DEVELOPMENT AND OPERATION OF ACTIVE DISTRIBUTION NETWORKS: RESULTS OF CIGRE C6.11 WORKING GROUP

Christian D'ADAMO
Enel – Italy
christian.d'adamo@enel.it

Chad ABBEY
Hydro-Quebec – Canada
abbey.chad@ireq.ca

Samuel JUPE
Parsons Brinckerhoff - UK
jupes@pbworld.com

Britta BUCHHOLZ
MVV – Germany
B.Buchholz@MVV.DE

Mariam KHATTABI
MVV – Germany
Mariam.khattabi@mvv.de

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

ABSTRACT

The results of the CIGRE Working Group C6.11 "Development and operation of Active Distribution Networks" (ADNs) are presented. The outcomes of the Working Group were to: (i) provide a shared, global definition of ADNs; (ii) review the actual status of implementation of ADNs worldwide; and (iii) make recommendations to relevant stakeholders in the electrical sector for the transition towards more ADNs.

INTRODUCTION

The results of CIGRE Working Group C6.11 "Development and operation of Active Distribution Networks" are presented. The WG started activity in August 2006, aiming to:

- Provide a shared definition of active networks;
- Assess the actual status of implementation of active networks worldwide;
- Provide recommendations/requirements for the integration of Distributed Energy Resources;
- Identify the enabling technologies;
- Identify limits/barriers.

At the beginning of the WG's activities, no clear idea of what was meant by *active distribution network* (ADN) existed, not to mention the status of the concept as a technology. As a result, it was decided to submit a questionnaire to relevant stakeholders in the electricity sector to review the present status of implementation of ADNs. After consolidating the data collected in the survey, a consensus was reached on the following definition of ADNs [1]:

"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 majority of respondents agreed that the proliferation of distributed generation (DG) was one of the key triggers for the ADN transition. Moreover, they identified integration of DG into system operations, to the extent that DG takes some degree of responsibility for the reliability and operation of the network, as a vital step for the success of ADNs.

The second action of the WG was to review current operational practices [2] and the actual status of implementation of ADN, using the answers to the questionnaires and through review of the most relevant projects on ADN worldwide. This allowed the identification of the key features of ADN, enabling technologies and how the researchers and stakeholders at the forefront are addressing the integration challenges. The results are presented in Section "Key Features of Active distribution networks".

This paper provides a summary of the main working group activities and their results, including the overall scope, definition (as presented above), and a review of pilot projects. Based on these results we conclude with a set of recommendations to relevant stakeholders. These recommendations cover the actions required, in terms of system operation, system planning, regulatory activities, to foster adoption of ADN technologies.

RELEVANT PROJECTS ON ACTIVE DISTRIBUTION NETWORKS WORLDWIDE

A comprehensive list of ADN projects was compiled and analysed in order to extract the key features and enabling technologies associated with this innovative approach for operation and control of distribution networks. There are a large number of projects worldwide that fall under the general term of active distribution networks. As a result, from the larger list of projects [3], a subset was selected to illustrate the most innovative concepts and cover the different applications presently deployed.

Table 1 presents the enabling technologies and applications associated with each of those projects. Through analysis of the relevant projects, the benefits and R&D needs were also extracted.

Table 1 Active Distribution Network Enabling Technologies, Applications and Benefits

Integration Level	Enabling Technologies	Application	Benefits	R&D Needs	Project
Hardware (advanced devices)	Power electronics (applied to distribution networks)	Active and reactive power control	• Grid Stability • Increased power transfer	• Lower cost of power electronics • Reliability of components	1 6
	Intelligent devices and communication media	Information and communication technologies (ICT)	• Active distribution network management • Coordination and control of new and existent elements of the network • Network information collection	• Cost • Reliability • Standards for interconnection • Integration capability	All
	Advanced metering infrastructure (AMI)	Demand side management (with variable pricing structures)	• Reduce consumer costs / consumption • Peak shaving / shifting	• Cost • Regulatory issues • Variable price structures	2 3 4 24
	Advanced protection devices	Active network management with high DG penetration	• Increased DG integration • Network reliability and power quality • FRT and islanding capabilities • Sensitivity and selectivity with communication based protection	•Integration capability • ICT reliability • Protection coordination	5 6
	Energy storage system (ESS) and battery energy management	Islanding, load peak shaving, and intermittent generation integration	• Increased renewable integration • Avoid network reinforcement • Peak shaving • Islanding capabilities	• Cost • Energy management and operation strategies • Power electronics reliability	7 8
	Distributed power interconnection and control interface	Power quality control, coordinate grid operation	• Islanding capabilities	• Interaction with protection and other grid assests (e.g. OLTC)	8 9 10 20 23
Distributed Monitoring and Control	Power flow management	Optimal network management and active generation constraint for wind farms	• Low cost solution for increased energy export • Avoid network reinforcement • Peak shaving	• ICT and protection devices reliability • Regulatory issues	9 10 23 24
	Automatic voltage control (AVC)	Voltage regulation to allow the increase of DG	• Facilitates increased capacity of DG • Avoid voltage rise on networks	• Lower cost solutions • Increased transformer tap changer operations	5 6 11 23
	Dynamic line rating (DLR)	Real-time thermal capacity of the network	• Increased capacity to accommodate DG • Avoid network reinforcement	• Losses increment • ICT reliability	12 13 14

Integration Level	Enabling Technologies	Application	Benefits	R&D Needs	Project
Network operation (procedures / strategies)	Demand side management (DSM)	Load reduction / shifting, price responsive, direct load control	• Frequency control • Reduce consumer costs • Avoid network reinforcement • Peak shaving	• Customers behavior • Regulatory issues • Variable price structures	2 3 4 10 15 16 17 24
	Distributed control of DER	Aggregation of small and medium DG / Virtual power plant (VPP)	• Integration of DG to optimal operation and economic maximization • Balancing of variable generation	• Cost • Regulatory issues	3 18 19 20 23 24
	Microgrid / feeder (islanding)	Operation of small communities and buildings or a feeder of a substation in islanded mode	• Autonomous power supply • Avoid network reinforcement • Lower network losses	• Cost of energy storage • Resynchronization with the main grid • Protection schemes	7 8 17 21
	Distribution management systems (DMS)	Active management of distribution networks with DG integrated	• SCADA • Optimal power flow • Integration with IEDs and RTUs • Web-access	• Costs • Integration with systems already in use • ICT reliability	5 9 10 19 22

<u>Project names / Leaders (Country)</u>

1. Demonstrative project on new power systems / NEDO (JP)
2. Olympic Peninsula project / BPA – PNNL (USA)
3. Fort Collins Demonstration Project / City of Fort Collins (USA)
4. Townsville: Queensland Solar City (Magnetic Island solar suburb) / Ergon (AU)
5. Smart Distribution Network Operation (SDNO) / ENEL Distribuzione (IT)
6. Active Distribution Network (ADINE) project / Hermia Ltd (FI) – 7 partners consortium
7. Balls Gap Station / AEP (USA)
8. Field test on actual Microgrids Gaidouromantra, Kythnos Island (More Microgrids WPF) / Cres (GR)
9. Interruptible contracts for wind-power generation in congested areas / Hellenic Transmission System Operator (GR)
10. Field test on VPP in Strutensee (Dispower) / MVV (DE)
11. Steyning Primary Registered Power Zone (RPZ) / EDF Energy (UK)
12. Orkney Registered Power Zone (RPZ) / Scottish Hydro Electric (UK)
13. Active Management of Distributed Generation based on Component Thermal Properties / Parsons Brinckerhoff (UK)
14. Skegness Registered Power Zone (RPZ) / E.On Central Networks (UK)
15. ADDRESS / ENEL Distribuzione (EU)
16. Demand Response Programs / ConEdison (USA)
17. Model City of Manheim / MVV Energie AG (DE)
18. PowerMatcher / ECN (NL)
19. Virtual Power Plant (multi-site remote dispatching software) / Encorp (USA)
20. European Virtual Fuel Cell Power Plant / Vaillant (DE)
21. Cell Controller Project / Energinet.dk (DK)
22. Development and demonstration of innovative distributed power interconnection and control systems / NREL – Encorp (USA)
23. FENIX (Flexible Electricity Networks to Integrate the eXpected 'energy evolution') / Iberdrola (ES)
24. LV distributed generation microgrid / ERSE (Italy)

STAKEHOLDER RECOMMENDATIONS

The research from the Working Group helps the industry to reach some consensus on the concept of active distribution networks and provides a picture of the progress thus far, in terms of development and deployment of these concepts. This allowed the Working Group to develop a set of recommendations as to future work required to help foster the adoption of, and transition towards, more active distribution networks.

The Working Group provided recommendations in the areas of Grid Operation, System Operation, Regulatory Environment, and Awareness Building.

The target audience consists of the following groups:

- Distribution network operators;
- Distribution network planners/asset managers;

- Equipment manufacturers;
- Academia/Research/Consultants
- Telecommunication providers
- Software developers;
- Manufacturers;
- Regulation Bodies,
- End-use or consumer representative groups.

Each of the recommendation sections does not necessarily address to all groups and therefore, readers should refer to the full report produced by the C6.11 Working Group that is due to be published early in 2011.
The main recommendations are summarised below.

Grid operation

- Review protection systems and safety measured in the context of ADNs;
- Grid codes should be updated to reflect the fact that DER owners need to share responsibility with DNOs for the application of ADN;
- Communication systems to support data exchange for ADNs should integrate industry standards and security must be maintained;
- Put mechanisms in place for grid users to provide ancillary services and receive remuneration for this service.

System planning

- Planners should dialogue with other stakeholders (government, grid users) and consider their needs in a strategic planning approach;
- Consider the move to meshed network topologies to simplify the integration of DER and the development of ADNs;
- Apply probabilistic, risk-based approaches to planning of distribution system. This includes consideration of DER and ADNs for asset management in conjunction with network reinforcement;
- Develop planning tools that model the impact of new loads, DER and innovative ADNs applications.

Regulatory environment

- Develop mechanisms that connect grid users to the market;
- Enable grid operators to integrate DER into operation of the network;

Awareness building

- Educate grid users on the operation of the distribution system, potential benefits and constraints;
- Develop communication strategies within distribution companies that allow employees from all parts of the business to exchange information and educate each other on the evolution of the system. Furthermore, it is important that is a link with the international community to ensure that the experiences of industry leaders are shared on that same network.

ADDED VALUE

In the C6.11 vision, the ADN concept is the one of the necessary building blocks of the future "Smart Grid". The ADN will be the infrastructure that enables customer participation to the market, matching their needs with new capabilities, and allows the DNO to integrate these resources in operation of the systems so as to optimize the use of its assets, improve energy efficiency and performance. The research of WG C6.11 showed that many of the leading utilities have spearheaded pilot projects and demonstration installations, yet this technology is far from commonplace. The lack of incentives of both grid operators and DER owners and appropriate regulatory environments has, for now, stalled the adoption of this concept.

The research of CIGRE Working Group C6.11 provides a number of added values, including:

- Identifies ADN as a vital step in the move towards the Smart Grid;
- Defines the ADN concept and its characteristics;
- Raises awareness on its status and challenges, and;
- Identifies priorities to be addressed in near future, to support further development of ADN.

Bearing the above in mind, any one reading the Final Report of the Working Group (due to be published early in 2011), will be brought up to date on what are ADNs, its status of implementation and barriers and what to do facilitate its acceptance by the industry.

The work of this group is continuing in the newly formed CIGRE C6.19 Working Group "Planning and Optimisation of Active Distribution Networks".

REFERENCES

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