DEVELOPMENT OF ADVANCED DISTRIBUTION AUTOMATION FUNCTIONS ON AN ANALOGICAL MICRO DISTRIBUTION NETWORK FOR TRAINING

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ABSTRACT

This paper deals to development of Advanced Distribution Automation (ADA) functions on an analogical micro distribution network in the framework of training. In the Smart Grid's perspective, it is essential to prepare future operators and engineers to the challenges during their training. And, these functions take increasingly important in the management of the Distribution Network (DN). A physical micro network which emulated a part of French distribution network allows us to integrate some functions such as reconfiguration and volt control management.

INTRODUCTION

The Electric Distribution Networks is undergoing a lot of evolutions in recent years, including the energy market deregulation and the increasing integration of Distributed Generators (DG). Therefore, Distribution Network Operators (DNOs) such as ERDF (Electricité Réseau Distribution France), try to improve the quality of power delivered by deploying many Advanced Distribution Automation (ADA) functions [1]. ADA functions allow more flexibility and bring networks more active.

Hence, it is important to sensitize future engineers to these evolutions during their training, especially on the challenges and skills which are necessary to manage the distribution network in such a context of Smart Grids. These skills include the New Information and Communication Technologies (NICT), algorithmic development and also electro-technical rules.

In this context, the platform PREDIS, which is dedicated to education and research in the field of energy, is used. PREDIS includes two analog networks (industrial and distribution networks) and allows studies of these real and representative networks. The analogical micro distribution network perfectly represents the behaviour of a real reduced size French distribution network of 30 MVA and 20 kV. The power of this micro network is reduced by a scaling factor of 1000 and 50 to the voltage.

The main purpose of this paper is to describe two ADA's functions: Sequential Opening of Branches (SOB) and Voltage Control (VC) with on-load tap changers without reactive power of Distributed Generators to minimize power losses. The aspects such as the measurements and communication means and the implementation of those two algorithms in this platform will be addressed. These two algorithms are easy to implement and adequate for education courses. But reference [2] provides more efficient and sophisticated solutions.

This paper is organized as follows. After a description of the analogical micro network, the communication's tools implemented are presented. Thereafter, the algorithms implemented such that SOB and VC (under Matlab) are provided. Some partial tests of the demonstrator are discussed and two different cases (simulation and real measurements) will be compared before to conclude and to state the future works.

ANALOGICAL µGRID

PREDIS is an experimental platform for innovation and education. Figure 1 shows one of the analogical networks of PREDIS: distribution micro grid that has a nominal power of 30 kVA and a reference voltage of 400 V. In this Figure 1, the dotted lines represent underground cables and the three consumption areas owned network: industrial, rural and urban. Table 1 provides the scale reduction between PREDIS's network and the French real network and characteristics of design (aggregated nodes) that allowed as well as the static and dynamic behaviors of ERDF network in presence of Distributed Generators [3]-[4]. PREDIS micro network offer many possibilities. Some other advanced functions such as self-healing were tested in INTEGRAL's project (Integrated ICT-platform based Distributed Control (IIDC) in electricity grids with large share of Distributed Energy Resources and Renewable Energy Sources) [4].
Thus, several means are used to coordinate the control and the management of the network such as remotely controlled switches (for all lines) for changing topology, the autotransformers that emulate the behavior of the on-load tap changers' (OLTC) transformers, Remotely controlled machines for distributed generators, many Remote Terminal Units (RTU) communications (real communication used in the real networks) and several sensors for the measurements. The Distributed Generators (DG) are reconfigurable on the three areas (industrial, rural and urban) according to the defined studies scenario.

Table 1: Characteristics of the analogical Distribution µGRID [4]

Characteristics	Analogical µGrid	ERDF Grid
Total load (kVA)	27	27.000
Total generation(kVA)	30	30.000
Voltage (Volt)	400	20.000
Number of nodes	14	300
Power's reduction ration (λ)	1/1000	
Voltage's reduction ratio (µ)	1/50	
Remotely controlled switches	12 in the grid 16 on components (Load/DGs)	
Remotely controlled machines	Active and Reactive Power	

	regulation

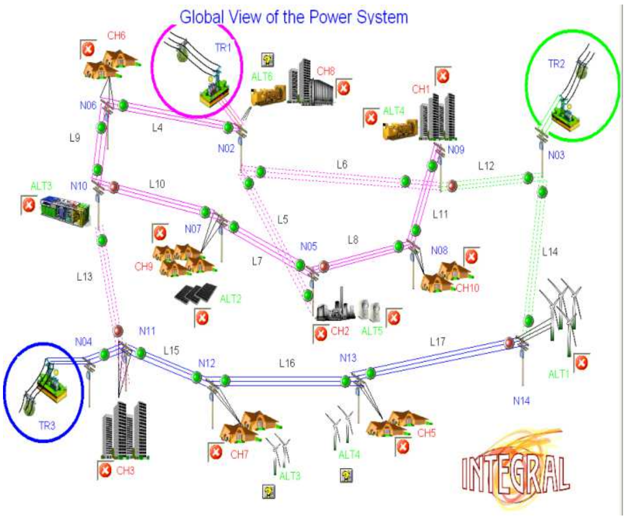

Figure 1: A topology of PREDIS's analogical Distribution µGRID

RECONFIGURATION AND VOLT CONTROL ALGORITHMS

Reconfiguration's algorithm

The reconfiguration problem is one of the favorite topics in the field of research in distribution networks. One purpose of this function is to find the optimal radial topology according to specified criteria such that optimizing the active power losses for example, even if the distribution networks are meshed designed. Today, the operators forecast to introduce more remote switches in distribution networks.

To demonstrate impacts of this function, the Sequential Opening of Branches (SOB) is implemented. SOB is a heuristic technique, which is proposed at first by Merlin and Back [5] for DC power flow. Shirmohammadi and Hong [6] have improved this heuristic method by using AC power flow. Its flowchart is depicted on Figure 2. Initially, all normally opening switches are closed to create a full meshed network. Then, there are opened successively until restore the final radial scheme. Switched candidate at each step of this procedure corresponds to line (or branch) with the smallest current. The corresponding current is computed with Kirchoff's equation without reactance component of all lines. In the flowchart, X is the reactance of the lines or the branches.

Voltage Control's algorithm

The main aim of Voltage Control (VC) algorithm developed here is to ovoid the under-voltages at each node of network. In the normal operating points, the voltage must be in the contractual bounds.

The aim of Voltage Control (VC) developed is to improve the voltage constraints at each node when they are over the limits. To do this, the voltage set-points of OLTC that are emulated by auto transformers are modified, at each step until the maximum number of iteration is reached. So, the basic idea of VC algorithm is depicted on the flowchart in Figure 2 and two strategies can be computed. For the first, this procedure begins, when the voltage of any node is low. Or, if the voltage measurement of secondary bus of autotransformer and his set-point are different. In both cases, the secondary voltage of OLTC is increased until the voltage of the node falls within the range defined or until the set-point is reached.

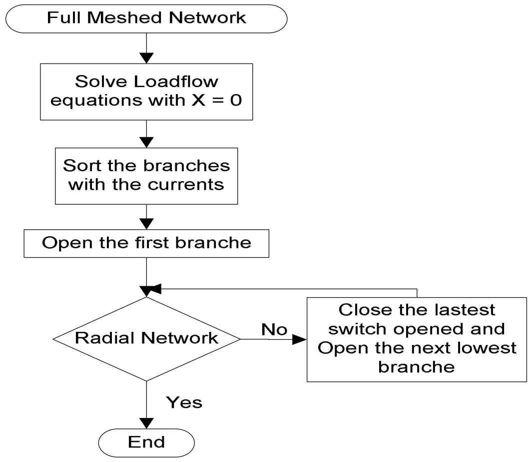

Figure 2: The Sequential Opening of Branches' flowchart

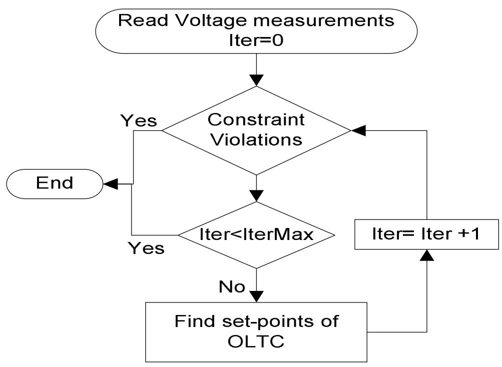

Figure 3: The Voltage Control's flowchart

COMMUNICATIONS TOOLS

The management of Distribution Networks is going on towards more intelligence and flexibility. This aspect is supported by the emergence of ICT technologies in the distribution network. Indeed, they are increasingly instrumented as the transmission network. Figure 4 shows a simplified example ICT architecture designed for ADA functions in PREDIS µnetwork. This architecture includes multiple communication layers because of the variety of these devices: sensors, power meter, Programmable Logic Controller (PLC) as RTU, SCADA supervisor and agents where ADA functions are developed among others. We describe the following communication tools and some functions of the devices used within the framework of those works:

- Communication between the FLAIR 200C / PM9C / IED / and PLC.
- Communication between the SCADA and the PLC.
- Communication between the SCADA (PcVue) and an agent (MATLAB).

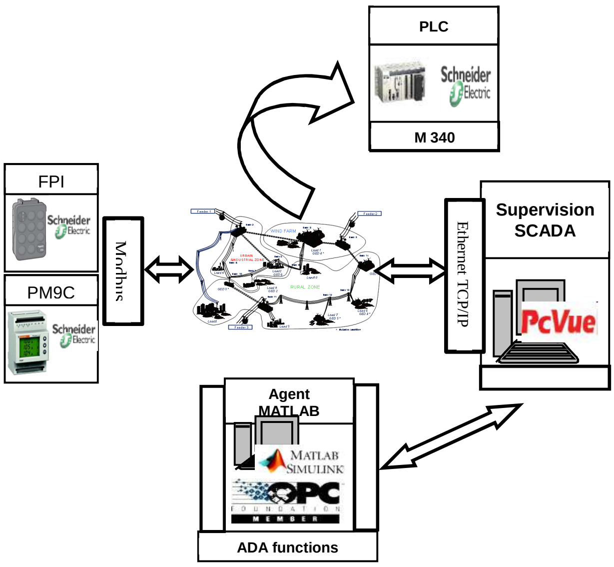

Figure 4: An example of the ICT architecture

Communication between the FLAIR 200C / PM9C / IED / and PLCs.

Flair 200C (Schneider Electric) are faults passage indicators (FPI). Furthermore, they are also designed to realize other functions such as to make measures and the calculation of the active, reactive and apparent powers. In the framework of those works, they are used as power meters such as PM9C which indicate the electrical quantities locally measured. Indeed, Flair 200C and PM9C provide electrical measurements such as voltages and currents. So, FLAIR 200C are dedicated to branches measurements whereas PM9C to nodal measurements. All these measures are sent to 3 Schneider PLCs (M 340) of each area through a master-slave communication (Modbus TCP/IP). Besides, the instructions of opening and of closing switches pass by these 3 PLCs while the power sets of loads, DG and autotransformers by a fourth PLC.

Communication between the SCADA and the PLCs.

SCADA software PcVue is used to design Supervisory to coordinate the control and the management of the network. A single-line diagram of the PREDIS µnetwork showing on Figure 5 is designed with PcVue software. Exchanges between SCADA and PLC are through Modbus TCP / IP communication.

Communication between the SCADA (PcVue) and an agent (MATLAB).

The ADA functions (flowcharts of Figure 1 and 2) have developed within MATLAB and run on an agent. Their data exchange is through OPC (OLE for Process Control), which is a common protocol for communication between devices that without the same drivers. Here, the OPC server associated with SCADA center and OPC client with MATLAB OPC Toolbox exchange information via Ethernet.

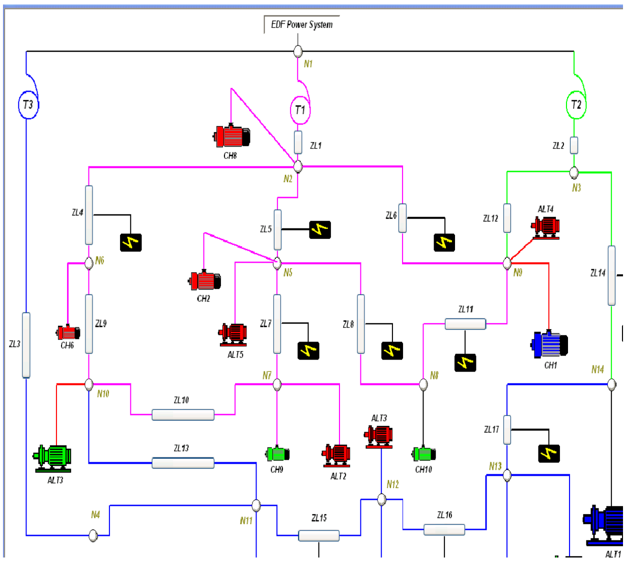

Figure 5: A single-line diagram of the PREDIS µnetwork (PcVue)

Table 2: Voltage measurements

Voltage measurements (pu)								
Configuration	VC	Autotransformer's set point			Simulation		Physical(real)	
Node		2	3	4	5	9	5	9
Initial	Without	0.957	1.0016	0.931625	0.8625	0.94115	0.85575	0.943625
	With	1.0325	1.022	1.0455	0.93875	1.018875	0.940675	1.02
SOB	Without	0.997	0.93825	0.92625	0.9225	0.97875	0.93275	0.9875
	With	1.0125	1.01375	1.022	0.9975	0.995	1.00875	1.005

IMPLEMENTATION AND RESULTS

These ADA functions have been developed within MATLAB. The agent proposes the operator of the SCADA center all the settings such as configurations and set-points of autotransformers for these two functions. These settings can be performed automatically by the agent or manually by the operator. Table 2 shows some results obtained with simulations compared the real measurements with an arbitrary operating point of the loads. The voltages of the most constrained nodes are indicated. No DG is used and both algorithms are used simultaneously or separately for case studies. Thus, results of simulations and of measurements are almost similar.

CONCLUSION AND FUTURE WORKS

The implementation of these ADA functions allows students to be aware of developments in the control and the management of the distribution network. In this paper, many aspects are discussed: implementation of ADA functions such as Sequential Opening of Branches' (SOB) and Voltage Control' (VC) algorithms. The communication tools of PREDIS μnetwork were also discussed. In future work, a more efficient function should be tested: Volt Var Control (VVC), which also manages the reactive power outputs of the Distributed Generators.

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