Monitoring and Control Technologies

Resilience Investment Guide

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Resilience Investment Strategy Overview

This resilience investment guide is one of six guides that describes the costs and benefits of a range of projects that are eligible under the Grid Resilience State and Tribal Formula Grant program and the Grid Resilience Utility Industry Grant program as described in Section 40101 of the Bipartisan Infrastructure Law (BIL). These two U.S. Department of Energy (DOE) grant programs are designed to enhance electric grid resilience against extreme weather, wildfire, and other natural disasters and are intended for states; federally recognized Indian tribes, including Alaska Native Village and Regional Corporations; U.S. territories; electric grid operators; electricity storage operators; electricity generators; transmission owners or operators; distribution providers; and fuel suppliers. This specific guide provides an overview of monitoring and control technologies which can increase system visibility and control, thereby either reducing the number of customers that experience an interruption during an outage event or reducing the time it takes to restore power.

Monitoring and control technologies have both hardware and software components that can have varying degrees of sophistication. For hardware, all power systems have protective relays and breakers, which are electrical devices that detect abnormal or dangerous grid conditions and initiate the appropriate control action to protect the system. In addition to mechanical upgrades, these devices can increase in sophistication through digitization (i.e. digital relays), automation (i.e. smart reclosers) or sensing capability (i.e. early fault detection technologies) [21]. The full benefits of these devices are enabled through software, requiring foundational communications and data management systems (i.e. supervisory control and data acquisition (SCADA) systems). Deploying these devices throughout the system and using them in an optimal way increases their effectiveness but requires an enterprise software platform, such as an advanced distribution management system (ADMS) to operate [1]. For example, Fault Location, Isolation, and Service Restoration (FLISR) capability consists of grid devices (such as fault indicators and smart reclosers) and software that integrate with ADMS to quickly locate and isolate faults on the grid and automatically restore power to as many customers as possible by transferring load to another, unaffected circuit [2,4]. Additionally, Distributed Energy Resource Management Systems (DERMS) integrate with an ADMS system to monitor and control Distributed Energy Resources (DERs) and optimize dispatch based on grid needs [1,7,8]. As shown in Figure 1 below, these monitoring and control technologies are closely integrated, with ADMS serving as the backbone technology that enables successful implementation of FLISR and advanced DERMS applications.[1]

[1] First generation DERMS and its predecessor, Demand Response Management Systems (DRMS), do not require ADMS integration, but the benefits are limited by a lack of coordination with distribution system needs. Advanced DERMS applications that require ADMS integration are expected to deliver a wider range of benefits by optimizing DER dispatch based on distribution system needs that ADMS identifies and optimizes in near real-time.

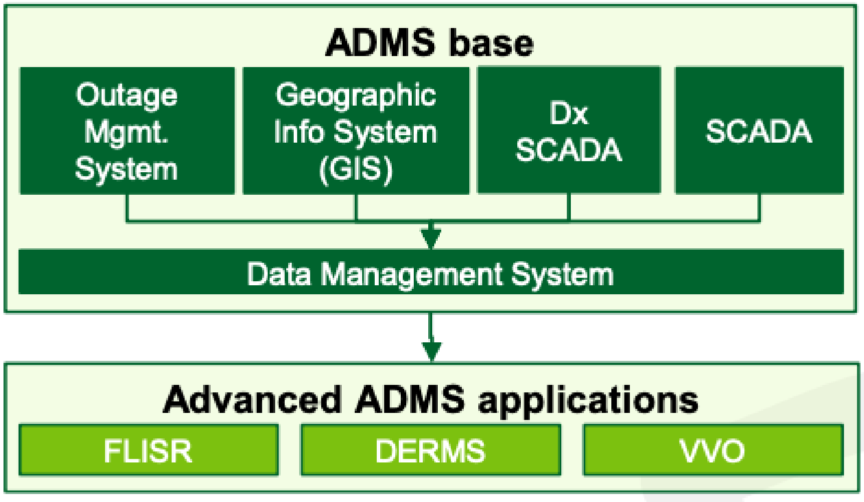

Figure 1. Advanced Distribution Management Systems (ADMS) serve as the backbone for other advanced monitoring and control technologies [17] VVO (Volt-Var optimization) is not discussed in this investment guide.

Strengthens grid reliability and resilience by:

- Preventing cascading outages
- Reducing restoration time
- Adding system reconfiguration capability
- Supporting islanded operations

Improves performance against these hazards:

- All Hazards

Advantages

Upgrading individual devices can, on their own, provide system resilience benefits. For example, the Duke Energy Florida Substation Hardening Program includes eliminating noncommunicating electromechanical and solid-state relays with digital relays and replacing oil circuit breakers with state-of-the-art breakers. These upgrades are expected to reduce transmission major event day[2] customer minutes interrupted by approximately 6 million to 8 million minutes annually (or 3.5 to 4.7 minutes reduced per customer). The two-way communicating relays are expected to reduce restoration times through increased overall system intelligence during extreme weather events [2].

[2] IEEE Standard 1366 defines Major Events as, “an event that exceeds reasonable design and/or operational limits of the electric power system” (such as during severe weather).

On the distribution system, most of the known benefits are reported from large distribution automation projects that include an overhaul of hardware and software on the system. For example, Duke Energy Florida's version of ADMS-FLISR, the Self-optimizing Grid Program, distribution automation applications such as FLISR can expect to reduce annual Customer Minutes Interrupted (CMI)[3] during major event days by over 100 minutes per customer, as shown in Table 1 [2]. Tampa Electric also expects significant reliability benefits during major storms, with its Distribution Feeder Sectionalizing and Automation program[4] expected to provide a 40% or more decrease in CMI during major event days on targeted circuits, accounting for a majority of the expected CMI benefit in its $1.6 billion Storm Protection Plan for 2022-2031. Despite only accounting for 20% of the 10-year plan's capital investment, "The Distribution Feeder Hardening" program contributes approximately 82% of the CMI benefit of the plan, mainly from feeder automation based on the historical 'grey sky' days"[5] [3]. PG&E deployed FLISR to distribution circuits serving 2.2 million customers over nearly 10 years, resulting in an estimated benefit of around $200 million annually[6] for customers on FLISR circuits [4]. Finally, EPB of Chattanooga reported a 56% reduction in the number of customers experiencing sustained outages during a major storm that occurred after completing distribution automation investments [5]. These reductions in sustained outages during major storms further enhance resilience because field crews can target restoration efforts on major faults and safety issues that involve damaged lines and, in some cases, impassable roads.

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[3] Per IEEE Standard 1366 [20], Customer Minutes Interrupted (CMI) is the aggregate number of minutes that customers experience a power interruption. For example, if 100 customers experience a power interruption for 60 minutes, CMI equals 6,000 minutes (number of customers interrupted multiplied by interruption duration in minutes).

[4] The "Distribution Feeder Sectionalizing and Automation," program includes 1) Automatic transfer of load to neighboring feeders; 2) automatic network reconfiguration to minimize the number of customers experiencing prolonged outages during both normal and extreme weather events; and 3) Reducing restoration time by isolating only those parts of the electrical system that contain faults that require assessment, investigation, follow-up and repair.

[5] Gray sky day: "An operating day or days in which a utility faces severe weather or other incident which causes reliability concerns. For example, a natural disaster that causes temporary power disruptions, but does not impact utility private ICT networks, allowing restoration and recovery to proceed as safely and quickly as possible." (citation: https://utc.org/wp-content/uploads/2018/10/Definitions_Final-Version_October-2018.pdf.)

[6] PG&E tracks avoided CMI due to FLISR for every outage event and then estimates the customer reliability benefit using its Value of Service reliability model. PG&E developed this model using estimates from an outage cost survey of residential, commercial, industrial and agricultural customers throughout its service territory. This type of analysis requires several assumptions to estimate the duration of power interruptions in the absence of FLISR, but the report does not provide details on the methodology for tracking avoided CMI due to FLISR.

Table 1. Utility monitoring and control examples

Utility	Investment Type	Period	Impact
Duke Energy Florida	Protective relays and breakers	2023-2032 estimate	Approximately 6 million to 8 million minutes annual reduction in transmission major event day customer minutes interrupted [2]
Duke Energy Florida	Self-optimizing Grid	2022 estimate	Expected to reduce total Customer Minutes Interrupted (CMI) during major event days by 179 million to 224 million minutes annually [2] Over 100 avoided CMI annually per customer [2]
Tampa Electric	Distribution Automation	2022 estimate	40% or more decrease in CMI during major event days on targeted circuits [3] Accounts for majority of expected CMI benefit in 2022-2031 Storm Protection Plan [3]
PG&E	FLISR	July 2019 through June 2020	81 million avoided CMI (37.1 avoided CMI per customer on FLISR circuits), including normal weather conditions [4] $199 million estimated customer reliability benefit ($91 per customer on FLISR circuits) [4]
EPB of Chattanooga	Distribution Automation	2012-2015	45% decrease in SAIDI [5] 56% reduction in the number of customers experiencing sustained outages during a major storm [5]

Utilities are increasingly integrating ADMS with DERMS to enable monitoring and control of customer-sited resources [6]. While DERMS is a nascent technology, utilities expect it to facilitate significantly higher penetrations of DERs with real-time monitoring, control and optimization of dispatch based on grid needs [1, 7, 8]. With higher penetrations of controllable DERs, including traditional demand response, a key advantage of DERMS will be reducing the likelihood of widespread blackouts for the bulk power system during extreme heat and cold [9]. As DERMS technology becomes more advanced and integrated with ADMS, it will deliver additional resilience benefits by optimizing DERs to meet local grid needs during major storms, further enhancing FLISR and microgrid functionality.

Disadvantages

The relatively high cost of hardware and integration required to enable the latest monitoring and control technologies is their primary disadvantage. While ADMS and DERMS are software solutions, they require widescale investments in grid sensors, systems integration, and communications infrastructure, including Advanced Metering Infrastructure (AMI) in most cases, to realize the full benefits of these technologies [10]. For DERMS, the technology is rapidly evolving [8], so utilities have pursued co-development agreements with software vendors to identify and launch novel solutions and integrations, particularly with ADMS providers [7, 11]. However, it can be risky to invest in previously untested functionality.

For FLISR, the primary disadvantage is that it increases momentary outages, given that customers experience a brief interruption while the system quickly locates and isolates faults on the grid and automatically restores power [12]. While FLISR delivers significant reductions in *sustained* interruptions during disruptive events, customers may still experience a momentary interruption (under 5 minutes for most utilities).

Finally, the digitization and automation of devices that monitor and respond to dynamic grid conditions, increases system complexity that can require difficult organizational changes and increased cyber security posture to ensure the technologies are used effectively [21].

Costs

Table 2 shows that monitoring and control technologies have a wide range of costs, primarily due to differences in the scope of what is included in each utility plan or program. For investments specifically in grid devices, sensors and fault indictors cost typically around $5,000-25,000 per device, whereas protective devices like smart reclosers are anywhere between $10,000-80,000 per unit [22 ,23, 24, 25]. For investments specifically in ADMS and/or DERMS, the total costs range from $10.7 to $20.9 per customer account over 4 to 5 years [8, 14, 15, 16, 18, 19]. These costs do not include any co-development activities that utilities may require to realize the full benefits of the technology, particularly for DERMS in its current nascent state.

Comprehensive plans that include a wide range of foundational investments in grid sensors, systems integration and communications infrastructure are higher in cost due to the scope of investments included. For example, the Grid Modernization Plan for National Grid in Massachusetts costs $336 million over three years, $280 per customer account, but it includes ADMS, FLISR, DERMS and a wide range of foundational investments [13]. The utilities that report costs specifically for ADMS or DERMS may have a similar level of investment in foundational technologies, but those costs are not available.

Table 2. Examples of monitoring and control technology costs.

Utility	Investment Type	Period	Cost[7]
Xcel Energy Minnesota	ADMS	2022-2026	$14.3 per customer account [8]
Xcel Energy Minnesota	FLISR	2022-2026	$32.4 per customer account [8]
Unitil Massachusetts	ADMS and DERMS	2026-2029	$20.9 per customer account [14]
Long Island Power Authority	ADMS	2023-2027	$19.9 per customer account (O&M costs not included) [15]
Long Island Power Authority	DERMS	2023-2027	$14.8 per customer account (O&M costs not included) [15]
Sacramento Municipal Utility District	ADMS	2017-2021	$16.4 per customer account (software vendor cost only) [16]
DTE Energy	ADMS	2021-2025	$17.4 per customer account (O&M costs not included) [18]
Consumers Energy	DERMS	2021-2025	$10.7 per customer account (O&M costs not included) [19]
Duke Energy Florida	Self-optimizing Grid	2023-2025	$206.3 per customer account (ongoing program of capital investments in grid capacity, connectivity, automation and intelligence) [2]
National Grid Massachusetts	Grid Modernization Plan	2022-2025	$280.0 per customer account (includes ADMS, FLISR, DERMS, Feeder monitors, Voltage Reduction and Optimization – CVR/VVO, communications networks, foundational IT investments and demonstration projects, including DERMS) [13]

[7] This column focuses on the total cost of technology implementation for the entire 3- to 5-year period specified. Costs are not shown on an annual basis because it is in each utility's discretion to decide how fast to implement a given technology.

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