CONTROL AND AUTOMATION SYSTEMS FOR ELECTRICITY DISTRIBUTION NETWORKS OF THE FUTURE – AN UPDATE ON THE ACTIVITIES OF JOINT WORKING GROUP CIGRE C6.25/ B5 /CIRED

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ABSTRACT

This paper presents an overview of the activities of the CIGRE/CIRED C6.25/B5 Joint Working Group (JWG), focusing on the control and automation systems for the future electric networks. This JWG is mainly focus to evaluate the level of automation and control necessary to better manage distribution networks with large penetrations of Distributed Energy Resources (DERs), as seen from the both the TSO and DSO perspectives, and to provide services and information about the two level of management (i.e at TSO and DSO level).
The C6.25/B5 JWG aims at addressing the following issues: (i) Survey on the state of the art on planning for active distribution systems; (ii) Requirements of planning methodologies; (iii) Identification of short, medium and long term models for active distribution system planning; (iv) reliability models of active distribution systems; and (v) algorithms for active distribution system expansion and upgrade planning, including demand-side integration and storage.

INTRODUCTION

The increasing diffusion of variable not programmable energy sources, the forecasted forthcoming diffusion of distributed energy storage systems (ESS) and the active participation of demand will characterize the Electricity Distribution Networks (EDN) of the future. General requirements from EDN are a secure and reliable quality of power, adequate for the digital age. Such requirements are achievable only with the support of control and automation systems that manage, command and regulate the behaviour of the diverse devices and systems that support operation of EDN. Centralised control functions and local control functions (e.g. governing active customers, distributed generators, microgrids and Virtual Power Plants) will have to coordinate their operation taking into account not only "internal inputs" coming from EDN monitoring and protection systems, but also "external inputs" coming from Electricity Transmission Networks (operated by the Transmission System Operator) and the forthcoming "smart world" (i.e. smart cities, smart transports, smart industries, smart customers etc.). The processing of all such inputs coming from different sources will be still subordinated to the possibility for Distribution Companies to operate EDN under their ultimate responsibility.

This paper presents an overview of the activities of CIGRE C6.25 Working Group (JWG), focusing on the control and automation systems for the future electric networks. This JWG aims at evaluating the level of automation and control necessary to better manage distribution networks with large penetrations of Distributed Energy Resources (DERs), as seen from both the TSO and DSO perspectives, and at providing services and information about the two levels of operation (i.e., at TSO and DSO level).
The JWG, convened for the first time in August 2013, builds on the recommendations done by WG C6.11 (Development and Operation of Active Distribution Networks); WG C6.15 (Electric Energy Storage Systems); WG C6.20 (Integration of Electric Vehicles in Electric Power Systems); WG C6.21 (Smart Metering – state of the art, regulation, standards and future requirements), WG C6.22 (microgrids), WG C6.09 (Demand side Management and Demand Response), WG B5.34 "The Impact of Renewable Energy Sources and Distributed Generation on Substation Protection and Automation and coordinate with ongoing B5.43 "Coordination of protection and control of future networks".
The C6.25/B5 JWG aims at addressing the following issues [2]:

1. Definition of Control and Automation Systems for EDN of the future: boundaries, constrains, possible architectures etc.
2. Survey on the current state of the art and expected requirements for the Control and Automation of EDN (a questionnaire will be sent to distribution companies).
3. Needs for interfacing EDN control and automation systems with control and automation systems of the transmission network and also with systems like EDM (Energy Data Management) and PFM (Portfolio Management) for exchanging market prices (dynamic tariffs

for end-user) and balancing group information (schedules).
4. List of control and automation functions relevant for the EDN operation in the new scenario (e.g. coordinated control of distributed generators and ESS; interface with system protections including islanding management; voltage and frequency control by active and reactive power management; etc.).
5. Requirements for the architecture of control and automation systems for future EDN (e.g. hierarchical, centralised, distributed, local control; etc.).
6. Communication requirements for control and automation of future EDN (e.g. protocols and information systems for a seamless data exchange; security; privacy; etc.).
7. New technology for control and automation of future EDN (e.g. control of power electronic at all voltages; etc.).
8. Roadmap for the evolution towards EDN of the future (The 2030-2050 vision).

In order to address these items, the JWG created a number of internal task focused on the challenging aspects of control and automation systems and, in particular, on the interface between transmission system operators (TSOs) and distribution network operators (DNOs) in unbundled electricity networks. An overview of the activities of each of the task forces is given in the sections that follow.
The task forces are focusing on the following areas:

1. **Definitions**: Many different terms are used in the industry to represent the variety of monitoring, control and automation systems in electricity distribution networks. This task force will recommend the most appropriate terminology for the international community use to provide constituency and will benefit of the joint work of AG C6.23 with a particular focus on the changes brought in the operation and control of the distribution networks..

2. **State-of-the-art**: The JWG is in the process of conducting a survey of DSOs around the world to establish the current state-of-the-art in control / automation systems and TSO / DNO interface.

3. **Control and automation systems – the TSO perspective**: This task force will explore the evolving requirements of TSOs, particularly as distribution networks become more active and DNOs can provide ancillary services (such as demand side integration for voltage regulation and frequency response) to the TSO.

4. **Control and automation systems – the DNO perspective**: This task force will explore the evolving position of control and automation systems within electricity distribution networks and will make recommendations on how distribution systems should adapt in the future to pursue goals (e.g., increased reliability for customers and accommodation of increasing levels of distributed generation with reasonable expenditures).

5. **Control and automation architectures for the future networks**: This task force will explore the architecture for control and automation systems to maximize the effective exchange of information between TSOs and DSOs.

6. **Control and automation – regulation and markets**: This task force will illustrate the regulatory and market mechanisms that need to be in place to facilitate control and automation systems and, hence, effective interactions between TSOs and DSOs.

SURVEY ON STATE OF THE ART

Task Force 1 has created and disseminated a survey to gather information regarding DSOs around the world to know the current state-of-the-art in control/automation systems and TSO/DNO interface.

This section gives an overview of the methodology used to gather information on the actual policy and future plans among DSOs for the control and automation of their network. The survey results have been analysed within the Task Force, feeding into the other task forces for further analysis. The results of the questionnaire act as a benchmark against which the transition towards active distribution systems may be assessed.

Survey Methodology
The WG developed a questionnaire to make inquiries about current planning methods and tools of distribution networks. The next step is to collate the answers of the energy companies into national reports.
The questionnaire starts from a standard level of automation of the network that includes the common activities as well as other activities with regard to monitor and control of distribution network, see table 1.

Overview of questionnaire results
To date, 20 survey responses have been received, representing a number of different energy companies in the geographical regions of Oceania, North America, South America, Eastern Europe, Western Europe. A binary analysis has been used to evaluate the

questionnaire responses and to determine the extent to which level of automation is used, at present, in the electrical industry.

In particular, the survey has investigated the current functionalities that are active in the network operation as reported in Tab 2.

Tab. 2 - Functionalities in current network operation

	Current Functionalities in DSO
1	SCADA
2	Distribution Management System (DMS)
3	Volt/Var control
4	Fault location isolation and restoration (FLIRS)
5	Energy Management System (EMS)
6	Automatic reconfiguration
7	Loss analysis /Loss Optimization
8	Others

The majority of the DSOs report the use of SCADA and some partial functionalities for fault location and reconfiguration. Very few DSOs reported the presence of a DMS in operation in their network.

The current practices for the majority of DSO, to what concerns the TSO–DSO interface are based on a manual interaction based on demand.

Preliminary results coming from the on-going survey are showing that DSOs across the world are conducting different testing to move from a "blind" exercise of the network to a more and more monitored and control ones.

The key features that are more promising for DSOs are the application of dynamic rating for feeders and transformers, and distribution state estimation as reported in Fig. 1.

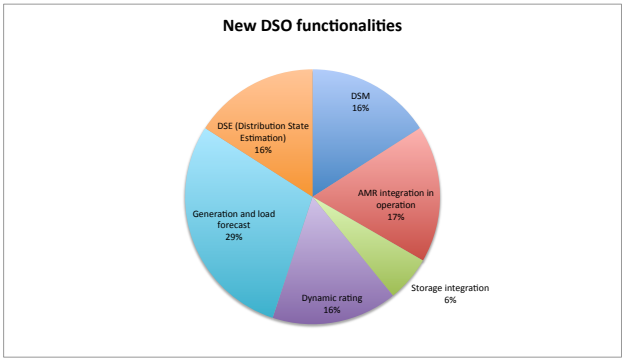

Figure 1 – The new functionalities envisaged by DSOs

CONTROL AND AUTOMATION SYSTEMS – THE TSO PERSPECTIVE

The relevant task force is investigating the evolving requirements of TSOs. Indeed, distribution networks have been becoming more active and DSO can provide system services to the TSO (such as demand side integration for voltage regulation and frequency response) [3]. The integration of DER and distribution networks into the TSO operation is fundamental to exploit the opportunities from load flexibility and/or from the novel markets for services. Anyway, since the coordination of TSO and DSO in not an easy task, in the short term it will be necessary to provide TSO information on real load and generation (aggregated according to the typology of source) with suitable time scale (namely 10 seconds).

The significant amount of intermittent generation into the DSO network is becoming extremely critical for the correct state estimation at the system level without a corrected estimation of the intermittent power in service of the DSO side.

Tab. 1 - Main topics of the survey

Main topics of the survey
Control and Automation Systems for EDN for MV level (V < 100 kV)
Control and Automation Systems for EDN for LV level (V < 1 kV)
List of control and automation functions in current network
Communication requirements
Information from TSO and markets
New functionalities for control and automation of future EDN
Barriers/tools for the operation of distribution network with respect to TSO interaction

CONTROL AND AUTOMATION SYSTEMS – THE DNO PERSPECTIVE

This task force will explore the evolving position of control and automation systems within electricity distribution networks and make recommendations on how distribution systems should adapt in the future to support various goals (such as increased reliability for customers and accommodating increased levels of distributed generation).

CONTROL AND AUTOMATION ARCHITECTURES FOR THE FUTURE NETWORKS

This task force will explore the architecture for control and automation systems to maximize the effective exchange of information between TSOs and DSOs.

CONTROL AND AUTOMATION – REGULATION AND MARKETS

This task force will illustrate the regulatory and market mechanisms that need to be in place to facilitate control and automation systems and, hence, effective interactions between TSOs and DSOs.

CONCLUSION

This paper has presented an overview of the activities of CIRED/ CIGRE C6.25 /B5 Joint Working Group (WG), focusing on the planning and optimization of active distribution systems. The JWG aims at addressing the following issues: (i) Survey on the state of the art on planning for active distribution systems; (ii) Requirements of planning methodologies; (iii) Identification of short, medium and long term models for active distribution system planning; (iv) reliability models of active distribution systems; and (v) algorithms for active distribution system expansion and upgrade planning, including demand-side integration and storage.

The JWG CIGRE C6.25/B5/CIRED is working towards a technical brochure, which will draw together the international perspectives and experiences when dealing with the control and automation systems for electricity distribution networks of the future.
Preliminary results coming from the on-going survey is showing that DSOs among the world are conducting different testing to move from a “blind” exercise of the network to a more and more monitored and control ones. The key functionalities that are more promising for DSOs are the use of dynamic rating for feeders and transformers and distribution state estimation.

Using real-world case studies, this paper will provide the international community with a useful point-of-reference. It will also support any DNOs that are looking to adopt control and automation systems in their future electricity distribution networks.

REFERENCES

[1] C. D’Adamo, P. C. Taylor, S. Jupe, B. Buchholz, F. Pilo, C. Abbey and J. Marti, 2009, " Active distribution networks: General features, present status of implementation and operational practices ", ELECTRA, 246, 22-29.

[2] Study Committee C6, 2010, “Distribution Systems and Dispersed generation”, http://www.cigre-c6.org/

[3] Eureletric, “DSO PRIORITIES FOR SMART GRID STANDARDISATION”, Position paper, January 2013

[4] G. Di Lembo, V. Agnetta, G. Fiorenza, G. Giannuzzi, "Integration of DSO control systems and TSO automatic load shedding system to improve the security of the national grid," *CIRED 2009. 20th International Conference and Exhibition on* , vol., no., pp.1,4, 8-11 June 2009