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Electrical Network Monitoring And Control System (ENMC) Application

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This revision of PTS **33.64.10.11 – Electrical Network Monitoring And Control System – Application (February 2011)** has been reviewed and updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font (if any).

The previous version of this PTS **33.64.10.11 – Electrical Network Monitoring And Control System – Application (February 2010)** will be removed from PTS binder / e-repository from herein onwards.

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1. INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for formulating the scope of supply for an Electrical Network Monitoring and Control system (ENMC system) as described in PTS 33.64.10.32.

The operational supply functions of generating systems and transmission functions are normally beyond the scope of supply of an ENMC system. However, a number of these functions may become applicable in large electrical network. The relevant functional diagrams and descriptions are incorporated in this PTS in case these functions might be required.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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This PTS is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/marketing installations.

If national and/or legal regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this document as closely as possible.

1.3 DEFINITIONS AND NOMENCLATURE

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Network function definitions

<i>Consistency analysis</i>	Determining anomalies and inconsistencies in network operation data.
<i>Distribution power flow analysis</i>	Analysing actual power flow in the distribution network and checking for out-of-range operating conditions.
<i>Economy A</i>	Evaluation of a possible energy transaction with an external company in terms of costs/profits without altering the unit commitment schedule.
<i>Economy B</i>	Evaluation of a possible energy transaction with an external company in terms of costs/profits taking into

	account alternative unit commitment schedules.
<i>Economic dispatch</i>	Allocating power resources to feed the network at a particular time, i.e. meeting the network load at that time with minimum overall production costs.
<i>Energy demand control</i>	Optimising the use of electrical energy over a particular time period.
<i>Fault calculation</i>	Calculating currents and all contributions to fault currents, comparing fault currents against circuit breaker ratings for each circuit breaker involved.
<i>Fault location</i>	Determining the probable equipment location of a fault.
<i>Fault isolation</i>	Indicating which equipment is faulted and should be isolated.
<i>Feeder reconfiguration</i>	A proposed feeder configuration that optimises the feeder according to a number of objectives.
<i>Generation area control</i>	Control of the total power output of selected generation units in a predefined area.
<i>Interchange transaction scheduler</i>	Planner and scheduler for energy exchange.
<i>Load/frequency control</i>	Control of the power output of a generator according to setpoints and generator constraints.
<i>Network security analysis</i>	Determining the security of the power system under specified contingencies.
<i>Network sensitivity analysis</i>	Calculating, for the actual network state, the sensitivity of network losses to changes in unit generation and to interchanges with other networks.
<i>Network voltage scheduler</i>	A real-time optimisation of the network voltages and MVar flows, recommending control settings to minimise active power losses and maintain bus voltages and branch flows within limits.
<i>Optimal power flow</i>	Determining a network solution that optimises performance under certain operational constraints.
<i>Power flow analysis</i>	Examining the steady state conditions of the power network that may exist under a wide variety of conditions.
<i>Production cost monitoring</i>	Monitoring and summarising production costs and fuel consumption of generating units, comparing them with optimum production costs.
<i>Real time sequence control</i>	A sequential run of network application functions.
<i>Reserve monitoring</i>	Calculating actual figures for active/reactive spinning and operating reserves, comparing these with defined classes and indicating shortfalls.
<i>Security checked switching</i>	Checking the power system state for limit violations as a result of an intended switching action.
<i>Security dispatch</i>	Achieving an optimum balance between security, costs and other operational constraints, and determining the most effective remedial actions if operating constraints are violated.

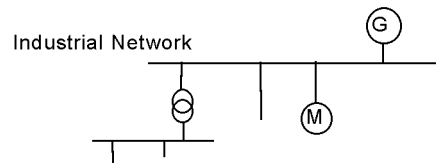
<i>Service restoration</i>	Determining alternatives for re-energising equipment and sections that are switched off but not identified as faulted.
<i>State estimator</i>	Providing a complete network solution from real-time measurements and network data, calculating the best possible 'image' of the actual load flow situation within the power system and creating pseudo measurements to allow estimated solutions for unobservable parts of the network.
<i>Transformer load management</i>	Utilisation of short-term overload capabilities of a transformer; load balancing between transformers by feeder reconfiguration.
<i>Unit commitment</i>	Scheduling operation of generating units to supply the load under certain constraints.
<i>Volt/VAr control</i>	Determining settings of transformer taps, voltage regulators and shunt capacitors/reactors to achieve selected objectives.

1.3.3 Terminology

Availability	The ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval assuming that the required external resources are provided. Availability is calculated from the formula: $\text{Availability (\%)} = (\text{total time} - \text{total down time}) / (\text{total time}) \times 100.$
Distributed Control System	A computerised system which is dedicated to monitoring and controlling defined aspects of process installations.
Electrical Network	the complete electrical network consisting of generation, transmission and distribution. Four types of networks are distinguished: G-type, GPO-type, P-type, PGD-type and PGT-type.
Electrical Network Monitoring and Control system	A computerised system which is dedicated to monitoring and controlling defined aspects of an electrical network.
Electromagnetic Compatibility	The ability of an equipment or system to function satisfactorily in its electromagnetic environment without imparting intolerable electromagnetic disturbances to anything in that environment.
Emission level	The amount of electromagnetic emission that is permitted

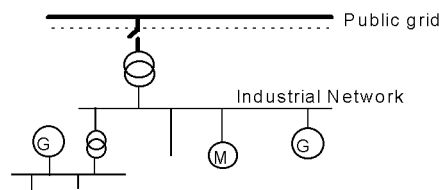
G (Generation) Type Network

Electrical network, self supporting, no coupling to the public network possible.



GPO (Generation, Public Optional) Type Network

Electrical network, normally self-supporting, coupling to the public network possible.



Immunity Level

The electromagnetic disturbance that is permitted without degradation of the performance of an equipment or system

Inputs / Outputs

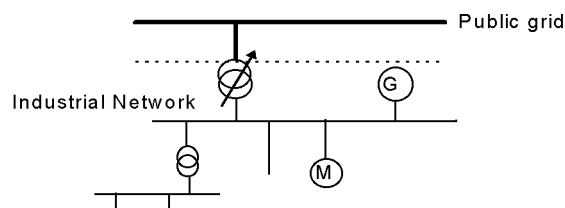
The actual interface of the ENMC system to other systems or equipment. It does not mean a 'serial link'.

Network function

Function needed for (electrical) network operational reasons, i.e. to operate the network in a safe and/or economical way.

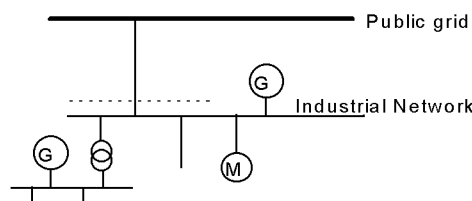
PGT (Public/Generation, Transformer connected) Type Network

Electrical network coupled to the local public network through transformer with on load tap changer, own generation in parallel.



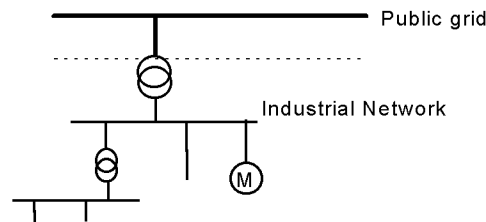
PGD (Public/Generation, Directly connected) Type Network

Electrical network coupled directly to the local public network, own generation in parallel.



P (Public) Type Network

Electrical network coupled to the local public network, no own generation available.



Reliability

The probability that an item can perform a required function under given conditions during a given time interval.

Satellite equipment

ENMC subsystems that are not at the 'central location' (which is usually the control centre), but are distributed over the electrical network.

Supervisory Control And Data Acquisition

A set of functions responsible for the acquiring and processing of data and issuing of commands.

Support functions

Functions not explicitly needed for the network but supporting the operation of the ENMC system or the operator.

System functions

Control and monitoring functions, inherent to a computerized ENMC system.

Test procedures

Activities to verify the actual performance of a system or part thereof.

1.3.4 Abbreviations

AVR	Automatic Voltage Regulation
LCD	<i>Liquid Crystal Display (monitor)</i>
DCS	Distributed Control System (process control)
EMC	Electromagnetic compatibility
ENMC	Electrical Network Monitoring and Control
HMI	Human Machine Interface
I/O	Input/Output
MCC	Motor Control Centre
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition

1.4 CROSS-REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents referenced in this PTS are listed in (8).

2. OBJECTIVE OF THE ENMC SYSTEM

2.1 GENERAL

In general, the objective of an ENMC system is to improve the operation of an industrial electrical network in terms of cost, safety, availability and power quality.

The functions required in an ENMC system depend on the type of network (1.3.3), the size of the network and the way in which the network is operated.

2.2 AVAILABLE FUNCTIONS

The majority of ENMC systems will only deal with SCADA functionality; relative simple and straightforward functions for monitoring and controlling the network. Possibly these SCADA functions may be complemented with applications to control power generation in the network.

If the network is relatively large and/or complex or it is operated close to its limits, energy management functionality may be included in an ENMC system, enhancing the security level.

Functions aimed at achieving cost and/or economic optimisation are traditionally used in very large systems (e.g. national control centres of public utilities). However, functions dealing with economic aspects in an ENMC system may be included for the following reasons:

- the industrial network also operates as a public utility;
- the increasing awareness of and need for “power quality”.

If the industrial electrical network operates as a public utility, liberalisation of the electricity sector, i.e. the growing competition in selling electricity, may be another motivation for including economic optimisation functions.

System and Support functions are inherent to an ENMC system. The number and extent of these functions depend on the extent of the ENMC system.

In sections (4) and (5) a description is given of the possible functions to be implemented in an ENMC system.

2.3 REAL TIME OR STUDY MODE

Many functions can either run in:

- real time mode: data originating from the actual network is utilised and results are directly related to the actual situation;
- study mode: this offers the operator a means to study behaviour of the network (using the same network model) under several conditions.

Configuring the system so that functions are accessible in study mode only might lead to a reduction of the system cost.

2.4 INTEGRATION OF FUNCTIONS

An important factor in the selection of an ENMC system is the degree to which functions are integrated in that system. The advantage of highly integrated products is the uniform user interface (menu structure having the same look and feel across all applications) and a uniform naming convention of objects across applications.

Poor integration is generally characterised by a non-uniformity of the user interface and naming convention. If equipment for such a system is selected on case-by-case basis this leads to one-off systems and raises the question of after-warranty support for such special applications.

3. NETWORK FUNCTIONS

3.1 GENERATION

Functions related to generation can be divided into three categories:

- generation control;
- energy scheduling;
- operational planning.

3.1.1 Operational planning functions

In general, functions dedicated to operational planning are required when economic constraints dictate to an important extent the operation of (large and extended and/or complex) electrical networks. Although these functions are normally beyond the scope of functions needed to monitor and control an industrial electrical network, a description of them is given in this PTS as they may be applicable to some networks or become required in the future.

3.1.1.1 General description of function aspects

The principal function for the economic optimisation of a set of generating units is *unit commitment*.

In most cases customisation is required to incorporate special features of the generation sets utilised.

Examples of customisation are:

- combined optimisation of electricity and heat;
- minimum-take constraints on some fuel types;
- exchange of power (import / export) with Utilities or other areas.

Prerequisites for application of *unit commitment*:

- generator incremental heat rate curves known;
- initial status of the units known in study mode (e.g. off-line or on-line and since when, actual generation level if on-line);
- system load must be known on half-hourly or hourly basis for several days, typically up to 8 days. This data could be supplied by load forecast (not a prerequisite but it facilitates the supply of data);
- desired spinning reserve (from *reserve monitoring*);
- all relevant data of the interchanges with other utilities or other areas if applicable. In large networks, the *interchange transaction scheduler* is used to supply this data. If the latter function is not included in the system, then the data needs to be supplied in another way, e.g. by importing a file from another application (for instance a Contract Management tool running on PC) or by manual entering by the user;
- loss penalty factors computed either by penalty factor calculation (from *network sensitivity analysis*) or in off-line mode and manually entered by the user.

Data from the *unit commitment* function is needed by the *load/frequency control* function and must be supplied automatically or manually. If the number of generators is limited to a few units, then probably a stand-alone *unit commitment* will do or even in some cases a program implemented in a spreadsheet. The user would then have the responsibility to supply data to other applications either semi automatically (e.g. file transfer) or manually. For example the optimal generation levels would be manually entered in the input displays of the load flow program or into the *load/frequency control* function.

It is important to:

- assess how often *unit commitment* needs to run;
- determine the degree of automation/integration that is required;
- define the desired user friendliness;
- highlight the special features of the generation units (needing customisation work!).

Economy A and *economy B*, in conjunction with *load/frequency control*, are tools for evaluating possible energy transactions not included in the *unit commitment* (last minute offers). It only makes sense to include one or both of them if *unit commitment* is also included in the scope of supply.

The need for *production cost monitoring* greatly depends on the economic constraints the network has to be operated under. For *production cost monitoring* an overlap may be possible with the functions of the Distributed Control System. To determine the necessity of this function this question shall be clarified and resolved.

To simplify the supply of input data to the *unit commitment* function, several applications, for instance *Interchange transaction scheduler* and *reserve monitoring*, can be used.

Unit commitment and *economic dispatch* functions in available ENMC systems are often closely related. Spinning reserve requirements are based on Economic Dispatch results taking into account transient spinning reserve capabilities of the committed units; reserve levels are not predetermined fixed values but are calculated on the basis of units available and their characteristics, the desired system response in case of system faults and other contingencies. Because of this close relation between *unit commitment* and *economic dispatch* these functions may be integrated into one single function.

3.1.1.2 Unit commitment

The objective of this function is to determine the optimal generation levels of generation units (typical study horizon one day to one week) and to determine a pre-dispatch schedule of these units.

Unit commitment offers the possibility of optimising the operation of thermal generating units to supply the load at minimum costs while meeting system loads and reserve requirements.

Minimum costs are achieved by considering the following constraints:

- start-up and generation costs;
- most economical start up and shut down times;
- minimum uptime and/or downtime;
- generation levels;
- spinning reserve requirements.

Unit commitment needs the following information:

- available generating units;
- units generating at present;
- units that have to be kept on-line (e.g. for voltage control);
- unavailable units;
- specific unit characteristics incl. costs and expected load (electrical, steam consumption and required import/export transactions).

Example:

This function offers for each generation unit a schedule showing when and how it can be applied to contribute to the network load or to meet contract agreements.

3.1.1.3 Economy A

This optimisation function enables the operator to evaluate a possible energy transaction with an external company in terms of the costs of the actual energy exchange and the costs of increasing or decreasing the committed generation resources in the network.

Commitment schedules are not changed (as is possible with *economy B*) meaning that only generation units that were scheduled can be regulated to generate more electrical power.

Example:

By adjusting the power output of the already running generation units, electricity can be sold to, for instance, a public utility. Because the generation units are already running, their start-up and shut-down costs are not applicable.

This may be a permanent situation where the industrial plant acts as a utility or in case of emergencies the industrial plant can help the public utility to survive.

3.1.1.4 Economy B

This optimisation function enables the operator to evaluate a possible energy transaction with an external company in terms of the costs of the actual energy exchange and of increasing or decreasing the generation resources in the network.

Unlike *economy A*, commitment schedules may be changed meaning that start-up of generation units that were not scheduled may be considered.

Example:

In the situation as described under the example of *economy A*, the use of non-scheduled generation units is additionally possible so the costs of start-up and/or shut-down of units also have to be considered.

3.1.1.5 Production cost monitoring

This function allows the operator to monitor and summarise the production costs and fuel consumption of the generating units and compare them with the optimum production costs.

Taken into account are:

- production costs;
- fuel consumption;
- start-up costs.

Note An overlap may be possible with a similar function implemented in the DCS.

Example:

When generation units can be regulated and the total load can be divided over a number of units, this function offers information for evaluating the efficiency of each unit in terms of costs.

3.1.2 Generation control

The following kinds of control can be distinguished in an industrial electrical network:

- primary control: directly related to the controlled device; not implemented in an ENMC system;
- secondary control: related to parallel operating devices that have the same type of primary control; can be implemented in an ENMC system;
- tertiary control: related to the exchange with an external network; can be implemented in an ENMC system; always related with economical aspects.

3.1.2.1 General description of function aspects

By controlling the power output and voltage of individual generator units the total electrical load is allocated to all power sources (generator units as well as connections to an external grid) and the network voltage is maintained within a certain bandwidth.

Volt/VAr control offers the possibility of controlling voltage and reactive power. When maintaining voltage within a certain bandwidth *Volt/VAr control* acts as a primary control function. For this purpose a number of control means can be available. The secondary control function, reactive power control, is superposed on the voltage control and is necessary if two or more generators run in parallel to maintain the distribution of reactive power among the generators.

Load/frequency control can be regarded as the central function for controlling selected generator units to maintain system frequency and scheduled power output. This function acts on the prime mover of the generator unit.

If the plant network is connected to an external grid, frequency is determined by that external grid and in this situation the *load/frequency control* function controls the electrical output of the generators in operation (primary function), the balance between them (secondary function) and, when applicable, the export/import of power (tertiary function).

If the plant network operates in island the electrical power output is determined by the load and the *load/frequency control* function maintains the frequency of the plant network within a certain bandwidth (primary control) and also balances active power output among the generators in operation (secondary control).

When considering the need for the *economic dispatch* function the following aspects are decisive:

- the number of regulating generators;
- whether the characteristics of the units involved differ considerably.

If the number of units is limited to a few units or the characteristics do not differ to a great extent, then the *economic dispatch* data can be manually entered by the operator.

For non-regulating generation units the output level is either manually entered in the *economic dispatch* function or is supplied by the *unit commitment* (if included in the scope of supply).

Generation area control is the tertiary control function for enforcing contractual obligations on the tie-lines (import/export contracts) in order to reduce any deviation between actual and scheduled net interchange. More than one *generation area control* function may be possible if a network is subdivided into smaller sub-networks.

The decision whether to include *generation area control* in the scope depends on the size of the network and the type of contracts.

The following questions need to be answered:

- are there “regulating contracts” i.e. contracts imposing obligations to stay in a MW band or are there security constraints whereby area exchange must be kept within certain limits?
- are there enough regulating units available to be controlled by the *generation area control* and optimised by the *economic dispatch*? If so, is the turbine side of each generator unit suitable for fulfilling the regulating requirements?

If the answer to either question is ‘no’ then this function is not required.

One way to measure the return on investment of the *generation area control* function is to compare its cost to the penalties applied when deviations on energy transactions occur, but the increased stability and security of the total system may be far more important. The generator units are operated at working points where the system as a whole can withstand a relative large disturbance before any generator will trip.

Generation area control requires as input:

- the scheduled net area interchange (from *interchange transaction scheduler*);
- the list of regulating units along with their participation factor (from *economic dispatch*).

Functions as mentioned above that automate the supply of input data to the *generation area control* function can be considered as optional. The absence of these functions generally entails an additional workload for the operator.

The *generation area control* function utilises the *load/frequency control* function to control generation in a particular area of an electrical network.

The need for *reserve monitoring* greatly depends on the economic and security constraints the network has to be operated under. The *reserve monitoring* function can be used to simplify the supply of input data to the *unit commitment* function.

Depending on the system losses, a link with the *network voltage scheduler* function may be required in order to minimise overall losses.