

Upgrading Intertie Protection to Meet Texas Public Utility Commission Rules

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Abstract: A wastewater plant in Ft. Worth, Texas, with two 5.3 MW generators on site had discrete solid state relaying on its interconnect with the local utility. The protective elements available from these relays were no longer sufficient to meet the present Texas Public Utility Commission rules. Two numeric relays were installed on the intertie circuits to provide the required protection. Negative sequence voltage polarization is being exclusively applied for line to ground fault detection at the Point of Common Coupling. Use of negative sequence polarization saved the cost of purchasing additional voltage transformers to provide zero sequence voltage polarization.

Besides providing the right protective elements, the numeric intertie relays also provide troubleshooting tools of oscillography, fault and sequence of event information for operation analysis, which was not previously available. In this application, oscillography was used to determine that a zero sequence source existed in the plant, so the ground element settings were adjusted to compensate for this source. This case history also points out differences between the Texas PUC rules and IEEE Standard 1547 "Interconnecting Distributed Resources with Electric Power Systems" plus the voltage operating requirements of some utilities who are members of the Western Electricity Coordinating Council, or WECC.

Introduction

A wastewater treatment facility in the Fort Worth, Texas, area has two 5.3 MW, 12.5 kV generators fueled by excess methane gas that supplement power to their facility distribution system. These two generators were installed in 2001 to replace older tri-fuel units. Since either one of these newer units had the capacity to supply the total facility load requirements, a contract was made to export power to the local utility. There are ties to two different utility substations about two to three 12.5 kV circuit miles from the facility. The facility operates with its tie circuit breaker open so that each generator supplies only part of the plant load (Fig 1). Protection on each intertie line was a 32 reverse power relay, a 47 negative sequence voltage relay with an under voltage 27 and over voltage 59 element, and a time overcurrent ground relay 51N, torque controlled by a 32R power relay. The 51N/32R combination functioned as a 67N directional overcurrent ground relay. In order to safely export power to the utility, safeguards had to be installed immediately. Consequently, as part of their power contract, transfer trip equipment was installed at each utility substation and at the facility site to provide fast tripping of the facility intertie circuit breakers before the utility automatically reclosed its feeder breaker in one second.

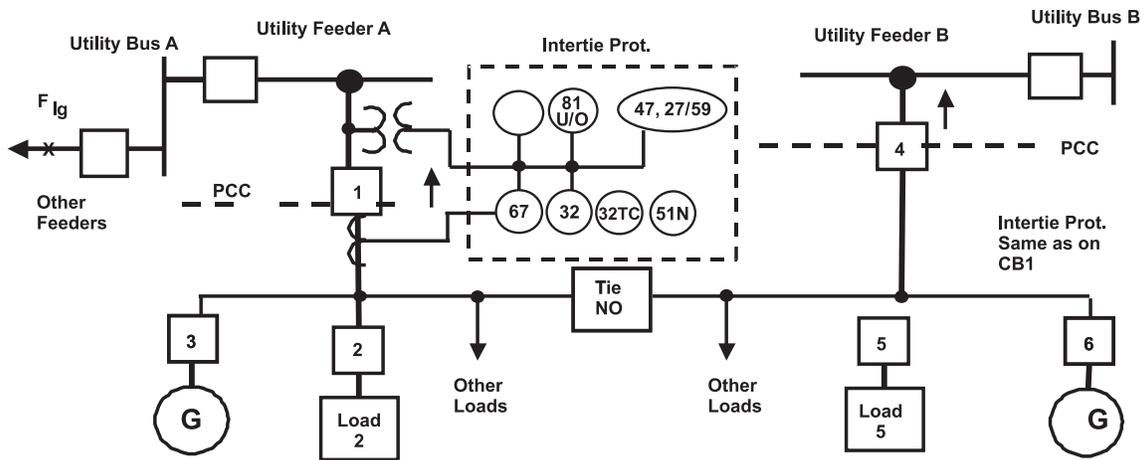


Figure 1: Facility One-Line Diagram

In 2002, when submitting its application for parallel operation with the utility, a review of the intertie relay test data was requested by the utility, as was its procedure for all Distributed Generation that operated in parallel. After the review, a request was made by the utility to change the facility's intertie protection to bring it up-to-date with Texas Public Utilities Commission, TPUC Rule 25.212 "Technical Requirements for Interconnection and Parallel Operation of On-Site Distributed Generation". In order to comply with Rule 25.212, the facility needed to add a second set of under and over voltage elements, change their over and under frequency settings, and change to a fault detecting type of directional ground overcurrent relay 67N. Their ground fault protection 67N relay needed to be set such that it cleared the facility end of the utility distribution circuit in less than the one second automatic reclosing time of the substation feeder circuit breaker.

TPUC Substantive Rule 25.212 Technical Requirements [1]

(c.1) Voltage Limits

"The customer shall provide an automatic method of disconnecting the generating equipment from the utility system if a sustained deviation in excess of +5.0% or -10% from nominal voltage persists for more than 30 seconds, or a deviation in excess of +10% or -30% from nominal voltage persists for more than 10 cycles."

This means that, on a 120 volt based secondary voltage with a band of normal service ranging from 119 to 126.5 volts, the voltage protection settings should be as shown in Figure 2:

Undervoltage: 107 volts for 30 seconds or 83 volts for 10 cycles.

Overvoltage: 132 volts for 30 seconds or 139 volts for 10 cycles.

The TPUC intertie voltage rules are different than the IEEE Standard 1547, June 2003[2] requirements, which have three different clearing times for under/over voltage conditions, as shown in Fig. 3.

Also shown in Fig. 3 is how intertie voltage protection requirements vary among three member utilities of the WECC. Since the U. S. Congress passed Federal Restructuring Legislation in 1999, individual states have the right to establish and enforce electric energy performance standards, including intertie protection standards. Some states that have established their own standards are Texas, California, and New York. Until a state approves electrical intertie standards by legislation, individual utility companies establish their own standards. As seen in Fig. 3, there are differences in those intertie voltage protection standards such as the Clearing Times on the first line of the chart. At some point in the future there will probably be a national intertie protection

standard, but getting agreement among the 50 states plus multiple utility companies in most states will be a very challenging task.

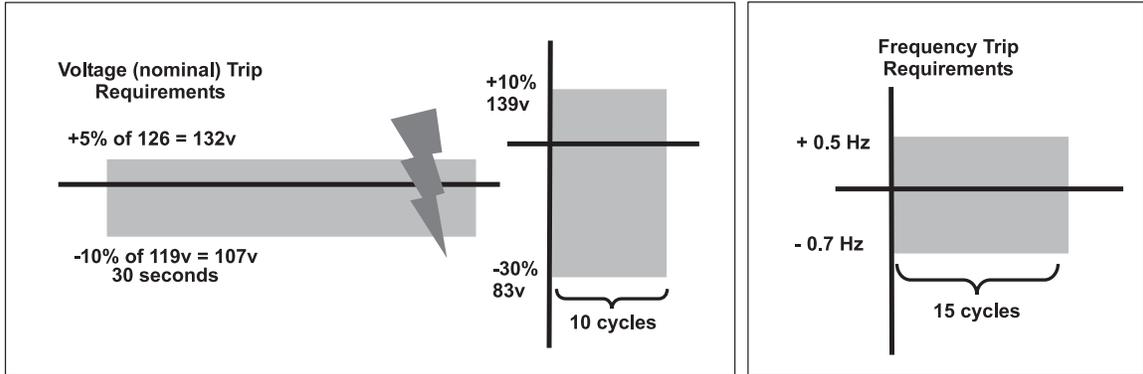


Figure 2: TPUC Substantive Rule 25.212 – Voltage Limits

IEEE Standard 1547 vs. TPUC Rule 25.212 and Other Utilities									
IEEE Std. 1547 Section 4.2.3		Texas PUC Rule 25.212.c1		Oregon IOU		Washington IOU		California Rule 21	
V in % Base	Clearing time in seconds	V in % Nom.	Clearing time in seconds	V in % Nom.	Clearing time in seconds	V in % Nom.	Clearing time in seconds	V in % Nom.	Clearing time in seconds
V < 50%	0.160	V < 70%	0.167	V < 50%	0.167	V < 80%	3.5	V < 50%	0.167
50% < V < 88%	2.000	V < 90%	30.00	V < 90%	2.00			50% < V < 88%	2
110% < V < 120%	1.000	V > 105%	30.00	V > 110%	1.00	V > 120%	0	110% < V < 137%	2/0.5
V > 120%	0.160	V > 110%	0.167	V > 120%	0.167			V > 137%	0.1

Figure 3: Inertie Voltage Protection Requirements

(c.3) Frequency Limits

“The operating frequency of the customer’s generating equipment shall not deviate more than +0.5 Hertz (Hz) or -0.7 Hz from a 60 Hz base. The customer shall automatically disconnect the generating equipment from the utility system within 15 cycles if this frequency tolerance cannot be maintained. The customer may reconnect when the utility system voltage and frequency return to normal range and the system is stabilized.”

Existing frequency relay settings need to be changed to these values.

(c.5) Fault and line clearing

“The customer shall automatically disconnect from the utility system within ten cycles if the voltage on one or more phases falls below –30% of nominal voltage on the utility system serving the customer premises. This disconnect timing also ensures that the generator is disconnected from the utility system prior to automatic reclose of breakers.”

Note that the under voltage element is the only required element for detecting phase faults not involving ground.

Directional Element Options and Selection

Power directional watt type elements are typically designed to provide their maximum operating torque when each phase current is in phase with its nominal phase to neutral voltage, i.e., C phase current operates with nominal value of C phase to neutral voltage (Fig. 4). This is sufficient to

detect power flow but not to reliably detect faults; because voltages become suppressed during fault conditions and both voltage and fault current magnitude and phase relationship will vary over the length of time of the fault. Selection of a polarizing method that does not rely exclusively on voltage from the faulted phase provides the most accurate means of detecting faults. Thus, a watt type-polarizing element is not a good element to use for polarizing of fault detection. Also, the existing 32R power relay design [3] used only one current element sensing from just one phase (Fig. 5) instead of each of the three phases. This made it dependent on utility circuit load to directionalize properly for single line to ground faults on the other two phases not monitored by the relay.

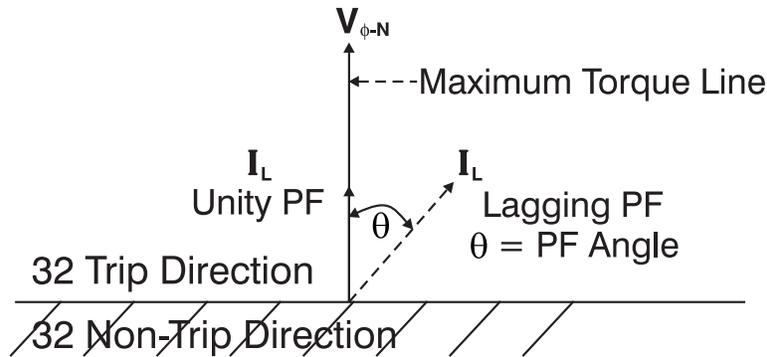


Figure 4: Single Phase Directional Power Relay Characteristic

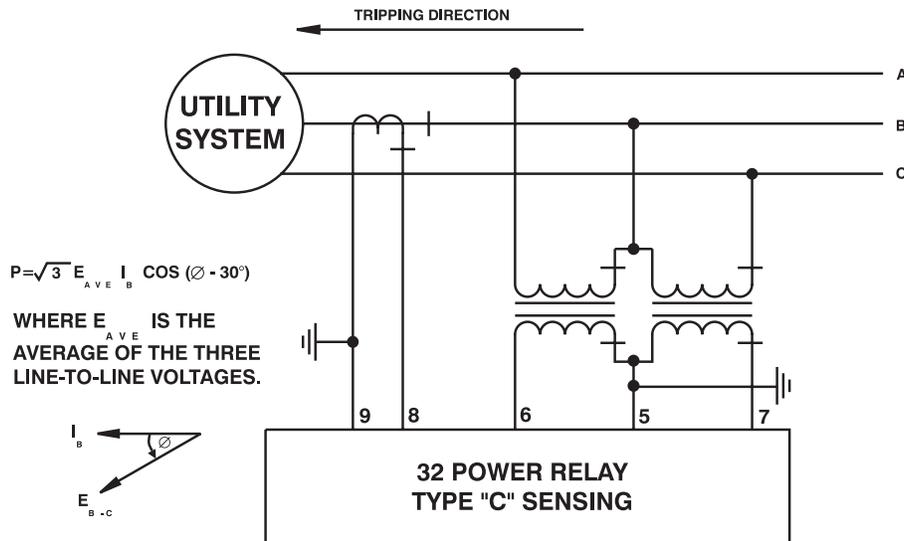


Figure 5: Existing 32R Power Relay Design

Figure 6 illustrates the traditional method of polarizing directional elements with quadrature polarization where the balanced phase load current at unity power factor leads its polarizing voltage by 90 degrees [4]. The polarizing voltage is usually selected so that two voltages are connected to the element with one of them being able to be sustained or not lowered during phase-to-phase faults. A forward direction of current is considered when the current, after being offset by the positive sequence line angle, is in phase with the polarizing voltage. As seen in Fig. 6, the area of coverage by this method is different than that of the power element.

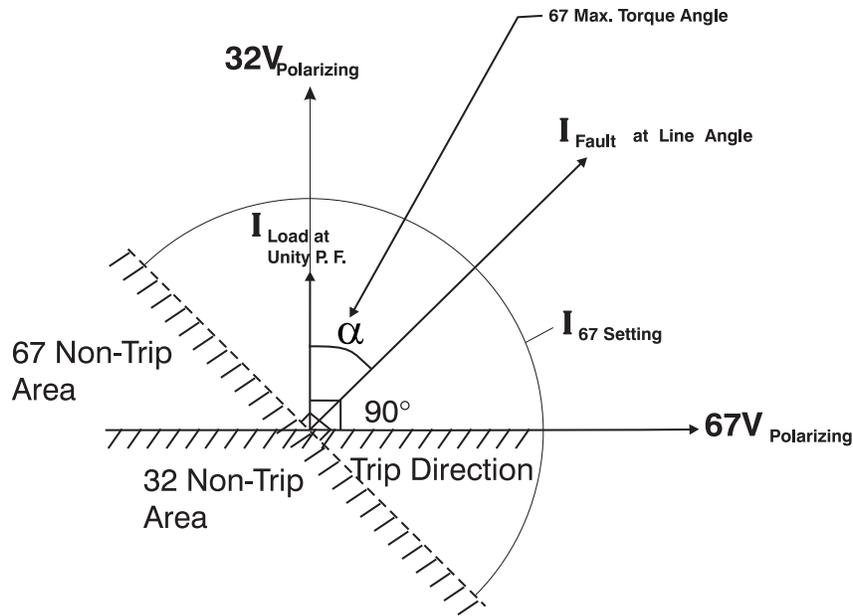


Figure 6: Power and Fault Directional Relay Characteristics

Negative sequence polarization elements compare only the negative sequence current I_2 and negative sequence voltage V_2 symmetrical component quantities for detecting unbalanced fault conditions [5]. The negative sequence quantities are present in phase to phase, phase to phase to ground and phase to ground faults or during unbalanced load conditions. The comparison is similar to that described above for quadrature polarized directional elements. The angle of comparison can be set to any value between zero and ninety degrees.

Since the existing protection relays did not give enough flexibility for additional voltage trip set points, a microprocessor based multifunction relay with two sets of voltage elements, programmable logic, oscillography and event information was desired as a replacement to provide the additional voltage elements. Also, to provide improved utility ground fault detection, the selected multifunction intertie relay has positive sequence voltage polarizing for three phase faults, negative sequence voltage polarizing for phase to phase and phase to ground faults. For faults involving ground, there are selectable polarizing combinations of zero sequence current, zero sequence voltage or negative sequence voltage. Negative sequence voltage polarizing for line to ground faults was applied which saved the facility the cost of installing two sets of phase to neutral voltage transformers to provide zero sequence voltage polarization. Current transformers were not available from the neutral of the generators to provide zero sequence current polarizing.

Compliance Action

In late 2003, the facility budgeted and purchased the numeric intertie protective relays to install on each circuit to provide the additional protective elements needed to meet Rule 25.212 as shown in Table 1. The new relays are microprocessor based with programmable logic and preprogrammed logic schemes for protective elements based on IEEE Standard 1547. The relays are packaged in a full drawout case that will fit in the same panel opening as the 51TC torque controlling element for the old ground protection scheme. The relays were commissioned in January 2004.

Table 1

	Intertie Settings	
Protective Elements	Previous relay settings	New Intertie relay settings
Negative Seq. Volts 47	12% V2, 2 seconds	
Under Voltage 27	108 volts secondary, 90 seconds	107 volts secondary 30 seconds
Under Voltage 127		83 volts 10 cycles
Over Voltage 59	132 volts 0 seconds	132 volts 30 seconds
Over Voltage 159		139 volts 10 cycles
Under Frequency 81U	58 Hz 0.5 seconds	59.3 Hz 15 cycles
Under Frequency 81U		
Over Frequency 281O	62.0 Hz 0.5 seconds	60.5 Hz 15 cycles
Over Frequency 381O		
Reverse Power 32	1800 kW primary	
Ground TOC 51N and 32 directional	51 TOC 200 amp primary, 1.2 seconds to 0.2 seconds; 32 directional 2,400 kW	
Ground directional 67N with Current or voltage polarizing per TPUC 25.212		Negative Sequence voltage polarized directional element for TOC ground fault detector set to clear faults on utility system feeder in less than one second: 200 amp Primary pickup, 0.9 to 0.2 seconds trip time

Tweaking the Settings

After the relays had been in service for a few months, the intertie relay began to trip for what was determined to be faults on feeders connected to the same bus in the utility substation. Fuses as small as 75 amperes cleared some feeder lateral faults without tripping any of the utility feeder circuit breakers.

In review of the oscillography data from the new intertie relays, load current flow was into the facility, but reversal of current on only one phase indicated that the facility was feeding ground fault current from a source inside the plant. Not shown on the facility one-line diagram was a set of wye primary, delta secondary transformers to serve motor load. This type of transformer connection is a source of zero sequence current for distribution system faults involving ground or unbalanced loads. Because of its sensitive minimum pickup current setting and the previously unidentified zero sequence current source in the facility, this 67N element was detecting the ground faults on the other feeders. After review of these conditions, it was determined that the trip time could be increased slightly without infringing on the one second automatic reclosing time of the feeder breaker. A time dial change was made and appears to be successful, at least until thunderstorms bring more distribution circuit faults.

Conclusion

The wastewater facility has since shelved the idea of exporting power back to the utility. Therefore, the multifunction relays have become the sole means of protection in lieu of transfer tripping, for the facility at its two Points of Common Coupling and for the utility by quickly separating the facility system from the utility feeder in accordance with the rules of the Texas Public Utility Commission.

References

[1] Public Utility Commission of Texas Rules – Chapter 25, “Applicable to Electric Service Providers, Division 2, Transmission and Distribution Applicable to All Electric Utilities,” December 21, 1999.

[2] IEEE Standard 1547, 2003, “IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems”, June 12, 2003.

[3] “Instruction Manual for Directional Power Relays, Rev M, 10/2003”, Basler Electric Company.

[4] “Protective Relaying Principles and Applications” Second Edition, by J. Lewis Blackburn, © 1998 by Marcel Decker.

[5] “Instruction Manual for Intertie Protection System, BE1-IPS100, Rev. C, 09/2004”, Basler Electric Company.



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