The background for this Attachment is summarized in Section 3.2.5 of the 2006 Report,[1] *"Approach to Advance Opportunities for DG on Networks," which presents the following conclusion: "The Massachusetts DG Collaborative therefore recommends that the RFP in Attachment F be implemented as soon as possible, with the support of MTC and funding agencies such as DOE, NYSERDA and CEC, and with the cooperation of Massachusetts utilities and other signatories to this DG Collaborative Report." The rest of this Attachment is presented as an RFP that could be utilized by the funding agencies.*

REQUEST FOR PROPOSALS (RFP) #_____

"Improving Network Protectors: Spot Network Interconnection Issues and Opportunities for Relaying and Control Development to Advance DG/Network Interconnections"

Due: _____________

Funding Available: $ _____________

SECTION 1: INTRODUCTION:

The Massachusetts Technology Collaborative, MTC, has diligently investigated all aspects of the DG/network interconnection question. The 2005 Annual Report devoted a full chapter to the subject. Also a comprehensive study of a Beta test installation was completed in 2005 and the report was submitted as an attachment to the Annual Report. Simultaneously other states have been pursuing the DG/network with California and New York maintaining a close liaison with the MTC efforts. All of this work has led to the conclusion that, to advance the general acceptability of DG interconnections with network service,

[1] See http://masstech.org/dg/collab-reports.htm.

advances need to be made in available network protector relaying and their communication with any DG to be connected to the network. To that end, this report reviews the salient findings of the MTC 2005 funded study "Generation Monitoring at the GSA Williams Building and Modeling of Feeder Fault Cases Recorded" and then sets forth suggestions for future developments in the form of a request for proposal.

The Study

A study on a Beta test site for DG operating on spot network service to the GSA owned and operated Coastguard facility on Atlantic Avenue, the Williams Building, was posted on the MTC website on May 18, 2005. The full report is available at:

http://masstech.org/dg/collab-reports.htm

The following are excerpts and observations from that study.

In June of 2002, an induction generator 75 kW CHP was commissioned for operation in parallel with the 480 volt spot network service to the GSA Williams Building. In 1999 a 28 kW PV array had been installed at the GSA Williams Building. Normally NSTAR does not permit any generation to be connected to spot or street networks that will require delaying the protectors from tripping on reverse power. However, in cooperation with the GSA, and with the installation of new relaying and a special control system, NSTAR agreed to make the Williams Building a beta-test site to gain first hand experience with the unique issues created by placing generation on a secondary spot network [References 1, 2, 3]. These issues range from possible degraded quality of service to, in the worse case scenario, a catastrophic failure in the network transformer vault. (For individuals not familiar with this range of concerns, the summary text of a brief lecture, given on January 10, 2003 and revised for an April 5, 2006 meeting, is included at the end of this RFP as Appendix C, "DR on Spot Networks.")

The network protector electromechanical relays were changed to modern microprocessor relays capable of having a low level reverse power setting with a time delay before tripping and an instantaneous high reverse current trip setting. A special auxiliary control unit, designed and built by the relay manufacturer, was installed to measure the power flow in the two spot network units serving the site and to force tripping of the induction generator for under-power conditions in either protector. By measuring under power in each network protector, a concern for a drop in future minimum loads and unbalanced load sharing by the protectors was eliminated. The need for detecting under power arises from experience with network installations that has shown a tendency of protectors to open if the load supplied through the protector unit drops below a few percent of the protector's rating [4]. In many spot network applications, and in particular this installation, the late night and weekend loads will fall to very near these minimums. For this installation, the utility had data to demonstrate that the minimum load supplied by the network units was 6.0% (60 kW) of rating per network transformer with no dropouts experienced.

A monitoring system was installed in the GSA Williams Building in the spring of 2003. The original purpose for collecting these data was to evaluate the protection controls of the induction generator, the PV inverter, and the network protectors to determine and document the need for, and settings of, the Auxiliary Control Unit. That study concluded at the end of May 2004 [Reference 1]. This initial study found that the Auxiliary Control Unit worked as planned. As a special design built and installed by the network protector relay manufacturer, it could use the protector's current transformers and potential transformers, thereby ensuring it would monitor the same under power conditions experienced by each protector's relays. This approach assured that the DG could not cause the protectors to cycle under any future minimum load conditions and that the DG would be sent a trip signal under any fault conditions that would cause the protectors to trip.

An extended study by the MTC reexamined the first year's data, evaluated the data collected in the following year, 2004-2005, and did simulation studies to try to resolve the following DG/Spot Network application issues. The findings from the extended study are listed after each issue.

Issue 1. *Must time delay be inserted in network protector trip circuits for:*
Synchronous generators?
Induction generators?

Study Findings: Induction generators as small as 25 kW and with very low inertia still can produce fault contributions for three cycles, a network protector's relay trip time. Synchronous generators will produce fault contributions longer than three cycles. Therefore, using presently available technology, the protector's trip time must be delayed for low reverse power in any spot network containing rotating DGs.

Issue 2. *Assuming that time delay tripping for low level reverse power conditions is required, how much time delay is required for:*

Synchronous generators?
Induction generators?
Inverter interfaced generation?

Study Findings: Given that detection of under power conditions is installed at the network protectors, 15 cycles of time delay for low reverse power in each protector will be sufficient for safeguarding the reliability of the network system. This short time delay assumes that the under power detection will instantaneously trip all DGs connected to the spot network. For synchronous generators, such a short time delay with instantaneous under power tripping will require either precise synchronizing equipment or only synchronizing at high load conditions. Larger induction generators may also experience over tripping for system faults as a result of instantaneous under power tripping at the protector during light load conditions. If occasional tripping during system faults and light network loading conditions is not acceptable then it may be necessary to install time delay in the underpower detection circuit plus more than 15 cycles in the network protector relays. For inverter interfaced generation with very low or no inertial characteristics, the 15 cycle time delay should be acceptable.

Issue 3. *With time delay, how is the permitted level of momentary reverse power setting to be determined for:*

Synchronous generators?
Induction generators?
Inverter interfaced generation?

Study Findings: The permitted level of momentary reverse power is the point set in the network protector relay for maximum reverse power with tripping time delayed. For currents that exceed this point the protectors will trip instantaneously. To maintain the highest level of service quality possible when DGs are interconnected to the spot network, this setting should be as low as possible while remaining above the largest contribution to a system fault from the DGs. Note that for presently available microprocessor network relays this setting is limited to a maximum of 250% of the network protector's rating [2].

For synchronous generators, this value is computed as the composite machine ratings times the inverse of the per unit sub-transient reactance of the generator.

For induction generators, this value is computed as the composite generation ratings times the inverse of the per unit transient reactance of the generator.

For inverter-interfaced generation, this value is computed as the composite generation ratings times the maximum per unit current output of the inverters.

For installations where mixed types of generation are installed, the setting is determined by summing each of the generation types contributions as computed above.

For any spot network, the relay settings can range from the values as computed above to a lower limit found by dividing the above values by the minimum number of network units that must be in service for the DGs to be online. This lower value must be adjusted up by a safety margin.

Issue 4. *If an auxiliary underpower relay is not installed in each protector circuit, are parameters available at the DG to assure reliable tripping for all fault conditions where tripping is necessary?*

Study Findings: For a network distribution system with high impedance grounding, there is little or no change in voltage at the DG for single-line-to-ground faults on the feeders. Absent some form of communications with either the protection at the network protectors or the substation bus, there is nothing to indicate a fault condition at the DG's terminals. Even in solidly grounded distribution systems, high impedance faults on the feeders will not cause sufficient voltage drops at the DG's terminals for detection. Therefore, some form of detection of conditions that requires tripping the DGs must be installed at each network unit.

Issue 5. *Absent an underpower relay in each protector circuit, how can cycling at light load conditions be avoided?*

Study Findings: Given the inherent unbalance in power supplied by the two protector units supplying the Williams Building, a review of two years of cycle-by-cycle data suggests that cycling would have occurred at the Williams Building absent the underpower detection system. While the time-of-day tripping employed by the induction generator installation had the unit offline during most of the time when underpower exposure existed, this approach may have been overly restrictive to economical operation of the DG. However, entirely relying only on time-of-day operation as a reverse power protection function leaves the system exposed to total network loss for system faults.

Issue 6. *When a time delayed low reverse power setting is selected, can the worst case of under voltage to be expected during the time delay be calculated by simple approximation or must it be simulated?*

Study Findings: The worst case of under voltage drop at the network bus can be reasonably estimated by the following formula:

$$\Delta V = I_{lmax}(Z_t/(N(N-1))) + I_{np}*P_R(Z_t/(N-1))$$

Where: I_{lmax} is the network's maximum load current,
Z_t is the impedance of the network transformer
N is the number of network units in service at the time of the event
I_{np} is the rated current of the network transformer, and
P_R is the reverse power setting in per unit of transformer's rating

It should be noted that generally this condition is met when the DGs are offline. Also note that, given an acceptable value of ΔV, this formula can be solved for the maximum value of P_R allowed.

Issue 7. *What additional cable and/or equipment damage might be expected due to time delayed tripping under low reverse power conditions?*

Study Findings: The study design was not set up to collect any data that would address this issue. Issue #7 was not addressed by this study because to gain any useful data to quantify this issue would take a much larger, longer, and costly study. The utility would have to make available their repair records on the feeders supplying the Williams Building, and, the repair records of at least two comparable network feeders that do not have timed-delayed network protectors on them. A scheme for scoring damage at the vicinity of feeder faults would have to be devised. All feeder repair crews would have to be trained in the scoring technique. Repair time would have to be incrementally increased to allow for scoring, etc, etc. It is unlikely that any utility would, or could, agree to perform such a study.

Future Efforts

In December of 2005, the author of the study presented the findings of the study to an audience of interested parties from the MTC and representatives from New York State and California. The study report concluded with suggestions for possible future studies which might try to answer the unresolved Issue #7. The discussions following the presentation suggested a different course for future action than had been presented at the end of the study.

The more cost effective and operationally appealing resolution of Issue #7, possible adverse impacts from inserting time delayed protector tripping, would be to eliminate the need for inserting time delay. To achieve this both network protector relay manufacturers (there are only two protector manufacturers) should be involved in a study. The May 2005 Report has conclusively shown that the decision to permit interconnection and to trip DGs under all required conditions must utilize information only available at the network protector for any commercially viable DG installation. The elimination of time delay would require the development and addition of a permissive trip scheme between the protectors and the DG units. In the microprocessor relays already available from both manufacturers, all the information and processing speed exist to continuously monitor underpower conditions and to provide trip signals.

Even for utilities that are not concerned about eliminating time delay, incorporating all the sensing and tripping functions into the protector relay would be a fundamental step in reducing the DG installation cost, and, increasing the security and reliability of the network protector system. The relay manufacturers would produce a standard, secure, and reliable trip circuit for either time delayed tripping or permissive tripping that could be taken outside the network protector vault. Reliability would not be dependent on the facility owner's commitment to maintenance, since all tripping functions would be in the utility's protector relay. Concern for changes in future building loading would be eliminated because the utility's relay would be monitoring and controlling the minimum permitted network load. Concerns for unbalanced load sharing between protectors would be eliminated since each protector's minimum acceptable load would be monitored.

To help initiate such development to advance the acceptability of DGs operating on spot networks, a suggested request for proposal, RFP, is given in the following section of this report.

SECTION 2: INSTRUCTIONS TO PROPOSERS

Request for Proposals
To Advance DG/Network Interconnections

Purpose**:** To advance the acceptability of DG on network service by developing advanced network protector relays and compatible high speed communication with the DG controls to react instantaneously to required switching conditions utilizing communications between the protector relays and the DG controls.

Approach**:** Form a development team of a protector relay manufacturer, DG interface manufacturers, and utilities to determine the specific requirements the new product(s) developed must meet for general acceptability, produce a prototype system(s), and devise a "test plan" to verify the functional performance of the product(s) in a demonstration project. Execution of the "test plan" (i.e., actual testing of the performance of the product(s) in a demonstration project) is not covered by this RFP. It is anticipated that up to two (2) proposals will be selected for award under this RFP.

Eligibility**:** The prime proposer must be a manufacturer of network protector devices with numerous years of commercial sales of such devices to electric utilities in the United States.

Background

Installing DG in facilities served by a spot network has a number of special application problems that do not arise in the usual radial service arrangement. A few of these problems are listed below to highlight the issues that are most limiting to interconnecting DG on spot networks. Additional problems that are unique to area (street) networks will be discussed later.

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 DG 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 DG. Even if a DG is sized to the site's minimum load, consideration has to be given to the possibility of sudden loss of a large load or transient stability power swings from rotating generation DG, 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 DG 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 DG demonstrated the reality of this problem.

3. The fault current delivered from a DG to external faults can cause network protectors to open, potentially isolating the customer's network.

4. If the network protectors open, isolating the network and the DG 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, often in a submersible enclosure, usually mounted in vaults in the street, and are not as easily modified as a typical relay control scheme.

6. There is a possibility that protector cycling would occur under light load conditions if the minimum net load supplied by the protectors is less than a few percent of the protector's rating.

The list of issues seems to vary depending on who is involved in organizing the list. Within the past year, Working Groups of two different state agencies have formally submitted their issues list to respective regulatory bodies.

The Massachusetts Technology Collaborative (MTC) lists 16 issues in Table 2.5 of its 2005 Annual Report to the Massachusetts Department of Transportation and Energy (D.T.E.). The issues listed in Table 2.5 (see Appendix A) give a description and design impact of the technical challenges identified by the

Technical Working Group for the interconnection of DG to secondary network systems. Some of these Table 2.5 issues have their genesis in proposed solutions suggested by DG manufacturers, e.g., Issue #9. Many have their genesis in the prevailing practice of some New England utilities not to delay protector tripping, e.g., Issues #8 and #10.

An issue raised but not placed in Table 2.5 was that 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, 480 volt bus differential, and, one Massachusetts utility has considered a protector wire system. All of theses protection schemes simultaneously trip all network protectors. The protector wire system operates on high temperatures allowing for detection of low current magnitude arcing faults. This would raise a concern that the use of network protector time delay might allow these low magnitude 480 volt collector bus faults to persist for a longer period of time and potentially result in additional 480 volt bus damage. If the protectors were tripped without time delay, the DG might momentarily expose the protectors to trying to separate two independent systems.

The California Rule 21 Working Group submitted a list of 27 issues to be addressed in its March 30, 2006 Report to the California Energy Commission (CEC) and the California Public Utilities Commission (CPUC). This tabulation (see Appendix B and note that GF means the same as DG in this document both of which are the same as DR in the IEEE Standards) took a step further in identifying issues that its authors thought might be resolved with technical development. In the Technology Development column of this tabulation, additional double red Xs (**XX**) have been inserted where it is hoped that the developments suggested below might aid in resolving the identified issue. Note that the California utilities prevailing practice is to allow low reverse power time delayed tripping in its network protectors.

Even with this daunting list of problems, some utilities have allowed DG interconnections on spot networks using a wide variety of schemes. However, if the prevailing practice of the utility is not to allow time delay of the network protector when tripping for reverse power conditions, little can be done at present. Only insignificant amounts (generally in the range of 5 to 10% of minimum load) of inverter interfaced, and load coincident, generation have been installed under these conditions. Inverter-based DG has the advantages that fault current is very limited, to about 100-200% of normal load current for no more than a few cycles, and that an inverter can respond very rapidly to signals controlling its power output level.

Where time delaying the protector trip time for power reversals does not violate the local utility's prevailing practice (IEEE Standard 1547-2003, Clause 4.1.4.2) then the amount and type of DG generation allowed on a spot network can be increased by a variety of interconnection schemes. Because the most critical aspect of DG on networks is that the local generation must never exceed the local load, most schemes use some form of tie-line control. This approach can either be simply tripping the DG off line when the minimum net loading of network is detected at the facility's service entrance (or in the individual protector circuits) or controlling back the DG's output as the minimum loading is approached. Note that the exact load point at which tie-line control must be initiated has to be determined based on the minimum loading of the lightest loaded protector serving the spot network to avoid protector cycling.

Even for utilities that accept delayed tripping of their protectors, Issues #14 and #15 of Table 2.5 of the MTC 2005 Annual Report are a major concern. Also, the wide variety of schemes, suggested or in service, may not be beneficial to either the DG manufacturer or the utility as implied by Issue # 12 of Table 2.5.

At the beginning of this section it was stated that problems that were unique to area networks would be discussed later. Since it is beyond the expectations of the requested effort to develop a relaying system that could resolve these problems, the following brief discussion of interconnection issues in area networks is presented to keep in mind that ultimately these issues may also need to be resolved. Conceivably, in the process of working out solutions to the spot network issues, insight may be gained that could lead to solutions for area networks.

Most of the spot network issues apply to area or street networks with the added problem of indeterminate power flow in secondary area networks. The secondary grid consists of multiple sets of low-voltage cables installed in ducts under the streets and avenues that are connected at the cross points in manholes or shallow service boxes. They generally follow the geographical pattern of the load area and customer services are tapped from them where required. In the early networks, cables for the secondary mains were rubber or paper-insulated, lead-covered, copper cables. . Practically all secondary mains that are installed now or replaced consist of single-conductor cables to eliminate the problems associated with splicing and terminating 3-conductor lead sheath cables and to maintain circuit continuity after a cable fault where parallel conductors per phase are used. Cable limiters are installed on network mains and service cables to protect the cables from extensive damage from severe overloads and/or short-circuits. The limiters will blow to provide isolation of the faulted cable from the rest of the system. The limiters are installed on secondary mains at each junction point of the grid.

The impact of DG interconnections is most problematic here because it is presently not practical to determine the status of this portion of the secondary network system, i.e., how many and where cables/limiters are burned clear at any given time. Therefore, how the power injected by the DG will flow in this secondary grid probably cannot be accurately predicted even by sophisticated load flow studies before installations are permitted and certainly not after a DG facility goes into service. In a worst-case scenario with sufficient cable/limiters burned off, the result could be a momentary condition where a single protector would be exposed to separating two independent systems.

Given the high degree of reliability that has been achieved through design evolution for these secondary grid networks over time, when IEEE Standard 1547-2003 was being drafted, it was not possible to envision any general DG interconnection strategy that could be assured not to negatively impact on the reliability of this type of service. The March 30, 2006 Rule 21 Report suggests a very limited approach to allowing small DG interconnections with area networks, but the approach relies on an assumption of a level of insignificance and not a technical solution.

Technical Direction for Product Development

A general philosophy that should have wide acceptance is "reduce the problem to one that has been solved before." That may translate to a new network protector relay that recognizes when DG(s) is online, takes all necessary action to keep power flow to the network in a system normal range that might exist absent the DG interconnection, and frees the protector relaying to react to system conditions as it has been evolved to do over the past 85 years.

For a two transformer spot network that could mean that the relay sends a signal to the DG to back down its output when the minimum power flow boundary (under power function) is detected. The relay has to have a hard minimum power boundary that when crossed would call for instantaneously tripping the DG(s) offline. Once the DG(s) has been required to trip, a third power import boundary (over power function) would control when the DG could come back on line and be settable at a level which would not cause the DG(s) to be cycled on and off.

Under any feeder fault conditions that would cause the current (power) to reverse in the network protector because of the DG(s) being online, the minimum power trip boundary would trip the DG(s). For utilities that permit protector time delayed tripping for low levels of reverse power, the protector's decision to trip or not trip would proceed as though no DG(s) interconnection existed; a problem solved before.

For three or more network protector units supplying the spot network, a high speed AND circuit would have to decide when enough protector relays were requiring DG(s) trips (the 50% requirement from IEEE 1547-2003 Clause 4.1.4.2) to actually trip the DG(s). This might require the development of a master control to link all the network protector units or it might require high-speed communication between all the network units.

Implementing this boundary protection approach may seem to be just a matter of programming the relay's microprocessor. However, the need for communication external to the protector and protector vault while maintaining all the reliability and security required of network protector relays may be the development challenge. The communication reliability and security extends to, and involves, the DG interface. For complete utility acceptance and to avoid warranty problems for the DG installer, reliability and security consideration should go beyond the as-built design. MTC Table 2.5, Issue #15 clearly suggests that the ideal system would at least alarm if unauthorized adjustment of any of these controls should occur after commissioning.

A requirement embedded in IEEE 1547-2003 Clause 4.1.4.2 is that a conventional network protector shall not act as a backup breaker to the DG breaker(s). Generally this requirement implies that a backup breaker must be installed between the spot network bus and the DG(s) which can set to trip if the DG breaker(s) fail to trip on a trip command from the network protector relaying system. In many applications, the utility may wish to own and/or maintain such a breaker. Regardless of ownership, the developed relaying system should have the communications and circuitry to determine when and how to issue a backup breaker trip command.

To this point, the suggested developments will be a major step in the direction of assuring utilities that they will not be abdicating any of their responsibility for maintaining and controlling a highly reliable power system. With all the relaying located in their equipment, they can be assured that all necessary and timely maintenance is performed. The DG installer can expect that more standardized interconnection procedures will evolve from having the necessary tripping and re-energizing commands coming from the utility's equipment. Also the DG installer should find his legal commitments lessened because any event that would adversely impact the utility's system is to be detected by the utility's equipment.

However, there is the salient issue of using time delay to provide coordination with DG breaker(s). For utilities that do not use time delay tripping for low reverse power conditions an additional development is essential. If the communication system can be made fast enough and secure enough, then a permissive tripping scheme for the protector could be instituted. Conceptually such a scheme would send a trip command to the DG when the hard minimum power boundary was crossed and hold the protector's low reverse power element from tripping until the DG had confirmed that it had tripped. Concurrently a breaker failure timer could be started which, when it timed out, would release the protector to trip. In implementing such a circuit speed versus security considerations will govern the design approach. The goal of such a permissive trip scheme would be to reduce the time for a desired low reverse protector trip from 30 or more cycles to approximately five cycles.

A variation on the permissive trip approach might be to block any network protector tripping if all network protector relays were calling for a trip (the adjacent feeder fault problem caused by the DG supplying fault current through all protectors). Since the minimum power hard boundary would necessarily have been crossed in more than 50% of all the protectors, tripping of the DG(s) would be initiated and the protectors would unblock as soon as one or more protector relays ceased to call for a trip. This would guard against dumping the network bus when DGs are operating and all the network relays call for a trip for a utility system fault. If the DGs were not online there would be no source to cause a reverse power flow.

All of these ideas are presented to stimulate thinking and are not considered complete. Consideration of relaying reliability and security will almost certainly require modifications and maybe even rejection of some of these suggested solutions. However, it is expected that the development team will propose different and/or additional measures to resolve issues listed above and in the appendices.

Goals of this RFP

To advance the acceptability of DG on network service by encouraging changes in the network protector (NWP) relays and in the DG controls to react instantaneously to required switching conditions utilizing communications between the NWP relays and the DG controls.
Encourage protector relay manufacturers, DG interface manufacturers, and utilities to determine what developments they feel are feasible, develop a prototype relaying and control system, and prepare a plan for a prototype demonstration project on a spot network test bed.

Increase the acceptability of DG interconnection with network service by utilities by assuring that all conditions that can cause protector operations are controlled by utility owned and maintained relays and controls.

Decrease the complexity and site-specific variability for DG suppliers in designing network interconnection systems.

Advance communication and control exchanges between network protectors and DG to achieve high levels of security while increasing operating range flexibility.

Minimum Development Effort and Project Performance Criteria

The flexibility, security, and reliability of network relaying capabilities that have evolved over the past 85 years should not be compromised.

The communication protocols should be based on standards available to the relay manufacturer, the utility, and the DG developers.

Basic application guidance as would be available with any new product release should be provided.

The design should meet or be able to pass all testing criteria that would qualify it to be accepted as a utility grade relay.

The prototype product(s) should be tested for functionality at the manufacturer's factory.

This development is to focus on advancing DG interconnection in spot networks but the design team is encourage to suggest any possible extensions that might also advance technically sound area network applications.

Proposal Format

It is expected that the overall number of pages for proposal excluding personnel resumes will be less the 50 pages. Of these pages, the executive summary should be no longer than four pages. The allocation of pages devoted to other subsections such as: description of existing product, approach to designing new product, approach to developing prototype, approach to configuration as basis for test plan, team qualifications, approach to seeking market acceptance of a successful product that might emerge from this effort, and a commitment from company management, pending successful field testing, to add the developed product as commercial product line. .

Proposal Evaluation and Selection Criteria (the following is not in any rank order)

1. Likelihood of success
2. Reasonableness of costs and extent of cost-match proposed
3. Qualifications of team and the team personnel assigned to the project
4. Reasonableness of strategy for seeking market acceptance.

SECTION 3: SUPPLEMENTAL INFORMATION

References

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http://www.masstech.org/renewableenergy/public_policy/DG/resources/Collab_2004Collab04_06_23_Network_CaseStudy_WilliamsFinalReport_May2004.pdf

2. M. Baier, W. E. Feero, and D. R. Smith, Connection of a Distributed Resource to 2-Transformer Spot Network, 2003 IEEE/PES T&D Conference Proceedings, available at:

http://www.masstech.org/renewableenergy/public_policy/DG/resources/Resource_Network_IEEESpotNetworkInterconAnalysis_February2003.pdf

3. D. C. Dawson and W. E Feero, Section 9.6 DG on Low- Voltage Distribution Networks of the text "Electric Power Systems Quality" 2nd Edition by R. C. Dugan, M. F. McGranaghan, S. Santoso, and H. W. Beaty, McGraw Hill 2002.

4. Electric Utility Engineering Reference Book, Volume 3 Distribution Systems, (the Green Book), Westinghouse Electric Corporation, 1959, page 165.

Websites

http://www.masstech.org/network.htm The Massachusetts Technology Collaborative, MTC, has collected and post at this website most of the known state actions and rulings that pertain to network interconnections. Also posted at this web site are documents such as the 2005 MTC annual Report (full or selected sections), various presentations given to the Collaborative on the network interconnection subject, and case study reports on specific network/DG interconnections.

www.rule21.ca.gov/technical_issues/network/ This website contains access to the Rule 21 list of resource documents, for example, detailed minutes from the Atlanta 2006 meeting of the IEEE 1547.6 working group's progress in developing an interconnection Recommended Practice on Network/DR interconnections.

www.dua1.com/duit.htm This website gives a brief description of mission of the DUIT (Distributed Utilities Interconnection Testing) facility

Appendix A: Excerpt from 2005 MTC Annual Report

The following table is extracted from the MTC 2005 Annual Report submitted May 31, 2005 to the Massachusetts D.T.E. The full reports for 2005 and 2006 can both be found at MTC website: http://masstech.org/dg/collab-reports.htm

Table 2.5. The description and design impact of the Technical Challenges identified by the Technical Working Group for the interconnection of DG to secondary network systems.

Technical Challenge	Description	Design Impact
1. 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.	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 deenergized. DG units must incorporate anti-islanding features.

Technical Challenge	Description	Design Impact
2. Reverse power method of protection employed by network protectors prevents power export	Exporting power into the utilities' primary system is not practical because of the reverse-power method of protection used on the network to prevent backfeeding from one transformer through another. If the DG output exceeds the total on-site load at any time, power will flow toward the primary feeders and the network relays will open each of the network protectors, thereby isolating the secondary network. Current DG protection systems cannot coordinate with network protectors that open in 3 - 6 cycles.	The requirement of a minimum site load to prevent reverse power flow may limit the size and/or operating hours of the DG. Additionally, in the case of the loss of a sudden large customer load there could be reverse power flow through the network units causing them to trip.
3. Potential for network protector cycling	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.	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.
4. Potential for network protector pumping	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.

Technical Challenge	Description	Design Impact
5. Inadvertent opening of network protectors under fault conditions	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.
6. DG contribution to fault current may exceed equipment ratings	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.
7. Fault current contribution of the DG to external faults	Fault current contribution of the DG for close-in external line and substation bus faults could cause some or all network protectors to open, thereby isolating network load.	To avoid inadvertently opening network protectors within the network system, the control scheme for the DG and network protector at the point of common coupling must be coordinated. This may involve delaying when the network protector opens[2] or use of other alternatives to enable the DG to disconnect before tripping network protectors.
8. Relying on time delays on network protectors to clear primary cable faults	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.	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. A consideration of types of faults might be appropriate. This problem is more significant for single line to ground faults on wye-wye connected network systems.

[2] Instituting an additional time delay in the protective function of network protectors will allow faults to exist for longer periods before they are cleared.

Technical Challenge	Description	Design Impact
9. DG's protection is unable to detect distribution line ground faults	The generator'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.
10. Network protector relay with time delay	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.
11. Export into the secondary network	1) For spot networks, export into the secondary network is the same as export into the primary system. This export would cause network protectors to open. 2) Area networks are more complicated. Exports into the secondary network would have to be studied with regards to power flow.	Exports into the utility primary distribution system will isolate the secondary network with attendant loss of load.
12. Safe parallel generator interconnection	DG interconnection facilities must be designed to nationally recognized guidelines that conform to specific and relevant standards formulated by industry committees and organizations like IEEE.	This approach ensures the design is based on prudent utility practices and consistent with regulatory requirements in order to ensure a safe parallel generator interconnection and operation.
13. Physical limitations of new installations	Network protector relays are part of an integrated assembly frequently in a submersible enclosure with tight access. This constraint is particularly frequent for secondary area networks.	Network protector relays are not as easily modified as a typical relay control schemes. Modifications may be difficult due to physical barriers and space constraints.

Technical Challenge	Description	Design Impact
14. Relying on customers' generator protection	Utilities do not rely on customers to protect other customers, equipment and utility personnel.	Interconnection arrangements must comply with and fully address the utility's safety, operational and maintenance criteria and concerns.
15. Location of protection and control equipment	Non-utility personnel inadvertently adjusting or modifying protective relay settings, control systems and related equipment when the equipment is located outside of utility locked vaults and facilities is not acceptable.	DG owners' operations and maintenance staff must be prevented from inadvertently adjusting or disabling control or protection settings.
16. Coordination of network protector and generator breaker opening times to detect arcing faults by heat detection system	A thermal detection system that opens all protective devices on a secondary (480 V) spot network upon detection of a fire, arcing fault or other abnormal event that generates heat above a prescribed threshold is necessary.	Opening of the generator breaker prior to the network protectors within an acceptable margin must be ensured.

Appendix B: Excerpt from the March 2006 Rule 21 Report

The following tabulation of network issues was extracted the California Rule 21 Report to California Public Utility Commission and the California Energy Commission. The full text of the report can be obtained from the website www.rule21.ca.gov/technical_issues/network/

In the Technology Development column of this tabulation, additional double red/**bold** Xs (**XX**) have been insert where it is hoped that the developments suggested above might aid in resolving the identified issue.

	Issue	Spot	Grid	Primary Fed	Technology Dependent	Area	Comments	Potential Solutions
1	How does the GF provide Network Transformer protection function normally provided by the feeder's protective relay?			X		Protection/ Coordination	GF connected to the Primary would be handled like any radial connected GF. Unclear what else this might address	
2	What kind of communication is necessary between the protectors and the GF?	X	X		XX	GF Impact on Network equipment/operation		Possibly NP status via monitoring system
3	How might the GF cause false tripping of the protectors?	X	X		XX	GF Impact on Network equipment/operation	Exporting across the NP; VAR swings?	Minimum import (Spot), limit GF capacity(Grid)
4	How might the GF prevent proper Opening protectors?	X	X			GF Impact on Network equipment/operation	Not sure how to cause this	
5	How might the GF prevent proper closing protectors?	X	X		XX	GF Impact on Network equipment/operation	Need to understand load levels necessary for proper closing	Reduce network Xformer size, minimum import (spot), GF capacity (grid) Testing Issue

	Issue	Spot	Grid	Primary Fed	Technology Dependent	Area	Comments	Potential Solutions
6	Will any Network equipment be overstressed (Fault) due to the GF interconnection?	X	X		X	GF Impact on Network equipment/operation		Limit GF or replace overstressed equipment
7	Will any Network equipment be over loaded (normal current) due to the GF interconnection?	X	X		X	GF Impact on Network equipment/operation	Not necessaraliy a “network” issue	Limit GF or replace over loaded equipment
8	What effects will the GF have on the Network Protector relays, and what are the new relay setting criteria? What are impacts of increased time delay for low level rev power setting	X	X		X	GF Impact on Network equipment/operation	Test to determine potential impacts of delay	See Feero report for possible relay settings.
9	How will the presence of the GF affect the protectors’ response to faults outside of their protection zones? (e.g. response to adjacent feeder fault, AFF)	X	X		XX	GF Impact on Network equipment/operation		Consider low level rev power time delays (similar to requirement for regn braking of elevators)
10	Is the operation of a single-phase overcurrent device (protector fuse) a concern with the presence of GF?	X	X			GF Impact on Network equipment/operation	Does not appear to be an issue.	

	Issue	Spot	Grid	Primary Fed	Technology Dependent	Area	Comments	Potential Solutions
11	What conditions must be satisfied before paralleling is allowed? What will be the paralleling procedure?	X	X		X	GF Paralleling requirements	Minimum import (across NP), Sufficient NP's closed, Sync tolerances met. Paralleling vs synchronization. Are different Sync tolerances required?	
12	Will a dedicated transformer for the GF be required?	X	X	X	X	GF Requirements	Does not appear to be an issue (not a network-specific issue)	
13	How do requirements vary with the number of Network Transformers (eg. Dozens to hundreds spread out over a wide area?	X	X		XX	Network configuration	Does not appear to be an issue	More xformers could ease the requirements
14	Will addition of GF impact arc detection (ozone, heat/smoke/flash)? Will requirements be different for 208 volt and 480 volt Networks because of the different arcing characteristics? How are the arcing characteristics different?	X	X		XX	Network Configuration	Testing needed to define issue.	

	Issue	Spot	Grid	Primary Fed	Technology Dependent	Area	Comments	Potential Solutions
15	Will the presence of, or lack of, Cable Limiters on the secondary cables result in different GF interconnection requirements?		X		XX	Network Configuration	Not aware of any different needs	
16	(combined with 13)							
17	Will changes in power flow over the daily or weekly load cycle result in protector Cycling at a point remote from the GF's PCC?		X		X	Network Configuration		
18	Will different protection requirements apply to Network systems supplied from three-wire and four-wire primaries? With delta-wye or wye-wye transformers?	X	X		XX	Network line configuration		
19	How will the protector be prevented from isolating distributed resources from the utility system? f the GF islands, will the Network Protector relay tolerate 180 deg out of phase voltage? If the GF islands, how will the Network master (/phasing?) relay be prevented from reclosing the protector switch during an out-of-synchronism condition?	X	X	X	X	Protector breakers are not designed to interrupt fault current from generators or withstand out-of-phase conditions across the open switch.	Another islanding problem 1) Test NP to see if it can withstand 180	Replace NP Anti islanding >50% NP closed requirement Limit GF capacity Minimum import

	Issue	Spot	Grid	Primary Fed	Technology Dependent	Area	Comments	Potential Solutions
20	What would be an acceptable ratio of the minimum customer load current over the maximum GF output to eliminate any possibility of reverse power through a protector?	X	X			Reverse power through Network Protector	This is the FIRST thing to test!!! (see 3)	
21	What action needs to be taken with a sudden loss of large load?	X	X		XX	Reverse power through Network Protector	Issue not understood Transient low load issue?, inadvertent export? Is this really a subset of 3?	
22	Can power swings or loss-of-synchronism, loss of field by rotating generators cause reverse power through a Network Protector?	X	X		X	Reverse Power through Network Protector	A testing issue	
23	Can insertion of customer PF caps cause reverse power through a Network Protector?	X	X		X	Reverse Power through Network Protector	Testing issue (Moh)	
24	(Combined with 19)	X	X					
25	(Combined with 19)	X	X					
26	How can addition of GF contribute to or exacerbate cycling or pumping of NP	X	X		X		Needs testing; what constitutes “exacerbate”?	

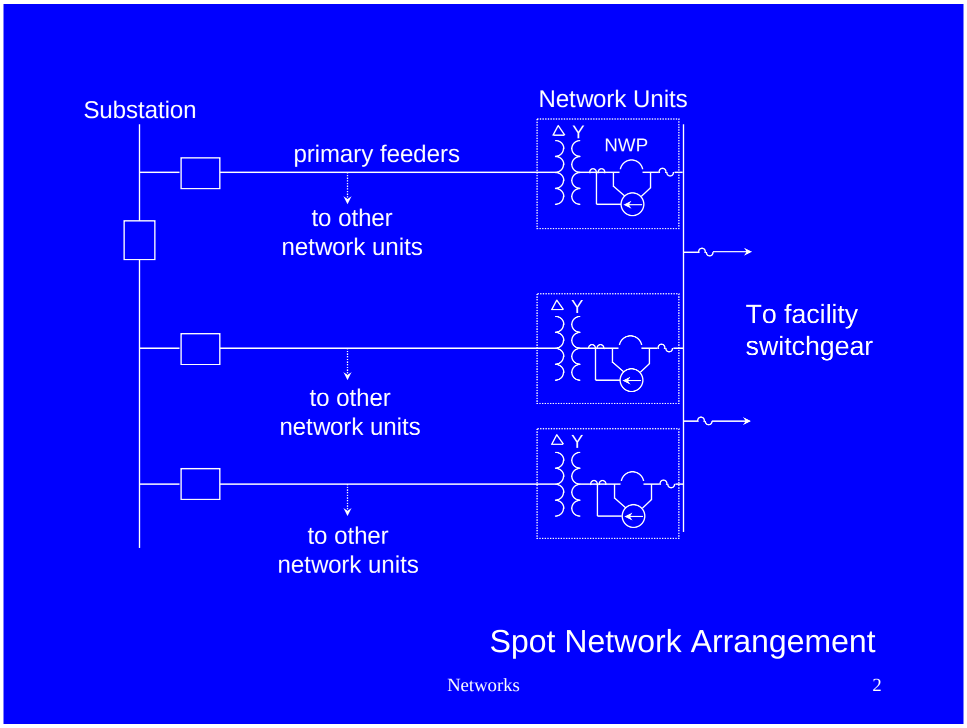
	Issue	Spot	Grid	Primary Fed	Technology Dependent	Area	Comments	Potential Solutions
27	Is there any fault detection (Phase or ground fault) required for GF? Should GF trip before NP?	X	X		X		Why? (MDGC issue)	
28	What equipment damage can occur due to increased time delay for low reverse power	X	X				(MDGC issue) testing needed to determine impacts	
29	Modifications to Network equipment may be problematic and costly due to access limitations, equipment age, etc.	X	X					
30								

Appendix C: Slide Presentation -- DR on Spot Networks

DR on Spot Networks

by W. E. Feero

revised for April 5, 2006
Massachusetts DG Collaborative
meeting on Network Interconnection
at National Grid, Northboro, MA



General Arrangement of Spot Networks

- 277Y/480 volt LV supply systems
- two or more utility primary feeders supplying network transformers
- primary feeders may be dedicated to the network or may have other loads
- integrated transformer, relays, and LV air-break switch (network protector)
- protector switch opens on reverse power flow to isolate primary feeder trouble

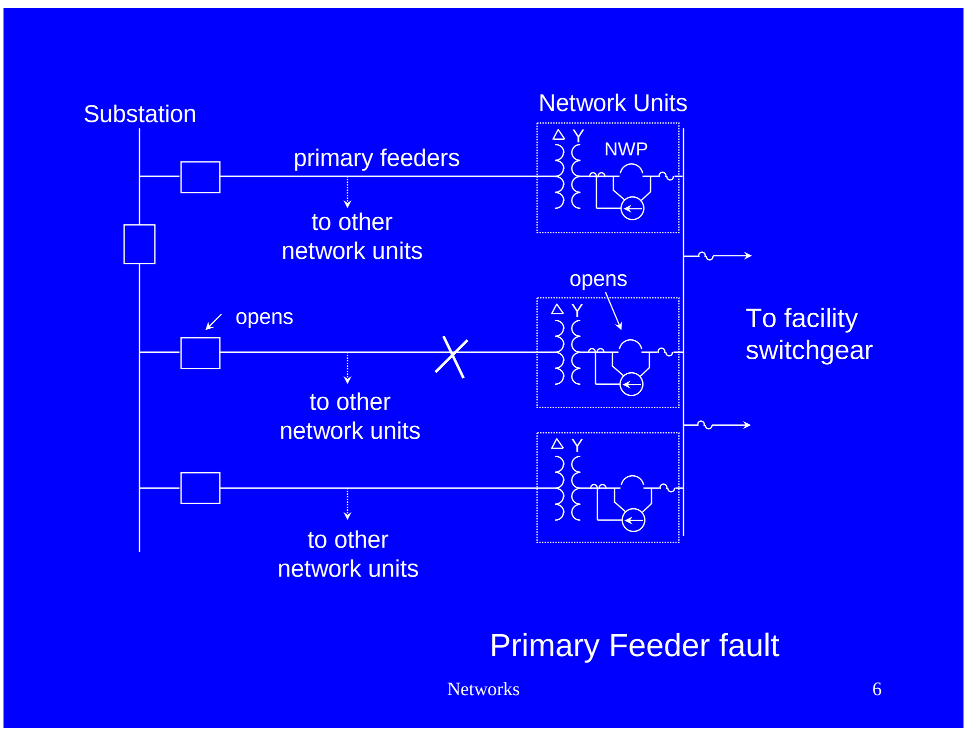
Network Relay Characteristics

- Master relay (a very sensitive three-phase reverse power relay) opens protector when real power flow is from the network to the primary feeder.

- Sensitive reverse power relay picks up on network transformer core losses in order to sense primary feeder outage even when there is no other load on the primary feeder

Network Relay Characteristics

- typically an electromechanical device, electronic types available
- no intentional time delay
- also sensitive to reverse var flow at current levels above normal load



Network Relay Fault Response

- Primary feeder fault opens substation CB and network protectors
- Primary feeder ground fault sensed by backfed power to other loads or just network transformer losses

- Secondary faults are cleared by fuses or may simply burn themselves clear; network relay does not respond

Network Relay Characteristics

- Master relay recloses protector when transformer voltage is higher than network voltage and leads the network in phase angle

- To some degree, network protection is like dispersed generation interconnection protection, i.e. the network is a weak source of backfeed to the primary system which must be removed for primary system faults.

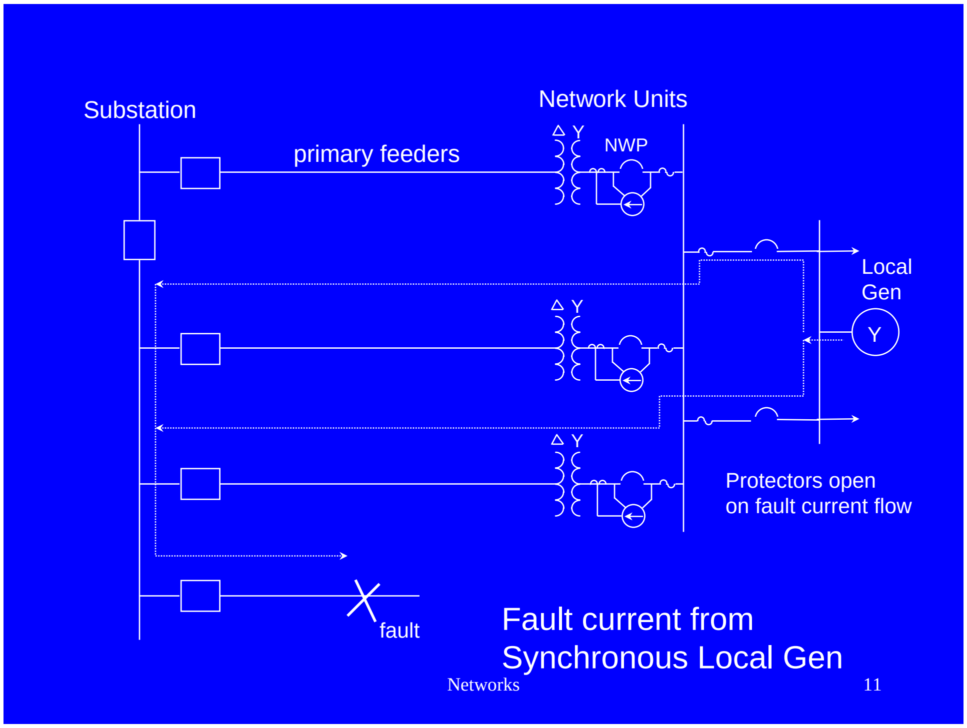
Network Protector Characteristics

- air circuit breaker specifically designed for the fault current conditions experienced on network systems
- no overcurrent protection; opens and closes only under the control of the master relay
- design standards (ANSI/IEEE C57.12.44-1994) have no requirements for withstanding 180 degree out-of-phase conditions or interrupting fault currents with abnormally high X/R ratios

Problems with Local Generation on Network

- if local generation exceeds local load, even momentarily, network protectors open and isolate the network from the utility supply.

- fault current contribution from synchronous local generation can cause network protectors to open for faults on other primary feeders, isolating the network.



Problems with Local Generation on Network

- attempting to resynchronize an isolated network to the utility may trip the network protector because of power swings; the protector may not be able to interrupt under such conditions
- protector circuit breakers are not rated to interrupt fault current from generators or to withstand out-of-phase conditions across the open switch

Problems with Local Generation on Network

- master relay may reclose the protector switch during an out-of-synchronism condition if the network is islanded

- network relays are part of an integrated unit in a submersible enclosure and are not readily modifiable for special conditions

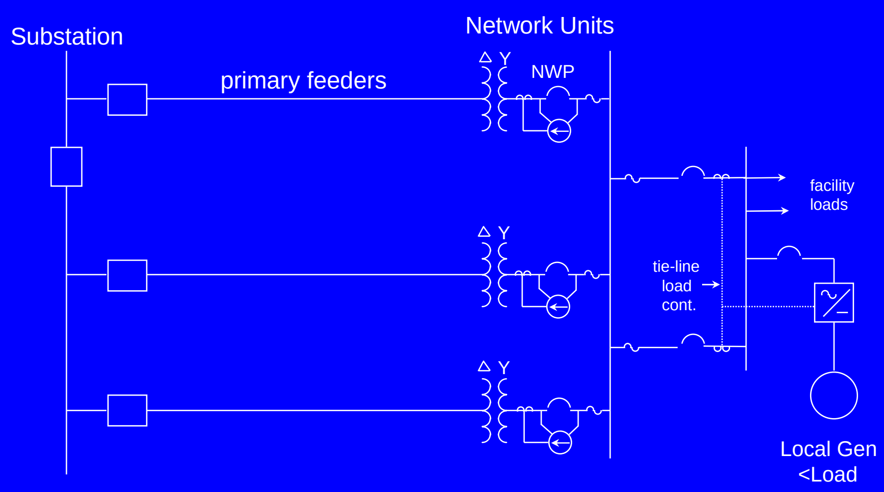
DG on Spot Networks

(modifications in red made 04/03/06)

- It use to be thought that inverter-based generation technology would not cause network protectors to opened by fault current contribution from the local generator but it can, so,
- time-coordinate network protector relay with {feeder} DR relaying to prevent NP opening from generator fault current contribution and,

DG on Spot Networks

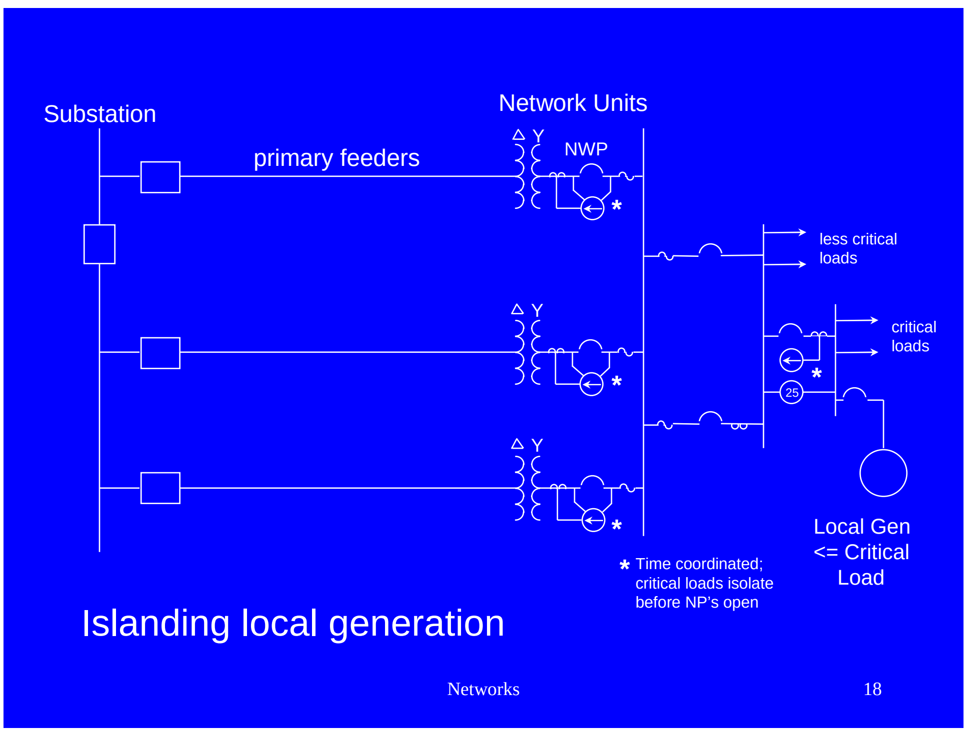
- limit generation to less than local load, with an adequate margin for sudden loss of load conditions, to insure no undesired reverse power conditions or,
- control inverter power output with “tie-line load control” so power flow from the utility to the network never reverses or,



Inverter-based, no-islanding local generation

DG with Network Units
Alternatives

- trip or isolate local generation from network if network protector relays sense low incoming power flow or,
- isolate local generation with critical loads by sensing reverse power from “critical load bus” to network



DG on Spot Networks

- UNACCEPTABLE (after the fact protection) prevent islanding of the network: trip generation or isolate it from the network unit with a circuit breaker whenever all network protectors open or when out-of-phase voltage is sensed across a protector switch

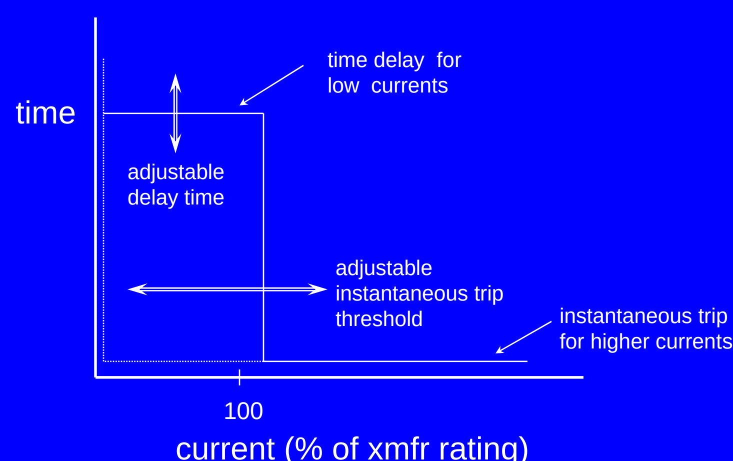
Coordinating Network Relays

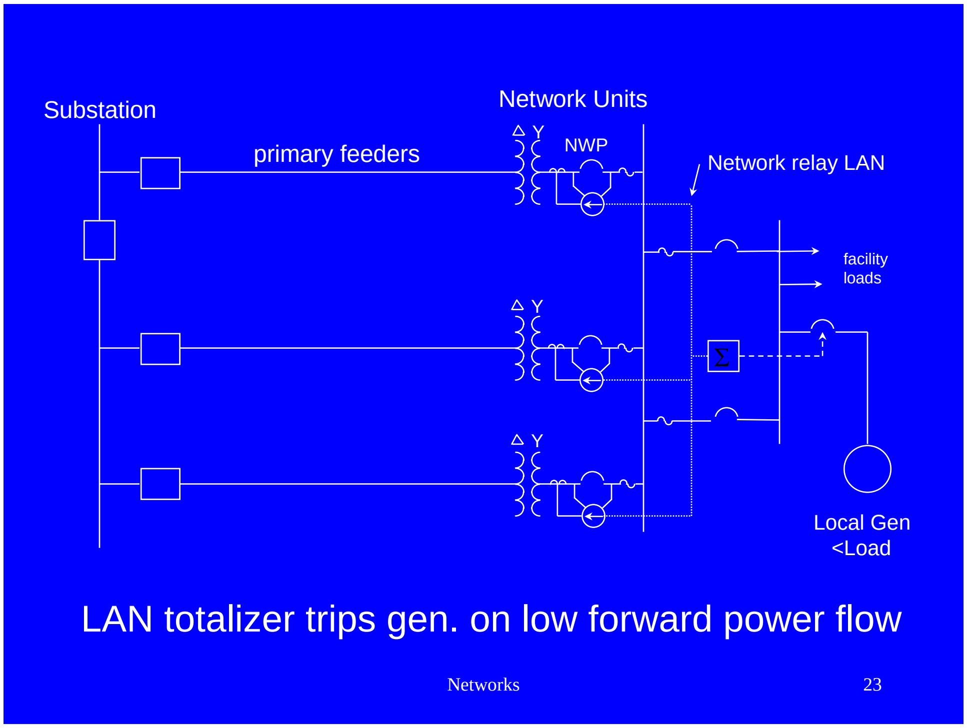
- Most NP relays are electromechanical with no intentional time delay
- Some microprocessor-based network relays can be provided with time delays
- Time delay slows the clearing of faulted feeders from the network, potentially degrading service quality

New NWP Technology

- Microprocessor network relays
  - – adjustable pickup and timing settings
  - – LAN capability
- High Interrupting Capacity Protectors
  - – Cutler-Hammer CM52 Network Protector

Adjustable Reverse -Power Characteristic



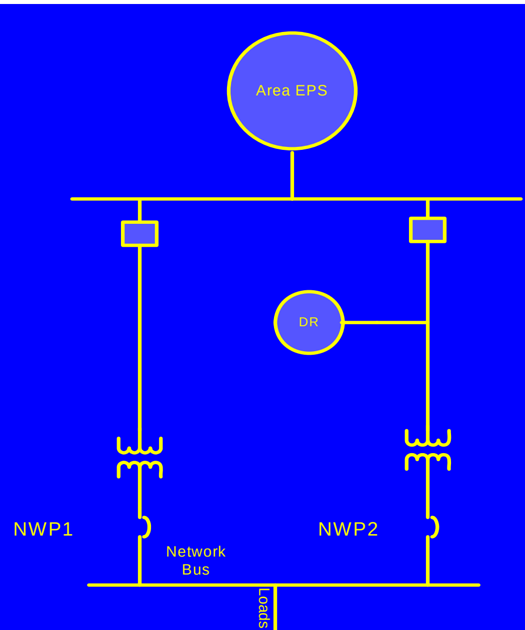


CM52 Network Protector

- 600 volt, 10 kV BIL
- Uses C-H Magnum DS breaker
- Built and tested to IEEE C57.12.44-1994, but also has breaker capabilities
- Can be retrofitted to many existing network units

CM52 Network Protector

- 800 - 2250 Amp rating (available soon)
  - 42 kA IC, 35 kA fault closing
  - rated and tested for separating two systems
- 3500 - 6200 Amp rating (available later)
  - 65 kA IC, 60 kA fault closing
  - rated and tested for separating two systems



- This presentation is available on-line at:
  http://www.masstech.org/renewableenergy/public_policy/DG/2005_annualreport.htm

- Other reports and information on network interconnection are available at:
  http://www.masstech.org/network.htm
  and
  www.masstech.org/policy/dgcollab