Mitigating the Impact of Unintentional Islanding on Electric Utility Transmission Systems from Distributed Energy Resources

Distributed Energy Resources (DERs) such as grid-scale solar and wind remain one of the most important issues facing utility organizations today. Fifty percent of utility professionals surveyed by Utility Dive are expecting to see a significant increase in utility-scale solar alone over the next decade[i]. This growth will add additional sophistication and complexity to the power grid and will thus require more innovative and scalable technology to meet the demand.

Solar and other DERs introduce another element of variability and unpredictability that adds complexity to planning efforts. Events such as sustained overvoltage conditions and bidirectional power flow can result from unintentional islanding of these interconnected systems and pose a serious threat to both employee safety and grid reliability.

Traditional protection schemes such as Direct Transfer Trips (DTT) offer some relief but can become limited as new DERs are installed in more remote, decentralized areas of the grid where visibility beyond the substation can become strained. Costs to extend hard lines into these far-reaching areas can quickly become expensive for both utilities and their customers.

This white paper will review current efforts to mitigate the impact of growing DERs on transmission and distribution systems and introduce point to multipoint communications architecture as a more reliable and scalable method for monitoring and controlling grid assets.

Unintentional Islanding

Unintentional islanding of interconnected DERs can lead to overvoltage and reverse power flow in distribution and transmission systems. These conditions can create a safety hazard for line technicians and can damage utility equipment. Overvoltage occurs when there is a rapid loss of load, such as when the interconnection breaker for a DER site opens to clear a ground fault. The ground source is often at the substation, so the main breaker is tripped but the feeder can remain energized by the DER site. This can result in overvoltage that exceeds 173% on unfaulted phases.[ii]

The revised Institute of Electrical and Electronics Engineers (IEEE) 1547 Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces (IEEE Std 1547-2018) outlines specific technical and performance requirements for anti-islanding protection. The standard requires the DER site to detect the unintentional island condition, de-energize the site, and trip the interconnection breaker within two seconds of the supply feeder's main breaker tripping[ii]. The standard also allows provisions for the system operator, in this case the utility, to determine the appropriate clearing time.

Existing Anti-islanding Protection

The IEEE 1547 standard requires that DERs re-connect to the feeder only once the reclosing sequences have been completed and the fault has been cleared. Utilities normally employ a sequence of multi-shot autoreclosure duty cycles to perform this task. When a fault is detected by the protective relays or other Intelligent Electronic Devices (IEDs), the feeder breaker trips with a typical open time of 0.3 seconds for a high-speed reclose, and closes within 3.5 cycles, restoring the system within 0.417 seconds[iii]. However, the current detected by these IEDs may be low given the high impedance that DERs introduce into the system. Consequently, this mismatch can lead to a failed reclosure attempt and a lockout of the entire feeder.

Time Delay

Some utilities have tried increasing their first-shot open-time to 1 second in order to allow the interconnection breaker enough time to detect the undervoltage trip and prevent feeder lockout, but this does not necessarily prevent the islanding condition for the DER site. As a result, voltage is maintained on the system from the DER site, preventing the fault arc from being extinguished. The protective devices in these schemes are typically not set for instantaneous operation and will usually require a time delay to allow sufficient time for the arc to clear. Some experts believe that this time delay makes DERs incompatible with the existing methods of auto-reclosing sequences and should therefore only be considered as a backup for disconnecting sites.[iii]

Intelligent DTT

Direct Transfer Trip (DTT) is one of several transmission relay protection schemes that have been employed by utilities to address unintentional islanding.[iv] DTT typically consists of a point-to-point configuration that requires a communication medium between the substation and the DER site.

Traditionally, this medium has consisted of leased telephone lines, distribution level power line carriers, point-to-point fiber, or microwave radio and requires sequential control commands to be sent to multiple locations. This approach has become less desirable to utilities, especially in regard to DERs, as most are installed in remote locations that are miles away and require a costly extension of communication facilities.[iv]

As an alternative, DTT over cellular and point-to-multipoint networks can be an effective anti-islanding method. DTT over these networks can send fast trips to interconnecting breakers through a local Ethernet network, simplifying relay configuration and setup, and allowing main breaker and interconnecting breakers to be tripped simultaneously.

Communication protocols such as IEC 61850, which uses Generic-Oriented Object Substation Events (GOOSE) messaging to broadcast multiple messages from a single point, can be used to coordinate and block overcurrent operations upstream.[iv]

Advantages of Intelligent Direct Transfer Trip Schemes

Communications protocols and standards have allowed electric utilities to implement new and innovative strategies with intelligent direct transfer trip protection schemes. Significant advantages are realized in information exchange between IEDs and other anti-islanding feeder components as these IEDs become compatible with protocols such as the IEEE Standard for Electric Power Systems Communications-Distributed Network Protocol (DNP 3.0) and the International Electrotechnical Commission (IEC) 61850.[vi] IEC 61850-capable IEDs can communicate using GOOSE messages, eliminating the need to support multiple communication protocols.

DNP 3.0 is considered by many to be the de facto standard for supervisory control and data acquisition (SCADA) applications and non-proprietary, standards-based interconnectivity beyond the substation fence.[vii]

Investor-owned utilities, municipalities and electric cooperatives have been able to see benefits using intelligent DTT over cellular networks. Dominion Energy and Central Virginia Electric Cooperative have been able to add additional layers of protection into their schemes, including:[iv]

- Obtaining a private wireless network from the cellular provider, preventing unsolicited access to the network.
- Securing machine to machine (M2M) data plans for the DTT system's modems, allowing layer 3 network to transmit layer 2 GOOSE messages between IEDs.
- Establishing a virtual wire link between cellular modems of DTT systems, isolating the DTT systems from all other possible IEC 61850 systems through a unique virtual private network.

Other utilities have found additional challenges to address, such as the discontinuation of copper lines. For instance, utilities like Pacific Gas & Company (PG&E) have used DTT over cellular network in three scenarios:[viii]

1. **All Fiber**, where fiber is the common medium between PG&E's substation, the telephone company, and DERs site.
2. **Fiber/Channelized T1 using fiber-based high voltage protection (HVP)**, a hybrid configuration that uses both copper and fiber and requires DER owners to sign a liability release waiver for nuisance trips due to loss in communication.
3. **Copper/Channelized T1 using copper HVP**, a point-to-point configuration that also requires DER owners to sign a liability release waiver for nuisance trips.

Of the three options, PG&E lists the all-fiber option as the most reliable and preferred option because it involves no metallic contacts, provides very high speed, and does not require a trip for loss in communication.[viii]

Utilities have the option of using public or private networks to communicate with their field devices. Publicly available spectrum is often obtained at no cost and used to transmit signals over unlicensed, mesh architecture networks, which are susceptible to interference and high latency. But for distribution engineers, high latency can cause confusion with system critical commands while interference impacts grid reliability.

Alternatively, private networks have been deployed by several large investor-owned utilities (IOUs) to modernize their distribution automation schemes. Among these IOUs is PECO Energy, a Philadelphia energy company and subsidiary of Exelon Corp., with over 1.6 million customers in the Greater Philadelphia region.

PECO recently upgraded from their traditional point-to-point network architecture to Sensus' FlexNet®, a two-way communication network that allows signals to be transmitted using primary-licensed spectrum over a point-to-multipoint network architecture. This licensed spectrum ensures a highly-secure environment optimizing solicited and unsolicited traffic, a critical objective for PECO's more than 3,000 DA devices spread across nearly 30,000 miles of distribution infrastructure, many of which operate over proprietary frequencies near the industrial, scientific, and medical band. [ix]

A Reliable Alternative with Smart Communication Gateway and Control has Emerged

New York's Reforming the Energy Vision is one of many initiatives across the country that are driving the growth of DER sites in many utility service territories. For Kevin Post and Ryan Yakush, electric operations engineers with New York's Central Hudson Gas & Electric Corp., mitigating the impact of DERs on their transmission system required a more reliable alternative to traditional protection schemes.

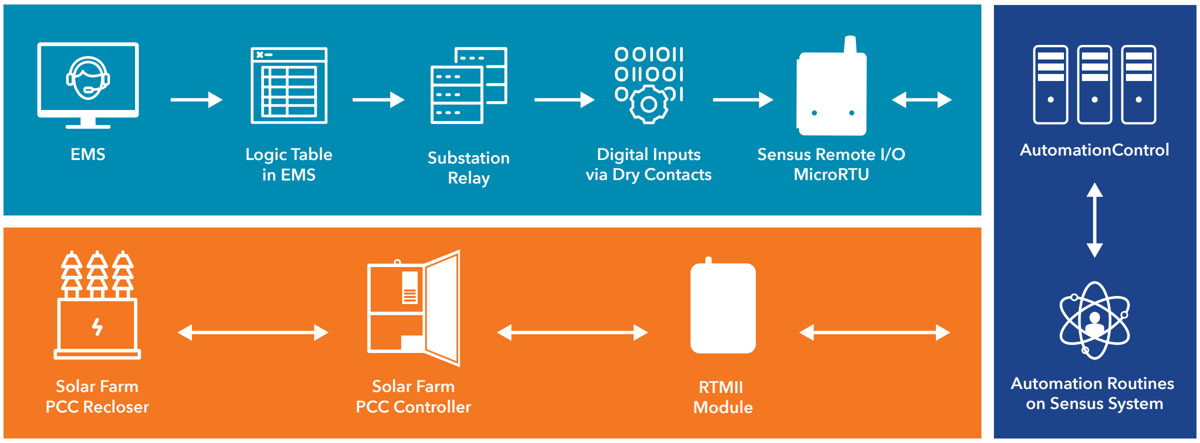
"The complexity of monitoring and tripping multiple sites and multiple breakers can get pretty intense," said Post, who mentions that as much as 125MW in commercial and residential solar has been added or proposed to their 69kV radial loop transmission system in recent years.

"Now, we have solar farms that have no load to offset the generation," explained Post. "They are clustering and that has major impacts on downstream distribution assets." Those impacts included reverse power flow and voltages exceeding 5% of nominal rating during abnormal conditions.

Conventional DTT schemes included poor quality POTS lines that would drop out and cause unnecessary tripping. In addition to poor quality, costs to install new fiber optic lines for new installations along their 60-mile transmission line could well exceed three million dollars. He and Yakush gathered a team of engineers and designers to develop a more economical, scalable and reliable alternative.

Their chosen alternative involved installing the Sensus T866 MicroRTU™ and Remote Telemetry Module™ (RTM II) in conjunction with each of their existing SEL 651R Viper reclosers for point of interconnection, AutomationControl™ software solution and a cellular network communications backbone.

Post and Yakush were able to program autonomous control operations between the substation's Supervisory Control And Data Acquisition (SCADA) system and Energy Management System (EMS) to communicate directly with the Sensus T866 through dry contacts. They designed the dry contacts to be 6-bit binary numbers that correspond to logic tables set up by fellow Central Hudson engineers. These logic expressions in turn autonomously send trip commands based on custom if-then scenarios, Control Action/Routines that were set up using the AutomationControl platform. "We wanted an extra level of protection," Post remarked.



Central Hudson's 69kV Loop Sensus DTT Configuration Schematic

- Remote DERs are disconnected based on the status of breakers in the loop that indicate an abnormal configuration. This function is performed by the Energy Management System (EMS) at the substation.
- EMS monitors those status points and sends a unique command to a central Remote Terminal Unit (RTU) in the loop, which in turn, asserts digital outputs to the Sensus T866 MicroRTU™. Using AutomationControl's Control Action/Routines, Central Hudson is able to autonomously send trip signals to the specified DER sites. It also allows for DERs to reconnect to the transmission system upon return to normal configuration.
- As an added measure of system integrity, Central Hudson engineers created a "heartbeat" function that was programmed within the system to provide alarms and disconnection of the DERs in the event of communication failures.

Post described the autonomous Control Actions/Routines in AutomationControl: "This gives us a lot of flexibility. With 32 different case potentials, each one of those can trip a variety of devices depending on where they fall in the system."

The Central Hudson team has been able to implement this scheme for over 14 megawatts of solar farm applications thus far, with more in the pipeline. Given the plug-and-play integration of Sensus products, Post and Yakush are seeking other applications, such as battery storage. "For the Sensus component, we did it in 20 mins…it's so simple. If we had to add another solar farm, I could have it done before finishing my coffee."

Conclusion

The growing adoption of Distributed Energy Resources on the power grid demands more sophisticated protection schemes to prevent permanent damage to utility assets from potential overvoltage and reverse power flow. Intelligent direct transfer trip over cellular networks offers an economical, scalable, and reliable solution, allowing utilities to upgrade and customize their transmission systems for optimal performance during abnormal events.

In addition, private networks can provide another layer of security and innovation to protective relay schemes through the use of licensed spectrum and point-to-multipoint network architectures, ensuring a safer and more reliable power grid for the future. PECO and Central Hudson are just two of several utilities that are currently leading the way toward a new age of grid modernization and helping to lay the foundation for future DER integrations.

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