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DER Integration and Control Using Existing Communication Infrastructure

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SUMMARY

Many system operators are in the process of planning or implementing DER Management Systems (DERMS). DERMS enable capabilities to assess performance, forecast, query, dispatch, configure, and coordinate DER but the system architecture and infrastructure for data acquisition and control must be developed by the system operator or aggregator. Active verification and management of DER has been outlined and discussed since the publishing of IEEE 1547-2018, but data connectivity has rarely been implemented at scale. Instead, specific telemetry solutions are implemented for large individual systems (critical systems).
In this paper, I provide an overview of existing information pipelines and assess the feasibility of simple messaging protocol for scalable interactions with customer behind-the-meter devices such as smart inverters, DER controllers, EV chargers, and thermostats. I explore this through the following three foundational capabilities necessary to orchestrate DER:

- Verify Configuration: Identify whether the settings profile of customer devices are compliant with the area network requirements.
- Dictate Operability: Set and forget configurations are forward-looking but not future-proof. System operators will benefit from the ability to adjust configurations for legacy installations as system needs evolve.
- Validate Performance: DER performance may be validated through device interrogation or periodic auditable self-reporting to receive benefits for generation or curtailment or load shedding.

KEYWORDS

DER; Distributed Energy Resources; Communications; Smart Inverter; DER Integration Control; DERMS

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A BACKGROUND

Distributed Energy Resources (DER) (i.e., generation, storage, demand response, energy efficiency) provide value to their owners through their coordination in making, moving, or using energy. As such, the integration of these resources is primarily evaluated with consideration to power flows and grid impacts. The dynamic of *system-operators* juxtaposed with *consumer DER-owners* tends to favor passive DER management techniques through configuration of set-and-forget devices. A lot of effort goes into the design and implementation of DER configuration, but what risks exist where there is no governance throughout operational life? Today these behind-the-meter assets are a small percentage of the resource pool in many distribution networks, so mis-operations or misconfigurations have minor consequences and often go undetected. As DER penetration increases and single or aggregate systems operation is more critical to network health, assurance of consistent operation or even reconfiguration will be increasingly valuable.

B PRACTICAL CONSIDERATIONS TO REALIZE CAPABILITIES

Devices in the DER space vary from smart thermostats and consumer appliances through electric vehicle charges of varying capacity to grid interactive smart inverter systems. IEEE 1547-2018 and UL 1741 SB have set a modern standard of communication *capable* smart inverters. The standards describe and test for a local interface, physical terminals and protocols to facilitate data transport to and from smart inverters. Many of the illustrations covered here are drawn from grid-interactive smart inverter systems, since they represent some of the most complicated, yet most under-represented assets in the utility operational portfolio. The telemetry concepts and principles apply to EV charging management and other controllable load.

Data Throughput

Feasibility of leveraging existing communication infrastructure by establishing a governance routine where the system operator or DER administrator routinely validates DER configuration by determining message size, and latency against bandwidth and latency limits of Power Line Carrier (PLC), Radio Frequency (RF) Mesh, LTE, private internet, and direct fiber.

Protocol Conversion and Physical Interface

Modern smart inverters may employ various protocols as local DER interface. Different protocols are used for EV chargers, for smart thermostats. As these technologies are customer-sourced and installed by various vendors, it is not practical to dictate a system compliant language. This creates challenges in determining whether to tunnel untranslated packets or where edge intelligence provides value. These options impact the overall costs of installation and operation of DER.

B.1 Physical and Data Layers

How will we transmit information between devices and Operations?

B.1.1 Medium

B.1.1.1 AMI

Next generation revenue metering includes interfaces with LAN enabling edge intelligence (capabilities to perform actions or aggregate data locally, rather than backhaul for central processing). This interface can prove valuable in governing smart device settings and validating metered performance of demand response or energy efficiency but introduces a utility challenge of *translation*. Various vendor and technology can introduce many protocol, all which require either local translation or backhaul of untranslated messages. This translation is an IT challenge that is manageable but introduces operational burdens as the vendor space and protocol evolve.

B.1.1.2 Microwave, Radio

Line of sight radio and microwave (utility wireless) channels are examples of communication channels leveraged in utility operational technology (OT). It is not uncommon to have large DR loads, distributed generation, or storage telemetry incorporated into the operational space. This practice could benefit from standardization, but is considered mature, but challenging to scale to small, less critical systems. Aligned with OT philosophy, this class of wireless solution tends to require higher reliability and real-time operational picture. These requirements are driven by DER criticality, enabling more advanced capabilities.

B.1.1.3 Internet

Modern inverters and smart appliances include Wi-Fi capability and are integrated into proprietary vendor solutions through the internet. These connections enable vendor managed telemetry and can facilitate firmware updates and configuration. This path is represented in orange in Figure 1. This is becoming especially standardized for grid-interactive smart inverters. US markets have seen vendor convergence in the smart thermostat space and will see more changes as EV charging standards mature over the next several years. This path represents the most mature and immediately accessible solution for DER coordination and management, especially on a non-real-time basis (non-critical operation).

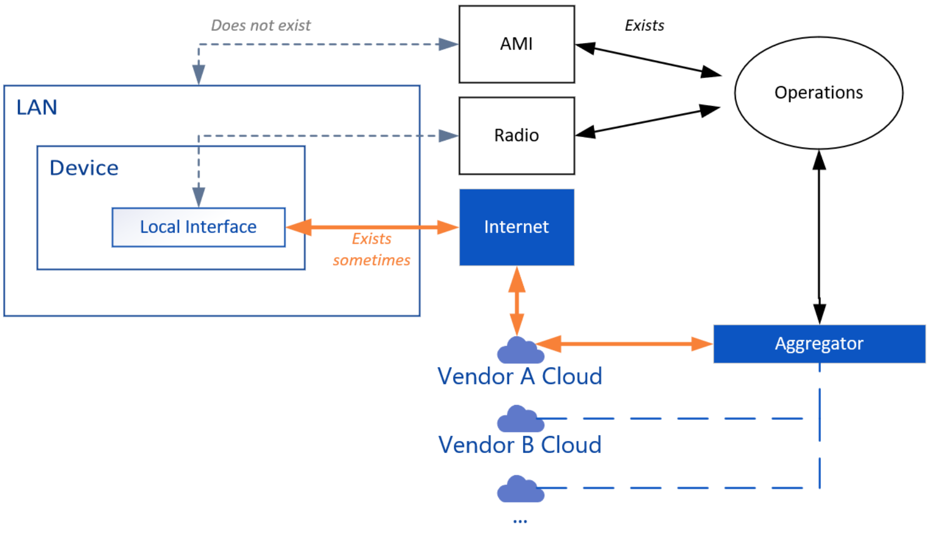

Figure 1: Communication Pathways for 3rd Party Owned & Operated OT Assets

B.1.2 Benefits of Enabling Capabilities and Risks of Passive Integration

B.1.2.1 Smart Inverter Advanced Capabilities

The following Smart Inverter data use cases were identified by electric operating companies in California as high importance through surveys published in Recommendations for Utility Communications with DER Systems with Smart Inverters (CEC & CPUC Smart Inverter Working Group, 2015). The capabilities have been paraphrased below, the recommendation report is public and provides additional use-case context. *Note: SIWG did not expect these capabilities would be realized for every DER.*

- Query or modify PCC export power rating. Notification when export rating is changed.
- Schedule changes to actual and maximum active power rating.
- Enable voltage-active power mode and adjust settings.
- Set a fixed power factor.
- Enable voltage-reactive power mode and adjust settings.
- Enable and configure frequency regulation.
- Detect when DER disconnects from Area Network.
- Detect when a microgrid leaves and re-enters area network.
- Configure settings profiles on schedules or seasonally. Ability to prioritize these profiles.
    - Schedule dynamic settings profiles which respond to local temperature.

All the high importance capabilities are described in IEEE 1547-2018 and are demonstrated in modern certified smart inverters where communication to the local DER interface is established. These capabilities and continuing integration efforts are ongoing and are a component of the strategic direction for DER integration for the state of California.

These capabilities represent a future state of deeply leveraging Distributed Energy *Resources* to meet grid needs. Modern system planning practices rarely include distributed resources in reliability, contingency, or capacity studies due to (1) limited DER penetration (2) limited ability to manage DER. Large resources **are** included in the planning as they have bigger impacts. DER configuration, telemetry, and impacts including value are levers in the planner's toolkit however, aggregations of small system are not. Recent evolutions in the United States: DERMS implementations and FERC Order 2222 will be drivers to integrate DER into the distribution system operational picture.

B.1.2.2 Smart Inverter Basic Capabilities

In every territory, grid-interactive DER are evaluated and incorporated through an interconnection process. System operators have varying levels of settings profiles from "default" to "highly tailored" smart-inverter settings. These DER are integrated largely with a "set and forget" mentality, considered active devices which will operate as dictated at commissioning throughout their fifteen to thirty-year operational life. This practice simplifies integration but makes these devices largely inflexible – presuming (a) their installed configuration is accurate and will remain accurate and (b) that there will never be any changes to the installed configuration. A 2023 audit conducted by The Australian Energy Market Operator (AEMO) found that less than 60 % of grid connected inverters were configured as dictated by system operators (AEMO, 2023). This could mean miscoordination during re-entry after an outage, failure to locally regulate voltage, or even failure to cease to energize the area system during an outage. As DER become larger participants in the grid, their flexibility, configuration, and subsequent coordination is even more critical.

B.2 Information Layer

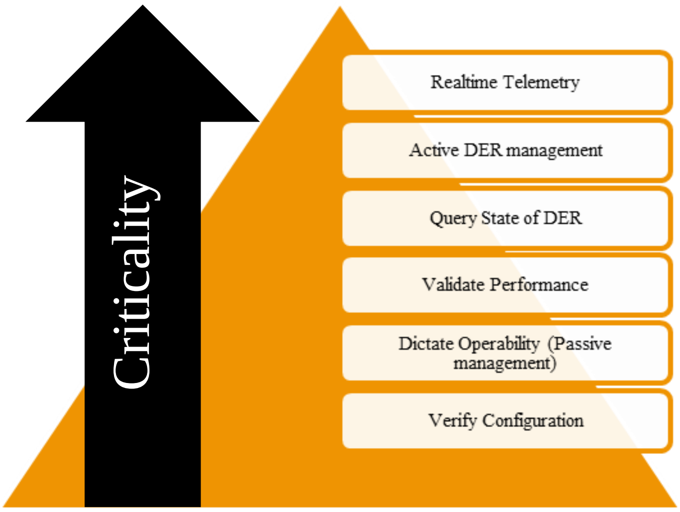

Figure 2: Capability Hierarchy. Even foundational capabilities are often not realized today.

What, fundamentally, should operations expect to achieve with established communication?

DER criticality will warrant higher levels of telemetry and control, but foundational capabilities represent a low effort opportunity for advanced system operation in DER Administration and Coordination. The following hierarchy represents an escalation in data, capabilities, complexity, and cost to implement. It should be noted that in 2023, the industry does not demonstrate any of these capabilities at scale. There is robust documentation and ongoing research covering **Realtime Telemetry**, **Active DER management,** and **Query State of DER**. These capabilities are common in DERMS requirements packages and are often implemented for large DER. Foundational Capabilities **Verify Configuration, Dictate Operability,** and **Validate Performance** are critical to next generation DER management.

B.2.1 Foundational Capabilities

B.2.1.1 Verify Configuration (read)

System operators of various regions manage the network under the assumption that DER configurations are reliable. These profiles may converge to be national or cover large multi-jurisdictional areas, but at medium voltage, where power quality may be most directly impacted by DER coordination, operators may fine tune profiles based on planning areas or other micro-divisions. The foundational capability to audit or govern these devices simple interrogation "Is this DER compatible with this region of the network?" is foundational to reliably considering DER performance in system planning, design, and operations. Without this capability, system operators will continue to plan and operate using traditional techniques.

B.2.1.2 Dictate Operability (write)

For distributed generation and storage, many operating agreements include clauses allowing the modification of settings. The system operator reserves the right to reconfigure the various set points to maintain reliable system operations. However, the process of reconfiguring <u>one</u> DER is not practical in an operational sense. Behind the meter DER are often installed and configured by third parties, leaving a significant effort to make modifications. Establishing DER communication and the capability to update the operational profile enables flexibility, allows the operator and end-user to tailor DER performance as use-case or network conditions evolve long term. 15 – 30-year life DER assets otherwise are set and left to operate as DER penetration, aggregation impacts, and coordination value increase.

B.2.1.3 Validate Performance (read)

Common metering practice for small DER is to measure net import and export at the point of common coupling. Some networks incorporate a practice of gross generation metering. The requires the installation of additional system operator owned and maintained instrumentation to measure and back-haul DER activity. Regardless, a combination of modern AMI and direct DER interface can build an incredible operational picture for DERMS. This informs DER functions at the top level, improving system wide DER insights. Operators can forecast available capacity, enforce export limits, and even measure DER performance degradation over time.

C DATA THROUGHPUT AND COMMUNICATION MEDIUM

C.1 Data for Smart Inverter Communications

The following API requests and responses are estimated based on trials using Enphase API v4 to communicate with a single residential, Wi-Fi connected system. Signal propagation will vary if alternate medium is used, but the exercise is intended to demonstrate the data simplicity of Foundational Capabilities and size them relative to known electric system operational information infrastructure (Enphase, 2023).

Table 1: Packet size and Roundtrip Time for Foundational Capabilities (per DER)

Capability	Action	Transmit	Receive	Roundtrip
Authorization	Generate OAuth2 Access / Refresh Token	310 B	2390 B	435 ms
Verify Configuration	Request and receive status (12 Parameters)	1004 B	868 B	519 ms
Dictate Operability	Transmit and verify parameters	**1004 B**	**868 B**	**519 ms**
Validate Performance	Request and receive power and daily energy total	**1004 B**	**317 B**	**486 ms**

Estimated results in bold.

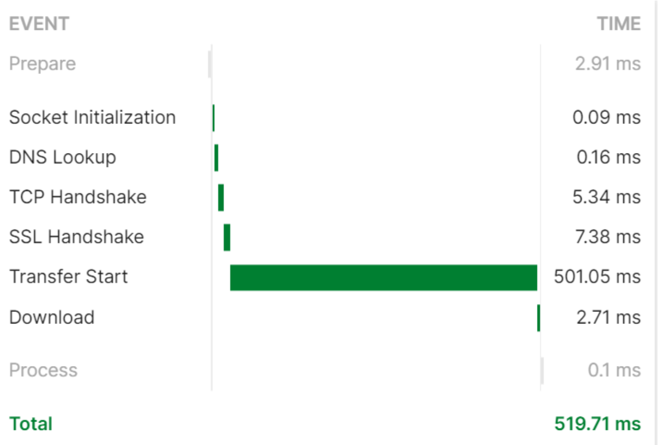

Figure 3: API Event-Time Performance for "Verify Configuration" GET Request

C.2 Communication Medium Relative Size / Throughput

Research conducted by Lawrence Livermore National Laboratory (LLNL) evaluated the change in size and throughput using mesh AMI (Huang, et al., 2022). The LLNL team estimated that a single premise AMI query is 1,200 bytes, and that including DER monitoring to that would increase the payload almost four times to 4,200 bytes. Their simulations reported an increase latency of 50 to 100 ms. Peak trial was around 300 ms. The estimations in Table 1, represent a similar payload requirement to realize Foundational Capabilities. Further, the premise Huang et al propose implements several daily readings in alignment with traditional AMI. Foundational Capabilities can be queried much less frequently where bandwidth is limited.

Table 2: Communication Medium and DER Packet Contribution

Type	Bandwidth	% bandwidth
PLC	200 Mbps	$9 \times 10^{-4}\%$
RF	200 Mbps	$9 \times 10^{-4}\%$
4G LTE	12-30 Mbps	0.16 %
Fiber	1000 Mbps	$2 \times 10^{-4}\%$

D CONCLUSIONS

The purpose of this paper is to illustrate existing pathways and propose a simple, light lift which can result in a large improvement in DER integration and management. Establishing Foundational Capabilities involves small steps and minor infrastructure investments which create value in the confident configuration and response of these grid resources. The additional awareness control and flexibility of DER will be even more important as wholesale market participation becomes more common.

System operators have been uninterested in small-scale DER information integration due to diverse behind-the-meter behavior and limited system impacts; however, these same operators are immensely concerned with conducting planning, design, and construction assessments to confirm that grid-interactive devices integrate with the electric grid. Improving the operational picture through establishing Foundational Capabilities will mature the DER and System Operator relationship. Information integration and administrative rights of customer DER should be incorporated as part of the System Operator interconnection program.

Aggregators are already emerging and represent a modular third-party approach to leveraging DER. Foundational Capabilities represent requirements when a System Operator is contracting aggregation services.

DERMS solutions are being implemented as part of the modern Advanced Distribution Management System (ADMS). Foundational Capabilities should be added to the DERMS.

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