GLOBAL SURVEY ON PLANNING AND OPERATION OF ACTIVE DISTRIBUTION NETWORKS – UPDATE OF CIGRE C6.11 WORKING GROUP ACTIVITIES

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ABSTRACT

This paper presents the progress of the CIGRE C6.11 working group: Development and operation of active distribution networks. The scope of the working group is to define the concept of active distribution networks (ADNs), review the status of implementation and actual operating practices, identify enabling technologies, and provide a vision of the future developments in the area. Here the progress of this working group is presented, which includes the definition of ADNs and the results of a global survey involving 27 utilities and research bodies worldwide. General features of ADNs, current status of their implementation and operating practises, as well as limits/barriers are discussed.

INTRODUCTION

The proliferation of distributed generation (DG) together with load growth, energy storage technology advancements and increased consumer expectations have significantly changed the approach to planning, design and operation of distribution networks. Around the globe, distribution companies, equipment manufacturers, electrical engineering consultants, research institutions, regulators and stakeholders are dealing with these issues. Several organisations worldwide are addressing these issues (e.g. IntellIGrid in the US, Smart Grids Technology Platform in EU) and promoting collaborative projects for the electricity networks of the future. Part of this new paradigm includes the possibility for distribution system operators (DSOs) to control, operate and thereby integrate distributed energy resources (DER) into the network under their responsibility. This vision sees the evolution of electricity distribution from passive to active distribution networks.

The CIGRE C6 Study Committee [1] considers the different aspects of integration of distributed generation. In this context, the C6.11 Working Group (WG) is specifically focused on “Development and operation of active distribution networks”. The WG has 27 members, experts and observers, representing 14 different countries. This WG aims to assess the various requirements to facilitate the transition towards active distribution networks (ADNs). Specifically, the WG scope includes:

- Assessment of network and generator requirements for the operation of DG and DER (protection, ancillary services, islanding criteria);
- Identification of enabling technologies both for demand and generators;
- Definition of limits/barriers (costs, infrastructures, investment remuneration);
- Evolution in the regulatory framework required.

To assess the state-of-the-art, identify the enablers, and provide a shared global definition of ADN, the WG submitted a questionnaire through its members to national CIGRE committees, distribution companies, research organizations and other stakeholders. The shared global definition of ADN resulting from this work is as follows:

Active distribution networks (ADNs) are distribution networks that have systems in place to control a combination of distributed energy resources (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.

This paper provides a summary of the survey results and WG analyses. This includes a high level summary of the key findings followed by detailed analyses of each section of the survey.

ACTIVE DISTRIBUTION NETWORKS INDUSTRY SURVEY

The industry survey was circulated by WG members within each of their countries and 27 responses were received during 2007. The questionnaires have been analysed by 5 sub-WGs during 2007 and first half 2008, and key results were presented to the C6 study committee at the meeting in August 2008. Here the key findings are provided, followed by summaries of the findings in the different areas.

Key findings

Perhaps the most significant outcome of the survey was to reach a consensus on the definition of active distribution networks, its key characteristics, and assess what are the strengths, weaknesses, opportunities, and threats. Utility respondents provided a great deal of useful feedback on each of these topics and helped the WG agree upon a
revised definition. The key characteristics complement the formal definition by providing a list of technologies, functionalities and benefits that are likely to be associated with specific ADN applications. The SWOT analysis provides a good summary of this technology and provides an indication of the most likely applications.

The penetration of DG moved from less than 1% in 2002 to 4.2% in terms of installed capacity and 5.6% in terms of energy output in 2007. While the survey results suggest that there are only limited applications of the ADN concept, some pilots and utility projects were mentioned. Follow-up with some of these projects is planned in order to extract greater information regarding enabling technologies, specific ADN applications and barriers encountered. Communication was highlighted as an essential technology although analysis of the responses revealed no clear trend in the communication medium most suitable or preferred.

Current operating practices are limited in terms of their evolution towards ADN. Current practices in networks with DER are biased more towards its interconnection rather than its integration into system operation. Very little remote control of DG is currently witnessed and intentional islanded is practised limitedly. However, with the anticipated continued growth of DG, certain utilities are evolving their practises suggesting a move towards more widespread adoption of ADN might be possible.

The identified priorities for future development of ADN practises were protection, safety and communication. Other developments that were more application based (e.g. ancillary services, intentional islanding) were given lower priority suggesting that utilities want to ensure that the transition to active distribution networks is done maintaining currently levels of safety, protection, and reliability. The results of current practises suggest that remote control of DER is almost an essential precursor to ADN, implying the need for appropriate communication infrastructure to make this possible.

As with DG, regulatory issues remain a focal point for ADN. Insufficient contractual and regulatory mechanisms lead to unclear responsibility and accountability of participating DER, remuneration to the DER for ancillary services and to the utility for ADN investments, all of which are significant disincentives to deployment of this technology. As many of these issues are local considerations, the best approach is to encourage an integrated approach that sees collaboration between utilities, DG suppliers and regulators. Also, information sharing on best practices, what has worked and what are the problems, could be a key catalysts to constructive progress in this area.

Definition, Main Features, and SWOT analysis
Within sub-WG 1, the questionnaire responses were analysed from three perspectives:
1. The definition of active distribution networks
2. The main features of active distribution networks
3. The strengths, weaknesses, opportunities, and threats to active distribution networks

Defining Active Distribution Networks
It is important to define the term ‘active distribution networks’ as this leads to a standardisation of the concept which, in turn, facilitates the sharing of experience, the communication of ideas and allows appropriate technologies to be developed and transferred. Within the questionnaire distributed by WG C6.11, a number of candidate definitions for active distribution networks were defined. As a result of comments regarding these definitions and discussions at the 2008 WG C6.11 meeting, a consensus on the definition presented in the introduction was reached.

Key Features of Active Distribution Networks
From the survey responses and the alternate definitions supplied, the main features of active distribution networks were ascertained. These are summarized in Table 1.

Strengths, Weaknesses, Opportunities, and Threats Analysis
This section analyses active distribution networks in terms of their potential advantages and disadvantages when compared to passive distribution networks. In doing so, the opportunities arising from, and the potential threats to, the development of active distribution networks are identified. The full “SWOT” (strengths, weaknesses, opportunities, threats) analysis, gleaned from questionnaire responses, is appended.

Strengths:
- Economic alternative to network reinforcement
- Increased operational reliability, including power delivery
- Electrical loss reduction
- Automation and control leading to improved network access for DG / load customers

Weaknesses:
- Maintenance issues
- Present lack of experience
- DNOs are not incentivised to take risks
- Existing communications infrastructure
Table 1: Main features of active distribution networks

<table>
<thead>
<tr>
<th>Infrastructure Needs / Specifications</th>
<th>Applications</th>
<th>Driver/Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Protection</td>
<td>• Power flow congestion management</td>
<td>• Improved reliability</td>
</tr>
<tr>
<td>• Communication</td>
<td>• Data collection and management</td>
<td>• Increased asset utilization</td>
</tr>
<tr>
<td>• Integration into existing systems</td>
<td>• Voltage management</td>
<td>• Improved access for DG</td>
</tr>
<tr>
<td>• Flexible network topology</td>
<td>• DG and load control</td>
<td>• Alternative to network reinforcement</td>
</tr>
<tr>
<td></td>
<td>• Fast reconfiguration</td>
<td>• Network stability</td>
</tr>
</tbody>
</table>

Opportunities:
- Ageing assets could be replaced with active management capable equipment
- Development and implementation of smart metering technologies
- Development of communications infrastructure
- Movement towards a low-carbon economy through the accommodation of distributed renewable energy sources

Threats:
- Regulatory issues impede the development of active distribution networks
- DG continues to grow in size and is connected to the transmission network
- Security of information on the communication infrastructure
- Active networks are not compatible with existing passive networks

Current level of implementation
The main feedback related to the current level of implementation was that the present level of development is quite low. Nonetheless, there were a number of pilot installations that were mentioned including those in: Australia, Denmark, the Netherlands, Spain and the UK. Also, a number of pilots known to the WG experts were not mentioned in the questionnaire response suggesting that there is a need to disseminate this information. As such, the WG decided to pursue the documentation of these existing pilots and then collate information related to technologies and applications.

On the issue of factors that would help facilitate future deployment of ADNs, a number of suggestions were received. These included (in level of priority, from highest to lowest): new investment remuneration / regulatory frameworks to foster utility adoption; research and development (including publicly funded demonstration projects), standardization. Demand growth and environmental factors were perceived to be only minor factors in the adoption of ADN.

The communication medium used by the companies surveyed varied greatly. Table 2 summarizes the technologies mentioned in the responses received. Only a limited number of companies cited the use of communication for remote operation of DER, with an even smaller percentage of the control extending down to low voltage networks.

Review of actual operational procedures
Section 4 of the questionnaire addressed the operational procedures currently implemented, summarized here by different issues.

Rules for parallel to the network
There is no general agreement as to the rules for operation in parallel with the network for MV and LV generators. The rules are mandated by National legislation, are published in the Grid Codes, or prescribed by the local utility. As a general rule the DG should not degrade the power quality of the network. In case of a fault or loss of the main grid islanding is generally prohibited and in most cases

Table 2: Communication technologies used by surveyed utilities

<table>
<thead>
<tr>
<th>Method</th>
<th>Wireless</th>
<th>Hard wired</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Voice only (telephone to local operator)</td>
<td>• Microwave</td>
<td>• Copper pilot table</td>
</tr>
<tr>
<td></td>
<td>• Radio, UHF radio, radio links</td>
<td>• Optical fibre</td>
</tr>
<tr>
<td>• Remote control</td>
<td>• Satellite</td>
<td>• Power line carrier (PLC)</td>
</tr>
<tr>
<td>• Connection to SCADA systems</td>
<td></td>
<td>• GSM</td>
</tr>
</tbody>
</table>
|                            |                                               | • GPRS
automatic disconnection is performed, either based on local signals or remotely from the substation.

**Fault clearing**

Fault clearing procedures are the same as for feeders without DG in 60% of the interviewed DSOs. Dedicated settings for feeders with DG are used by 40% of the respondents but no coordination is granted in case of embedded MV and LV generation.

**Remote control**

Only 41% of the interviewed DSOs have the possibility of remotely controlling the DG at the MV and LV level. Few DSOs have the responsibility (or capability) to dispatch or regulate the output power produced by the DG. Most DSOs are obliged to accommodate all DG power injections and as mentioned in the section 2.4.1 the interface protections disconnect the DG in case of voltage transients or faults.

**Voltage control**

The only experience cited in the responses related to coordination of voltage regulation for MV feeders with DG is done with the adjustable setting of the tap changer of MV/LV transformers. The situation is even less common at LV in which no contribution of DG to voltage control was mentioned.

**Intentional islanding**

Presently there is very limited application of intentional islanding; 22% of DSOs interviewed perform intentional islanding of DG under very specific conditions. In most cases this represents islanding of the DG owner’s load (generally an industrial load) only and consequently the island does not include utility infrastructure. However, 14% of the DSOs interviewed may perform intentional islanding that includes the utility system in emergency cases.

**Future operating practices**

Present operational procedures reveal that ADN applications are applied in only limited cases. The interviewed DSOs indicated development of the following areas, in order of priority (from highest to lowest) as critical for the success of ADNs: protection approaches, safety, fault management, communications, intentional islanding and ancillary services. This suggests that further development of different areas is a necessary precursor to widespread implementation.

These responses indicate the utility position vis-à-vis this technology and the steps required for its adoption. There seems to be a perception that safe operation of a number of DER in a distribution network still requires further consideration. Also, it seems that communications are required before some of the ADN applications (ancillary services, intentional islanding) can be taken advantage of. This supports the view in the previous section that there is only limited remote control of DER, something that most probably needs to change in order for ADN to become adopted more universally.

**Regulatory barriers to ADN**

Although the survey did not specifically focus on regulatory and contractual issues, the responses from DSOs interviewed indicated that these aspects will likely be the determining factor as to whether ADNs are adopted or not. Even more so than in the connection of single DER, these can pose significant barriers to ADNs, in that a fundamental prerequisite for ADNs is that DER be integrated and not simply interconnected.

To implement the ADN concept a DSO must be allowed to control and regulate the output of at least the major DG units. A DER that relinquishes some level of control to the DSO will require different contracting and remuneration than those that simply inject real power into the network. Implicit is the varying degrees of responsibility associated with each. Intentional islanding requires an additional level of complexity as, during islanding, participating generators become the sole mechanism for ensuring the reliability and quality of the energy supplied. As such, this will warrant supplemental regulatory and contractual considerations.

Market models, regulations and responsibilities of different actors (TSO, DSO, generators, etc) will likely vary according to the operational procedures of the ADN. Successful treatment of these issues will require an integrated approach including utilities, DG owners and the regulator. Ultimately the system should be optimized in terms of overall energy usage, which would include the use of electricity, heating and cooling. As examples of this level of integration do exist at present, these should be used as starting points for the discussion.

**CONCLUSIONS**

This paper has presented survey results and working group analyses relating to active distribution networks. A definition for this concept was reached and main features were outlined. With only modest implementation of this new concept, future working group activities will focus on classifying the range of applications, identifying enabling technologies and charting future development based on experience from practical case studies taken from the industry.

**REFERENCES**