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# The Road to Active Network Management

Utility Solutions and Services

TECHNOLOGY JOURNAL

Volume 1, Number 3, March 2010

TABLE OF CONTENTS

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## Smart Grid is about DG

In its "Smart Grid System Report[1]" of July 2009, the U.S. Department of Energy (DOE) observes that

> *"The ability to accommodate a diverse range of generation types, including centralized and distributed generation as well as diverse storage options, is central to the concept of a smart grid."*

After all the recent publicity on Smart Meter deployment, it is refreshing to be reminded that Distributed Generation (DG) is at the heart of the Smart Grid initiative and that the percentage of Grid-Connected Distributed Generation and storage implementations is currently on the rise (DOE identifies this trend to be "high").

But so are the challenges—starting with the electrical connection and the impacts of standing the electrical structure literally on its head. For, the introduction of DG into distribution can completely change the topology of the network with its reversible energy flows.

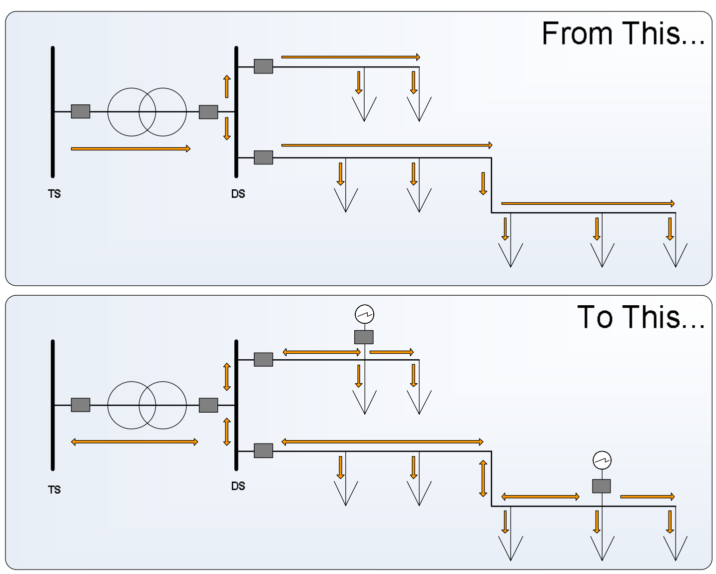


**Figure 1—DG and Reversible Flows**

[1] "As the first in a series of biennial smart-grid status reports, aspects of this report are expected to form the framework for future reports." (page xxiii)

## The Challenges of DG

Traditionally, the power in Distribution came from Generation in Transmission and flowed from "top to bottom" as it were. Consequently, all protection systems were designed to see energy flowing in the same direction and the level of voltage would progressively diminish with the resistance of distribution lines. But DG changes all that by introducing new sources of power on those feeders, reversing the flow of supplies and upsetting everything that comes with it—for example:

- These flows invalidate the existing protection systems, which were designed and installed to protect against faults where the power flows in a unidirectional manner.
- They also invalidate certain types of equipment like regulators that were designed to boost or lower current in one direction only.
- Switching order management programs have to be aware of such non-reversible equipment and take this into consideration in their plans.
- Outage management systems have to take into consideration the presence of multiple sources when trying to identify the faulty source causing the outage. As a matter of fact, having to manage more than one location for the outage may result from this.
- Outage management systems have to take into consideration the presence of multiple sources when considering restoration procedures.
- Permit management within outage and distribution management systems have to consider possible energy flows from the multiple sources, before considering devices to be fully isolated.
- Conductors that are part of the wires installed may have to be replaced because of the additional power that could circulate between the different sources, lest they become rapidly overloaded.

These and many other considerations make it difficult to envisage introduction of DG without radical changes to the underlying electrical infrastructure—which represents huge investments. To Utilities that envisage the interconnection of hundreds of potential generating companies, major reinforcement of network infrastructures like this is certainly not the best way of sustaining a constant rise in "Grid-Connected Distributed Generation and storage implementations"… There has to be another solution.

## ANM to the Rescue

The latest solution calls for managing DG in real time, using distributed agents that can share network management functions while being integrated with other smart grid technologies. Why distributed agents? By taking monitoring and control actions as close as possible to the generation sites, this effectively spares costly upgrades to the rest of the distribution network, thereby limiting the deployment of expensive communications backbone, and enabling compliance with the time requirements for handling the quasi instantaneous events associated with DG operations.

This latest trend called Active Network Management (ANM) works by transferring a subset of Supervisory and Control functions traditionally found in centralized SCADA, directly into the field where monitoring and control actions can be taken closer to the action site. Remote agents performing selected network management functions interoperate with Intelligent Electronic Devices (IED) within the DG area to accumulate data locally, perform fault processing locally, intervene locally on protection schemes (thanks, in part, to GOOSE messaging[2]), optimize the DG segments with integrated Volt/Var controls[3], eventually running balanced and unbalanced load flows and engaging some generation and load forecasting analysis locally.

Clearly, the concept of a sub-network of smart platforms interacting to solve a common problem is necessarily interdisciplinary, as it integrates notions of Distributed SCADA (or D-SCADA), multi-agent system technology and distributed operations. This requires blending classical engineering processes like power analysis, supervisory controls and protection equipment applications with purely IT concerns like:

- Managing the programmable, distributed platforms;
- Configuring them remotely;
- Defining them to the DMS[4] operational model;
- Upgrading their firmware;

[2] GOOSE: Generic Object Oriented Substation Events, a protocol of IEC 61850 for extremely rapid (4 ms) communications between IED components like protection applications.
[3] Control of Voltages (Volts) and of reactive power (VARS).
[4] Distribution Management System

- Controlling their operations and “orchestrating” their automation functions
- Retrieving their data and event collections, etc.

This IT complexity is a necessary evil to reap the benefits of a Smart, self-healing and self-powered Grid. Already, simply adopting D-SCADA over centralized SCADA can bring about some tremendous benefits, solving problems that centralized DMS/SCADA cannot overcome easily—for example:

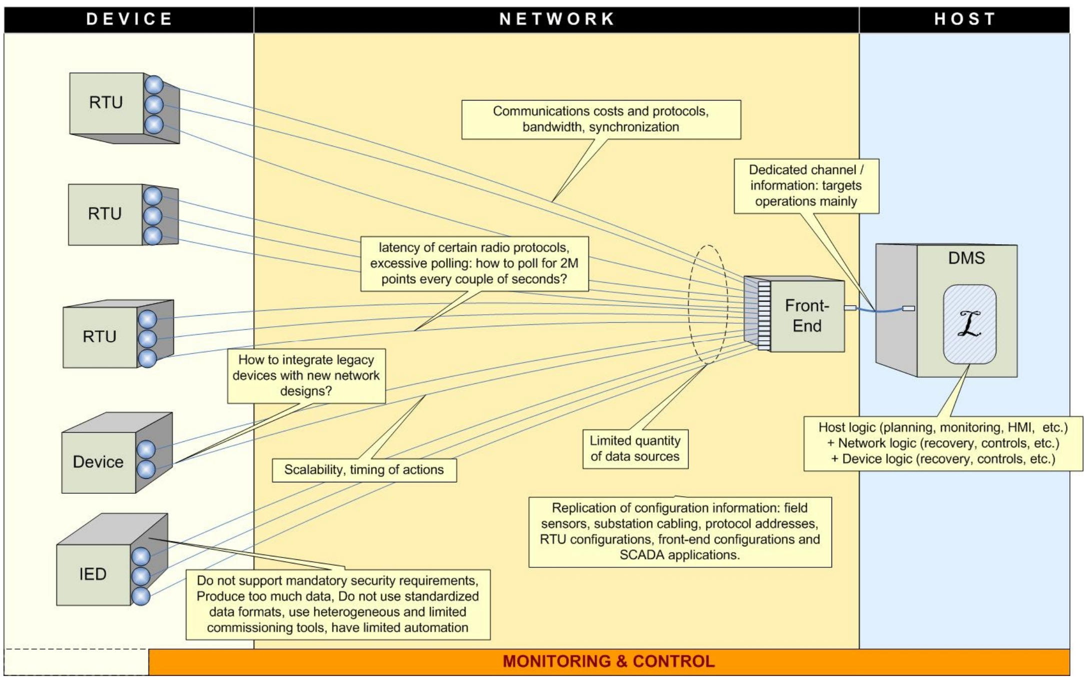


**Figure 2—Issues of Centralized SCADA**

- Communications costs and protocols, due to unproductive or excessive polling
- Bandwidth utilization, due to data concentration at a single location
- Event retrieval, in the context of low latency radio protocols
- Speed and timing of actions, versus scanning rate and other delays
- Scalability: how does central SCADA manage to poll 2 or 3 million data points every couple of seconds?
- Integration of legacy devices with new network designs

…not to mention all the replicated configuration data that enters the definition of field sensors, substation cabling, protocol addresses, RTU[5] configurations, front-end configurations and SCADA applications.

- Use of distributed 'Smart Stations' (or Agents or Gateways) changes all that, by:
- Providing a scalable "network" of multi-level control points to monitor and control different portions of the electrical topology;
- Performing data concentration and protocol conversion locally;
- Establishing connections to equipment agnostic of IED type, protocols or data format,
- Polling devices locally and reporting information by exception, to reduce bandwidth and communications costs
- Bringing automation closer to the operating site
- Performing intelligent feeder reconfiguration such as isolating devices on fault detection, voltage loss, or current overloads, or FISR[6] ;
- Fragmenting links prior to restoration when necessary;
- Optimizing voltages with bi-directional voltage regulation and reducing losses with Vars controls.

[5] Remote Terminal Unit - ancestor of the IED, this is a microprocessor controlled electronic device that manages local objects like digital and analog inputs, control points etc.
[6] FISR: Fault Isolation and Service Restoration (also sometimes called FDIR) implements the self-healing grid. When performed inside DMS, it involves automating the detection of fault, identification of failed sections, generation of switching orders to isolate them and other orders to restore supplies to the healthy sections. All this is now being performed outside the DMS and inside the Smart Agents

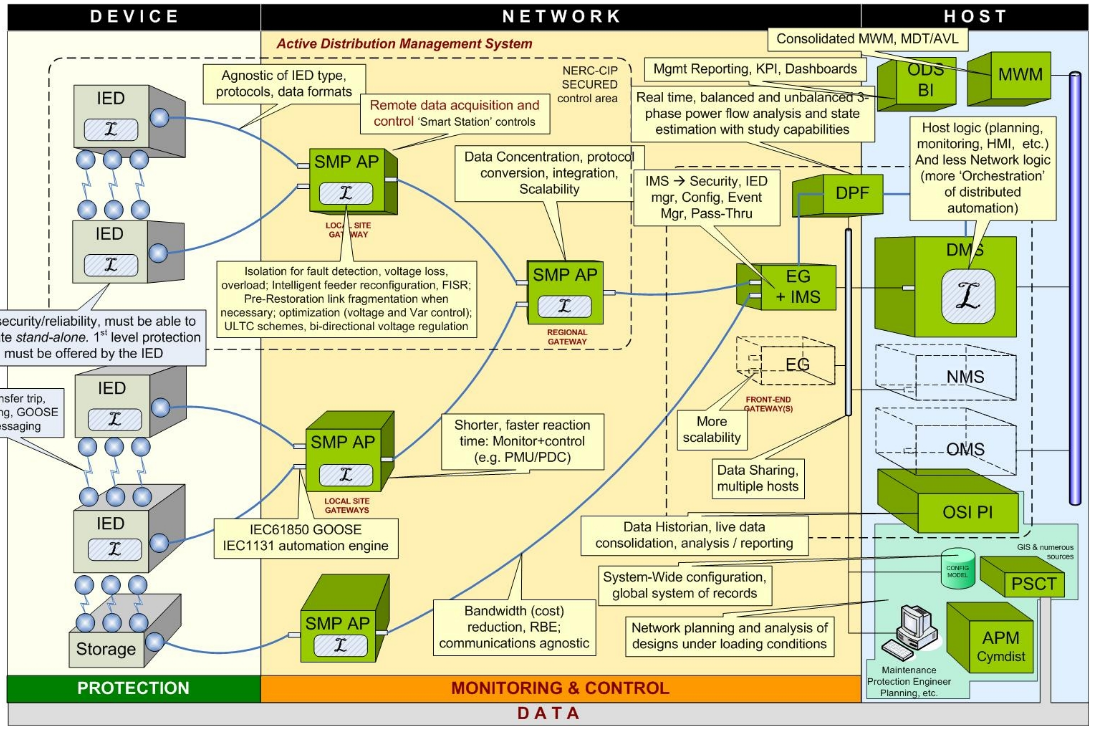


**Figure 3—Advantages of D-SCADA**

## DG is Still Core Business

Simply put, ANM uses modern IT and communications technologies to define a new framework that allows network management becoming more "active". But the framework is just half the story: the rest, especially as it relates to distributed generation, remains a challenge that, once again, necessitates inter-disciplinary efforts from power engineering, construction planning and distributed controls—for example:

- When DG is installed at the end of a feeder, premises located near the end of the wire can experience sudden changes in voltage—certainly when circuit loads are at a minimum and generation is at a maximum, or vice-versa.
- When large DG plants are in operation, a sudden loss of power can cause system-wide voltage trip that could lad to plant islanding.
- Islanded operations can be very dangerous because supplies are then unregulated, unchecked by Utility controls, making the islanded network unsafe to crew intervention, etc.

 

- Reconnecting islanded networks to the power grid is also a challenge in itself due to possible differences in phase angles and frequencies, etc.

- When synchronous machines start generating fault current, the fault levels can last for some time depending on the type of power generating equipment; the longer these levels are sustained, the greater the damage to breakers, contacts and other equipment, especially if ratings are exceeded.

- Hence, when faults occur in the vicinity of DG, remedial action must be taken to prevent the generator from continuing to supply current into the fault. Protection equipment must isolate the fault (based on conditions like UFLS[7]) and the DG must isolate itself. This action must be taken very quickly (e.g. within 34 ms), hence the use of IEC 61850 GOOSE messaging to enable coordinated actions amongst the protection equipment.

- The purpose of DG is both to provide stable supplies that can be consumed locally and to enable surpluses to be sold by injecting them into the Grid. But when DG connects and disconnects from the network, this sends transient voltages and harmonic distortions (or spikes) that can be harmful to electronic equipment on the circuit.

## Transforming the notion of 'DMS'

These challenges notwithstanding, the growing level of intelligence in the field does mark a transition from today's manually operated distribution network (e.g. often managed with geographic dispatch), towards an automated (self-healing) network (managed with single-line diagrams). Distributed agents supporting standards like IEC 61850 are an inherent factor in this transition; by enabling auto-discovery of intelligent devices[8], they will ultimately lead the "network" to configure the DMS, rather than the other way round.

As for the DMS, the idea of performing FISR within the application— by using fault analysis, switching order generation and power analysis— will become inadequate in the context of the fast response required for DG, or the scalability needed to automate a large distribution Grid. ANM and Smart Agents

[7] UVLS — Under Voltage Load Shedding and UFLS (curtail generation when voltage is below threshold) — Under Frequency Load Shedding (curtail generation when frequency (e.g. 60 cycles) is below threshold). Also an Over Voltage condition (voltage exceeds threshold) may trigger this

[8] Thanks, in parts, by standards like IEC 61850

 

are thus at the root of a paradigm shift within traditionally network-centric applications like OMS[9] and DMS, compelling them to a return to basics.

With automation and optimization functions delegated to distributed platforms, the very term of 'DMS' becomes a hybrid definition of hardware and software solutions blended under a common acronym. At the same time, this forces DMS to adopt an 'Orchestration' logic, whereby it starts or stops, suspends or resumes the distributed pockets of automation based on the operational constraints of permit delivery, field repair work, outages, network extension projects, commissioning of automation components, etc.; and it sets or changes global optimization objectives based on system-wide load management considerations.

Hence, as DMS continues to attend matters of priority planning, network monitoring and state estimation, SCADA HMI[10] , safety and permit management, switch order planning and execution, it also gradually shifts the focus onto the broader issues of load forecasting, load balancing, demand response forecasting and load management.

All this is straightforward consequence of the digital revolution of the power grid; it represents a long-term opportunity to widen the operational control of the grid across all voltage levels and will lead distribution companies to consider operating their network like that of Transmission.

[9] Outage Management System
[10] Human Machine Interface (involves schematic diagrams, single-line diagrams, diagram dressings, alarms and events, SCADA controls, etc.)

 

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