P1547.6 Minutes – Working Group Meeting Feb 2-3, 2006, Atlanta GA

Draft Recommended Practice For Interconnecting Distributed Resources With Electric Power Systems Distribution Secondary Networks

Executive Summary.

The P1547.6 initial working group resource materials were reviewed, additional writing volunteers and assignments were established, and proposed revisions to the draft outline were discussed. *(Secretary's note:* during the meeting several resource materials were identified and these are included in an "Information Resources Summary" at P1547.6 WG password protected web page http://grouper.ieee.org/groups/scc21/1547.6/private/special_topics.html).The next meeting of the P1547.6 working group was discussed and no commitment is made yet, but August 2006 was suggested.

Introductions, agenda, and IEEE introductory material.

Introductions. The attendees (**Annex A**) were welcomed by the P1547.6 Chairman J. Koepfinger who requested the attendees introduce themselves. Travis Johnson (of Georgia Power, sponsor for the meeting rooms and refreshments) made some welcoming and house keeping remarks.
Agenda. The Chairman referred to the agenda and resource materials that were posted (**Annex B**). The agenda was approved as modified with time for M. Davis to present background material (included at end of **Annex B**) he provided too late to be included in the posted agenda, and, it was decided to have everyone meet as one breakout group for this meeting.
Introductory Material. The P1547.6 Secretary T. Basso showed the information on IEEE P1547.x titles, scopes and purposes, and, IEEE meeting policy, copyright/patent policy and inappropriate topics to discuss at IEEE standards meetings, etc. IEEE and P1547.x Meeting Introductory Material at http://grouper.ieee.org/groups/scc21/1547.6/1547.6_archives.html.

Status review of past breakouts and presentation of new material.

- A summary was provided by John Bzura concerning the progress on P1547.6 outline areas 7.2.1 and 7.2.2 (**Annex C**). John also identified some background/reference materials.
- A summary was provided by Larry Gelbien on protection considerations – technical issues (**Annex D**). Discussion led to a number of proposed resolutions or approaches.
- A summary was provided by Jim Watts in regards to P1547.6 draft outline Clause 8 Issues that he compiled (**Annex E**). Jim stated these issues included those identified by a Massachusetts working group that has been addressing network considerations that we could additionally use a resource. Discussion led to some clarifications and potential approaches to address those issues.
- A summary was provided by Murray Davis on P1547.6 outline Clause 7.2.1.2.6 Secondary Grid Network Modifications for DR Interconnection (material added to end of **Annex B**). He identified approaches, including a case where a customer facility is modified to be removed from the network, and another example(s) that might not strictly meet 1547 but would be technically OK and could be accepted by agreement between the area EPS and local EPS.

A suggestion was made by the Chair (Joe) that there is a need to get to the root cause of issues/problems and to identify verified solutions/documented cases (preferably peer-reviewed and published). Further, he invited the task forces to help by providing suggestions to improve the P1547.6 draft outline. Additionally, Joe challenged the group to recommend and write (external to this standards development) new papers on networks (e.g., including new technology advances) addressing topics such as communications related to networks, protection philosophy and implementation, security philosophy and implementation, and, business and economic models. In general, Joe provided additional detailed notes for this meeting (**Annex F**).

Secretary's note. The following guidance should be considered by working group members developing P1547.6 inputs and presentations. This guidance had been sent out to the participants presenting at this meeting, and was included as the first slide by J. Watts.

Target Information For P1547.6 Document Development

Topical Heading (e.g., draft outline heading or more generic heading of your choice)

1) **statement** of the interconnection issue/concern

2) establishment of the pertinent **functional attributes of the interconnection** in relation to the issue/concern

3) **approach and implementation to resolving** the interconnection issue/concern

4) proposed **recommended practice, specification or criteria/requirement** toward satisfactorily overcoming the interconnection issue/concern

5) proposed **evaluation/test criteria** to show conformance

6) provide **figures, definitions, references, citations, test reports, etc. as bibliography/background**.

Breakout to discuss information for Clause 7.x

The full working group decided to meet as a single breakout group, led by John Bzura, with notes taken by Bob Peterson (**Annex G**). Numerous fruitful discussions ensued leading to various action items and identification of issues and concerns for P1547.6 document development by the task forces (see Annex F and Annex G).

Next Actions and Adjournment

- John Bzura presented suggestions for a revised outline (**Annex H)**. That will need to be reviewed in conjunction with additional discussions on the remainder of the outline. However, this should not detract from drafting text for the P1547.6 document.
- Those interested in conducting a mini-teleconference to work on targeted P1547.6 actions should contact Tom Basso for a teleconference number.
- John Bzura will contact the task force members for him to receive the multiple writing assignment inputs in about a month. Then, a draft of all the inputs will be compiled and circulated to the full P1547.6 work group for feedback (about two week review). After that feedback, another draft and review iteration will be undertaken prior to summer.
- See **Annex F and Annex G** for various action items and identification of issues and concerns for P1547.6 document development by the task force.
- Next meeting was suggested for early August 2006, but no commitment was made.

The Chairman, Joe Koepfinger thanked Travis Johnson for sponsoring the meeting facilities and refreshments, and thanked the attendees for their participation. The meeting adjourned at noon. Participants were invited to stay on and work in adhoc groups.

Respectfully Submitted, Joe Koepfinger and Tom Basso.

List of Annexes for Minutes

- Annex A – Attendees P1547.6 Meeting Atlanta GA; February 2-3, 2006
- Annex B – Agenda and Resource Materials for Meeting; includes onsite added material (M. Davis)
- Annex C - Status Update P1547.6 Planning Considerations Task Force: Draft outline areas: 7.2.1 & 7.2.2 (J. Bzura)
- Annex D - Presentation Materials: Protection Considerations Issues (L. Gelbien)
- Annex E - Presentation Materials: Clause 8 Issues - P1547.6 Draft Outline (J. Watts)
- Annex F – Detailed Meeting Notes (J. Koepfinger)
- Annex G – Breakout Meeting Notes (R. Peterson)
- Annex H – Proposed Draft Outline Revisions (J. Bzura)

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Annex A - Attendees
P1547.6 Meeting Atlanta GA; February 2-3, 2006

Chairman J. Koepfinger joseph_l_koepfinger@msn.com Secretary T. Basso, Thomas_Basso@nrel.gov

Chad Abbey	Mark Faulkner	Jock Moffat
Martin Baier	William Feero	David Nichols
Thomas Basso	Andris Garsils	Robert Peterson
David Beach	Larry Gelbien	Daniel Sammon
Forest Bigenho	Tom Gordon	Elisabeth Tobin
John J. Bzura	Tom Greely	Amy Vaughn
James Daley	(C.) Travis Johnson	Mohammad Vaziri
Murray Davis	Joseph Koepfinger	Tim Wall
Stephen Early	James Lemke	Reigh Walling
Mohammed Ebrahim	Scott Malinowski	James Watts
George Ello	Sam McAllister	Charles Whitaker

Annex B – Agenda and Resource Materials for Meeting

P1547.6 Meeting Atlanta GA; February 2-3, 2006

Draft Agenda Meeting Feb 2 - 3, 2006
IEEE P1547.6 Draft Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks

Atlanta GA, Georgia Power Conference Center

J. Koepfinger, Chair joseph_l_koepfinger@msn.com T. Basso, Secretary Thomas_Basso@nrel.gov

February 2, 2006 Thursday 8:00 am - 5pm

8:00 am – 8:15 am arrive/register

8:15 am – 10:00 am

- Welcome/introductions; presentation of P1547.6 and IEEE background material
- Past minutes including initial outline review
- Agenda review, organize into breakouts; approve agenda
- Status review of past breakout groups: J. Bzura/M. Vaziri (15m); and L. Gelbien (15m).
- Presentation of new material: Issues (15m) – L. Gelbien; Clause 7.1.1.2 (15m); Clause 8 (15m) J. Watts

10:15 am – 10:30 am Break

10:30 am – 11:30 am

- Breakout groups: review work and feedback; discuss follow on work

11:30 am – 12:45 pm Lunch (On own)

12:45 – 2:15 pm

- Breakout groups continued

2:15 pm – 2:30 pm Break

2:30 pm – 5 00 pm

- Reports by breakout groups
- Open discussion

February 3, Friday 8:00 am – 3 pm

8:00 am – 8:15 am arrive/register

8:15 am – 11:30 am

- Breakouts (break included)

11:30 am – 12:45 pm lunch on your own

12:45 pm – 1:15 pm

- Summary by breakout groups; future actions - next meeting: summer, Colorado Denver area.

1:15 – 3:00 pm

- Breakout groups

3:00 pm Adjourn

P1547.6 material for Feb 2-3, 2006 WG meeting

Contents

<u>IEEE P1547.6 Initial draft outline (August 5, 2005)</u>

1. Introduction

2. Scope

3. Purpose

4. Limitations

5. References

6. Definitions/Acronyms

7. Types/characteristics of network and control systems

7.1. Spot networks

7.1.1 Consideration for integration of DR into spot networks

7.1.1.1. Map 1547 requirement to networks

7.1.1.2. Planning consideration

7.1.1.3. Protection Considerations and settings – impact of DR on

7.1.1.4. Communication Considerations

7.2. Grid Networks

7.2.1. Consideration for Integration of DR into spot networks

7.2.1.1. Map 1547 requirements to networks

7.2.1.2. Planning consideration

7.2.1.3. Protection consideration – impact of DR on

7.2.1.4. Communication considerations

8. Essential issues to be addressed for interconnection of DR on networks

8.1. Spot network

8.2. Grid network

Annex A – Bibliography

Issues - L. Gelbien
Technical Issues Prohibiting Generator Interconnection on Distribution Networks

Background Discussion:
There are two major subtypes, the *secondary network* (also referred to as an area network, grid network or street network) and the *spot network.* The objective of the network distribution design is to achieve high service reliability with high power quality. To accomplish this, the primary feeders are often chosen so that they originate at different substations or, at least, different bus sections of the same substation separated with a bus-tie breaker. High power quality is achieved by designing the system to carry full load with any feeder out of service and, by rapidly removing any faulted feeder from connection to the low voltage network.

To illustrate how the operation of network service differs from radial service, the discussion concentrated on the spot network. (The major additional problem in considering street networks with interconnected DR is the complex problem of determining load flow impacts on street network operation.) In normal operation, the spot network is supplied simultaneously from all the primary feeders, by paralleling the low-voltage side of the network transformers on the spot network bus. In order that the spot network can continue to operate if a primary feeder becomes faulted, the network units are each equipped with a low-voltage circuit breaker, called the *network protector*, and a directional-power relay called the *network relay* or *master relay*.

When a primary feeder is faulted, the network relay senses reverse power flow (from the network toward the primary feeder) and opens the network protector, thereby isolating the network bus from the faulted feeder and allowing service on the network to continue without interruption. This function is the reason for the name network protector, and, the reason why DR interconnection to networks becomes a complex issue. Later, when the faulted primary feeder is repaired and returned to service, the network relay senses voltage at the transformer side of the open network protector. If this voltage is such that power will flow from the network unit to the bus when the protector is closed, the network relay commands the protector switch to close. Determining when this close will take place may become an interconnection issue.

The network relay is a very sensitive reverse-power relay, with a pickup level on the order of 1 to 2 kW. It is the mission of the reverse power relay to be capable of sensing reverse power flow with no other feeder loads than the core losses of its own network transformer.

This sensitive reverse power function means that no DR can be connected to the network with the intent to export power to the utility system. It further means that even momentary power reversals under abnormal conditions must be considered in the interconnection design.

The traditional network relay is an electromechanical device and has no intentional time delay. The typical operating time is about 0.05 seconds (3 cycles) at normal voltage levels, thus the reason that even momentary power reversals caused by the DR are of concern. Microprocessor-based network relays have replaced the electromechanical types in new network units and these relays can be retrofitted into many types of existing network units. The basic performance of the microprocessor types is similar to the electro-mechanicals, but they have more flexibility and new features.

The network protector is an air circuit breaker specifically designed for the fault current conditions encountered on low-voltage network systems. The most critical design characteristic of most all network protectors in service is that they are not intended to separate two operating electrical systems. Therefore, a DR can never be allowed to island on a network bus.

Network Interconnection Issues

Installing DR in facilities served by a spot network has a number of special application problems which do not arise in the usual radial service arrangement.

1. Exporting power from a spot network, or even serving the entire facility load from a DG, is not practical because of the reverse-power method of protection used on the network units. If DR generation exceeds the on-site load, even momentarily, power flows from the network towards the primary feeders and the network relays will open their network protectors, isolating the network from its utility supply. Minimum site loads, as for example late at night or on weekends, may severely limit the size or operating hours of a DR. Even if a DR is sized to the site's minimum load, consideration has to be given to the possibility of sudden loss of a large load, which might reverse power flow through the network units.
2. Network protectors, built in accordance with ANSI/IEEE Std. C57.12.44-1994, are not required to withstand the 180 degree out-of-phase voltages which could exist across an open switch with DR on the network, nor are they required to interrupt fault currents with higher X/R ratios than those usually encountered in low-voltage network systems. A serious failure of a network protector on a network equipped with DR demonstrated the reality of this problem.
3. The fault current delivery from synchronous DR's to external faults can cause network protectors to open, potentially isolating the network. It was noted in the presentation that it cannot be determined how induction generators will contribute to unbalanced and high impedance faults at such locations without detailed studies. Absent such studies, induction generators should be treated as if they have synchronous generation capability in selecting the appropriate interconnection response to this remote fault issue.
4. If the network protectors open, isolating the network and the DR from the utility source, the network relay may repeatedly attempt to reclose the network protector, leading to destruction of the protector and the possibility of catastrophic failure of the network unit.
5. The network relays are part of an integrated assembly in a submersible enclosure, often mounted in vaults in the street, and are not as easily modified as a typical relay control scheme.
6. If the utilities bus tie breaker is operated open, or, a second substation is used to supply the network transformers, then the possibility protector cycling exist under

light load conditions. The addition of DR to the network bus will worsen this condition. Making the determination of when and where the cycling problem might emerge is particularly difficult on street networks without the aid of sophisticated load flow simulations.

7. Increases Cable Damage:
   Time delay should not be used on the Network relay in an attempt to avoid inadvertent network protector operation. The increase time delay would permit the fault to remain on the cable for a greater period of time. This would increase utility source side cable fault propagation and additional cable damage.

8. Power Quality:
   Continuous Network relay time delay will decrease building supply power quality. Continuous time delays will result in failure to meet Computer Business Manufacturers Association (CBEMA) curve. Note a 50% drop in voltage needs to be cleared within roughly 4-5 cycles to prevent adverse impact to equipment.

9. Generator's Protection Ability to Detect Utility Line Short Circuits:
   The generator's protective relay system must be able to detect and clear before the network protector relay opens for a ground fault on the 13.8kV ungrounded side of the network distribution transformer. Note much of the NSTAR 13.8kV network source is resistively grounded. In many cases it is not possible to detect a high side phase to ground short circuit by the generator protection on the low voltage side.

10. Security/ Operational Concern:
    Utilities do not rely on customers generator protection to protect other customers or utility equipment and personnel.

11. Engineering Design Standards:
    The interconnection "must" be designed to guidelines that conform to specific standards. This is to assure the design is based on prudent utility practices needed to maintain a safe parallel generator interconnection.

12. 480 Volt Arcing Detection Design Concerns:
    Some utilities have additional protection on spot networks to increase detection of both 480 volt arcing and low magnitude phase to ground faults. This protection consists of a low pick up ground overcurrent relaying scheme and as NSTAR has plans for protector wire system. Both protection schemes simultaneously trip all network protectors. The protector wire system operates on high temperatures allowing for detection of low current magnitude arcing faults.

    The following are some of the parallel generation design concerns that may result with the use of this type of protection system:

    - Separation of two dynamic systems via network protector (Parallel generation/Utility). Separation of dynamic systems could occur anytime these two protection systems operated.

- Greater then 1.0 PU across network protector voltage during separation?

- Ability of the parallel generator protection to detect an arcing ground fault.

13. Reliability:
    Maintaining sufficient forward load flow to keep network protectors closed as the building load cycles/changes daily, monthly, etc.. The added generator load can result in the inability to keep all network protectors closed.

    Daniel G. Butterfield, PE, NSTAR Electric, Protection, 9-09-05

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- **7.1.1.2 Planning considerations (spot networks) – L. Gelbien**

Date: November 8, 2005
To: IEEE Member 1547
From: Larry Gelbien, NSTAR Electric
Subject: Planning Consideration Section 7.1.1.3 Items of Concern for Discussion

1. We need to understand where the power will flow when the generator is on or off line. Load levels itself is not sufficient to prevent network protectors from cycling. We need a planning process in addition to the control and protection (section 7.1.1.3) requirements. System impact studies and power flow studies must be performed periodically to determine how flows have changed.
2. A Planning analysis needs to be performed to determine the fault contribution on the secondary cables, crabs, limiters, collector bus, protectors, etc.
3. The DG scheme needs to be incorporated into the fire suppression system. (should this go into section 7.1.1.3)
4. The planning analysis needs to consider when a DG unit fails to operate or when a customer's load is lost by an internal circuit breaker opening in the building. (Suggest this goes into section 7.1.3 also)
5. In network areas, where installation of several DG units are being installed will a planning "queue" or study be set up so that each DG installation could be addressed on a first-come, first-serve basis? A collection of several DG units in a study area may prompt upgrades necessary for interconnection, which may have been required by the last unit coming online. Do all units share these costs, or does the last DG developer proposing the project?
6. Work rule practices must incorporate the operation of DG.
7. Secondary fires do occur. Since the secondaries are energized, Direct Transfer Trip and Supervisory Control of the generators will be necessary. What is needed for remote indication of the controls of DG units? Possibly phone lines or radio or SCADA system, PC and software, monitoring equipment, people/dispatcher, someone on call? (Does this also belong in Section 7.1.1.3)
8. We may need to have the customer automatically shed load when the unit connected to the network system trips off. What is the confidence level that customers will agree to shed load when network protectors are open and not override the protection system.

9. How do we assure that the building load will not increase or decrease without the controls being adjusted to prevent the network protectors from cycling? Who bears the financial costs associated with the changes?
10. How will a secondary network system perform when one or multiple DG units are connected to the network grid?

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- **<u>Issues for interconnection of DR on networks (J. Watts)</u>**

IEEE P1547.6, Section 8 – Essential Issues to Be Addressed for Interconnection of DR on Networks

Suggested Initial List of Issues, J. Watts, November 2, 2005

8.0 General Issues

The following sections describe issues that may occur in any type of secondary distribution network.

<u>Network Protector Design Limits</u>

<u>Issue:</u> Network protectors built in accordance with ANSI/IEEE Standard C57.12.44-2000 are not designed to withstand 180 degree out-of-phase voltages. When DG is disconnected from the distribution company's power system the DG phase angle will drift out-of-phase with the utility-side. Network protectors and relays are not designed with the intention of opening and reclosing two out-of-phase electricity sources. Additionally, network protectors are not designed to interrupt fault current with higher reactance to resistance (X/R) ratios than those usually encountered in low-voltage network systems.

<u>Discussion:</u> New design standards and enhanced interrupting capabilities for network protectors are necessary to prevent failure due to out-of-phase closing. This condition is relevant only if the DG unit remains in operation when the Company electric power system is de-energized. DG units must incorporate anti-islanding features and any DG/facility island that results must be limited to the facility EPS itself without energizing the network bus. In addition, it must include a synchronizing capability that meets the requirements of Section 5.1.2 of IEEE Std 1547.

<u>Network Protector Cycling</u>

<u>Issue:</u> If a bus tie breaker is open or if feeders from a second substation are used to supply the network, there is a possibility that protector cycling could occur under light load conditions while DG is operating. Even with the tie breaker closed, a small imbalance in transformer impedances could cause network protector cycling with the DG operating under certain light load conditions.

<u>Discussion:</u> This issue limits the amount of DG output under light load conditions. In addition, grid reliability or power quality can be adversely affected if there is network protector cycling.

<u>Network Protector Pumping</u>

<u>Issue:</u> If a network protector opens, thereby isolating the secondary network and DG from the utility primary source, the network relay may repeatedly attempt to reclose the protector. The result of network protector pumping could lead to the destruction of the network protectors, transformer(s) and ancillary equipment.

<u>Discussion:</u>

Inadvertent Opening of Network Protectors Under Fault Conditions

Issue: Fault current supplied by the DG could cause all network protectors to open for faults on the primary side of a network transformer. This opening would isolate the entire secondary network with a complete loss of supply to all customers served by the secondary network.

Discussion: The amount of potential short circuit current contribution from a DG installation must be viewed in context with the spot network to which it interconnects. In many cases, the short circuit current available from the utility system through network feeders may dwarf the potential contribution from the DG. For example, consider a spot network with three feeders (and network protectors) connected to a common bus. In the event of a fault on the primary side of the transformers, the network protector on that feeder would see the potential fault current available from the utility system through the remaining two feeders. The potential fault current from the DG would not be seen at the other two network protectors. The short circuit contribution of the DG may be significant for faults on or in the vicinity of the network bus. There are a number of solutions that may mitigate short circuit current from exceeding the breaker fault duty and the ratings of the network protectors. For example, it may be possible to apply standard current limiting fuses to disconnect a customer's generation in less than 1 cycle as a means of mitigating breaker duty stress on the low-voltage breakers. Such an application would likely require negative sequence protection of the DG. For relatively small units (<500 kW), contactors can be substituted for breakers and can be opened in less than 2 cycles.

DG Fault Current Contribution May Exceed Protection Equipment Ratings

Issue: The additional fault current contribution from DG could cause the total fault current to exceed equipment ratings. Fault current levels on network systems are typically higher than radial systems. This contribution could cause equipment failures and interruptions to other customers served by the network.

Discussion: In some systems the EPS substation equipment may already be near its maximum fault duty capability. In such cases, even a modest addition of generation on the network grid may cause aggregate fault current to exceed breaker or other device ratings. Because the network protector tripping might be delayed to give time for the generator breaker(s) to clear, the substation breaker responsible for clearing the fault will see the DG fault contribution during its clearing time. Such conditions might be resolved by the addition of current limiting reactors to the feeders supplying the network with generation. However, the impact on power quality at the network bus would have to be reassessed.

Relying On Network Protector Time Delays To Clear Primary Cable Faults

Issue: The increased fault clearing time associated with the time delay feature causes the fault to remain on the primary cable for a longer period of time.

Discussion: The preferred method of protection is to clear faults as quickly as possible in order to prevent additional damage and provide further protection to the public. Instituting an additional time delay in the protective function of network protectors will allow faults to exist for longer periods before they are cleared. This would increase utility EPS source side cable fault propagation and additional cable damage. This problem is more significant for single line to ground faults on wye-wye connected network systems.

One possible option is to use time delays on the network protector that will cause DG protection relays to operate prior to the network protector for low level faults or power flows. This option is designed to prevent network protectors from inadvertently tripping due to DG fault contribution. The size of the DG may need to be limited in order to maintain power quality. A consideration of types of faults might be appropriate.

DG's Protection Unable To Detect Distribution Line Ground Faults

Issue: The DG's protective relay system must be able to detect the fault and open prior to the network protector relay for a primary line ground fault. It may not be possible to detect all high side phase to ground short circuit by the generator protection. This problem is more significant for single line to ground faults on wye-wye connected network systems.

Discussion:

Power Quality and Network Protector Time Delay

Issue: Network protector relays with time delay could decrease building supply power quality. A 50% drop in voltage needs to be cleared within 4-5 cycles for sensitive customer-owned equipment and processes. Distribution companies strive to achieve Computer Business Manufacturers Association (CBEMA) or other criteria to avoid adverse impacts to customer-owned equipment.

Discussion:

480 Volt Arcing Detection Design Concerns

Issue: Some utilities have additional protection on spot networks to increase detection of both 480 volt arcing and low magnitude phase to ground faults. This protection consists of a low pick up ground overcurrent relaying scheme and a protector wire system. Both protection schemes simultaneously trip all network protectors. The protector wire system operates on high temperatures allowing for detection of low current magnitude arcing faults. The following concerns might result with the use of this type of protection system:

- Separation of two dynamic systems via network protector (DG/Utility EPS). Separation of dynamic systems could occur anytime these two protection systems operated.
- Greater then 1.0 PU across network protector voltage during separation?
- Ability of the DG protection to detect an arcing ground fault.

Discussion:

8.1 Spot Networks

The following sections describe particular issues with respect to spot networks.

DG Capability Exceeds Facility Load

Issue: If facility loads drop below the power output level of the DG, it will open the network protector(s) due to reverse power flow.

Discussion: The DG output must be kept significantly below the demand of the facility loads to avoid tripping the network protector(s). Some states allow interconnection to spot networks for systems that have inverters that pass UL 1741, are <10kW in capacity, and have aggregate DG capacity less than 1/15 of customer's minimum load. Inadvertent operation of network protectors under normal (non-fault) conditions is highly unlikely for these small, inverter-based DG sources.

A possible option is to time-coordinate power flows on the network protector and isolate or reduce output from the DG whenever flows across the protector drop below a specified level. A similar option is to install a load totalizer on critical load buses and isolate the DG whenever reverse power flows occur on that bus. In all cases, the size of the DG may need to be limited in order to maintain power quality.

8.2 Grid Network

The following sections describe particular issues with respect to grid networks.

Network Protector Cycling

Issue: Determining where and when light load condition network cycling may occur is particularly difficult on grid networks without the aid of sophisticated load flow simulations.

Discussion:

Self-Commutating DG Might Affect Network Bus Voltage Under Reduced Protector Conditions

Issue: Synchronous generators and invertors capable of self commutation could potentially affect voltages on the network side of the Point of Common Coupling (PCC) when the number of network feeds are reduced (such as under emergency conditions).

The issue begins with a loss of one or more network feeds to the secondary grid network bus which will act to instantaneously lower bus voltage. Even with some form of reverse power protection installed, synchronous generators or self-commutated invertors might sustain bus voltages near the PCC which could lead to current flow within the network bus sufficient to trip network protectors.

Discussion:

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Addenda (for J. Bzura by T. Basso January 22, 2006)
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Overview of network protection design and typical operating practices

(P. J. Della for P1547.6 WG 200601)

Network Systems:

Network Systems (both spot and grid) are typically comprised of the following components as illustrated in the following figures (5 & 6)

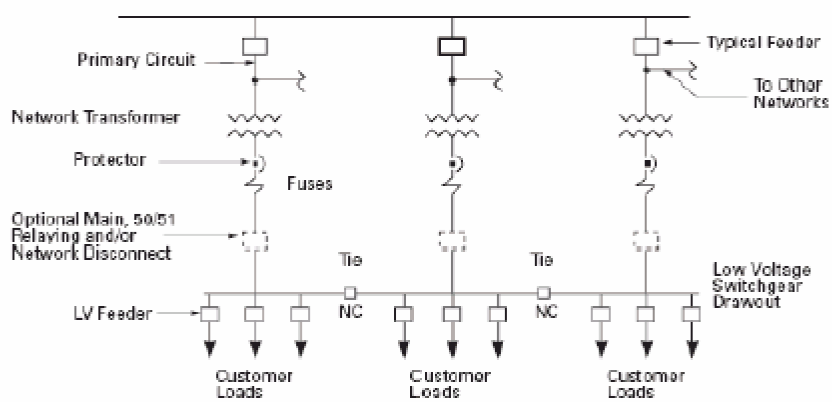

Figure 5. Spot network system

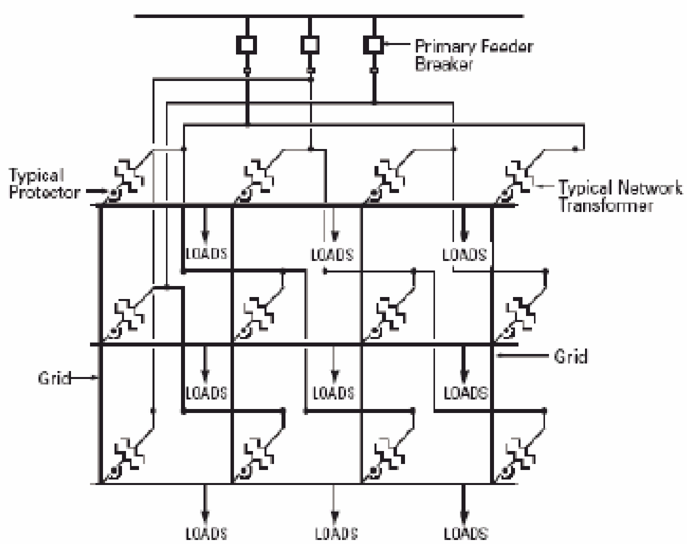

Figure 6. Secondary grid network system (one primary source shown; may have two or more)

The major components in both figures above are as follows:

1. Network Transformer
2. Network Protector
3. Primary Feeder Breaker
4. Fuses
5. Optional Relaying and/or breaker

Of the following items, the latter four are involved in the protection of the electrical system (i.e not the transformer). Typically the relays are set to trip for values of current specific to each circuit which are above the load current and at least the minimum asymmetrical fault current present on the circuit as determined by the fault current study.

Table 1. Interconnection Issues.

	Issue	Spot	Grid	Primary-Fed	Technology-Dependent	Questions to Address
1	All network transformers connected to a primary feeder are protected by the feeder's protective relays.			X		How does the DR provide this protection function for all transformers?
2	Coordination	X	X			What kind of communication is necessary between the protectors and the DR?
3	DR impact on network equipment/operation	X	X			How will the DR cause (prevent) false tripping or prevent closing of the protectors?
4	DR impact on network equipment/operation	X	X		X	Will any network equipment be overstressed because of the DR interconnection?
5	DR impact on network equipment/operation	X	X		X	What effects will the DR have on the network protector relays, and what are the new relay setting criteria?
6	DR impact on network equipment/operation	X	X			How will the presence of the DR affect the protectors' response to faults outside of their protection zones?
7	DR impact on network equipment/operation	X	X			Is the operation of a single-phase overcurrent device (protector fuse) a concern with the presence of DR?
8	DR paralleling requirements	X	X		X	(What conditions must be satisfied before paralleling is allowed?) What will be the paralleling procedure?
9	DR requirements	X	X			Will a dedicated transformer for the DR be required?
10	Network configuration	X	X			How do requirements vary with the number of network transformers?
11	Network configuration	X	X			Will requirements be different for 208-V and 480-V networks because of the different arcing characteristics?
12	Network configuration		X			Will the presence, or lack, of cable limiters on the secondary cables result in different DR interconnection requirements?
13	Network configuration		X		X	Will the presence of dozens to hundreds of network transformers spread out over a wide area result in different requirements?
14	Network configuration		X		X	Will changes in power flow over the daily or weekly load cycle result in protector cycling at a point remote from the DR's point of common connection?

	Issue	Spot	Grid	Primary-Fed	Technology-Dependent	Questions to Address
15	Network line configuration	X	X			Will different protection requirements apply to network systems supplied from three-wire and four-wire primaries? With delta-wye or wye-wye transformers?
16	Protector breakers are not designed to interrupt fault current from generators or withstand out-of-phase conditions across the open switch.	X	X	X	X	How will the protector be prevented from isolating DRs from the utility system?
17	Reverse power through network protector	X	X			What would be an acceptable ratio of the minimum customer load current over the maximum DR output to eliminate any possibility of reverse power through a protector?
18	Reverse power through network protector (Note: This is really a subset of 4.)	X	X			What action needs to be taken with a sudden loss of large load?
19	Reverse power through network protector	X	X		X	Can power swings or loss of synchronism by rotating generators cause reverse power through a network protector?
20	Unintentional islanding within the network	X	X		X	If the DR islands, how will the master relay be prevented from reclosing the protector switch during an out-of-synchronism condition?

Table 1. Interconnection Issues.

Of the issues listed in table one for interconnection issues, the issues related to network protection design, numbers 8 – 14 don't deal directly with protection of a network system. All of the remaining issues from a design perspective will have an impact on the effective operation of a network system.

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Clause 7.2.1.2.6 Advanced concepts for prevention of inadvertent network protector operation (J. J. Bzura, 508-421-7642)

Since network protectors are designed to detect reverse power flow, and trip when sufficient current flows in the reverse direction, ***advanced*** concepts for integration of DG at a building supplied by a grid network should rely upon methods to guarantee that reverse power flow never occurs. It is acknowledged that some utilities allow a small amount of reverse power flow to accommodate DR under specific circumstances.

The first concept is very straightforward: monitor building load supplied by the network, monitor the DG output, and develop a protective system (PS) to trip the DG unit off-line whenever the building load falls to a chosen level near the DG output. For example, a building with normal load of 900 kW and a DG unit supplying 250 kW in baseload operation may use a PS programmed to trip the DG unit whenever building load falls to 300 kW. A modern programmable meter or under-power relay may be used to trip a reverse power relay (#32) under normal circumstances.

The second concept would employ a combination of two technologies: (1) a custom-designed advanced reverse power relay that is capable of operating within one cycle, and (2) a fast-reaction-inverter (FRI) as the power source of the DG unit. The FRI would be capable of shutting down within a quarter-cycle (4 ms). The reverse-power relays available now appear to take several cycles before operating, which is comparable to fast network protectors, and therefore not feasible. Inverters would also need to be modified to include a quick-shutdown terminal, where an input would stop the high-frequency (well over 1 kHz) waveform generation circuits within 4 ms.

The third concept would employ a waveform envelope monitor*, applied to the incoming current sine wave, and an FRI. This monitor would detect the first sign of any abnormalities (faults, voltage sags or swells, etc) within a fraction of a cycle and send a signal to the FRI, thus shutting off power within 4 ms.

‘* Waveform monitoring technology is employed by modern high-speed UPS systems to detect an incipient outage and quickly switch over to the DC source of energy.

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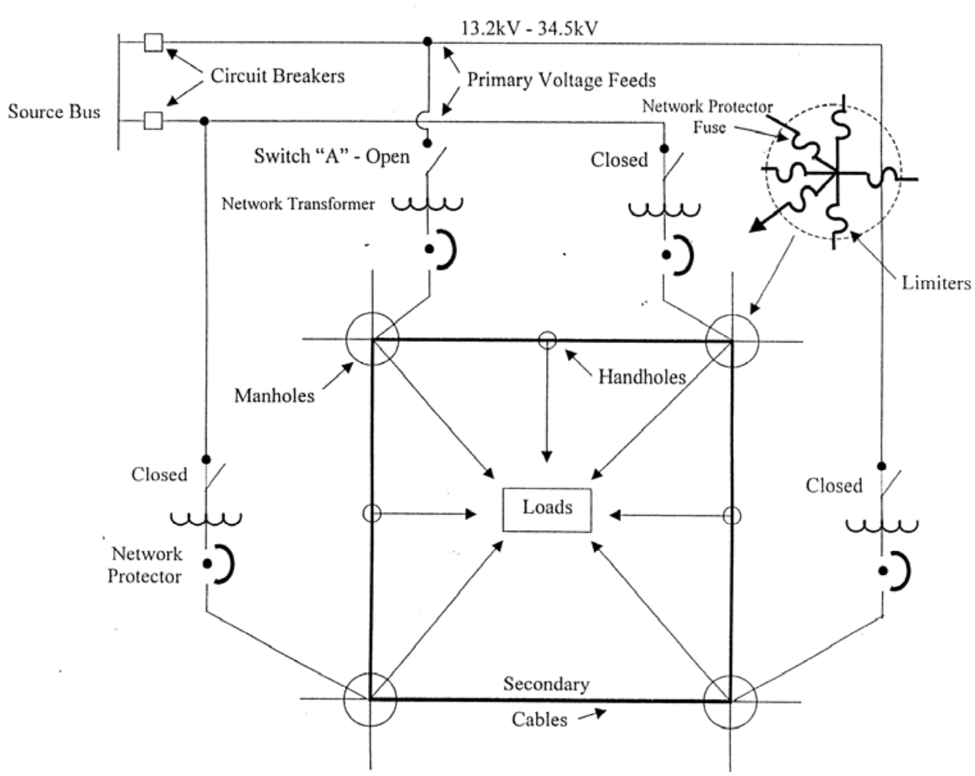
The following pages 17 – 21 were not ready in time for the draft agenda but were presented by M. Davis at the P1547.6 meeting February 2, 2006.

P1547.6 7.2.1.2.6
(a) Secondary Grid Network Modifications for DR Interconnection

Murray W. Davis Jan 30, 2006

1. It is difficult to insure that reverse power flows, through the network protectors due to the DR generation, will not cause the network protectors to open. Typically, the network protector will open for reverse current of 5% or more of the network protector rating. If all the loads and all the generation is monitored on the grid, so that the generation never exceeds the load on the secondary grid then this could be an acceptable solution.

2. A network relay can determine the difference between reverse <u>fault</u> current from DR generation and reverse <u>load</u> current. The phase angles for fault currents are generally much greater than for load currents. Also, consideration must be given to the DR units causing high voltage during light load periods.



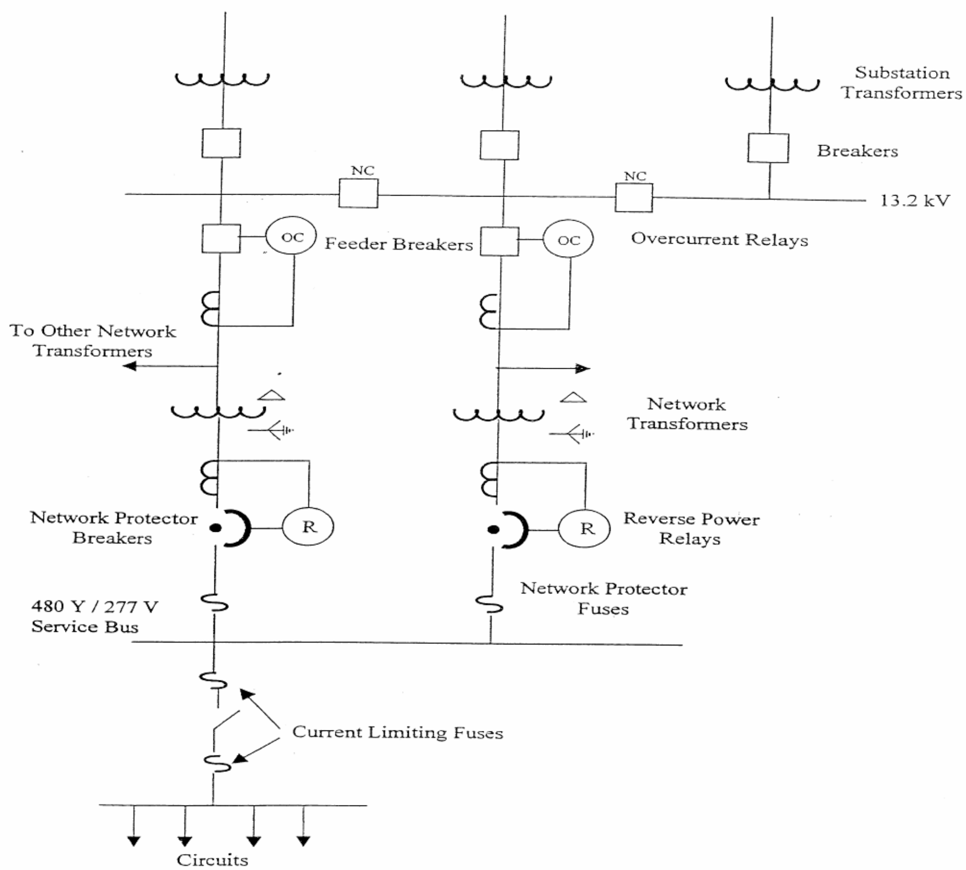
7.2.1.2.6
(b) Secondary Spot Network

What Does the Standard Say?

1. The connection of the DR's to the Area EPS is only permitted if the Area EPS network bus is already energized by more than 50% of the installed network protectors.

2. The DR output shall not cause any cycling of network protectors.

3. The network equipment loading and fault interrupting capacity shall not be exceeded with the addition of DR's.



Spot Network One - Line Diagram

(c) Secondary Spot Network Modifications for DR Interconnection

1. The reverse power relay and breaker clearing time (i.e. sense time of the protective function and opening time of the interrupting device) is about 3 to 5 cycles. Some utilities have much longer clearing times, as much as 20 cycles, which allows more time for the reverse power relay (32) of the DR to operate at the PCC and thus prevent the network protector from opening.

2. Another solution is shown in Figure 1 where a separate generator and facility load bus are created with an additional breaker at the PCC including a (32) relay function. The breaker at the PCC opens under system fault conditions while the generator continues to serve the facility load. It should be noted that if three network protectors are serving load, two must be in service to meet more than the 50% criteria. The concern of the 50% rule above is the reduced reliability of the network if there is 50% or less of the network protectors remaining (considering protectors out of service for maintenance).

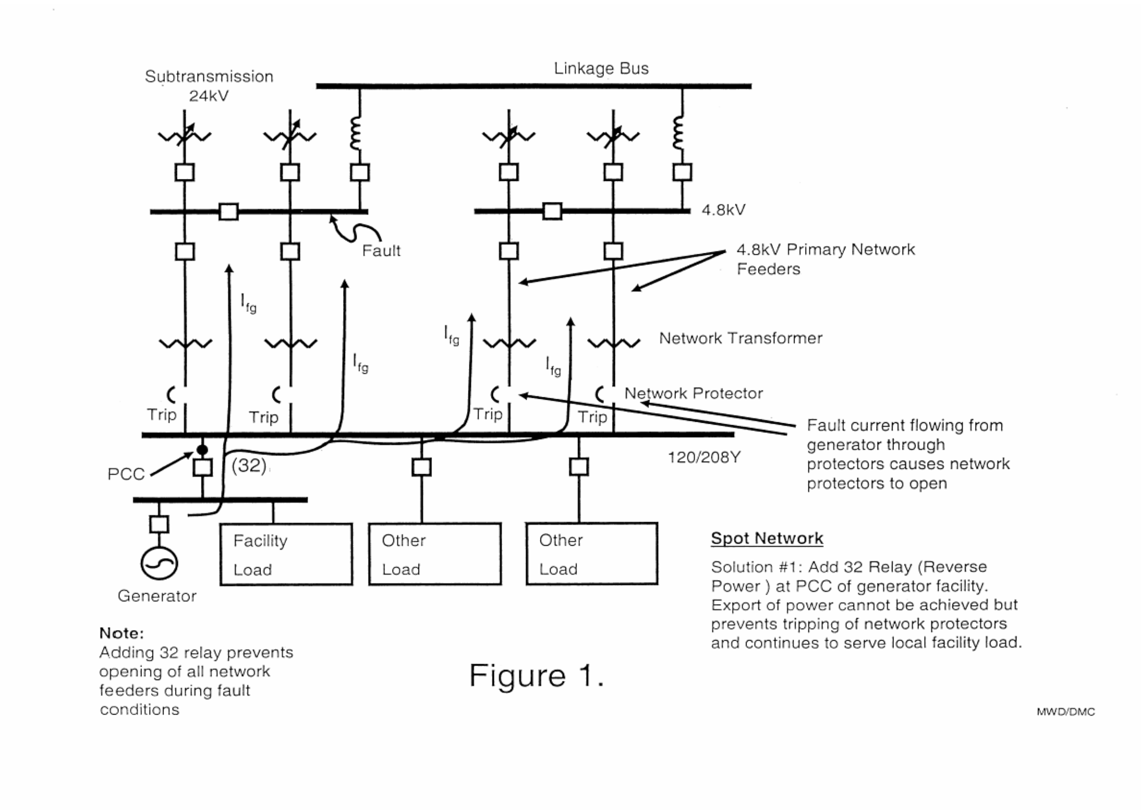
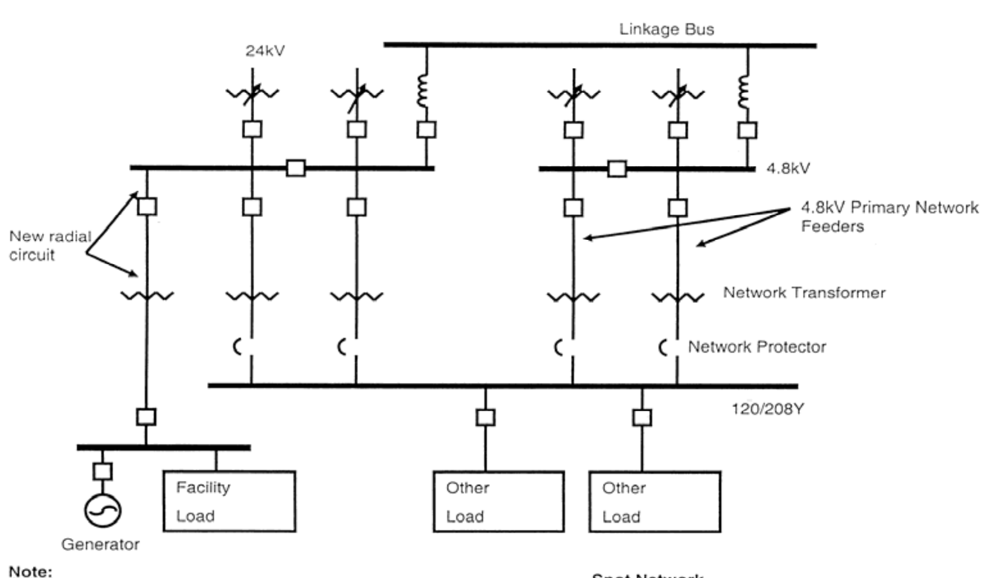


Figure 1.

3. Another solution for installation of DR's is shown in Figure 2. Here a new radial circuit serves the DR and facility load which allows for exporting power and alleviates the reverse power issue of directly connecting to the spot network.



4. Another solution is given in Figure 3, where the network protector relays sense the reverse current under fault conditions and initiate a generator trip. Separate contacts are used in each reverse current relay to close and pick up the generator trip coil.

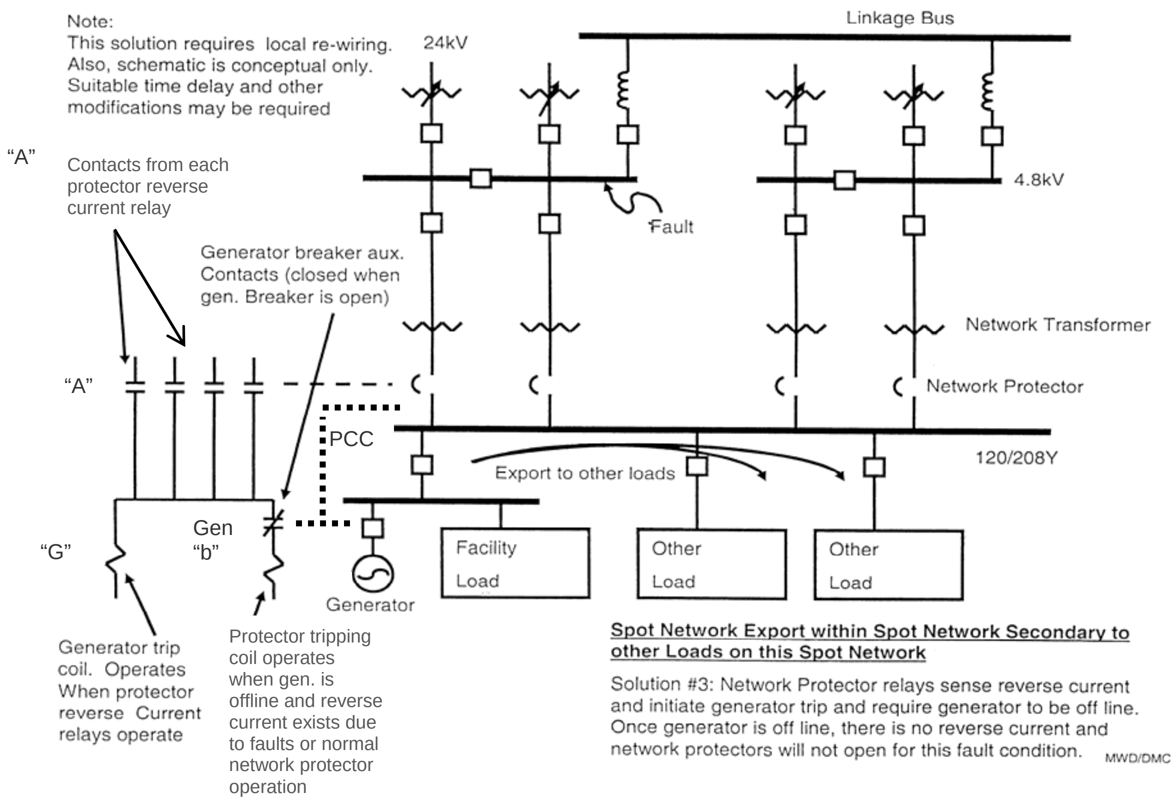


Figure 3.

If the generator causes reverse power through the network protector under normal load conditions the reverse power relay (32) of the network protector causes one or more of the "A" contacts to close and trip the generator via "G" trip coil. If the reverse power condition is eliminated by tripping the generator breaker then there is no reverse power through the network protectors and same remain closed, thus avoiding a potential interruption.

If the generator is operating when a fault occurs this causes reverse current through the network protector. The reverse current relay contacts "A" (not the main contacts of the network protector) close thus energizing the trip coil "G" of the generator breaker. This trip coil trips the generator breaker and isolates the DR from the network. Another option is to trip the breaker at the PCC which allows the generator to continue operating and serve facility load (if the capacity is large enough).

It should be noted that the time delay tripping of the network protector may be required to permit resetting of the directional overcurrent relays to insure the relay contacts are open before the generator breaker auxiliary “b” contacts close. See Figure 3.

5. Another solution is to use a Solid State Switch generator breaker to isolate the generator from the network protector secondary bus within 1/8 to ¼ of a cycle thus preventing the opening of the network protector (typically 5 cycles to open) for either normal reverse load current from the generator or reverse current due to a fault on the primary of the spot network. The sensing of reverse current for the solid state switch is typically on the load side of the interconnection breaker at the PCC of Figure 1., but the solid state switch is installed on the generator terminals, especially for multiple unit installations.

6. Finally, another solution is to install Fiber Optic communication links between any sensing point on the system and the generator breaker to cause a transfer trip when an abnormal system or generator output in excess of its local load condition occurs.

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Annex C – Status Update (J. Bzura)

P1547.6 Meeting Atlanta GA; February 2-3, 2006

P1547.6 Planning Considerations Task Force: Draft outline areas: 7.2.1 & 7.2.2 Integration of DR on Networks (J. J. Bzura, National Grid; M. Y. Vaziri, PG&E)

1. Fundamental Hypothesis (origin - J. M. Daley & R. L. Siciliano)
**The primary function of a protective relay scheme for a power system comprising a DR unit operating in parallel with a network grid is to separate the power source (with no intentional time delay) on the occurrence of any anomaly in the network voltage or frequency **

2. WG efforts to date: A. Re-search and B. Research
A. Re-searching literature in this area proved quite valuable: through WG members, several integration methods identified using purely ***conventional*** technologies.
B. Research in the innovative sense: two new relevant technologies noted, both using high-speed solid-state power electronics.

3. Contributions from WG members

A. Jim Daley: 2 formal (IEEE) papers and 2 monographs
B. Murray Davis & Dave Costyk: document with 6 potential solutions
C. Paul Della: document on overview of networks and protectors
D. Bob Peterson: document on network operations & types of DG
E. John Bzura: document on possibly useful advanced concepts

4. Network and DG material from outside the WG
A. NREL report by Chuck Whitaker, et alia, on network issues and interconnection of DR units
B. Advanced power electronics: Northern Power Systems converter
C. Technologies from UPS manufacturers

5. Questions for consideration
A. Will there be a P1547.6 writing group, as used in 1547-2003?
B. How will we coordinate our work with other Working Groups?

6. Concluding Comment
I think we have enough material to create a useful, safe, conservative and yet progressive standard for integration of DG on networks.

<u>Annex D – Presentation Materials</u>

P1547.6 Meeting Atlanta GA; February 2-3, 2006

Protection Considerations Technical Issues L. Gelbien

Slide 1 **Protection Considerations Technical Issues**

L. Gelbien – presented at P1547.6 Meeting Feb 2, 2006

Section 7.1.1.3

Slide 2 **Network Interconnection Issues**

- Exporting Power or even serving entire facility load is not practical, unless isolated from the grid
- Network Protectors are not designed to interconnect Generators
- External Faults can cause protectors to open
- Cycling of network protectors due to reverse power

Slide 3 **Network Interconnection Issues**

- Adding time delay to protector relays will increase damage to cable and other equipment
- Maintaining the same level of power quality with DG connected
- DG's inability to detect Utility line short circuit

Slide 4 **Network Interconnection Issues**

- Utilities do not rely on customer equipment to protect other customers
- Arcing fault detection intergraded with DG
- Separation of two dynamic systems
- Assure that all network protectors have sufficient forward load to keep protectors closed

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Annex E – Presentation Materials

P1547.6 Meeting Atlanta GA; February 2-3, 2006

Clause 8 Issues -- P1547.6 Initial Draft Outline

J. Watts – presented at P1547.6 Meeting Feb 2, 2006

Slide 1 **Target Information For P1547.6 Document**

Topical Heading (e.g., draft outline heading or more generic heading of your choice)

1) **statement** of the interconnection issue/concern

2) establishment of the pertinent **functional attributes of the interconnection** in relation to the issue/concern

3) **approach and implementation to resolving** the interconnection issue/concern

4) proposed **recommended practice, specification or criteria/requirement** toward satisfactorily overcoming the interconnection issue/concern

5) proposed **evaluation/test criteria** to show conformance

6) provide **figures, definitions, references, citations, test reports, etc. as bibliography/background**.

Slide 2 **General Issues**

- Network Protector Design Limits
- Network Protector Cycling
- Network Protector Pumping
- Inadvertent Opening of Network Protectors Under Fault Conditions
- DG Fault Current Contribution May Exceed Protection Equipment Ratings
- Relying On Network Protector Time Delays To Clear Primary Cable Faults
- DG's Protection Unable To Detect Distribution Line Ground Faults
- Power Quality and Network Protector Time Delay

Slide 3 **Spot- or Grid-Specific Network Issues**

Spot

- DG Capability Exceeds Facility Load
- 480 VAC Arcing Detection Design Concerns

Grid

- Network Protector Cycling
- Self-Commutating DG Might Affect Network Bus Voltage Under Reduced Protector Conditions

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Slide 4 **Network Protector Design Limits**

Issue

Network protectors built in accordance with ANSI/IEEE Standard C57.12.44-2000 are not designed to withstand 180 degree out-of-phase voltages. When DG is disconnected from the distribution company's power system the DG phase angle will drift out-of-phase with the utility-side. Network protectors and relays are not designed with the intention of opening and reclosing two out-of-phase electricity sources. Additionally, network protectors are not designed to interrupt fault current with higher reactance to resistance (X/R) ratios than those usually encountered in low-voltage network systems.

Discussion

New design standards and enhanced interrupting capabilities for network protectors are necessary to prevent failure due to out-of-phase closing. This condition is relevant only if the DG unit remains in operation when the Company electric power system is de-energized. DG units must incorporate anti-islanding features and any DG/facility island that results must be limited to the facility EPS itself without energizing the network bus. In addition, it must include a synchronizing capability that meets the requirements of Section 5.1.2 of IEEE Std 1547.

Slide 5 **<u>Network Protector Cycling</u>**

<u>Issue</u>

If a bus tie breaker is open or if feeders from a second substation are used to supply the network, there is a possibility that protector cycling could occur under light load conditions while DG is operating. Even with the tie breaker closed, a small imbalance in transformer impedances could cause network protector cycling with the DG operating under certain light load conditions.

<u>Discussion</u>

This issue limits the amount of DG output under light load conditions. In addition, grid reliability or power quality can be adversely affected if there is network protector cycling.

Slide 6 **<u>Network Protector Pumping</u>**

<u>Issue</u>

If a network protector opens, thereby isolating the secondary network and DG from the utility primary source, the network relay may repeatedly attempt to reclose the protector. The result of network protector pumping could lead to the destruction of the network protectors, transformer(s) and ancillary equipment.

<u>Discussion</u>

Slide 7 **<u>Inadvertent Opening of Network Protectors Under Fault Conditions</u>**

<u>Issue</u>

Fault current supplied by the DG could cause all network protectors to open for faults on the primary side of a network transformer. This opening would isolate the entire secondary network with a complete loss of supply to all customers served by the secondary network.

<u>Discussion</u>

The amount of potential short circuit current contribution from a DG installation must be viewed in context with the spot network to which it interconnects. In many cases, the short circuit current available from the utility system through network feeders may dwarf the potential contribution from the DG. For example, consider a spot network with three feeders (and network protectors) connected to a common bus. In the event of a fault on the primary side of the transformers, the network protector on that feeder would see the potential fault current available from the utility system through the remaining two feeders. The potential fault current from the DG would not be seen at the other two network protectors. The short circuit contribution of the DG may be significant for faults on or in the vicinity of the network bus. There are a number of solutions that may mitigate short circuit current from exceeding the breaker fault duty and the ratings of the network protectors. For example, it may be possible to apply standard current limiting fuses to disconnect a customer's generation in less than 1 cycle as a means of mitigating breaker duty stress on the low-voltage breakers. Such an application would likely require negative sequence protection of the DG. For relatively small units (<500 kW), contactors can be substituted for breakers and can be opened in less than 2 cycles.

Slide 8

DG Fault Current Contribution May Exceed Protection Equipment Ratings

Issue

The additional fault current contribution from DG could cause the total fault current to exceed equipment ratings. Fault current levels on network systems are typically higher than radial systems. This contribution could cause equipment failures and interruptions to other customers served by the network.

Discussion

In some systems the EPS substation equipment may already be near its maximum fault duty capability. In such cases, even a modest addition of generation on the network grid may cause aggregate fault current to exceed breaker or other device ratings. Because the network protector tripping might be delayed to give time for the generator breaker(s) to clear, the substation breaker responsible for clearing the fault will see the DG fault contribution during its clearing time. Such conditions might be resolved by the addition of current limiting reactors to the feeders supplying the network with generation. However, the impact on power quality at the network bus would have to be reassessed.

Slide 9 **Relying On Network Protector Time Delays To Clear Primary Cable Faults**

Issue

The increased fault clearing time associated with the time delay feature causes the fault to remain on the primary cable for a longer period of time.

Discussion

The preferred method of protection is to clear faults as quickly as possible in order to prevent additional damage and provide further protection to the public. Instituting an additional time delay in the protective function of network protectors will allow faults to exist for longer periods before they are cleared. This would increase utility EPS source side cable fault propagation and additional cable damage. This problem is more significant for single line to ground faults on wye-wye connected network systems.
One possible option is to use time delays on the network protector that will cause DG protection relays to operate prior to the network protector for low level faults or power flows. This option is designed to prevent network protectors from inadvertently tripping due to DG fault contribution. The size of the DG may need to be limited in order to maintain power quality. A consideration of types of faults might be appropriate.

Slide 10 **DG's Protection Unable To Detect Distribution Line Ground Faults**

Issue

The DG's protective relay system must be able to detect the fault and open prior to the network protector relay for a primary line ground fault. It may not be possible to detect all high side phase to ground short circuit by the generator protection. This problem is more significant for single line to ground faults on wye-wye connected network systems.

Discussion

Slide 11 **Power Quality and Network Protector Time Delay**

Issue

Network protector relays with time delay could decrease building supply power quality. A 50% drop in voltage needs to be cleared within 4-5 cycles for sensitive customer-owned equipment and processes. Distribution companies strive to achieve Computer Business Manufacturers Association (CBEMA) or other criteria to avoid adverse impacts to customer-owned equipment.

Discussion

Slide 12 **Spot: DG Capability Exceeds Facility Load**

Issue

If facility loads drop below the power output level of the DG, it will open the network protector(s) due to reverse power flow.

Discussion

The DG output must be kept significantly below the demand of the facility loads to avoid tripping the network protector(s). Some states allow interconnection to spot networks for systems that have inverters that pass UL 1741, are <10kW in capacity, and have aggregate DG capacity less than 1/15 of customer's minimum load. Inadvertent operation of network protectors under normal (non-fault) conditions is highly unlikely for these small, inverter-based DG sources.

A possible option is to time-coordinate power flows on the network protector and isolate or reduce output from the DG whenever flows across the protector drop below a specified level. A similar option is to install a load totalizer on critical load buses and isolate the DG whenever reverse power flows occur on that bus. In all cases, the size of the DG may need to be limited in order to maintain power quality.

Slide 13 **Spot: 480 VAC Arcing Detection Design Concerns**

Issue

Some utilities have additional protection on spot networks to increase detection of both 480 volt arcing and low magnitude phase to ground faults. This protection consists of a low pick up ground overcurrent relaying scheme and a protector wire system.

Both protection schemes simultaneously trip all network protectors. The protector wire system operates on high temperatures allowing for detection of low current magnitude arcing faults. The following concerns might result with the use of this type of protection system:

- Separation of two dynamic systems via network protector (DG/Utility EPS). Separation of dynamic systems could occur anytime these two protection systems operated.
- Greater then 1.0 PU across network protector voltage during separation?
- Ability of the DG protection to detect an arcing ground fault.

Discussion

Slide 14 **Grid: Network Protector Cycling**

Issue

Determining where and when light load condition network cycling may occur is particularly difficult on grid networks without the aid of sophisticated load flow simulations.

Discussion

Slide 15 **<u>Grid: Self-Commutating DG Might Affect Network Bus Voltage Under Reduced Protector Conditions</u>**

<u>Issue</u>

Synchronous generators and invertors capable of self commutation could potentially affect voltages on the network side of the Point of Common Coupling (PCC) when the number of network feeds are reduced (such as under emergency conditions).

The issue begins with a loss of one or more network feeds to the secondary grid network bus which will act to instantaneously lower bus voltage. Even with some form of reverse power protection installed, synchronous generators or self-commutated invertors might sustain bus voltages near the PCC which could lead to current flow within the network bus sufficient to trip network protectors.

<u>Discussion</u>

Annex F – Detailed Meeting Notes – J. Koepfinger

P1547.6 Meeting Atlanta GA; February 2-3, 2006

Introduction.
The perfunctory comments and rules were introduced followed by introductions of those present. The agenda was approved as presented

Reports by Task Force Leads and Presentation of New Material.

Clause 7.2.1 and Clause 7.2.2 -- John Bzura (see presentation).
The prime consideration is not to do anything that damages the network system. Literature search has been done to see what has been done which shows that application of DR to network system can be accomplished. In this presentation many useful technical references were identified.

Clause 7.1.1.3 Protection Considerations -- Larry Gelbien (see presentation)
Network protector equipment manuals note that the protector is not rated to be used to separate generators. This does not mean there are not other methods/equipment to use with protectors to allow the use of a generator. Network protectors do not contain overcurrent relays. It is basically a voltage measuring device. The concern is if additional time delay were introduced, then that would result in increasing damage to the system. It was noted that 1547 states that the addition of generators applied to secondary spot networks are not to result in delay in the operation of the network protector {Secretary's note: 1547 wording addresses "practices": … "Any DR installation connected to a spot network shall not cause operation or prevent reclosing of any network protectors installed on the spot network. This coordination shall be accomplished without requiring any changes to prevailing network protector clearing time practices of the Area EPS."}.

There is a utility philosophy that utilities have to own the protective equipment. In a network system the utility typically owns the secondary cable. In this case the owner of the generator would be asked to protect utility equipment.

The more protectors that are closed the more stable the system. In practice it has been found there are frequent incidents that protectors become non-operable.

Information for P1547.6 for Clause 8 Doc -- Jim Watts.
Jim informed us of, and discussed a Massachusetts collaborative group that involves manufactures and utilities. He presented a list of issues that came from the MA effort. (See presentation).

List of interconnected issues

Statement of the issues
Establishment of the pertinent functional attributes of the interconnection
Approach and implementation to resolve
Proposed recommended practices, specification
… etc.

Potential Solutions to the Integration of DR into a network System – M. Davis (see presentation)

The presentation contained several examples for maintaining the reliability of network while integrating DR into the network. Some of the solutions may not strictly meet the requirements IEEE 1547.

P1547.6 Development Process.

The Chair suggested a process for getting the standard developed.

Task Force (TF) lead would prepare a progress notes/report of the meeting within 30 days and circulate that to the respective task force members. The team members then respond within 30 days to the TF lead. The lead would then summarize the comments and establish suggested resolutions. This may require a teleconference(s) that can be arranged via Tom Basso. Based on these exchanges, a draft document could be prepared for posting prior to the next meeting and discussion at the next face-to-face meeting.

Review of P1547.6 Initial Strawman Outline (led by J. Koepfinger)

A walk through was made of the outline. It was determined that at this meeting further work on Clause 8 may not be productive since everyone wanted to be involved with the different breakouts. Consideration of Clause 8 will be pursued later.

After a review of the draft outline it was concluded that at this time there are only two primary clauses.

a) Planning – convenor John Bruza
b) Protection – Larry Gelbien

With this being decided two Task Forces began work initial as a combined group.

Fault Conditions.

There was a discussion of sensing time of the reverse power relay. Sensing is typically 2 to 5 cycles and the breaker time is typically 5 cycles. The reverse power sensing is as low as 0.05% of the rating of the protector.

What do manufacturers do for reverse flow? One uses a reverse power function and a directional overcurrent function. Another uses a positive sequence directional reversed current design.

Is it acceptable to use the protector reveres power relay to provide pre-trip signal to trip the DG? One manufacturer offers a pre-trip signal. It can be coordinated with the network protector

IEEE 1547 does not mandate that it is not possible to use selective coordination between the DR and the network protection operation. Since P1547.6 is a recommended practice, we could sometimes include other alternatives to be discussed and addressed.

In general where there is DR installed in a spot network the load is transferred with the generator when the generator is separated from the interconnection by tripping at the PCC. This could solve the problem of inadvertency?

<u>FAULT CURRENT CONTRIBUTION AFFECTING THE RATING OF THE NETWORK PROTECTOR</u>. One would have to consider the momentary fault current withstand rating as well as the protector fault interrupting rating.

Only recently have breakers being given a close and latch rating beginning in the 1960's. The sub-transient reactance varies from 10% to 16% and time of 25 ms until the current falls to 3 PU. The breakers maximum duty occurs between the protector and the transformer.

<u>IMPACT OF TYPES OF ENERGY CONVERSION UPON FAULT CURRENT CONTRIBUTION.</u>
Inverters cannot contribute significant fault current. Daley stated what inverter based generators, synchronous generators and inductions generators do.

The inverter allows one to set the fault current contribution and the length of time it can supply fault current (1.2 to 2.0 pu @ approximately 40% to 60% voltage).

Induction Generator – e.g., a 75 kW generator fault current of 6-7 pu (900 amperes for 1.2 to 2 cycles). The fold back curves determine the fault current for up to 10s. ACTION: Davis to provide a copy of the curve. The inverter can be programmed to look like a synchronous machine up to the thermal limit of the inverter. Inverters can be made and programmed to achieve "any" level of fault current and time of operation.

Connecting a synchronous generator to the network through an inverter is being done. Using innovative interconnection technology can be useful in making a network interconnection feasible.

The Chair feels that it is desirable to address how different technologies could affect the decision how DR is interconnected to the networks.

The difference between an induction generator on a fault current contribution vs. a motor was explained by Mr Feero. He noted the peak contribution value is no different, however it will have a different decay time (10%-20% longer when acting as a generator). In the case of a generator, it would be running above line frequency, whereas a motor would be running below line frequency.

SYNCHRONOUS MACHINE.

ASCO equipment is typically tripped at 1 pu current or greater. This is done in 3 cycles or less. The fault current typically runs 6 to 8 times the full load rating of the generator. Normally, it isolates the generator with the load, separating it from a fault on the local or area EPS. The voltage at the terminals of the generator for either a three-phase or phase-to-ground fault will be essentially be zero.

For a fault on the HV supply bus to the network feeders provides a path for reverse flow from the DR connected to the spot network to this fault. It was noted that motors with adjustable speed drive do not cause significant regenerative current. A general office building has about 9 watts per ft^2 load. HVAC in a typical office building is about 30% of the building load.

It was stated that under the bus on the fault on the network feeder supply bus all of the reverse power relays will trip dropping the service even if the generator were to receive a trip signal from the network relays.

It was stated that the network breaker can withstand twice normal voltage, but not the protective equipment.

CLAUSE 8 Discussion – Continuation by Jim Watts.
AREA NETWORKS – Presented by Con Edison representative'
What is going to happen when there are problems on the network when there are installations of generation on the area network.

<u>Scenario</u>
The synchronous generator and inverter capable of self commutation could potentially affect voltage on the network side of the PCC when the number of network feeders is reduced such as under emergency conditions.

The issue begins with a loss of one or more network feeds to the secondary grid network bus which will act to instantaneously lower bus voltage. Even with some form of reversed power protection installed sync generator or self commutated inverters might sustain bus voltage near the PCC which could lead to current flow with the network bus sufficient to trip the network protector

Bill Feero noted that he has a model that he can use to model a spot network. Daley indicated that it appears that when a DR is placed on a grid network to determine how it would impact all elements of the network.

It is very difficult to set up criteria for connection of DR to grid network. Con Ed now allows inverter based DR of some size. Another criterion that could be established is the DR has to be non-exporting. A statement was made by Jim Daley that profit cannot be made by exporting power from a DR.

ACTION: The Task Force should establish guidelines that could be used to establish criteria for the interconnection of DR. This would consider something as a minimum import level of load at the point of the PCC to which the generator is connected so there is not export.

ACTION: The Task Force needs to address single failure criteria for failure of the DR protective and control system.

ACTION: Address whether or not the 1547 requirement for spot network (it is necessary to have 50% of the network protectors closed) is applicable to grid networks.

A synchronous generator can blow a secondary limiter (fuse in series with each cable) remote from the fault. This can cause cascading problems. Problems on networks tend to cascade and can shut down the entire network.

A solution to prevent network protector pumping is to add about 400 watts across the protector terminals.

The use of DR on a grid network to serve a level of load above the minimum load of the customer can result in masking the load growth on the network. This is a planning concern.

Today was a very productive exercise. Martin Baier suggested that based on today's discussion some of the manufacturers may find it desirable to make tests to determine equipment capability.

It was suggested that perhaps DOE could provide some funding for a testing program.

Meeting to reconvene at 8:30 AM on 3 February 2006.

MEETING RESUMED AT 8:30 AM Friday 3 February 2006; full group breakout led by John Bzura.

It was requested that consideration be given to establish what impact DR on a network would have on other customers. Further, there should be a discussion of the types of services that are supplied from a network grid. Smaller services are supplied by bus bar. Larger services are supplied via transformers in vault(s). Some of these vaults have fire detection systems. Smaller services, e.g., restaurant or smaller apartment house, are sometimes called grid customers.

NEW ISSUES

1. There are some installations of PV systems on residential that are tied into the network grid system. These need to be considered. Network configuration in a grid needs to be considered to see how they could be impacted by DR.

ACTION: Should or should not net metering be allowed to be implemented on any network installation. Seattle City Light does not allow net metering.

2. In some grid network installations the fire suppression system operates isolating switches in the grid. PG&E allows any 2 kW inverter based system to be connected to the network grid. In some instance as much as 7 kW has been generated by the PV in residential installations. In the future it may be necessary to keep track of the aggregation of net metering and/or PV installations connected to a grid network. The concern is that there could be a problem at some level of penetration, depending upon the load flows.

Betty Tobin provided reference to a network tutorial available on the IEEE Website, T&D committee, Distribution Subcommittee http://grouper.ieee.org/groups/td/dist/sop
username wgsop password DisTaF

3. Some network protectors on closing have to charge a spring and then the closing takes place. Others have stored energy mechanism. The trip time is about 6 cycles. In those network protectors that use electromechanical equipment the tripping time is a function of the value of the current. As a result it can be extremely slow if the current is very small.

REVISED PROJECT OUTLINE – see Annex H these minutes.
NEXT ACTIONS
Drafts on 7, 8, and 9 to be prepared by March 1, 2006

Circulate drafts to members for comment within two weeks.

Next Meeting: It was suggested to meet the first week of August.

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Annex G - Breakout Group Meeting Notes – Bob Peterson

P1547.6 Meeting Atlanta GA; February 2-3, 2006

IEEE P1547.6 Breakout Group Meeting: 2/2 & 2/3/06

Recommended Practice:

The primary function of a protective relay scheme for a power system comprising a DR asset for parallel operation with the grid, should be to separate the power sources (with no intentional time delay) on the occurrence of any anomaly.

Reverse Power Relay (32) – Can sense and clear in 3 cycles. Trip time at various multiples of pick-up.
Sensing time: 3-5 cycles

Breaker time:

The total clearing time is important. Generator must clear before the protector operates.

Reverse Power can be installed (monitored) at the protector, at the PCC, at the generator interconnect

Conventional breaker vs. electronic breaker

Under Power Relay (37)

Standard relays Vs. Custom Relay?

Network protector to be insensitive to regenerative power (elevators).

Response time varies Inverter,

Reverse power on setting on protectors 0.05% low end, Sense time 3 cycles. Network breakers 5 cycles (one design 3.5 cycles). The relay derives the positive sequence voltage and current and compares the angle.

Functions for fault vs. functions for load dropping

Is it acceptable to use the protector reverse power relay to provide a pre-trip signal to trip the DG? One manufacturer already has a pre-trip signal on the DG unit. It can be coordinated with the network protector.

Get a trip signal from the protector, trip the generator breaker, get positive feedback from the generator breaker and then trip the protector. Without time delay?

Generator system must comply with 1547 section 4.1.4.2
Use 1547 as a starting basis. Can we develop beyond 1547? Since this is not a standard, we can go beyond what 1547 states? Yes, can provide another solution beyond 1547 that both parties can agree to within the recommended practice.

You don't have to trip the generator breaker. You can trip the breaker at the PCC and leave the generator connected to the customer.

J. Daley – His experience, cases of tripping on network, will take the load with the generator, leaving the generator connected to the load.

Generator Fault Current Contribution: Additional fault current that the protector cannot handle. The protector will not see the fault or fault current until the utility breaker opens. Must look at the momentary rating of the network protector. Old protectors were butt contacts. Interrupter rating of the protector was based upon the through fault current of the network transformer. Any additional fault current could over-duty the protector. Protectors are not tested on the first half loop of fault current. They are tested to symmetrical fault current. They remain closed during the first half loop and contacts must stay closed.

Generator can increase the X/R ratio that the protector will see.

Does the protector need fault sensing in addition to reverse power?

If block the protectors from operating due to over-duty, will burn up the entire network vault.

Only recently have close and latch protector breakers been available, late 1960's.

Synchronous Generators - Approximate values - Subtransient 10 –16% lasts for approx. 25 mSec. After this falls to 3 PU for up to 10 sec. Network transformers 5-7% impedance. When is the protector over-dutied? Can be when fault is between the network transformer and the secondary bushings of the transformer. Can use current limiting fuses on the protector. Must trip instantaneously for this case?

Generators can have less than 1% zero sequence impedance. Single phase fault current can be 50% higher than the three phase fault current.

Generators are not connected directly to the network bus. It is always connected to the load side of the building service breaker to be able to detect reverse power.

There are partial range current limiting fuses for use with protectors.
Most are an expulsion type or links that provide a visible break.

A fault on the secondary windings or between the transformer and the protector? Unprotected zone.

Inverters, Synchronous generators, Induction generators
Inverters cannot contribute significant fault current (1.2 – 2.0 PU for 10 seconds. The voltage will be approx. 40-60% voltage. (MWD) At 2 PU, it was set up to allow coordination with other protective equipment.). "Fold Back Curves" (Volt-amp curve) to determine fault current, voltage and pF. Murray to supply a copy of a curve. Inverters may supply rated load during a fault or it can be programmed to look like a synchronous machine up to the thermal limit.

UPS - Don't let the inverter see the fault. Will bypass the inverter.

Connect synchronous generator to the network through an AC-DC-AC converter, as is planed for one site on the ConEd network.

Let the application determine what the specification should be. Make it technology neutral? Performance specification? Does each technology need to be treated separately?

The difference between an induction generator on fault current contribution Vs. as a motor. Peak contribution no different, however will have different decay time (10 –20% longer when acting as a generator). In the case of a generator running above line frequency vs as a motor below line frequency.

Report on induction generator (Bill Feero's) on Web site. See if can make available to the group.

Induction Generator – 75kW generator fault current 6-7PU (900 amps for ¼ cycle).

Synchronous generator fault current – add trip to generator breaker at 1PU (<Jim D), to separate power sources in 3 cycles or less (50 device - sense and clear). Network could see 6-10 times normal current for 25 msec. Cycles, falling to 3 PU. True for three phase or phase to ground fault (Solid ground).

For a fault on the primary side, the generator may see this as load current. Protector will trip on reverse power.

Since all feeds are off the same substation bus, a primary fault can cause a voltage depression on the substation primary bus that will lower the voltage of all primary feeds to the network vault. This would make the network bus at a higher voltage than the primary feeds. All protectors may trip. The generator can cause a reversal on the unfaulted feeders by feeding the fault through the utility substation bus. This is more prominent under light loads on the vault. Why do large motors not cause this to happen? Add delay to trip. Adjustable drives do not exhibit the same characteristic as induction motors. HVAC is approx. 30% of building load.

If there is a low reverse power time delay, this may not be a problem. If this setting is not present, all protectors can trip. The effect of load goes away once the fault occurs.

Use caution of using aux contacts from the protector in a protection scheme. Aux contacts can stick and be slow to operate.

No one wants to use the network protector as a breaker to separate the generator from the utility (paralleling device). Cannot use the impulse level of the protector to see what withstand the protector has.

Breaker contacts will survive 180 Deg out of phase. Other equipment in the protector will not survive the over-voltages.

Area Networks: ConEd no delay to operate. Area networks are not static. Temp services to customers, blown limiters on cables, and equipment out of service for maintenance or unexpected failures. The area network could break into two sections.

Adding generation will change the normal load flows on secondary mains. This could overload other secondary cables remote from the generator. Protectors may open remote from the generator site.

Why is a 1000kW load on a building, being offset by a 1000kW generator, any different from a customer going out of business? Buildings on networks rarely go out of business.

Spot networks have limited load (up to 6 for ConEd). Grid networks have much heavier load.

DR on a network grid must be evaluated at the point of application and load flows. Customer loads are not always known at time of day. Network vault loads may be a thermal totalizing meter. With a generator, will you know if the generator is on?

On weekends what happens. Protectors do operate (open) under light load times. Light load time flows can be done for this case. Generators add additional uncertainty. If only lowering load by a generator, is this the utility problem.

Is anyone interested in allowing backfeed on a network grid? If sufficient monitoring is present, it may be possible.

Injecting load into a grid, transformers closest to the load center will provide most of the load.

If accept that most utilities don't know exactly what the network is like, can I go out and view flows after the generator goes in? How much money does it cost to do the necessary studies.

You need to communicate with the generator to know what is going on to prevent problems.

A synchronous generator can contribute to blowing secondary cable limiter (fuse in series with each cable) remote from the fault. Can cause cascading problems. Problems on networks tend to cascade and can shut down the entire network.

Tripped breaker at a customer site can cause a loss of load. This can have an effect on back-feeding into the network. Need load following system.

Network studies can be costly. Will the utility be able to recover these costs?

Generation cannot be larger than the largest load? Power flow into the network needs to be larger than the largest load the customer can shut off. Power flow will still be into the network after the load is shut off. Minimum building load + largest load to be shut off + a margin = Minimum import to the building - Generator fuel controls to keep the minimum import. A problem with generator controls will trip generator or interconnect breaker.

Grid network requires study. Must have redundant protection/controls to prevent back-feed.

If an island occurs on the grid, the generation must be separated per 1547.

Abnormal condition, where the network is isolated to only one transformer feeding a section, a generator back-feed can cause the opening of the last feed to the secondary cables, all customers will be out off that secondary cable section. The generator has two seconds to come off. Will the master relay call for a close of the protector out of phase? How do you account for 50% of the protectors being closed on a network grid?

Not only do you have to look at tripping the network protectors, you have to look at closing the protectors.

Generation can fool the planners of the network. How much load is actually on the network? Loss of generation must be considered.

In the past, a light bulb was used to keep the protector closed at light load.

DG could cause more tripping and closing of protectors.

Testing of network protectors. Will the relay allow a close out of phase? Other issues associated with protector operation. The protector is not a paralleling device. Closing of the protectors is slow.

2/3/06

PG&E has allowed a 2kW inverter on the network grid.

Have seen larger PV on residential up to 7kW.

Will net metering be allowed on networks? ConEd has residential net metering on the network (less than 10kW). Will limit the amount on the network. Will need to keep track of generation on the network.

IEEE tutorial on networks. IEEE Power Engineering Society, Transmission and Distribution Committee, Distribution Subcommittee web site http://grouper.ieee.org/groups/td/dist/sop Select “Members-only area” User ID: wgsop Password: DisTaF

Eaton to do some tests on protectors. Close time can be 4-5 seconds. Motor must charge springs. Trip time about 8 cycles overall. 3 cycles for the relay and 5 cycles for the contacts. Test old electro-mechanicals and various protectors. At lower current the arc time increases,and can be 15 cycles. Not enough magnetic field to force the arc into the arc shoots. When the substation feeder breaker is opened. The protector can take up to 15 minutes to open?

- Fastest and slowest times for tripping
- See the effect of syncing across a network protector

Paper on generator connections (Martin Baier & Bill Ferro). Put on 1547.6 web site

Adding delay on tripping the protector. Delay can cause power quality problems (Voltage sags). Equipment damage from slowing protectors. Two trip levels on Microprocessor network relays. There is a window of 50% to 250% of transformer rating where a time delay can be set, above that will trip instantaneously.

The failure of a breaker to open on the customer site needs to be considered. A redundant breaker could be used. What breaker/s would be the redundant breaker?

Do we want to trust the customer to maintain his relaying? 1547.1 has language about periodic testing. WG make recommendations on what to do if maintenance is not performed?

What type of communications are necessary to install DG on networks? Monitoring customer and network? Controls communications.

A large synchronous generator connected to the network, what are the concerns for loss of field? There are a few cycles before it can be tripped. Large VAR requirements for this case. If the network is soft, what affect will this have on the network?

Went over new outline, which had items of communications added. Added names for writing sections.

Complete in write-ups in one month. Send writing to others in the group. Post writings and ask for comments within two weeks.

<u>Annex H – Proposed Draft Outline Revisions – J. Bzura</u>

P1547.6 Meeting Atlanta GA; February 2-3, 2006

PROPOSED REORGANIZATION OF P1547.6 - OUTLINE OF NEW AREAS 7 – 10

7. <u>Overview of Network Distribution Systems: Design, Components and Operation</u>
(***Joe Koepfinger***, Martin Baier, Dave Costyk, Jim Daley, Bob Peterson, Betty Tobin)

    7.1 Spot Networks
    7.2 Area Networks

8. <u>Primary Concerns of Operating DR on Networks</u>
(**Moh Vaziri,** Larry Gelbien, F. Bigenho, Jim Watts, Tim Wall, Dan Sammon, Chuck Whitaker, Travis Johnson, David Smith, other volunteers)

    8.1 Reverse power flow
    8.2 Fault current contributions
    8.3 Effects of DR on area network load flows
    8.4 Effects of potential network system component failures

9. <u>Procedures to Alleviate Concerns of Operating DG on Networks</u>
(**Murray Davis**, John Bzura, Marty Baier, Murray Davis, Jim Daley, Jock Moffat, David Beach, Larry Gelbien, Moh Vaziri, Sam McAllister, _ Ebrahim, Tom Greely, other volunteers)

    9.1 Measures to sense and ameliorate (prevent) reverse current flow
        9.1.1 Minimum power level DR trip
        9.1.2 Reverse power flow sensing for DR trip

    9.2 Fault current minimization
        9.2.1 Limitation by DR technology
        9.2.2 Limitation by switching technology

    9.3 Site-specific analysis of DG on area networks (**Larry G** to lead?)

    9.4 Coordination of DR with network operations (**Murray D** to lead?)

        9.4.1 monitoring and control specific to DR on networks

10. Requirements for Integration of DG on Networks
(**John Bzura**, Martin Baier, Murray Davis, Jim Daley, Jock Moffat, David Beach, Larry Gelbien, Moh Vaziri, Sam McAllister, _ Ebrahim, Tom Greely)

10.1 Fundamental Hypothesis

The primary function of a protective relay and control scheme for a proposed DG unit operating in parallel with a network grid is to separate the power source from the network immediately* on the occurrence of any anomaly in the network voltage, frequency or power flow direction.

10.2 Reverse Power Flow Criteria

The Interconnection System (IS) shall prevent the occurrence of reverse power flow through the network protector(s) under all normal conditions and absolutely minimize reverse power flow under adverse conditions such that network protector capability is never impaired. There shall be at least two independent subsystems employed in the IS to accomplish this requirement.

10.3 Fault Current Contribution Criteria

The IS will respond to any indication of a fault on the network by immediately* disconnecting the DG unit from the network so that the fault current contribution from the DG unit is either zero or minimized to the point of being inconsequential.

10.4 Area Network Load Flow Analysis and Conclusion

The utility customer or the customer's agent will work with the utility to analyze network load flow parameters at the proposed DG site to determine whether the proposed type of DG unit can be accommodated for operation. If the conclusion is negative, alternative measures such as reconfiguration for a radial interconnection shall be evaluated.

* Immediately is defined for present purposes as within 3 cycles (50 milliseconds).

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