PLANNING AND OPTIMISATION OF ACTIVE DISTRIBUTION SYSTEMS – AN OVERVIEW OF CIGRE WORKING GROUP C6.19 ACTIVITIES

Fabrizio PILO
University of Cagliari – Italy
pilo@diee.unica.it

Samuel JUPE
Parsons Brinckerhoff – UK
JupeS@pbworld.com

Federico SILVESTRO
University of Genova - Italy
federico.silvestro@unige.it

Khalil EL BAKARI
Elitechs BV – Netherlands
k.el.bakari@tue.nl

Chad ABBEY
Hydro-Québec – CANADA
abbey.chad@ireq.ca

Gianni CELLI
Affiliation - Country
celli@diee.unica.it

Jason TAYLOR
EPRI – USA
jtaylor@epri.com

Alex BAITCH
BES (Aust) Pty Ltd – Australia
baitch@besaust.com.au

Clinton CARTER-BROWN
Eskom – South Africa
cartercg@eskom.co.za

ABSTRACT

This paper presents an overview of the activities of CIGRE C6.19 Working Group (WG), focusing on the planning and optimization of active distribution systems. This builds on the recommendations of CIGRE WG C6.11 that focused on the development and operation of active distribution networks (ADNs). The C6.19 WG 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

This paper presents an overview of the activities of CIGRE C6.19 Working Group (WG), focusing on the planning and optimization of active distribution systems. The Working Group was convened in August 2010 and builds on the recommendations of CIGRE WG C6.11, which focused on the development and operation of active distribution networks (ADNs) [1]. In previous work, a shared global definition of active distribution networks was developed:

"Active distribution networks (ADNs) have systems in place to control a combination of distributed energy resources (DERs), defined as generators, loads and storage. Distribution system operators (DSOs) have the possibility of managing the electricity flows using a flexible network topology. DERs take some degree of responsibility for system support, which will depend on a suitable regulatory environment and connection agreement."

The C6.19 WG aims at addressing the following issues [2]:

1. Survey on the state of the art on planning for active distribution systems;
2. Requirements of planning methodologies (a questionnaire has been sent to distribution companies and a summary of this questionnaire will be presented);
3. Identification of short, medium and long term models for active distribution system planning;
4. Reliability models of active distribution systems;
5. Algorithms for active distribution system expansion and upgrade planning, including demand-side integration and storage.

In order to address these issues, the Working Group has created five Task Forces. An overview of the activities of each of the task forces is given in the sections that follow.

SURVEY ON STATE OF THE ART

Task Force 1 has created and disseminated a survey to gather information regarding the state of the art practices used in industry at present.

This section gives an overview of the methodology used to gather information on active distribution system planning practices. The survey results have been analysed within the Task Force, feeding into the other task forces for further analysis. The questionnaire results act as a benchmark against which the transition towards active distribution systems may be assessed.

Survey Methodology

The WG have 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 regional reports which represents a predefined region. For this purpose a standard regional report is developed by the working group in order to provide comparable information. Beside the information delivered by the respondents, the regional reports make use of the knowledge and experience of the WG members as well as results of other CIGRE working groups. Finally, this survey report is produced based on available information in the regional reports as well as questionnaires; an overview of the build up of this survey report is in Fig. 1 illustrated.

Questionnaire

The questionnaire departs from a standard planning process that includes the common activities as well as other activities with regard to planning of distribution network, see table 1.

Overview of questionnaire results

To date, 25 survey responses have been received, representing a number of different energy companies in the geographical regions of Africa, Oceania, North America, South America, Eastern Europe, Western Europe and Asia. A binary analysis has been used to evaluate the questionnaire responses and to determine the extent to which active distribution system planning tools are used, at present, in the electrical industry. A more in-depth analysis of the current practices for active distribution system planning is given in the section the follows.

A key finding from the preliminary analysis was that, whilst regional trends may be drawn in order to share ADS planning best practices, within geographical regions the transition towards adopting ADS planning tools can vary significantly from one energy company to another.

CURRENT PRACTICES FOR PLANNING ACTIVE DISTRIBUTION SYSTEMS

This section presents an overview of current industry practices for planning of active distribution networks. The objectives of distribution planning and how these objectives will change with the advent of DER are presented, followed by the role of software tools in each of these domains. The overall picture is completed by a discussion of theoretical approaches developed by academics and the barriers to their acceptance by industry, barriers that will likely dissolve as the complexity of planning increases, associated with the evolution towards active distribution networks.

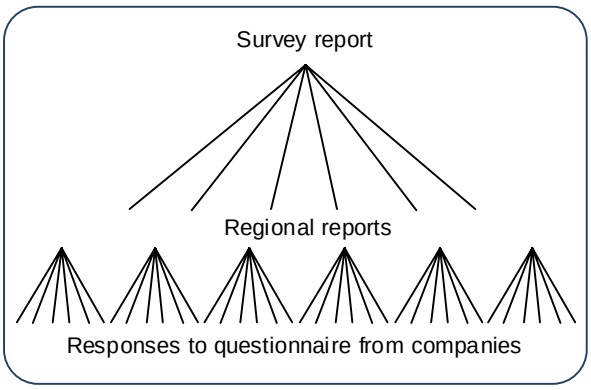

Fig. 1 – The survey analysis methodology

Table 2 illustrates the planning considerations under the different paradigms. The table highlights how distribution network planning is evolving from a system in which planning is focused around the load peak, to a problem that is orders of magnitude more complex. This is due in large part to new technologies (DER, demand side integration, electric vehicles) and new network applications, such as VVO, that make it such that analysis of numerous scenarios and points of operation becomes necessary. Furthermore, distributed generation will modify system dynamics, most notably, short circuit behaviour, requiring that planning engineers consider all possible combinations in the protection analysis.

Task Force 2 will identify various case studies, in order to illustrate the application of tools to active distribution network concepts. More specifically, the study of DER integration with a Volt-Var Control will be studied and presented. Initial results of the study show how an existing tool is adapted in order to evaluate active distribution concepts, in the planning context, and to show how and why metrics other than system capacity need to be evaluated.

	Activity	***Explanation***
1	Acquiring information from markets and customers	Information which may affect the development of demand or generation.
2	Forecasting of demand or distributed generation	For coming years the demand is estimated by the company
3	Network analysis	Simulations are performed to identify problems in the network that may occur at present or in the future
4	Alternatives research	To identify and produce alternatives for mitigating the expected problems in the network identified in the previous step
5	Evaluation and selection of alternatives	Alternatives are evaluated and prioritized according to predefined conditions in order select preferred solution.
6	Design of selected alternative	Definition of activities and basic engineering of the selected alternative.
7	Other activities, with regard to planning of distribution network	If your organization perform other activities which are not listed

Table 1 Questionnaire overview

	Conventional Network	*Active Distribution Network*
Degree of automation	- Very little or none	- Ubiquitous
Control philosophy	- Local control	- Integrated - Hierarchical
Planning metrics	- Capacity requirements - System losses - Short-circuit level	- Capacity requirements - System losses - Energy conservation - DG curtailment - Short-circuit levels
Planning options	- Addition of new capacity - Phase balancing	- Addition of new capacity - Phase balancing - Peak load management measures - Addition of storage
Modelling DER	- If relevant, synchronous machine model	- Multiple DG types - Accurate short-circuit model - Energy forecasts - Various control modes
Demand side integration	- If relevant, contribution of large customers to system peak	- Multiple participation classes - Probabilistic or behaviour based models
Screening tools	- Not applicable	- Required to identified networks where detail studies are required
Reliability	- Rules of thumb	- Numerous potential points of failure (both network equipment and DER) - Need for detailed models, integrated with other analyses
Modelling communication networks	- Not applicable	- Analysis required to assess the dependence of different Applications on telecom performance
Advanced distribution applications	- Not applicable	- Quantify benefits and build business cases - Ability to analyse many applications in parallel

Table 2: Summary of planning considerations for traditional distribution planning and in the context of active distribution networks

IDENTIFICATION OF MODELS FOR ACTIVE DISTRIBUTION SYSTEM PLANNING

A key challenge in planning active distribution systems (ADSs) is the uncertainty of the future: What level of active management will be implemented in practice? How will regulatory frameworks and connection agreements evolve to support ADSs? For this reason it is necessary to develop new planning tools that enable system planners, regulators and other key stakeholders to make informed and correct decisions. Due to the uncertainties that result from the integration of high levels of intermittent generation from renewable energy sources, traditional deterministic planning approaches may no longer be fit-for-purpose. Three characteristics have been identified by Task Force 3, which need to be fulfilled by new planning tools: (i) probabilistic-based approaches; (ii) multi-objective optimization (to arbitrate between the contrasting goals of the distribution system stakeholders); and (iii) the integration of operation aspects. An assessment of these characteristics will be based on the questionnaire analysis.

RELIABILITY OF ACTIVE DISTRIBUTION SYSTEMS

Task Force 4 aims to address another key challenge: To understand the impact on the reliability of ADSs, which results from the integration of information technology and telecommunication infrastructure.

The work of Task Force 4 aims to illustrate and review reliability evaluations of active distribution networks through simulation, modelling, and data analytics. A set of candidate benchmark circuits (based on actual utility models and measurement data) have been identified. Additionally, behavioural and control characteristics for devices such as distributed renewable sources and energy storage characteristics are also being identified. Tools and methodologies for assessing distribution system reliability and operation are also being evaluated and developed.

For example, one study case is using the OpenDSS platform to simulate the distribution system performance given distributed energy storage operations providing both customer backup power as well as feeder load levelling. By simulating the complete system response over a period of time, potential reliability indices benefits can be evaluated while also accounting the specific system impacts to voltages and loading levels.

Findings and lessons learned from this and similar studies will be shared, in order to derive conclusions and potential reliability assessment guidelines.

ALGORITHMS FOR ACTIVE DISTRIBUTION SYSTEM EXPANSION

Task Force 5 is addressing the issue of demand side integration and storage in the context of planning and optimisation of Active Distribution Networks.

With active distribution networks, the planning approach needs to be modified as conventional methodologies are not appropriate. When the combination of storage and DSI are applied, load modelling needs to be modified to consider the variety of directions of current flow and the possible impact of local overloads due to the impact of large embedded generation or storage. This impacts on diversity factors that may be applied when reviewing demand. A variety of tools need to be adopted to accommodate appropriate analytical analysis of networks. Application of appropriate algorithm control together with multi-objective and stochastic analysis are techniques that need to be utilised.

Task Force 5 is also considering the optimum planning and siting of storage devices and the factors that lead to optimum siting of storage devices and DSI resources. A further dimension that requires consideration in Active Distribution Networks is that of the overall risk associated with reliance on DSI resources and on Storage. The risk factors for such analysis include the nature of the contractual relationships and the level of control and responsibility associated with the DSI resources and storage resources.

A further important factor in the application of active distribution networks is the impact of power electronic devices. This impacts on the normal operation of protection systems as a result of the limited overload capability of power electronic devices. The issues that need to be addressed are being reviewed in the context of planning and optimisation of Active Distribution Networks.

CONCLUSION

This paper has presented an overview of the activities of CIGRE C6.19 Working Group (WG), focusing on the planning and optimization of active distribution systems. This builds on the recommendations of CIGRE WG C6.11 that focused on the development and operation of active distribution networks (ADNs). The C6.19 WG 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.

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", *on-line*, available: http://www.cigre-c6.org/