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The development of a new concept for optimization of regulating means of electrical networks

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ABSTRACT: The conduct of the electrical networks has known in recent years major changes induced mainly by the technological development of power electronics as well as information systems and communication (Smart Grid), in addition to this is the integration of intermittent sources of production and competitive requirements advocating the power quality and the continuity of service as major objectives. That said it is understood that the electrical networks have a set of vulnerabilities due to the intrinsic parameters.
The new concept of electrical networks regulation based on topological control can prevent major incidents following a saturation of transmission lines by providing a means of optimized regulation and means of safer and more effective communication.

KEYWORDS: Electric Network, Smart Grid, FACTS, topological control, communication

1 INTRODUCTION

Regulating electric networks reflects a desire to remain in a stable condition of service for electrical installations while providing the necessary adjustments to adapt to the fluctuations of the electrical parameters of the network because of internal and external requests. This research is based on a first phase of study, which was dedicated to the study of the impact of electrical network's intrinsic parameters [1] and a proposal for a coordinated regulation of power distribution provided with developing a new way of regulating electrical networks based on topological control in order to address vulnerabilities while ensuring optimal management control and a more effective communication.

2 PROBLEMATIC & OBJECTIVES

As previously described the electrical network is facing a set of hazards that affects its stability including:

- VOLTAGE COLLAPSE
- FREQUENCY COLLAPSE
- LOSS OF SYNCHRONISM
- CASCADING OVERLOAD

The inability to control physical parameters of the system may encourage the development of these hazards and degenerate to unstable conditions that could lead to a blackout. The present study, as illustrated in Figure 1, serves to develop a new approach to regulation for the purpose of ensuring the stability of power distribution in different nodes of the network.

The approach leads to the optimization of power regulation through a system enabling a change of the network topology as necessary.

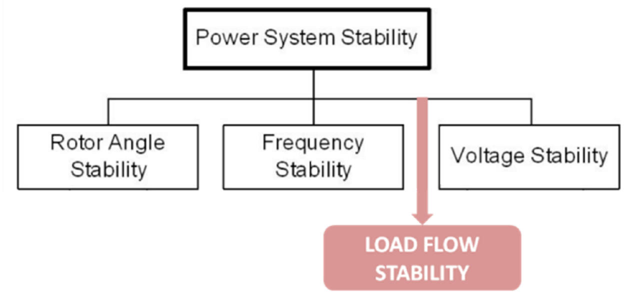
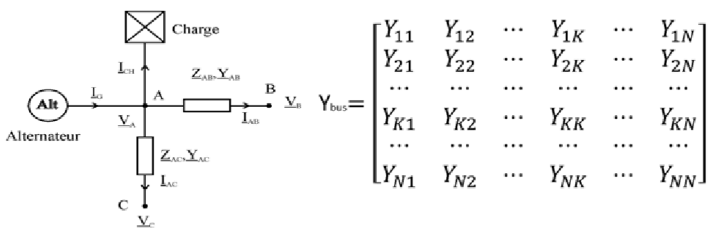


Fig. 1. Power System Stability

3 Statement Of The Approach Adopted

3.1 Global View

The calculation of load flow allows the determination of the electric state (current, voltage and power) at various nodes constituting the network. As illustrated in a simple case shown in Figure 2, the resolution of power assessments at each node allows to determine the complex voltages at each point and; thus, to infer the power flows in the network.



$$P_K = V_K \sum_{n=1}^{N} Y_{Kn} V_n cos(\delta_K - \delta_n - \theta_{kn}) \tag{1}$$

$$Q_K = V_K \sum_{n=1}^{N} Y_{Kn} V_n \sin(\delta_K - \delta_n - \theta_{Kn}) \tag{2}$$

$$Y_{kn} = Y_{kn} \angle \theta_{Kn} \tag{3}$$

$$V_k = V_k \angle \delta_K \tag{4}$$

$$V_n = V_n \angle \delta_n \tag{5}$$

Fig. 2. Load Flow

3.2 Control Of Electrical Parameters

The impact of the addition of FACTS on the performance of an Electric line is demonstrated on several levels.

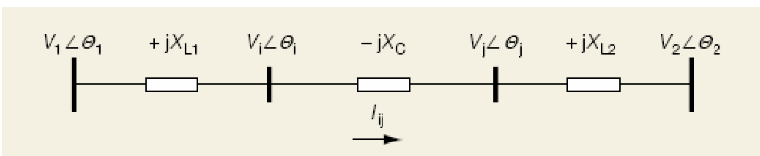
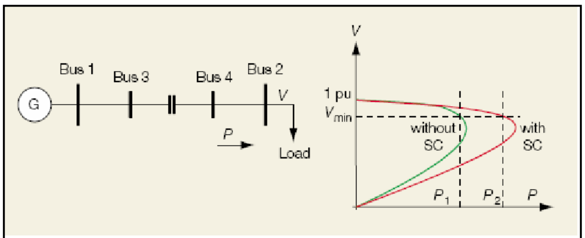


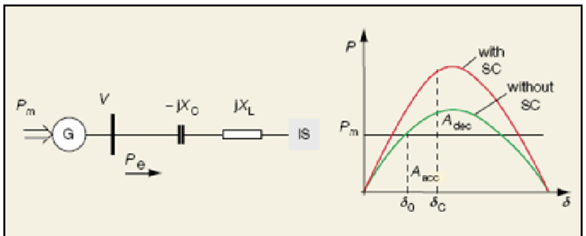
Fig. 3. Equivalent Model Addition Fact series on the electrical line

As shown in Figure 3, we can see that the equivalent reactance of the electrical line now depends only on the reactance of the line and also on the variation of the integrated FACTS reactance. This option provides flexibility in order to control the intrinsic electrical parameters of the network as shown in Figures 4 and 5 and in the impact of the variation of the reactance of FACTS on the curves of power and voltage.



$$\frac{\Delta U}{U_{ch}} \approx \frac{Q_{ch}.\sin(\alpha_L)}{S_{cc}} \approx (X_L - X_C).\frac{Q_{ch}}{U_{ch}^2}$$

Fig. 4. variation of the voltage as a function of the reactance of the line



$$P_{\max} = \frac{.U^2}{2.(X_L - X_C)}\left(\frac{\cos(\varphi_{ch})}{1+\sin(\varphi_{ch})}\right)$$

Fig. 5. variation of the power as a function of the reactance of the line

We formulate the following equations between the nodal voltages and injected current for a network with n nodes:

$$I = Y.V \qquad (6)$$

$$I_i = \sum_{j=1}^{n} Y_{ij}.V_j \quad (i = 1, \dots . n) \qquad (7)$$

In practice, the system is known by the apparent power injected. The n complex equations are divided into 2n real equations:

$$S_i^* = P_i - Q_i = V_i^* . \sum_{j=1}^{n} Y_{ij} . V_j \qquad (8)$$

$$P_i = V_i \sum_{j=1}^{n} V_j \,(G_{ij} \cos\theta_{ij} + B_{ij} \sin\theta_{ij}) \qquad (9)$$

$$Q_i = V_i \textstyle\sum_{i=1}^{n} V_j \,(G_{ij} \sin\theta_{ij} - B_{ij} \cos\theta_{ij}) \qquad (10)$$

3.3 NEW CONCEPT OF REGULATION FOR THE ELECTRICAL NETWORK

It was given to us to see from our literature review [3] [4] [6] [7] and after our first study [1] that the development of solutions based on FACTS devices in the electrical network is very efficient hence our approach to the development of this new concept which aims to coordinate regulation that best meet the various compromises imposed by the power grid.

The principle of this concept is to migrate to a new mode of regulation of the electrical network coordinated by the addition of a device called FACTS (Flexible AC Transmission Systems) in the arteries of power lines (figure 6) to counteract on the reactance. These FACTS will be ordered from a centralized processing centre (Dispatching) according to algorithms and converging towards the following objectives:

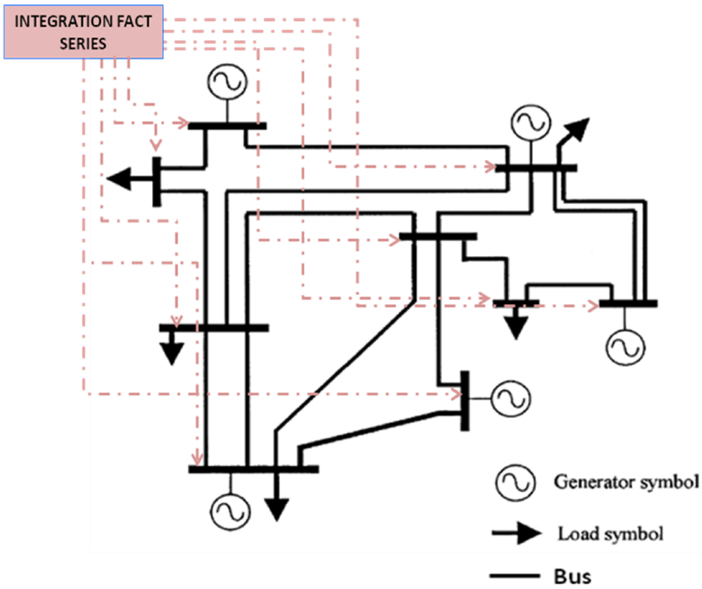


Fig. 6. Integration of FACTS at the nodes of the electrical network

4 MEANS OF INTEGRATON OF THE FACTS

The integration of FACTS series at nodes of electrical networks as detailed in figure 7 will be carried out by adding FACTS series at the busbar of transfer to allow a flexible control that can affect all the power lines leading to the main busbar and to optimize the operating cost and the modification of the structure of the items making up the network.

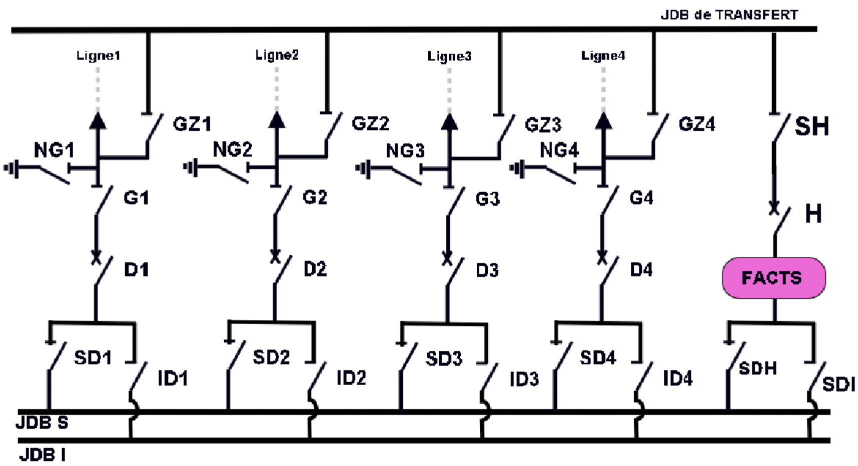


Fig. 7. Implementation of the system FACTS

4.1 COORDINATED REGULATION OF THE SHARING OF POWER

Our expected objective is to adjust the distribution of the power in the electrical network by controlling the FACTS integrated in the network and according to our algorithms (figure 8) migrate to a stable operating state.

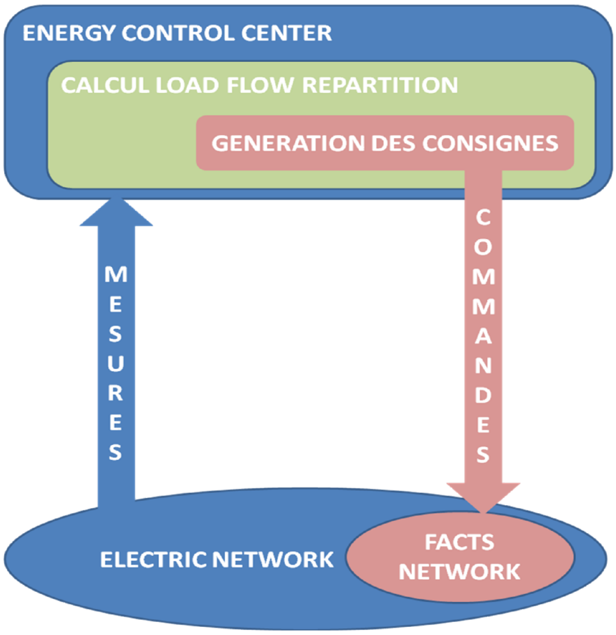


Fig. 8. Principal view

4.2 Flow Chart Of The Coordinated Control Algorithm

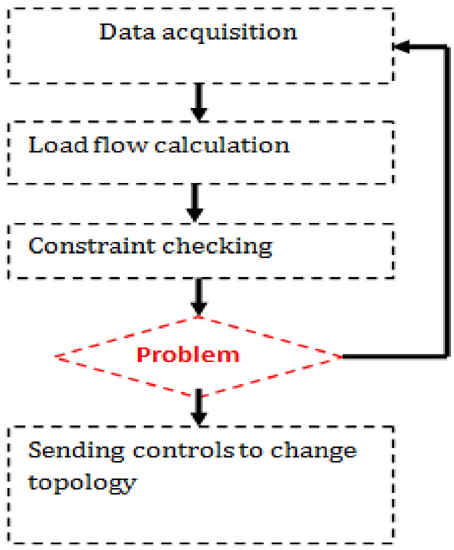


Fig. 9. Algorithm of Topology change

5 Suggested Solution For Communication

5.1 Actual Communication

The existing communication of the studied electrical network shown in figure 10 does the control and management of the electrical network. The DN(National SCADA) communicates with other electric substations using the IEC 870-5-101 protocol with fiber or CPL as physical media, in case of a fault on the DN the control of the network will be impossible.

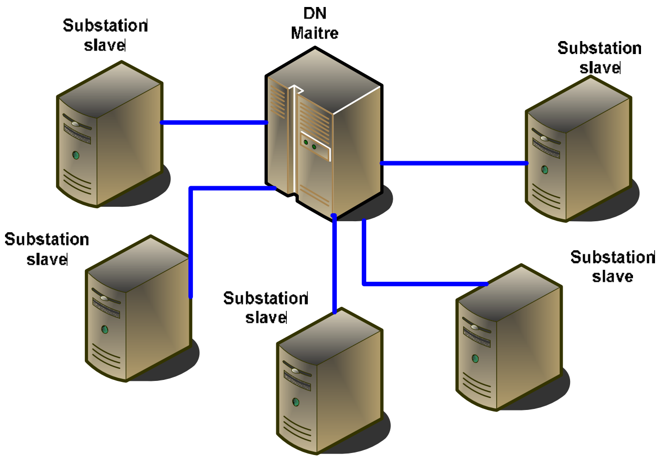


Fig. 10. Actual communication

5.2 SUGGESTED COMMUNICATION

To strengthen the actual communication we suggest to use WIMAX (Worldwide Interoperability for Microwave Access) technology for communication and the IEC61850 protocol , WIMAX technology can provide a long private wireless network [10,11] , The 61850 protocol provides interoperability and flexibility[11].The advantage of this solution is the control can be decentralized , electric substations can communicate to each other , the ability to integrate other equipments to the communication network (wind park, solar park, other customers ..)

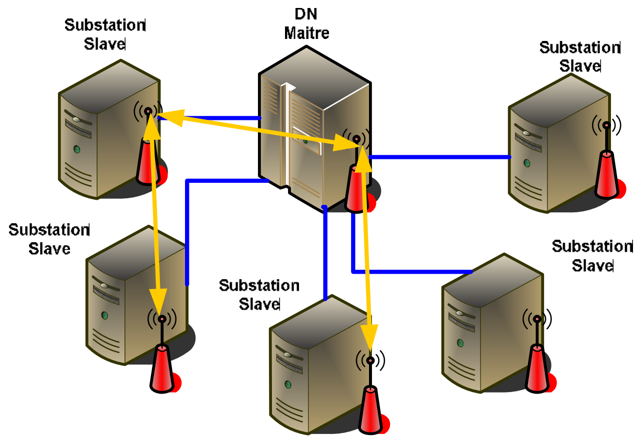


Fig. 11. Suggested communication

5.3 IMPLEMENTATION OF THE SOLUTION

For the deployment of the algorithm of figure12, we propose this architecture:

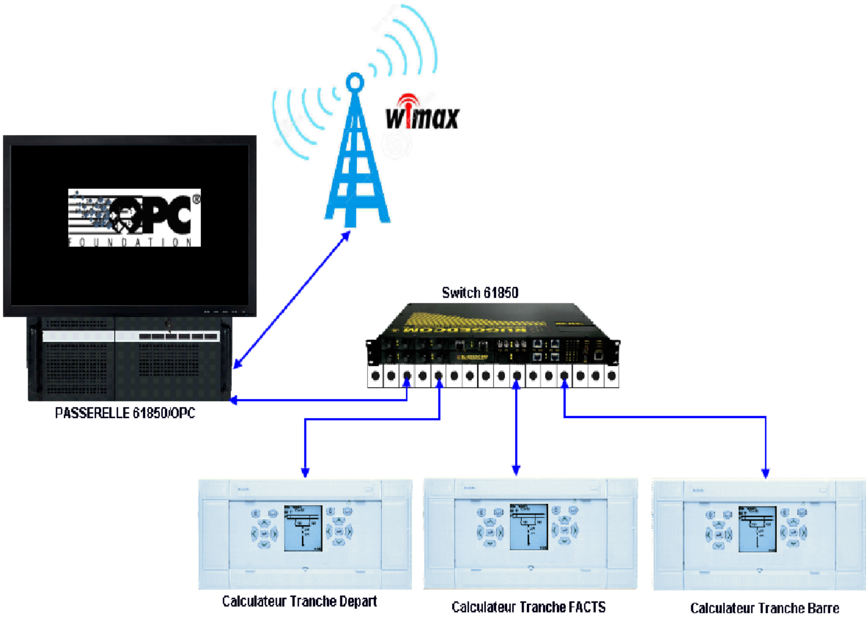


Fig. 12. Architecture of the suggested solution

The architecture in figure 12 is based on the use of the numerical control equipments. Data will be read from the calculators of the incoming feeder, information will be converted from IEC 61850 protocol to OPC protocol to communicate with the software that can calculate and check the constraints.

5.4 SIMULATION

To validate the proposed solution we used the case of a FACTS inserted in a electric substation with 4 feeders shown in figure 7, each feeder calculator was simulated with an IEC61850 simulator to update the position of circuit breakers, switchgears and power measurement of each feeder. The Gateway has been programmed to convert the data from 61850 protocol to OPC protocol, we programmed an OPC client for data acquisition and an algorithm for the calculation and sending commands to circuit breakers and switchgears.

When power exceeds the max in a line for a period Tpec (power exceeded confirmation time) the program sends the open command to the circuit breakers and switchgears of the feeder and close command to the circuit breakers and switchgears of the transfer to switches the line on the FACTS.

We simulate the surpassing of the maximum power allowed in line 2 of figure 7, the system automatically switches to feeder 2 on the transfer of chronogram. Figure 13 shows the change in the topological cycle.

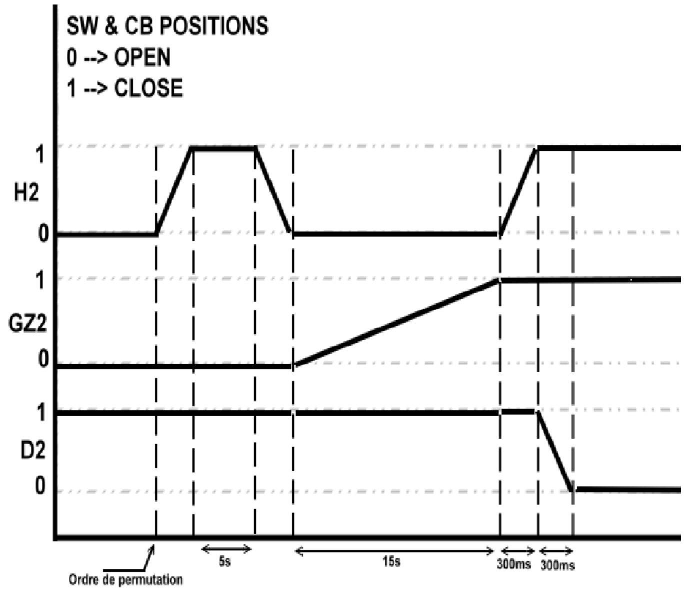


Fig. 13. Topology change chronogram

The operation time was estimated to take **51.52s** for calculation and execution of the commands.

Figure 14 shows trace of the operation. The first phase is checking on the transfer to the busbar and the second phase is for the transfer to the FACTS.

START P>0.7*Plimit

February 25, 2015 11:10:44.433 PM

CONFIRMATION P>0.7*Plimit FOR 30s

February 25, 2015 11:11:14.379 PM

START CHECKING TRANSFER BUSBAR

February 25, 2015 11:11:14.385 PM

TRANSFERT BUSBAR OK

February 25, 2015 11:11:19.395 PM

START TRANSFERT

February 25, 2015 11:11:19.907 PM

CLOSE CONTROLE GZ2

February 25, 2015 11:11:19.908 PM

GZ2 IS CLOSE

February 25, 2015 11:11:34.918 PM

CLOSE CONTROLE H

February 25, 2015 11:11:34.920 PM

H IS CLOSE

February 25, 2015 11:11:35.431 PM

CLOSE CONTROLE D2

February 25, 2015 11:11:35.432 PM

D2 IS CLOSE

February 25, 2015 11:11:35.444 PM

Elapsed time is 51.526167 seconds.

TRANSFER SUCCESSFUL

February 25, 2015 11:11:35.959 PM

Fig.14. Simulation of the operation of the transfer

5.5 Synthesis & Openings

The results obtained allowed us to appreciate the basis of the approach taken in the later stages, we supplement the realization side of the communication and control. Furthermore we will continue our research on modeling, simulating and computing tools that are able to identified the constraints in a short time and also on other fast, smart data transfer and control technologies.

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