TOWARDS MV NETWORKS AUTOMATION

Olivier CARRÉ
ERDF – France
olivier.carre@erdfdistribution.fr

Emmanuel CERQUEIRA
EDF – France
emmanuel.cerqueira@edf.fr

ABSTRACT

To improve network remote control efficiency, ERDF decided to add a set of advanced distribution management functions to its remote control system “SITR” with the ultimate aim to achieve an automatic network restoration. The paper presents a complete overview of these functions, the basic architecture and the problems raised by such a system deployment.

INTRODUCTION

The network remote control is a daily challenge and is a task which is becoming increasingly complex: the networks are larger and larger and are often equipped with sophisticated automation devices which are sometimes difficult to correlate and interpret especially during climatic events, even for an experienced operator. Finally networks are also more and more constrained. A set of DMS functions have been developed by EDF R&D. These functions assist the network operators and make it possible to improve the quality of service by reducing customer minutes lost.

THE SYSTEM ARCHITECTURE

The EDF Distribution Management System is an open remote control architecture including a set of “operation help” functions. The system can evolve by the addition of external functions, and the EDF functions could also be connected to other remote control systems. This openness allows for the progressive renewal of a dispatching system, making the broadest possible use of the DMS functions available on the market.

Based on modern and internationally recognised standards (C++, CORBA communication interface), the EDF DMS architecture has been defined to facilitate the connection of useful control functions in a client/server environment. The EDF DMS is also based on a multiplatform architecture, thanks to the CORBA layer. On EDF control centers it will run under LINUX, allowing for the use of relatively cheap computers. The architecture consists of a SCADA module that is an evolution from a previous system, a data configurator and a software data bus.
control images, etc. It offers graphic tools that will make it possible to update these data and to enter new data. Its purpose is to provide the data necessary for the SCADA, for the man machine interface and for the functions via the Software Data Bus. The database representing the network is an object-oriented database, that defines a data set.

REAL-TIME FUNCTIONS

Based on the architecture previously described and to increase remote control efficiency, EDF’s Research and Development Division has developed the DMS functions. This is a set of advanced functions operating on real-time data supplied from a SCADA. The main objective is to reduce the overall outage time by increasing the understanding of operators of what is happening on the network and, by proposing actions to be carried out for solving identified problems. The DMS package is composed of three main functions. The Event Synthesis Function (ESF) aims at reducing the number of events displayed in the logging function and at providing a diagnosis of the cause of main outages. ESF is completed by FLF, the Fault Location Function. The NRF function (Network Restoration Function) is invoked when part of the network is found to be faulty and de-energized.

When a fault occurs on a distribution network, the operator should react with as soon as possible (restoration must be finished in less than 3 minutes for the customers connected to the fault-free sections of the feeder). He has to interpret the flow of incoming events and alarms in order to make an accurate diagnosis: what has happened, where is the fault and which customers are de-energized? ESF and FLF provide support for this step. On the basis of this diagnosis, action is then taken: remote switching orders are sent to isolate the fault and restore power for the maximum number of customers. NRF provides optimal plans (switching sequences) according to protection scheme, topology and load level. Finding an optimal solution for power restoration may become difficult for a non standard situation, or for important outages. Advanced functions attempt to assist the operator throughout this procedure.

The DMS functions operate directly on real time data. They input actual incoming remote signals and remote measurements, supplied by the remote control system. Integration to actual SCADA is one of the major feature. The advanced functions are strongly integrated with the basic SCADA; they share the remote control system MMI and then present a fairly similar look and feel. In the same way, there is no specific database for advanced functions. They use the data stored in the common database and don’t need any specific data administration system.

The Event Synthesis Function (ESF)

General objective

Many automatic devices operate on the network. These devices return a substantial amount of information for display to the operator, and some remote signals perform an alarm function. In certain situations, the operator may be required to cope with an avalanche of events, and the interpretation of the information returned can become very difficult. The first objective of the ESF function is therefore to reduce the total amount of data presented to the operator. From the operator’s point of view, the original logging function, displaying all remote signals, will be supplemented by synthetic information managed by ESF. The second objective of ESF is to provide a deeper analysis of incoming events, in terms of outage diagnosis. Around types of synthesis and diagnosis have been identified. Synthesis usually involves interpreting the behavior of the automatic device. Diagnosis is based on event synthesis, but also provides an explanation of the cause. All diagnoses are triggered by a breaker opening or closing.

Temporal matching in ESF

ESF inputs a stream of incoming time-stamped events. A set of events, occurring in a given temporal window, could develop into what we call a Pattern. ESF manages a set of predefined patterns and tries to match them against the incoming stream of events.

A pattern is described as a sequence of the expected presence or absence of events associated with time constraints. A specific event in a pattern serves as a trigger event. The pattern becomes active when this event is detected. Then the sequence of registered events is compared with the pattern. If the pattern is partially or completely recognized, a message is sent to the SCADA, and if the pattern corresponds to a diagnosis that calls for a restoration procedure, the operator has the opportunity to call up the fault location function.

The main features of the temporal reasoning engine in ESF are as follows:

- it takes into account the actual topology and the actual configuration of automata (for instance, the feeder really connected to the HV/MV transformer when the fault occurred, or the actual topology in the primary substation);
- it is able to deal with expected non-occurrence of events (for instance, to describe that during a certain length of time, no fault should be detected by the protections, i.e. the fault has been cleared by automata);
- it makes it possible to specify optional events (facultative events) that may produce a complement of the diagnosis message (for instance, a missing event may not invalidate the pattern but will produce a warning).

A highly configurable function

ESF consists of a generic engine added with a electric specialization and an API. ESF can easily be adapted to many kinds of distribution automation schemes thanks to the pattern library. A specific software program has been designed for knowledge acquisition (pattern library
description). It is worth noting that ESF can diagnose an action of protections and automata after a fault occurs. It can also diagnose a certain kind of incorrect behavior of protection devices. Furthermore ESF is also used to diagnose the behavior of pricing signals.

The Fault Location Function (FLF)
The EDF DMS Fault Location function (FLF) is invoked by the operator when a permanent fault occurs on the network, causing circuit-breakers to remain permanently open. The defective section must be located and isolated, before trying to restore power to the fault-free sections. FLF uses fault detector information to deduce fault location. Several different assumptions are generated, including some that consider incorrect behavior of fault detectors. It makes it possible to handle inconsistent fault detector information. The location is given as a section comprised between two remote controlled switches. Fault location depends greatly on the fault detectors reliability.

The Network Restoration Function (NRF)
NRF has to deal with various kinds of fault. The most common are localized faults on MV feeders, which cause the circuit-breaker upstream from the feeder to remain open (meaning that the automatic device was not able to clear the fault). NRF is invoked after ESF has detected a permanent fault and FL has located the faulty area on the lost feeder. NRF is provided with identification details on the fault and a description of the breakers that switched off. NRF will calculate a set of restoration plans and will display to the operator the one which is the best choice regarding protection scheme and constrains on the network. The restoration process performed by NRF uses remote-controlled equipment. For restoring the power downstream of a fault, the system must determine the downstream area's former load and decide whether this load can be transferred to one or more emergency feeders, in compliance with maximum admissible current intensities for all system sections. Customer re-energizing strategies must accommodate several criteria and constraints.

The main constraints and criteria considered are the following:
- maximum load in the lines and transformers;
- compatibility with protection scheme;
- total number of customers resupplied;
- total amount of load unrecovered;
- complexity of the solution (number of remote orders, etc.)

The NRF function accommodates the operator with level-1, level-2 and partial plans. A level-1 plan only uses emergency feeders that are directly connected to the area to be supplied. Level-2 plans partly transfer the emergency feeder load to a third feeder before using it. Partial plans (level 1 or level 2) re-energize only part of fault-free areas since complete plans re-energize the entire network and isolate the exact fault area.

In interactive mode, the operator is responsible for applying the sequence of commands to power restoration.

The expected improvement of the NRF are to take into account the voltage drops, the power short-circuit current and the next peak load.

Automatic restoration
The final aim of this project is to completely automate the process of diagnosis, location and restoration. For these steps all the DMS function will activate each other without any actions of the operator. A command sequencer will be used to optimise the orders sent to the network and to reduce operation time for remote restoration.

Functions under development
Other advanced Distribution Management functions are currently under development.
- A state estimator for MV network which will have the capability to deal with the lack of measurements on the network to offer a realistic and predictive view of main electrical values
- A voltage/reactive power control function which will enable operators to optimise the voltage plan and minimise losses by using the substation regulators efficiently, as well as the capacitors and the dispersed generation available on the network.
- A function for the management of dispersed generation that will make it possible to monitor the production level of independent producers, then to be able to benefit from their regulation options in the event of a problem on the network.

IMPLEMENTATION POLICY
ERDF policy in this concern is a stepwise approach organized in two stages to ensure state of the art reliability and security levels while in each step allowing room for a sufficient experimentation period:
1. A first phase during which the functions run in a "semi manual" mode: once a permanent fault is elaborated by ESF and listed with a multi-criteria ranking, the operator chooses to launch FLF & PRF on a selected outage from the list.

This phasing allows a progressive familiarization of the operators with the new functions while giving the utility the
opportunity to assess their reliability/security before stepping for automation.

In this respect, the implementation of the “Operation Aid Functions” – namely ESF, FL, NRF– in the 30 ERDF Distribution Control Centers (DCCs) is in an undergoing process since January 2008. The phasing schedule is as follows:

**Step 1**
- Jan.-Sept. 2008: experimentation and tuning of ESF in 3 Distribution Control Centers (sufficiently representative of the different MV network contexts in France)
- Oct.- Nov.2008 tests and tuning of FL, NRF
- Dec. 2008- March 2009: implementation of ESF in all ERDF DCCs
- Jan-March 2009: experimentation of FL, NRF in 3 Distribution Control Centers,
- March- April 2009: implementation of FL, & NRF in all ERDF DCCs in “semi manual” mode

**Step 2**
- Oct-Dec 2009: experimentation of FL, & NRF in 3 ERDF DCCs in “automatic” mode
- Jan-March 2010: implementation of FL, & NRF in all ERDF DCCs in “automatic” mode

So far, the major lessons of the deployment are manifold:
- Site experimentation reveals essential whatever simulation methods and tools are used during the testing phases
- A stepwise approach allows for a better acceptability among control people and somehow the success of the project,
- The global quality of automatic restoration mostly relies on the accuracy of the Fault Diagnosis function (ESF) which itself requires a high level of expertise and a long tuning process. ESF also requires a robust design to cover the versatility of substations and network control equipments. This implies the setting up of powerful software development tools to build the patterns library, In addition, the effort to achieve a non ambiguous identification of signals issued from the acquisition systems (RTU/ SCMS) militates for a standard “data list” design.
- The standardization effort needed for ESF implementation reveals globally beneficial since: it renders the concentration of control Centers more efficient
- Reliability of acquisition systems (i.e. fault detectors) is fundamental at deployment stage. However, the implementation of the control aid functions is a driving force for improvement (through the equipment malfunction diagnosis),
- a major effort has to be made on the network description data reliability and consequently due to the amount of data needed for a proper analysis, there is a need for a IT urbanism strategy (CIM wise).

**CONCLUSION**

The implementation of “Operation help functions” (Fault Diagnosis/Fault Operation/Supply Restoration) is a major project for ERDF and EDF.

So far, it showed how essential a diagnosis function is mostly in the frame of MV networks DMS functions suite so as to cope with Control Systems concentration. facing a higher frequency of “crisis” conditions

The chosen design for system architecture based on a “real time software bus” coupled with a high level of modularity of the functions allowed to cope with the short design/development/ implementation schedule. It also opens new perspectives for future aid function adding. The stepwise implementation improves the security and acceptability of these sensitive functions.

The needed standardization of data lists, data accuracy and remote control equipment reliability improvements allows for a better Network operation and Control quality while entering in a virtuous maintenance improvement circle.