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Implementation of a Power Line Carrier Solution to Support Anti-islanding Protection and Reduce Interconnection Costs for Distributed Generation

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SUMMARY

In 2014, National Grid launched its Solar Phase II program, a project created to install and operate a set of solar sites with a range of new technologies intended, among other things, to reduce barriers for integration of Distributed Generation (DG) of renewable nature. Currently, as the DG capacity keeps increasing on National Grid's territory, customers are expected to see an increase on the amount of complex distribution system upgrades derived from their integration. This is particularly true for large units that can create protection concerns, requiring system upgrades that can be lengthy and expensive. For example, National Grid currently uses a vendor's provided phone line system to support anti-islanding protection for some of its DG sites. The cost of installation and maintenance of this type of scheme has historically been considerable, suffering from reliability problems and a dependence on the local communication provider. The following paper describes the implementation of a Power Line Carrier scheme that could provide the same functionality than the existing solution at a fraction of the cost, with a faster time for deployment and superior scalability characteristics, representing an effective alternative to reduce interconnection barriers for future renewable integration.

KEYWORDS

Distributed Generation, Renewable Energy, Interconnection Costs, Anti-Islanding

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1. INTRODUCTION

In recent years National Grid has actively taken steps to stimulate the growth of renewable generation in Massachusetts. Through the implementation of several programs of renewable integration, such as Solar Phase I and II and III [1], National Grid will own, operate and test on company and customer properties, almost 30 MW of solar generation facilities using equipment with diverse characteristics. Under the umbrella of these programs, the Company is taking on a unique opportunity to test new solutions and technologies intended to remove integration barriers that could prevent future grow of renewables in its territory. Some of the principles behind National Grid's implementation of these programs are based on the following concepts:

- Deployment of solar generating sites in locations where potential benefits could be maximized
- Configuration of individual sites to minimize adverse impact and improve operational conditions
- Coordination of solar sites to improve system conditions and assets utilization
- Test of communication and control schemes to minimize or eliminate significant integration costs

Testing new technologies that could reduce interconnection costs could have a significant impact on the way that renewable integration grows in the state of Massachusetts. Currently, more and more distribution circuits are seeing their operational limits reached which is resulting into greater interconnection costs and delays for new projects. This trend is directly against the expectations of the state of Massachusetts that has set up a target for Renewables Generation capacity of up to 1.6GW by the year 2020 [2].

The following paper describes the implementation, following the principles of the programs described above, of a new solution to support anti-islanding protection functionality at a reduced cost, with a faster time of deployment and scaling flexibility.

2. EXISTING ANTI-ISLANDING SOLUTION - DTT

Following the provisions of IEEE 1547 regarding anti-islanding protection, National Grid has sepcified as part of its interconnection process that, when required, anti-islanding functionality must be provided by the interconnecting customer [3]. This requirement is normally impossed when the result of an analysis performed during the impact study phase reveals the existence of risk of islanding for the generating facility.

Since National Grid, among other things, considers risk of islanding from Distributed Generation a safety concern for its customers and workers, it has specified on the interconnection requirements that any anti-islanding solution must receive The Company's approval before implementation. As such, through time, a natural approved solution, which has been found to be the most reliable and least expensive, has been adopted and it's regularly specified for all the interconnecting entities requiring of anti-islanding protection. The solution is based on Direct Transfer Trip (DTT) functionality through a dedicated communication line between the feeding substation and the generating site. The use of this type of scheme is considered by National Grid as a definitive protection means for anti-islanding protection under what is believed to be good utility practice.

The general characteristics of the current National Grid accepted scheme for DTT implementation are:

- Point to point communication line (typically by analog phone line)
- RFL Transmitter at the station with set frequencies for Trip and Guard
- RFL Receiver at the distributed generation site with set frequencies for Trip and Guard
- Trip signal feed from the receiver into the site's recloser
- Implementation cost per project: $300,000 (utility work)
- Monthly cost per project: $700 (line lease) with an activation wait time of between 8 to 12 months (depending on the relationship between the customer and communication company)

A general diagram of this implementation can be seen in Figure 1.

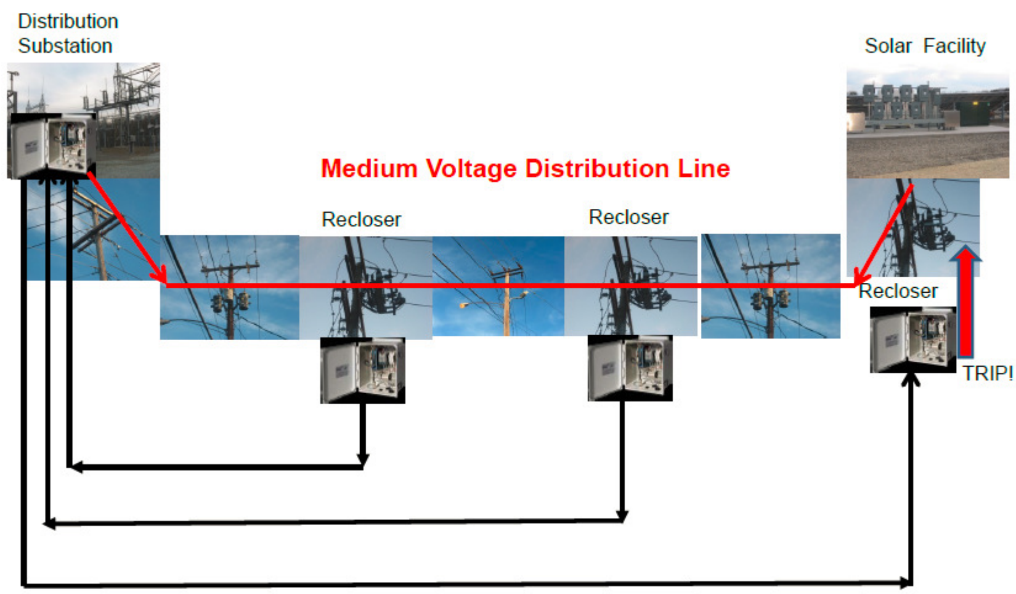

Figure 1 General diagram of existing DTT scheme (point to point communication)

This type of scheme requires for the customer to be responsible for all initial and recurring costs associated with the leased communication line for the DTT circuit. This implies a contractual relationship between the local communication company and the customer. As such, this regularly translates into scheduling and troubleshooting problems during the interconnection process and/or when technical difficulties arise. This way of reliance on a third-party entity has also posed questions regarding future operation of these systems in a scenario where the existing technology is no longer supported. Additionally, there's the need of setting up individual communication lines for each interconnecting entity, making it difficult in some instances to accommodate the required interfaces in the control house. This is a problem that is deemed to get worse as additional sites of considerable size get integrated and distribution circuits start to get saturated increasing the probability of creating islanding conditions.

3. PROPOSSED DG-TTP SOLUTION

The alternatives considered as a potential replacement for National Grid's conventional DTT solution needed to be in alignment with the principles of cost reduction, safety and reliability described earlier in this paper. As such, a relatively new product from a company called GridEdge [4] was selected for implementation and testing. The product consists of a Power Line Carrier (PLC) implementation of a transfer trip scheme as described in Figure 2.

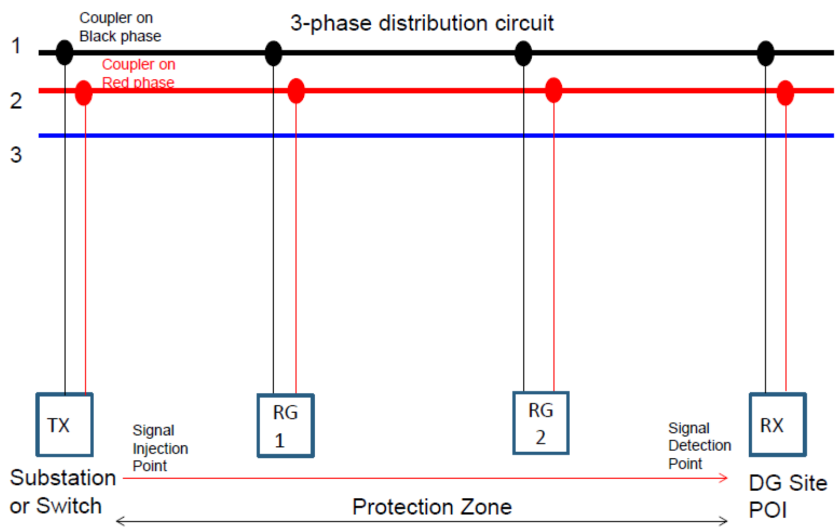

Figure 2 General diagram of the propossed DTT supporting scheme based on PLC

This solution makes use of the distribution line conductor as a communication medium to implement the anti-island functionality. In general terms, it has a similar architecture than the conventional DTT (connectivity between transmitter TX to receiver RX), using the propagation of a high frequency signal, with a special signature, through the medium voltage conductors. In this particular case, to ensure the integrity of the signal along the way, it is necessary to install regenerators (RG) in charge of reconditioning the signal to a higher power level to fight attenuation. At the receiver end, a trip signal is fed to the existing site recloser from the receiver. The protection functionality provided by this communication scheme can be summarized in Figure 3.

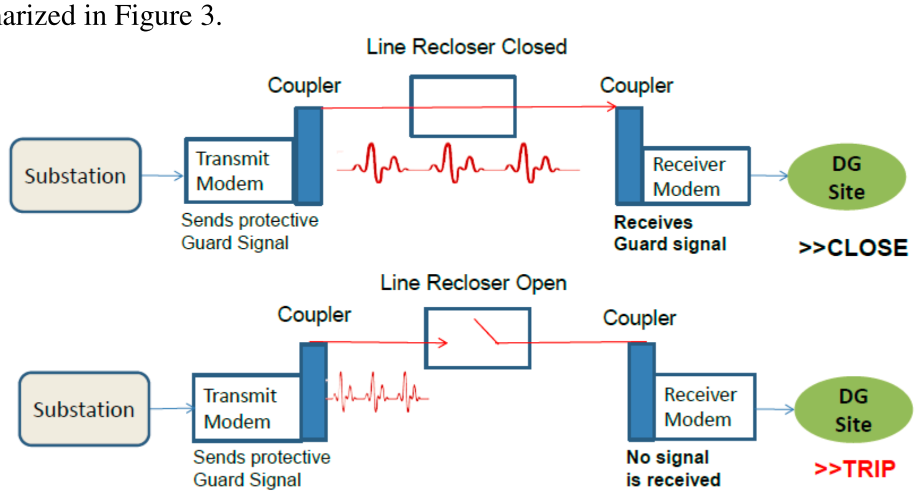

Figure 3 Functionality provided by the propossed anti-islanding supporting scheme

As shown in Figure 3, the interface between the communication port and the distribution line is provided through a coupler detailed in Figure 4.

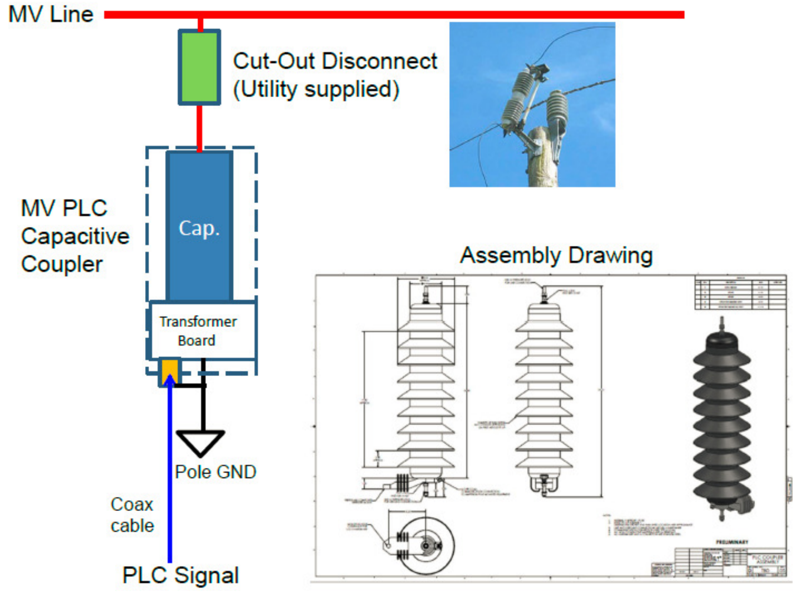

Figure 4 Interface between the communication port and the power line (Coupler)

This coupler is designed to work with a communication signal with a very low power level (0.1W) and a frequency spectrum located within the 50 kHz to 500 kHz range. Such frequency range and the use of adaptive modulation allows for a reliable operation without interference from other conventional sources in medium voltage circuits. The response and attenuation of the signal through the circuit will depend on the type of equipment used in the distribution line. Therefore, the number of regenerators used for each implementation depends on the way that the feeder is constructed. Each design will consider the worst-case scenario for signal propagation and can be modified after the fact to include additional regenerators if needed.

In general, the system provides the following advantages when compared to the conventional DTT scheme currently utilized:

- Removes the problems related to reliance on a third-party entity for construction and troubleshooting
- Simplifies construction and operation by being a one to many instead of a one to one system
- It can easily and economically be expanded to accommodate additional generating units with reduced infrastructure development (if the feeder is DTT ready the new customer will only need a receiver at the facility)
- Eliminates the monthly cost associated to the lease of the communication line which will reduce the total cost of ownership for interconnecting customers over time

Since this brings the control of the communication portion back to the hands of the utility, it is easier for companies to create investment strategies to prepare for a massive deployment. This represents an attractive proposition for utilities due to the fact that most of them regularly make money based on the amount of infrastructure they develop.

4. IMPLEMENTATION

The Solar Phase II program mentioned in the introduction, contemplates the installation, testing and operation of approximately 20 solar sites with sizes ranging from 600kW to 1MW. Since the implementation and test of this new anti-islanding solution has been considered an R&D activity for this program, the generating sites selected for this anti-islanding pilot were also part of such program. Figure 5 shows the location of the Solar Phase II selected projects where the scheme is being tested.

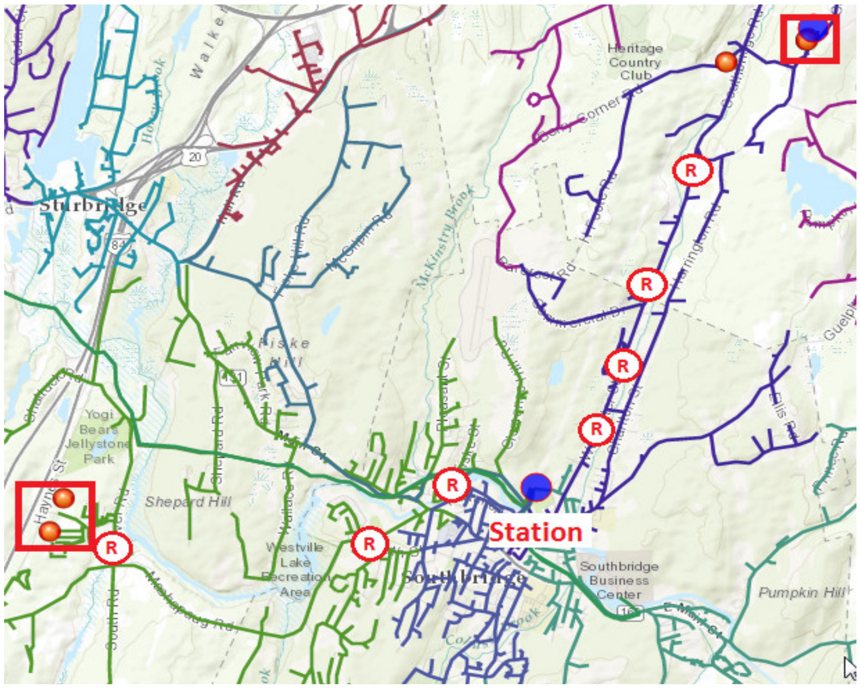

Figure 5 Location of the substation (center blue dot), the 3 solar sites (red boxes) and regenerators (R circles) selected for implementation

The figure shows three sites operated by two separate transfer trip schemes (the ones on the left are right next to each other) installed in two distribution circuits fed from the same substation. As mentioned in the previous section, the implementation of this solution depends heavily on the way that the feeders are constructed. The figure also shows the amount and locations for the regenerating units specified for the project based on the circuit layout and existing equipment.

Since the project contemplated two distribution circuits, the station work included the installation of two transmitters, one per each feeder. Initially, the idea of installing just one transmitter at the station bus to distribute the guard signal to all the feeders simultaneously was explored, however the existence of feeder regulators acting as a low pass filter for the specific frequencies, made it impossible to accomplish. As such, the implementation at the station was designed as described in Figure 6. This limitation has been addressed by the provider who is in the process of creating a solution that can reduce the amount of hardware needed at the station with existing line regulators.

Figure 7 shows pictures of the equipment installed (control cabinets for transmitters, regenerators and receivers look all very similar) at the station and on the distribution line.

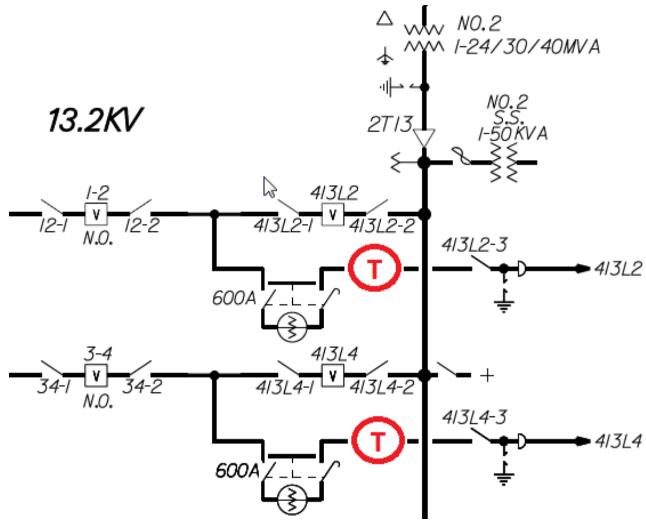

Figure 6 Placement of transmitters at the station for each distribution circuit

Figure 7 Equipment installed on the field (regenator on the left and station transmitter on the bottom right) and detail of the control cabinets (upper mid section) and coupler (upper right)

The work at the station was done by Substation O&M services while the distribution line work was done by Distribution Line Crews and PTO technicians.

The commissioning process was conducted following the procedure established by the provider with modifications required by National Grid. In general terms, the process involves the activation of each segment (regenerator to regenerator) before activating the transmitter at the station and test the transfer trip functionality with coordination between the a station crew and a site crew.

5. RESULTS

The implementation took approximately 9 months from purchase and delivery of the equipment through commissioning. This included the time required to train crews, design, scheduling and implementation of the required modifications to get the system to work. In terms of cost, the equipment per feeder including commissioning service had an approximate cost of $120,000. Design, construction and Installation costs have been estimated to be $130,000 with some cost share at the station (2 transmitters installed at once).

Once the system is running there are no recurring costs for a lease line to the customer and the operation and maintenance is handled by the utility and the vendor. Since the functionality of the system is such that allows for sharing of the signal through the distribution circuit by multiple customers, it is expected that each additional customer would only incur in a $15,000 one-time cost per receiver installation and related work (receiver installation).

Since this system is directly related to a protection scheme that could affect safety for the public and the workers, National Grid engineers have requested a period of thorough testing before considering it for general adoption. To ensure that this system is reliable and safe, it will be running for a 2-year period with an evaluation at the end of the first year.

6. SUMMARY

The implementation discussed in this paper represents an opportunity for National Grid to help reduce the cost of interconnection for Distributed Generation and therefore incentivize the adoption of Renewables in the Company’s territory.

In general, the advantages of this new system are the following:

- Removes the problems related to reliance on a third-party entity for construction and troubleshooting
- Reduces the implementation and maintenance costs (no monthly lease fee for the communication line). During the life of a generating system, it is expected to save each customer several thousand dollars in recurring costs
- Shortens implementation time which translates into increased revenue for the customer (speeds up the process to have the facility online)
- Provides a simple, faster and economic way to add new interconnecting customers requiring anti-islanding protection (all share the same signal)
- Opens a new stream of Capital Construction development for the Company

National Grid continues to diligently work towards a future where clean energy is increasingly adopted into its system. The value and experience gained by implementations like the one presented here, will continue to shape the path towards a modern and efficient grid. This is how National Grid is helping to create the future, one project at a time.

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