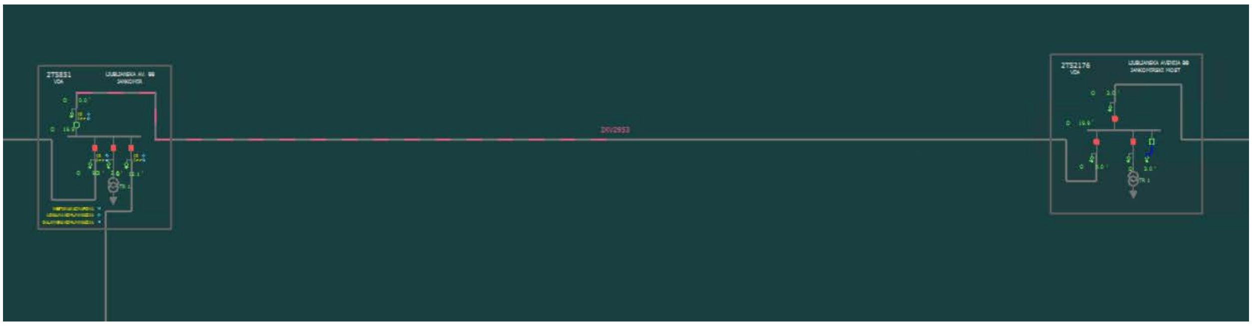

Figure 4 Open end colouring

2.5.5. Dynamic Contour Colouring

The aim of the intelligent visualisation of the electric energy system or *Dynamic Contour Colouring – DCC*), is to prevent too low or too high voltages and increase the quality of the delivered energy. DCC function monitors deviation of voltage or some other value from the required condition at individual points within the network using a special manner of displaying. That technique colours not only points with values, but the surround area as well.

The DCC function is a part of visualisation and it uses calculated values and measurements at certain points on the display picture, most frequently set on a geographical display. Measured values mark local extremities on the chart, while areas between them are shown as a weighted average of values measured at surrounding locations. Shades of colour represent deviations of the measured value from the normal value for that point. The DCC visualisation shown together with the distribution network display gives a direct overview of the status of voltage and other statuses in stations in the network. Colour is gradually transparent in such a way that it is completely transparent alongside the areas having normal values, while it is completely opaque alongside areas having extreme values.

The following parameters are configurable: a colour for values higher than its nominal value and a colour for values lower than its nominal value, a range of percentages considered to be a normal condition, a range of percentages for extremely high / low values, the number of shades and the calculation algorithm.

DCC function has the following possibilities:

- A choice of several different algorithms for calculation of visualisation of the network conditions at one display, but only one type at a time;
- Switching on and off of visualisation from the menu;
- Using of estimated values if there is no measured value;
- Values from the study data base are used in the study mode of operation;
- Voluntary selection and positioning of points;
- Processing values for visualisation are not set in the visible layer.

An example of DCC of the voltage on a screen display of the distribution network is shown in the Figure below.

Figure 5 An example of dynamic contour colouring

3. CONCLUSION

Upgrading of SCADA/DMS system to a new version has provided to distribution system operators of Elektra Zagreb and Elektroslavonija Osijek utility a modern system for monitoring, control and energy analyses of the corresponding distribution network. The enhanced DMS system together with its upgraded network analysing functions enables planning and development of the future distribution network and analyses of the current network, as well as decreasing of its losses in everyday operation. For a correct operation of all DMS functions, the network model should be continuously improved, correctly updated with correct data and manual entries of the switches that are not monitored. Enhancements and improvements of the new version of SCADA/DMS system are extremely helpful in that respect.

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