ICONO – INTELLIGENT CONTROL NETWORK OPERATION

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ABSTRACT

Compensation of reactive power through capacitor banks and correction of voltage through transformer taps affect important objectives in network management such as guaranteeing the quality of supply and reducing the operational and energy costs.

In this paper, an intelligent system to automate the deployment of capacitor banks and transformer taps is described.

INTRODUCTION

For legal, ecologic and economic purposes, low power losses and stable voltage levels are required conditions to have an acceptable network performance.
These two conditions are reached by connecting or disconnecting capacitor banks to the network and by moving transformer taps.

The management process that goes from the determination of which capacitors and taps to use up to their actual physical operation is usually based on simple decision-making systems, many times manual. Thus, the decisions made are in general far from optimal and the repetitiveness of the process is costly –for instance, a network of 600 nodes might require the processing of 30,000 commands per year.

MOTIVATION

Intelligent COntrol Network Operation (ICONO) project was born in ENDESA to meet the following needs:

- Improving Product Quality
- Improving Operating Safety
- Minimising power losses and observing Network Operator restrictions (power factor)
- Decreasing of Control Centres operating stress and cost
- Setting up protections based on network topology
- Restoring high and medium voltage power lines automatically

These points and some tools involved with them are discussed below.

Product Quality improvement

Product Quality has been improved through automatic execution of complex manoeuvres on distribution network capacitor banks.

Operating safety improvement

By crossing real time network database and preventive maintenance works database, it is possible to develop algorithms with the following functional capabilities:

- Warning (and stopping, if necessary) of switches and transformer taps manoeuvres if their maximum operation limit is approaching.
- Obviating manoeuvres on elements connected to lines and buses, if they are out of service because of maintenance works, incidents or any other reason.

Power losses minimization and Network Operator conditions

Some interconnected tools have been or have to be developed to reach an optimal network configuration:

- *Load Forecast*: it provides a forecast of demanded power curve.
- *Next 24 hours scenario creator*: joining that foreseen load information and programmed maintenance works information, it is possible to create network scenarios containing data of load, generation and network topology for the next 24 hours.
- *Contingency analysis (N-1)*: previous created scenarios are submitted to a contingency analysis to detect any possible distortion and correct it with appropriate actions.
- *Optimal Power Flow (OPF)*: after preparing all the foreseen scenarios, it's time to optimise network performance taking into account power factor limitations and power losses.
- *Network recalculation and distortion corrections in case of incidents*: if an incident occurs, the system has to stop any programmed action and should help to minimize distortions by doing manoeuvre proposals. When a new stable network state is reached, the system rearms itself and goes to its standard operation state.

Control Centres stress and cost decrease

All those tools help to decrease Control Centres operation workload. In addition, keeping an optimised network performance is easier and cheaper.

Dynamic protections set up

In the future, an automatic protections setting up depending on each network topology will improve even more network operation and performance.

Power lines automatic restoration

Nowadays, there are already systems to inform about high voltage network recovery actions. These proposed manoeuvres have to be propagated to SCADA systems to be applied sequentially on the network.
After that, taking information from medium voltage buses, it will be possible to isolate outages automatically and restore the power in minimum time.

ICONO DESCRIPTION

ICONO is a network control system to automate, assist and improve network operation tasks by foreseeing future network states and providing appropriate control actions to guarantee stability and security as well as to optimise network performance versus cost of operation.

System overview

This network control system is based on a network mathematical model and on periodically updated telemetry data. Three main processes act upon these data: OPF determination, Load Forecast and Contingency Analysis. These processes are coordinated and joined with other tools to meet the required security, quality, operative, legal, and economic criteria (Fig. 1).

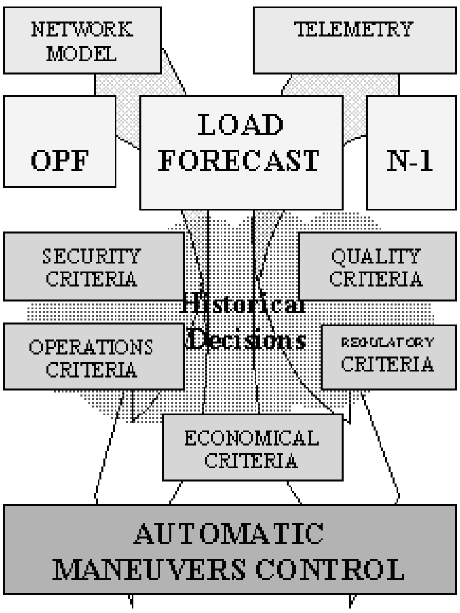

Fig. 1. ICONO needed data

The Command Manager system process will automatically generate a sequence of low-level commands for the capacitors and transformer taps. Before actually executing the commands, the system will verify whether the commands are going to be valid on the following hours. To do so, the verification process analyses several scenarios obtained from the Load Forecast, which contain the possible changes of load and generation.

Execution of the described processes, as well as recording of all decisions made, will be done in real time. Historical information will be fed back into the system to be used by future decision-making processes. This "learning" mechanism increases the system effectiveness along time.

Functional diagram

A general diagram with information that ICONO uses to perform its calculations is shown in Fig. 2.

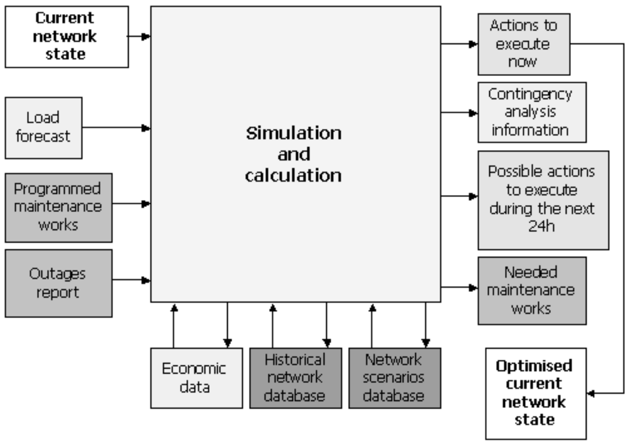

Fig. 2. General system diagram

Current network state
This block contains the present network distribution of load and generation as well as the state of all the control elements (switches, transformer taps, capacitor banks, etc.). This is the starting point from which network performance can be improved in order to reduce power losses to a minimum, gain stability and evolve network model from present to future states.

Load forecast
Load forecast application foresees future energy demand based on historic data, type of day (workable or holiday) and month (summer, winter…), weather forecast, etc.
This forecasted load provides detailed information about every power station and bay. All this information is crucial to build future network scenarios on which to perform power flow calculations.

Maintenance works and outages
Information of foreseen network maintenance works is very useful to optimise network operation. Having data of which elements will be connected or disconnected and when it will take place permits the operation system to prepare previous network scenarios being aware of which elements will be active or not in the future.

Moreover, unexpected outages and failures can occur at any time. Alarm systems and outage reports take charge of warning both computerized operation system and the technician about any undesired situation.
On unexpected outage detection, the system stops any calculation until a technician performs appropriate corrective actions. After that, control system reads network situation again and restarts calculations to improve this new state.

Economic data
Economic data is needed to evaluate operation costs. Also, power losses can be translated into money losses.

The system can decide if an operation is good or not by comparing the cost of each one. This information provides a way to calculate money savings from taking a solution or another.

Network databases
Two databases are needed by the system to read and write network information:

- Historical network elements database that contains information about every switch, line, transformer, etc. The system controls wearing on these elements and informs when some of them need a revision.
- Network scenarios database that contains data of past network states and their power distribution, and of future calculated scenarios and their foreseen operation procedure.

All this information is used to decide which actions to take at the time and in the future by comparing present and past situations and their possible or taken solutions.

Actions to take
Once the calculation algorithm has finished its operations, it provides a list of actions to get an optimised network.
Moreover, a foresight of the next 24 hours operation actions can be consulted too.

Network state information
Additional outputs are a list of critical failure elements and a list of network elements that need an immediate preventive maintenance or will need it soon. Those data are very important to improve network failure prevention.

Process results
As a result of this process, we obtain an optimised network state that also assures a good future network performance and optimal economic resources investment in network operation.

Simulation and calculation system
The simulation system and the calculation algorithm (Fig. 3) take needed information from inputs and, by using some mathematical tools, provide desired outputs.

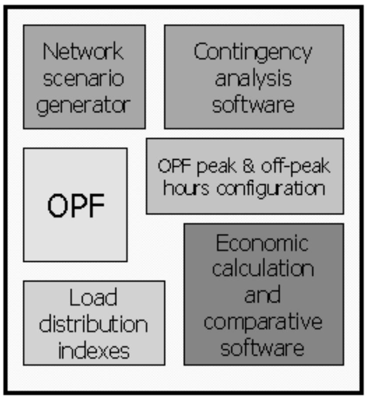

Fig. 3. Tools included in the simulation and calculation block

Many of these mathematical tools are already implemented but not interconnected to work together.
Other required software has to be developed to perform all necessary calculations and allow the system to work on-line.