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Roles and Responsibilities for Distribution Grids: DER Sensing and Communication Networks

February 2017

JD Taft

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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1.0 Introduction

Traditional distribution grids require sensing and communications for grid operations. In many cases the communications networks are owned by the Distribution Operator (DO); in some cases, carrier services such as leased telephone land lines or cellular services are used. In recent years, wireless mesh field area networks and optical fiber have become viable options for distribution. Fiber in particular has improved in cost to the point where its high performance (large bandwidth, low latency, and low packet loss) has become practical for distribution systems where geographic circumstances permit.[1,2]

As grid modernization proceeds, utilities find a need to improve or upgrade distribution communications; this represents a significant investment and it is natural that both utilities and regulators would seek both to future-proof and minimize their costs. Given the development and rising penetration of smart grid edge devices such as Distributed Energy Resources (DER) that have local sensing and intelligence and can communicate via the internet or other non-utility communications channels to cloud-based services, the idea of using such devices for grid sensing and communications to support grid operations has emerged as a potential means to avoid utility investment. To a great extent, however, these DER and communication channels will be owned and operated not by the DO but by end-use customers, aggregators and other third parties pursuing their own energy needs and business models.

The question of whether such devices and systems can effectively substitute for DO grid modernization investment can be assessed and resolved using grid architecture methods and by considering the appropriate roles and responsibilities of the entities and systems involved in distribution grid operations. This approach reveals that there are several compelling reasons to dismiss the idea of eliminating DO owned and operated sensing and communication entirely and relying on DER-based sensing and third party communications.

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[1] D O'Leary, ESB, *Fibre to the Building (FTTBN) Project*, EPRI International Technology Innovation Summit 2015.

[2] CPUC, *Fiber in Gas*, available online: http://www.cpuc.ca.gov/Environment/info/esa/sempra-fig/fig/2_prjdesc.pdf

2.0 Description of the Issue

Prior to the proliferation of DER, distribution grid communications were mostly structured as shown in Figure 1 below, where the arrows indicate primary information flows. Sensor and control data transport is of primary interest, but note that in many cases, the communication network(s) also carried meter data, asset management data, and mobile field crew voice, data, and video. This often has been via multiple siloed communication networks but more recently has been done in a single converged physical network.

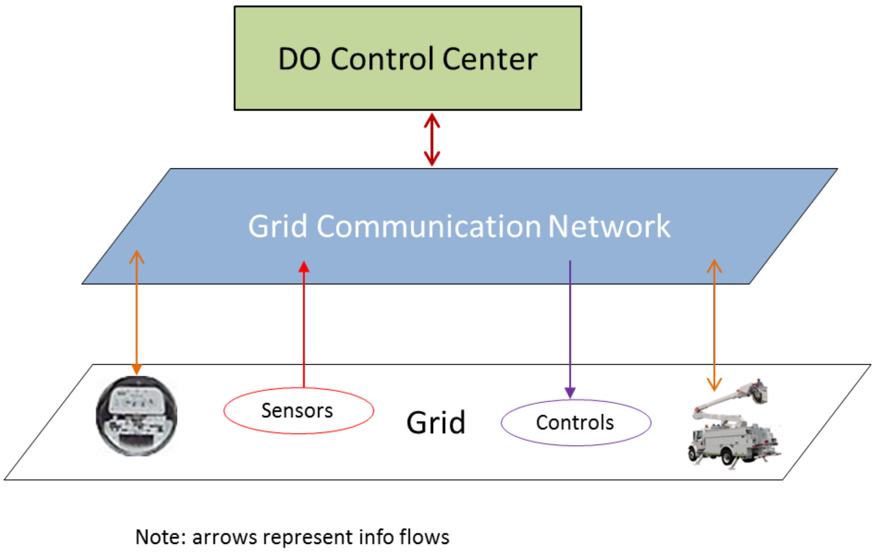

Figure 1. Traditional Distribution Sensing, Control, and Communication

The responsibility for operation of the communication network(s) rested with the same organization that had responsibility for distribution reliability, the DO, even when some parts of the communication system were leased. Likewise, the responsibility for network cyber-security belonged with the DO, although in the past this was not considered a high priority issue.

The combination of smart edge devices and DER has led to an emerging structure for the combination of traditional grid and internet-connected DER that is shown in Figure 2. (The double arrow between the internet and the ISO/RTO/BA represents the fact that many, but perhaps not all, DER will provide grid services to the transmission level and participate in wholesale market.) The distribution grid and the DER are electrically coupled but the arrangement involves two distinct communication systems and two distinct coordination and control mechanisms. The distribution grid functions as before, but DER that may participate in grid operations in an active manner are generally not controlled directly by the DO. Rather, an Energy Services Organization (ESO) communicates with the DER (typically via the internet) to perform data acquisition and control or coordination. The ESO may be a Demand Response or DER aggregator, a third party operator of DER or a private party providing DER as services to a grid operator.

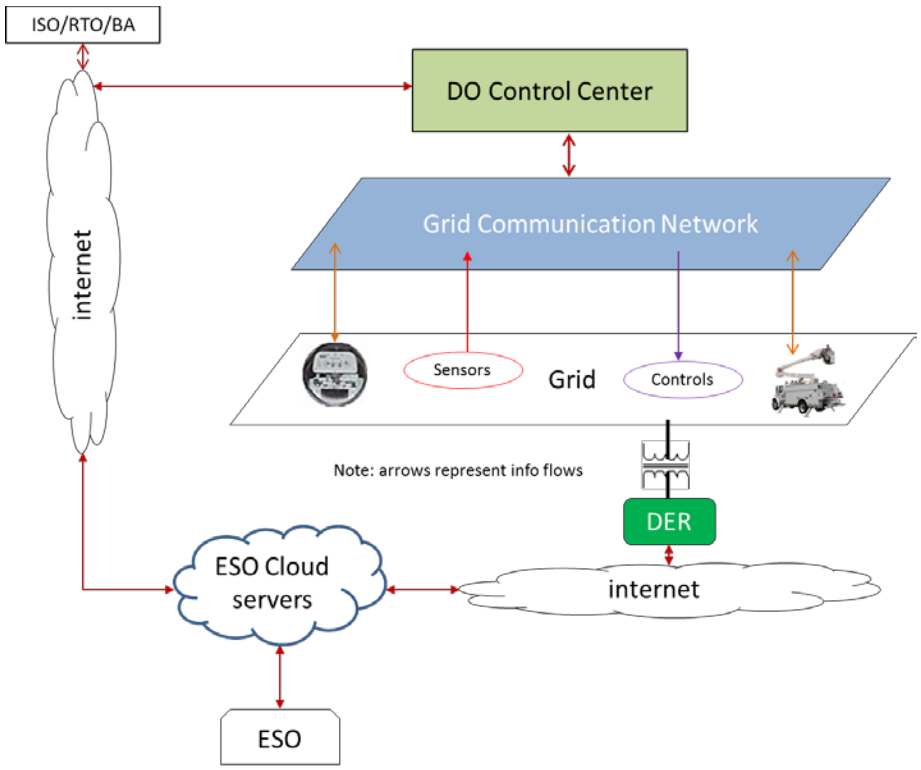

Figure 2. Distribution Grid with DER and ESO

Under this model, two different communication systems exist – one is the conventional grid communication network and the other is a non-utility network that may use any of various communication service provider data transport mechanisms, including ordinary internet services and cellular services. In this case, the DER has *electrical* connectivity to the grid, but not *communication* connectivity (except in a very indirect manner via the ESO).

As DER devices have matured, they have incorporated sensing of not just internal device variables and ambient conditions, but also of local grid variables, notably voltage, but in principle could include harmonic and other distortions and system frequency. A complication in this regard is that much DER is electrically connected behind the end-use customer meter and therefore on a distribution secondary, whereas grid line sensing is done on primary feeder lines. Variations in service transformer parameters make accurate sensing via the secondary level measurements complicated. It appears to be the case however, that grid edge sensing has the potential to enable determination of grid topologies and admittance matrices, and therefore power flows.[3,4,5]

The question is whether distribution utilities can avoid investment in new distribution sensing and communications systems by relying upon third parties and the DER they may own and/or operate to provide both grid sensing and grid communications.

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[3] Y Yuan, et. al., CalTech, *On the Inverse Power Flow Problem*, Oct. 2016,available online: https://arxiv.org/pdf/1610.06631.pdf

[4] D Deka, et. al., *Structure Learning and Statistical Estimation in Distribution Networks – Part I*, Feb 2015, available online: https://arxiv.org/pdf/1501.04131.pdf

[5] Y Liao, et. al., Stanford University, *Urban Distribution Grid Topology Reconstruction*, available online: https://pdfs.semanticscholar.org/744e/b4cbd3f4cd26030fa2a1dda467e23157dd4c.pdf

3.0 Analysis

Consider the structure of a distribution system that would use DER devices and third party ESO communications instead of DO owned and operated sensors and communication for grid sensing and measurement, such as is depicted in Figure 3. Grid sensors have been removed, as has grid sensor communication. DER sensing is used instead, with the sensor data flowing from the DER devices via the internet or other telecommunications service provider arrangement to the ESO's cloud-based servers, and then from there again via the internet or telecommunications service provider to the DO control center.

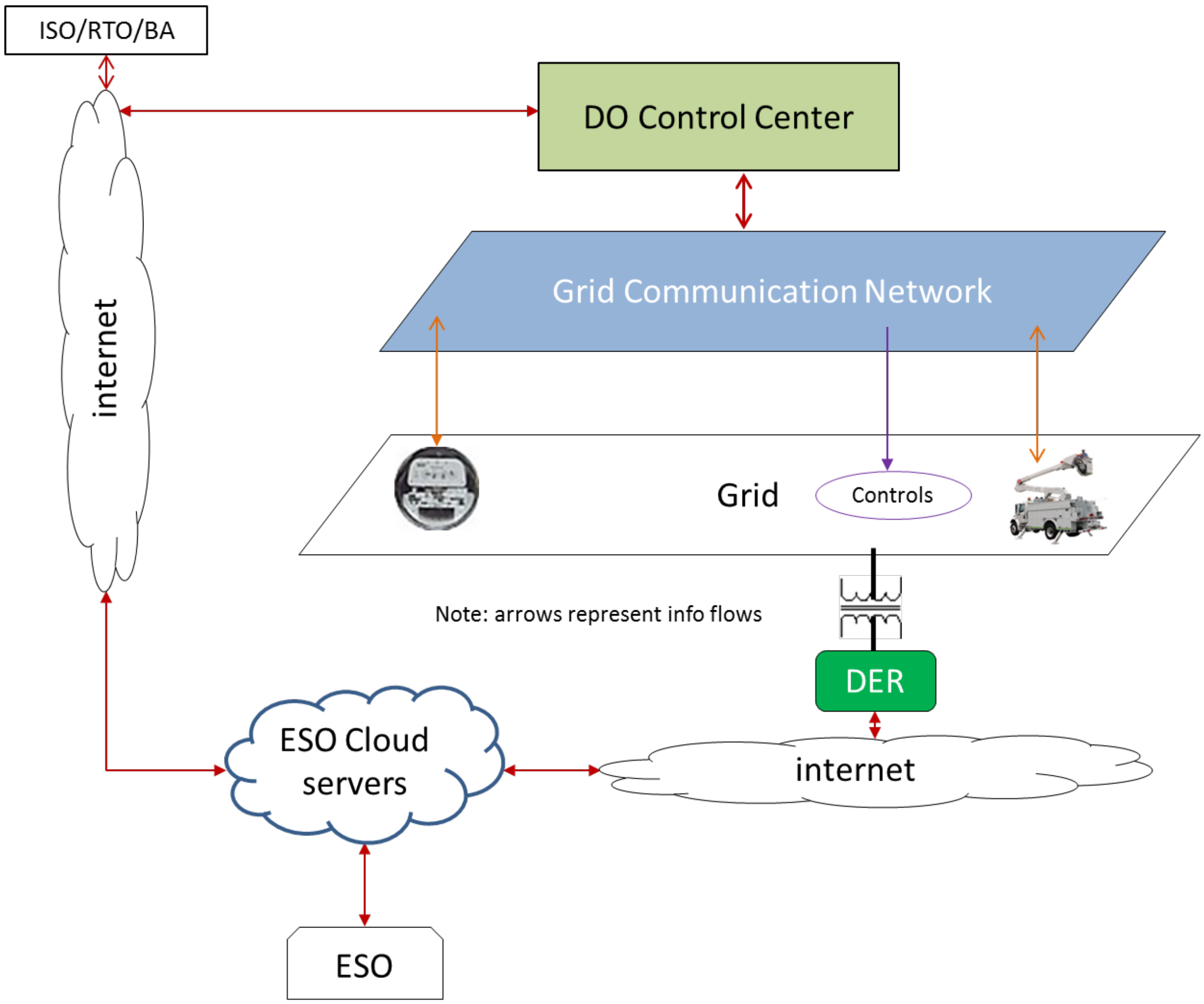

Figure 3. Concept for Distribution Grid Sensing via DER

To resolve the issue of utilities relying on third party DER-based sensing and communications, consider some of the functions that are needed for grid control and management, as shown in Table 1.

Table 1. Distribution Grid Operations

Function	Comment	ESO Could Supply?
Flow Control	Switching and fault isolation/service restoration	No
Volt/VAr regulation	Feeder level control of voltage and reactive power flow	Depends on implementation
Protection	Fault sensing, characterization, localization	No
Asset monitoring telemetry	Health and status; utilization	No
Operational effectiveness	Verification of grid device operation	No
Power quality monitoring	Waveform analysis for harmonics, unbalance, etc.	At DER locations only
Environmental monitoring	Weather data and related telemetry from the service area	Yes
Metering	Electric energy consumption metering for billing	Possible
Mobile field force support	Voice, data, and video (all bi-directional)	No
DER management	Forecast, availability, dispatch, and DER M&V	Yes

A wide variety of grid-based measurements and device data are needed to support the above-listed functions and these functions require communications in order to support automated operation. The necessary measurements include typical electrical variables (voltage, current, real and reactive power flows) but also many kinds of device data and non-operational data, such as mobile field force data, voice, and video.

Note the following points:

1. There is no guarantee that DER sensing will be located at the right places for grid operation or will sense all of the variables need for grid operations
2. Data paths for DER sensor data communications pass through potentially long latency paths not controlled by the DO, which is detrimental to high speed control on grids with some types of DER[6,7]
3. The security perimeters of the ESOs are effectively unknown, as are the ESO sensor data security measures (regulatory measures *might* address this provided the ESOs were willing to be regulated); passing security credentials across organizational boundaries complicates cyber security measures
4. There is no guarantee that only one ESO will have DER on a given distribution system, so a DO could be forced to deal with multiple ESOs and their fragmented, interpenetrated, and likely incompatible sensing and measurement systems, thus creating complex integration and security issues, and therefore costs, for the DO
5. The DO would be dependent on the ESO(s) for grid operations and reliability, but the ESOs are not subject to the same regulatory oversight as the DO presently

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[6] Masoud Farhoodnea , Azah Mohamed, Hussain Shareef , and Hadi Zayandehroodi, *Power Quality Analysis of Grid-Connected Photovoltaic Systems in Distribution Networks*, June 2015, PRZEGLĄD ELEKTROTECHNICZNY, ISSN 0033-2097, R. 89 NR 2a/2013, available online: http://pe.org.pl/articles/2013/2a/45.pdf

[7] Gopi Krishna Ari, *Dynamic Modelling of Single Phase Grid Connected Photovoltaic System*, May 2012,available online: http://digitalscholarship.unlv.edu/cgi/viewcontent.cgi?article=2532&context=thesesdissertations

6. Access to data could be used in ways that raise market power concerns
7. The DO would still need communications for other grid operations functions, even if the DO were to rely upon ESO/DER sensing and communications for some parameters
8. With greater numbers of third party DER owners, operators and aggregators becoming participants in the wholesale markets, the DO's crucial role as provider of "open access" distribution service would be challenged if not compromised if some of those parties were also providing the DO's essential operating data
9. Given the possibility of determining grid state from edge measurements, an entity that did so while participating in markets at either the wholesale of distribution levels could exercise some degree of market power not available to others.

Use of ESO/DER sensing and communications introduces several problems (longer latency, security vulnerability, integration complexity and cost, inability of the DO to assure reliability) but does not eliminate the need for the DO to have communication networks because the ESO cannot provide all of the services that need grid sensing and communications.

It has been suggested that DER with smart inverters could aid in grid control.[8] While this may be effective in performing Volt/VAr regulation, many other grid control functions would remain unaddressed (refer back to Table 1). Consequently, while DER with smart inverters may aid in grid control, they cannot replace other grid control devices such as flow control switches and sectionalizers.

Fundamentally, there are two different communications systems in the model of Figure 2, for two different types of organizations with two different sets of roles and responsibilities. The ESO has the responsibility to aggregate DER and provide services to the system operator and/or the DO. The DO has the responsibility to operate the distribution grid reliably. The organizations operate under different regulatory regimes and have differing business models and objectives. This leads to differing requirements for capabilities and performance of the sensing and communication systems.

DO grid sensing and communication networks and ESO DER communication networks exist for different reasons; ESO DER communications cannot substitute for DO grid sensing and communication networks.

[8] Masoud Farivar , Christopher R. Clarke , Steven H. Low , K. Mani Chandy, *Inverter VAR Control for Distribution Systems with Renewables*, available online: http://www.smartgridwiki.info/mediawiki/images/archive/6/64/20140706052340!Low.InverterVARControl.pdf

4.0 Final Comments

While it may seem attractive to avoid distribution utility investment in communications for grid modernization by making use of ESO DER sensing and communications, in fact not only is this problematic from a functional standpoint, it is not even possible to eliminate the need to invest in DO communications. Furthermore, it would clearly be problematic to put a core functional capability of the grid into the hands of a third party that does not accept the same level of responsibility shouldered by the utility and which may even exit the business, leaving the DO with a gap in its ability to operate the grid. Finally, whereas it is conceivably possible to address some of the points of concern listed above in order to try to reduce DO grid modernization investment, the added complexity of creating regulatory certification and oversight for third party grid data provision and managing multiple DER owners and operators within the same distribution grid will likely outweigh the benefits to ratepayers.

So if utility-operated grid sensing and communication cannot be displaced, can it be augmented by third party ESO sensing and communication? Clearly this is possible on a technical basis with the same issues as listed above (integration, security, etc.), but the likely benefit to the utility (avoiding some utility sensor installations needed to achieve a given level of observability) is not offset by the new cost to the DO to integrate the external third party data into the DO's grid operations systems. The other issues from the list above that represent risks remain as well; consequently, augmentation of grid state sensing through the use of third party ESO sensing and communication does not have a strong case.

Comparing functions to the roles and responsibilities of the respective organizations is a powerful means to resolve architecture questions without the need to perform detailed technical or economic analyses. In this case, an understanding of the assignment of functions based on roles shows very clearly why ESO DER sensing and communications, while potentially helpful to grid operations, is no substitute for DO sensing and communications.

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