IEEE 1547 Unintentional Islanding Protection for Biogas Power Generation Facilities

Timothy Hedquist
Director of Standards and Development
Caterpillar, Inc.

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ABSTRACT

Distributed generation (DG) facilities need a dependable, cost-effective means of providing protective functions for the connected utility and utility customers to comply with the IEEE 1547, Standard for Interconnecting Distributed Resources with Electrical Power Systems. While this need applies to all DG providers, it is most keenly felt today by biogas to energy providers, who use large reciprocating engines to generate electric power. This paper addresses the challenging unintentional islanding protection requirements using the techniques defined under US Patent Application 12/967,688.

INTRODUCTION

The majority of distributed generation resources are small, privately owned electric power generators that are connected to a utility grid at various locations to augment utility generation capacity. Biogas power generation facilities are one example of distributed generation resources. CO_2 and methane gases are extracted from a landfill or digester, taken through a process of cleaning, drying and pressurization, and then used as fuel for a reciprocating gas engine. This engine drives an electric power generator, producing electricity that is sold to the local utility through a connection to the power grid. Biogas power generation is considered an environmentally friendly technology, since emissions resulting from the combustion of CO_2 and methane are far less detrimental than the traditional practice of releasing these gases into the atmosphere.

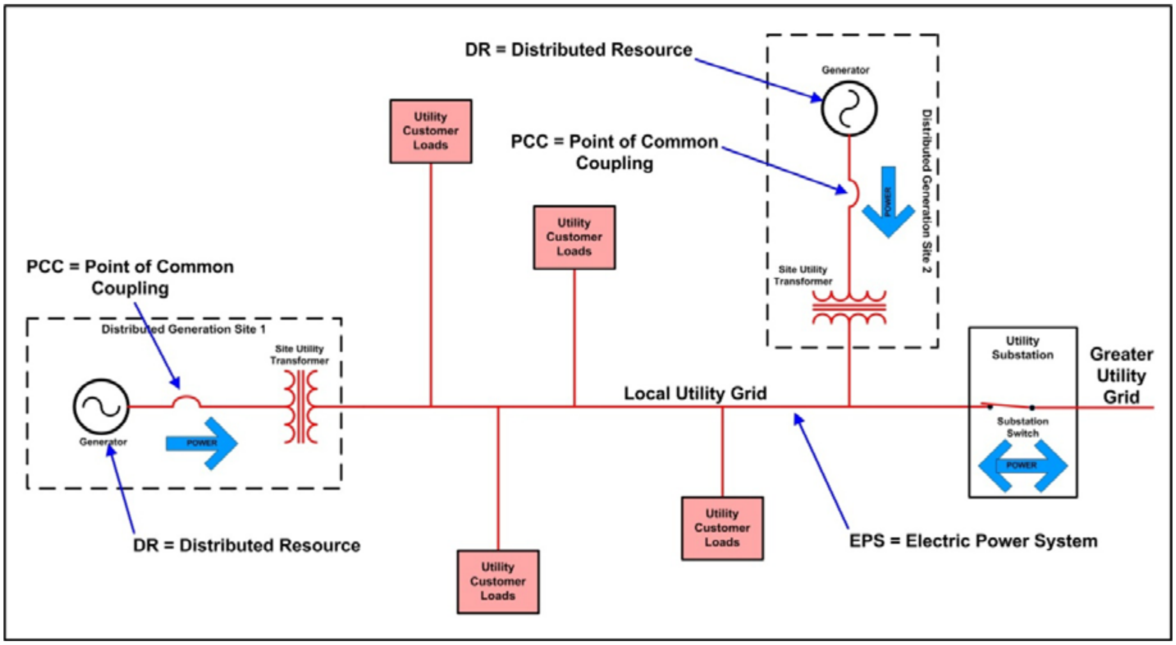
The importance of distributed generation systems is clearly recognized, but as these resources continue to make inroads into the bulk power system, guidelines are needed to stipulate how they connect to it. To this end, the Institute of Electrical and Electronic Engineers (IEEE) worked with the United States Department of Energy (DOE) to develop the IEEE 1547 standard, which provides a set of criteria and requirements in the U.S. for the interconnection of distributed generation resources into the utility power grid.

This standard was approved by the IEEE Standards Board in 2003, after which it received an American National Standards Institute (ANSI) designation. Further updates to the standard were affirmed in 2005 and 2008. By following the requirements of IEEE 1547, distributed power producers can improve the safety of their installations, minimize equipment risks, and reduce service interruptions to utility customers while interconnected to the utility power grid.

DESCRIPTION

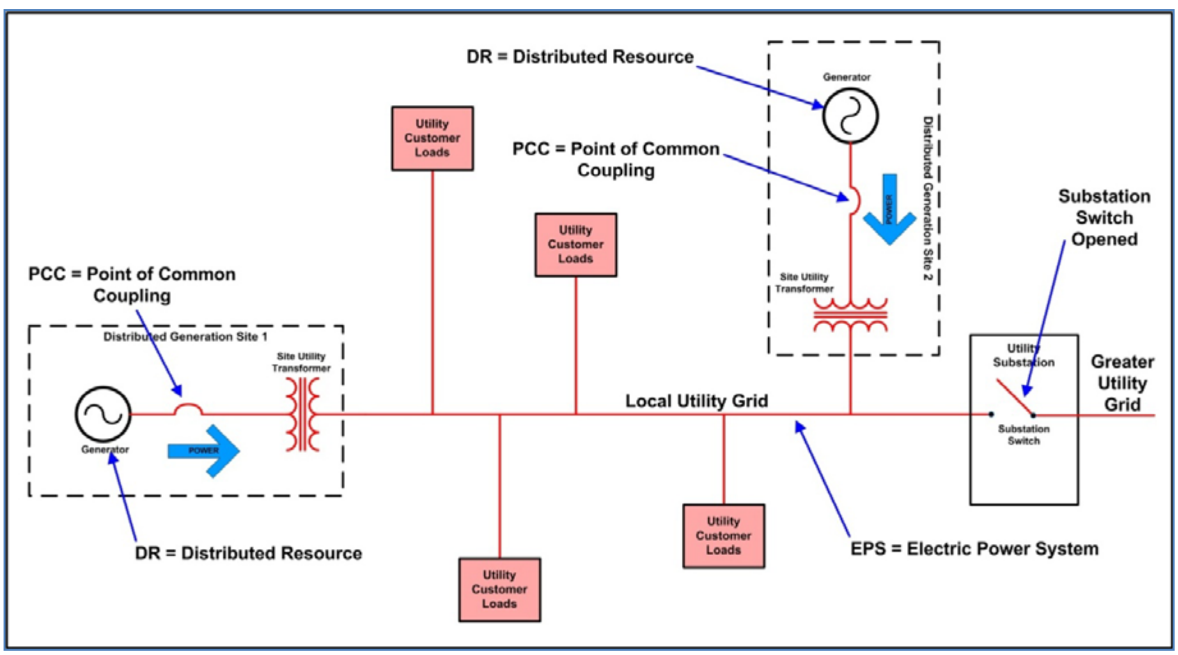
The IEEE 1547 standard covers a wide range of requirements for interconnecting distributed resources (DR) with electric power systems (EPS). By and large, compliance with most requirements can be achieved using traditional means without incurring significant additional cost, such as the protective features offered by conventional utility-grade protective relays. However, there is one IEEE 1547 requirement that could add significant cost to an installation: protection against unintentional islanding. An unintentional island is formed when distributed generation continues to energize a portion of the utility power grid that the local utility has de-energized. This paper provides a cost effective solution for the detection of an islanding condition in a biogas power generation facility.

Figure 1 – Normal Distributed Resource Operation



Under normal conditions as shown in Figure 1, distributed resources such as biogas power generation facilities are attached to the local utility grid through their respective points of common coupling (PCC), e.g. generator circuit breakers, and export power to augment utility generation capacity. Depending on the magnitude of utility customer loads, the utility may supply power to the local utility grid, or some of the power generated by the distributed resource may be exported to the greater utility grid through a utility substation.

Figure 2 – Unintentional Island

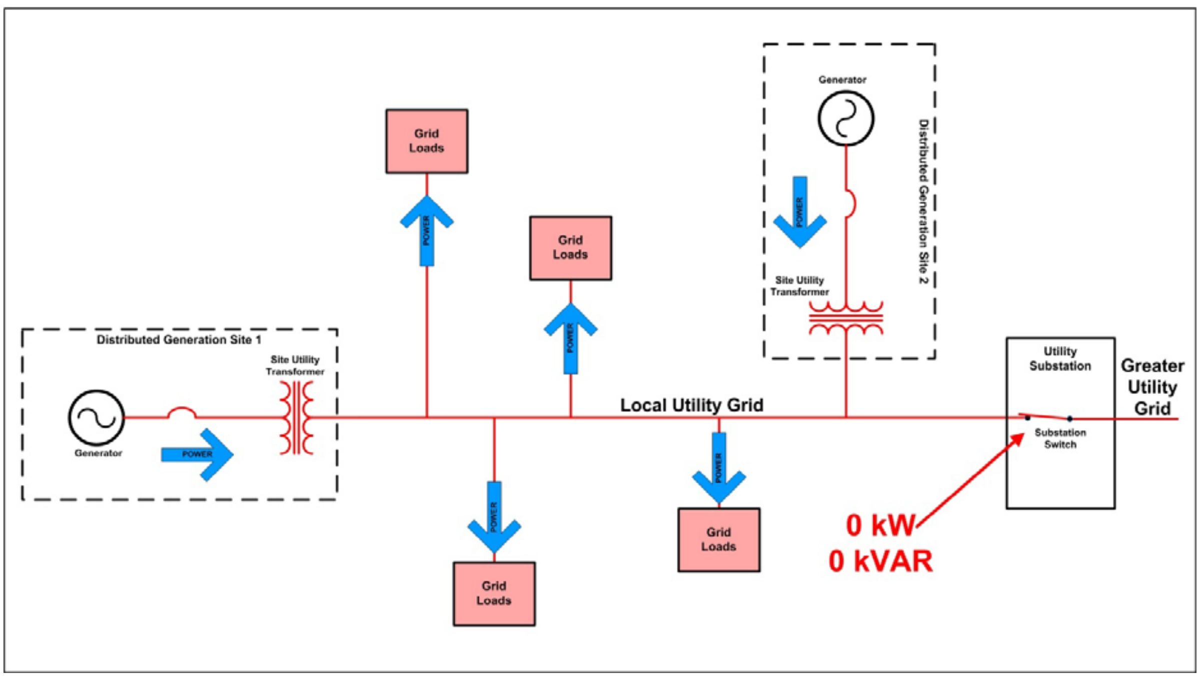


As shown in Figure 2, an unintentional island is formed when the utility substation switch is opened for reasons such as protection or maintenance, and the distributed resource continues to power the local utility grid.

Section 4.4.1 of the IEEE 1547 standard states: "For an unintentional island in which the DR energizes a portion of the Area EPS through the PCC, the DR interconnection system shall detect the island and cease to energize the Area EPS within two seconds of the formation of an island."

Under most conditions, when significant amounts of power are imported or exported through the substation switch, the detection of an unintentional island by the distributed resource is simple. In these instances, the opening of the utility substation switch will impose a step change in distributed resource kilowatt (kW) or kilovar (kVAR) output. In turn, this step change will cause a step change in distributed resource output voltage or frequency. Conventional protective means, such as over/under voltage protection (ANSI Device 27/59) or over/under frequency protection (ANSI Device 81 O/U), will trip the PCC and de-energize the area electric power system (EPS) within 2 seconds to eliminate the unintentional island.

Figure 3 – Total DR Power equals Total Utility Customer Loads



However, there is one unintentional island scenario that is very difficult to detect. This can occur when distributed resource output exactly equals the utility customer loads being served on the local utility grid. For the example shown in Figure 3, the output of the distributed resource exactly equals the power needs of the utility customers on the local utility grid.

Under the scenario depicted in Figure 3, there is no real or reactive power flow through the utility substation switch. If the utility substation switch were opened under this condition, there would be no step change in either kW or kVAR demand on the distributed resource, and the means of conventional protection would see no change in voltage or frequency. An unintentional island would be formed, and the distributed resource would not sense the unintentional island condition.

TRADITIONAL SOLUTIONS

The solutions listed below provide examples of unintentional islanding protective functions, but they do not include all available passive protection means.

Solution #1
Change in Frequency over Change in Time (ΔF/ΔT) – Early after the publication of IEEE 1547, some protective relay manufacturers attempted to meet the need for unintentional islanding protection by furnishing a ΔF/ΔT protective function. This protective function looks for small step changes in frequency over time to detect an unintentional islanding condition.

This passive protective function offers additional protection against unintentional islanding, but it cannot protect against the scenario described in Figure 3. Under the Figure 3 scenario, no step change in distributed resource frequency will be realized, and the ΔF/ΔT function will not generate a PCC trip.

Solution #2
Direct Transfer Trip (DTT) – Through this traditional means of insuring that an unintentional island is not formed, a signal is sent from the utility substation instructing the distributed resource to trip the PCC/circuit breaker. The installation and maintenance of DTT is expensive for the utility, and this expense is often transferred to the biogas power producer. With the high capital expenditures for the biogas power producers to incorporate DTT, there are instances when a negative profit picture exists, dissuading the biogas power producer from participating.

IV. ACTIVE PROTECTION FOR BIOGAS DISTRUBUTED RESOURCES
Section 8.4.3.1.5 of the IEEE 1547.2 standard states: “In some cases, reactive scheme protection can be fooled if the generator is able to carry the load of the island without a substantial change in voltage or frequency. Some inverter manufacturers have added an additional ‘active’ non-islanding compatibility.”

To better detect an islanding condition, many utilities require DTT unless an active alternative for unintentional islanding detection/protection is provided. Active islanding detection methods have been successfully applied to inverter-based DGs, but they have not been available for use in engine-driven generator set DGs until now.

In the continental U.S., there are several assumptions that impact the implementation of cost-effective IEEE 1547 unintentional islanding protection:

1. Utility frequency will vary approximately +/- 0.03 Hertz under normal operations.
2. A distributed resource is of insufficient power to impact utility frequency.
3. Due to item 2 above, the distributed resource will always be at utility frequency when in parallel with the utility source.
4. Under unintentional islanding conditions, the distributed resource can change the frequency of the EPS.
5. When a distributed resource is in parallel with a stiff utility, any attempt to change engine speed (frequency) will result only in a change in generator load, not frequency.
6. When a distributed resource is islanded, a change in engine speed will result in a change in EPS frequency.

Under these assumptions, imposing a “push-pull” on engine speed bias effectively provides an active means of detecting an unintentional island condition. For normal operating conditions when the distributed resource is in parallel with the utility source, there will be no change in frequency. In an unintentional island condition, the speed bias push-pull will cause a change in distributed resource frequency, which can be captured to drive an unintentional island trip of the distributed resource PCC/circuit breaker.

For biogas power generation sites, profitability depends upon consistent engine-generator output power. Therefore, the push-pull of engine speed bias must be gentle enough not to negatively impact power production, but strong enough to move generator frequency outside limits and trip the engine-generator circuit breaker/PCC in an unintentional island condition.

For sites in the continental US, utility frequency variance is about ± 0.03 Hertz. Therefore, an unintentional island trip point of ± 0.05 Hertz (59.95 to 60.05 Hertz) will prevent spurious trips of the distributed resource while capturing any unintentional island condition and tripping the distributed resource circuit breaker.

In addition to this protection, a ΔF/ΔT function is included to capture steps or drifts in utility frequency that would indicate an unintentional island or utility conditions outside of normal, expected operating parameters.

Figure 5 – Unintentional Island Trip

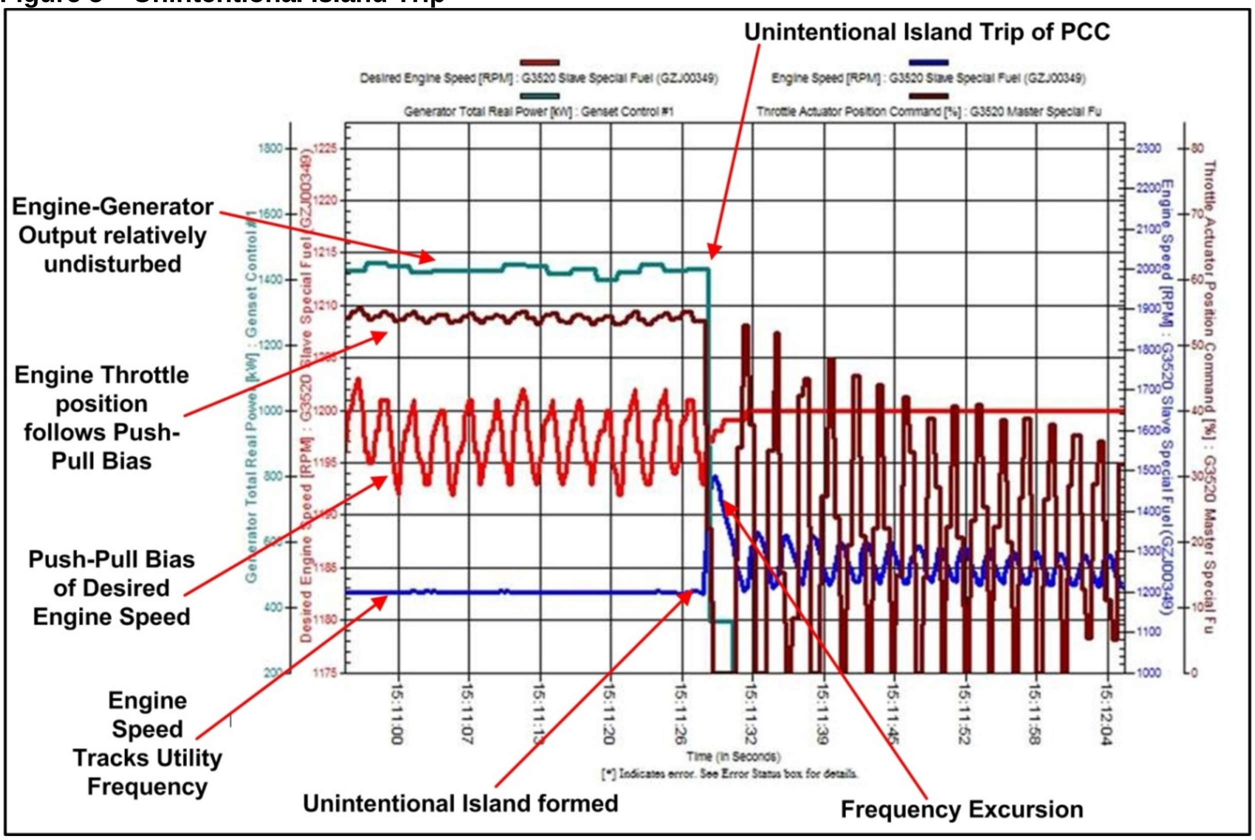


Figure 5 illustrates an actual example of an unintentional island trip recorded on Cat® ET software. The push-pull of desired engine speed causes corresponding changes to the position of the engine throttle. Under normal conditions, this causes little change to generator power output. When an unintentional island is formed, the desired engine speed push-pull causes an excursion in engine speed and therefore generator frequency. This excursion is captured by the IEEE 1547 unintentional island protective function and a trip signal is sent to the PCC/circuit breaker.

Without an active function to bias engine speed, an unintentional islanding condition could not be detected if real or reactive power is not transferred across the utility substation switch. Under File No. 333738, Project 09CA48164, United Laboratories has certified that Cat G3500 generator sets comply with the unintentional islanding protection requirements of IEEE 1547 when operating at minimum recommended load and maximum recommended load at power factors from 0.90 lagging to unity. UL compliance required the successful execution of 15 consecutive tests at various generator set loads and power factors.

IMPLEMENTATION

Due to variances in utility frequency stability and individual engine-generator dynamics, the implementation of IEEE 1547 unintentional islanding protection requires the following steps:

1. Observation of “normal” frequency variations by the local utility over time.
2. Establishment of protective function setpoints to accommodate normal utility frequency variations with enough margin to eliminate spurious PCC trips.
3. Calculation of sufficient push-pull bias for a specific engine-generator to insure PCC trip on an unintentional island condition, and minimization of operational engine-generator output variations.
4. A protection test plan that local utilities can execute to assure the functionality of the IEEE 1547 unintentional islanding protection.

SUMMARY

When used in place of DTT strategies, Cat switchgear configured for IEEE 1547 unintentional islanding protection can reduce the capital expenditure for biogas power providers. At the same time, this protection can benefit local utilities by eliminating their need to install and maintain DTT infrastructures.

To learn more from your local Cat dealer about unintentional islanding protection and other issues in power generation, visit www.catelectricpowerinfo.com/gas.

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