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UTILITY INTERCONNECTION BY NON-UTILITY GENERATORS: CASE STUDIES

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Abstract

Utility interconnection case studies for paralleled, Non-Utility Generators (NUGs) are presented, each of which is unique and each of which has something to teach us about the design of interconnection facilities and the basis for negotiations between NUGs and utilities.

Each interconnection is unique because of differences in:

1) utility's basic interconnect requirements,
2) the existing utility system arrangement and equipment,
3) the host facility's objectives and
4) the existing host facility equipment.

The utility and host facility perspective and concerns are compared in this speech. The perspectives and concerns are not always compatible but in most cases there is opportunity for helpful negotiations.

These utility interests are usually in the following areas:

1) personnel safety,
2) equipment safety,
3) effects on power quality to other customers and
4) non-technical issues (such as commercial, legal and political issues)

and **the host facility's interests are usually in the following basic areas:**

1) personnel safety,
2) equipment safety,
3) power quality to the host facility (including reliability and continuity)
4) cost of capacity, energy and backup power

Introduction

This paper is divided into the areas of interest mentioned above. Within each division there are case studies used to illustrate the points. The projects are all real projects less than 100 MW with which the author or ANNA, Inc were directly involved, however names of the projects and utilities involved are not provided because they are not important to the lessons learned. Also, in one case, the project name is confidential because the project is still under development.

Each Interconnection Is Unique Because Of Differences In Utility Requirements And Utility & NUG Equipment

The utility's basic interconnect requirements

Almost all utilities have a basic interconnect requirement document. This document will usually include the basic protective relaying requirements for several cases which may be generator size, mode of operation, type of generator and interconnection voltage.

While these requirements are a good starting point for discussion and negotiation, the NUG design engineer should not take these requirements as non-negotiable. Some requirements will be clearly justified such as the need for a generator breaker and synchronization equipment. Others, such as the need for transfer trip schemes, should be based upon the characteristics of the specific application.

The chart is made from one typical utility's interconnection requirements package. It is not meant to provide a guide for design of interconnection protective relays in other utility areas nor is it all inclusive; since it was prepared by a utility to protect their interests, the list does not include complete generator, transformer or bus protection. Note the requirement for a transfer trip scheme on a medium voltage plant which will sell energy to the utility.

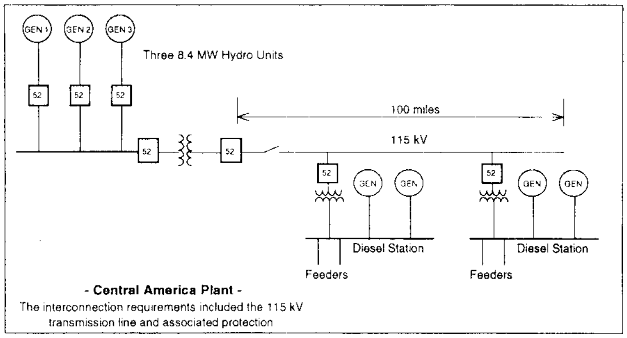
Typical utility basic requirements

Requirements with ANSI relay designations	Low voltage (Less than 480 V) Non-isolated operation	Low voltage (Less than 480 V) with stand alone capability	Medium voltage (up to 33 kV) supplimentary service	Medium voltage (up to 33 kV) Buy back service
Phase Time-overcurrent protection with voltage control (51V)	X (3)	X (3)		
Phase Time-overcurrent protection (51)			X (3)	X (3)
Neutral Time-overcurrent protection (51N)			X	X
Reverse power (flow to generator - 32M)	X	X	X	X
Reverse power (flow to utility - 32R)	X	X	X (3)	
Watt meter	X	X	X	X
VAr meter	X	X	X	X
Power Factor Meter	X	X	X	X
Ammeter	X	X	X	X
Frequency Meter	X	X	X	X
Volt Meter	X	X	X	X
Synchroscope	X	X	X	X
Synchronizing supervisory relay (25A)	X	X	X	X
Additional synchronizing supervisory relay (25C)	X	X	X	X
Phase sequence relay (47)	X (optional)	X (optional)		
Under and Over Frequency (81 O/U)	X	X	X	X
Over voltage (59)	X (3)	X (3)	X (3)	X (3)
Undervoltage (27)	X (3)	X (3)	X (3)	X (3)
Directional overcurent (flow to utility - 67)	X (3)	X (3)	X (3)	X (3)
Ground fault relay applied to generator neutral (59G)	X	X	X	X
Trip & Lockout relay for generator breaker (86)		X	X	X
Trip & Lockout relay for utility breaker (86)	X	X	X	X
Trip & Lockout relay for utility breaker from transfer trip scheme (86)				X
Undervoltage on DC control power supply (27dc)	X	X	X	X

The existing utility system arrangement and equipment

Interconnection requirements vary depending upon whether the power plant will tie into a local distribution line, transmission line or a new transmission line. In the case of a large hydropower plant in Belize, the 100 mile long , 115 kV transmission line was built for the plant but tied together eighteen diesel generators in the country. This is obviously a very expensive interconnection capital expenditure for the plant but one which was necessary to have an adequate market for the electrical energy.

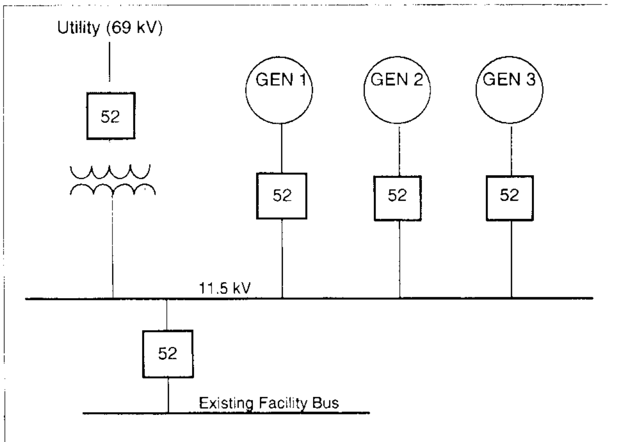
In this case, the interconnect requirements included a transmission line and associated protective relaying. Not only did the line deliver power across the country but it established the first country-wide interconnection of generator stations and loads.



- Central America Plant -
The interconnection requirements included the 115 kV transmission line and associated protection

The host facility's objectives

The objectives of the host facility for inside-the-fence power plants is usually to reduce electrical and thermal energy cost and to provide a more reliable source of power. In the case of a power plant in the islands, the host facility has need for all the thermal energy which may be recovered from three large, medium-speed reciprocating engine-generators. The electrical power available from these engine-generators is more than what the host facility needs therefore the utility will buy the excess power. Meeting these objectives will require building an extension of a 69 kV line and abandoning the facility's power supply originally taken from a 11.5 kV, 50 Hz distribution line.



- Islands Cogeneration -
with three medium speed reciprocating engine generators

The existing host facility equipment

In the example above, the host facility's power equipment was capable of withstanding and interrupting only a limited amount of current available from the 11.5 kV distribution line. When the 69 kV feed is used instead, the available fault currents will be higher which may require upgrades to the existing power system.

UTILITY AND NUG INTERESTS ARE IN THE FOLLOWING AREAS

Personal safety

This is appropriately the most important item on the list for utilities and host facilities alike.

The disagreements in this area are not whether to make the interconnection safe save but how to make the interconnection safe. Here is a good example using a dual-fuel combustion turbine cogeneration project.

We designed the project to run in parallel with the utility providing most of the host facility's electrical needs (a New Jersey college). The local utility provided power to meet the peak demands which were more than the turbine-generator could supply. In rare cases where there was low usage, turbine generator electricity could be sold to the utility.

The project was able to operate as an island when the utility was not available. This feature was possible because there are circuit breakers at the generator and at the utility connection which are controlled by protective relays at the incoming utility line and at the generator to detect voltage and frequency variations.

The relays upstream of the utility breaker were set more sensitive than the relays above the generator. Therefore, when the utility had a problem with voltage or frequency the utility breaker would open, loads would be shed to get power requirements below the turbine generator rating and the generator would remain in operation feeding the most critical loads of the host facility. Synchronization capability across the utility breaker allowed recovery from a utility breaker trip without an outage to the most important loads.

During the design phase of the project, the utility asked for a switch to be mounted outside which would be capable of tripping the generator and locking out the breaker. In addition, the utility wanted this switch to be lockable in the tripped position.

All these requirements were easy enough to do with off-the-shelf components and a few thousand dollars but the request caused us concern because we were afraid there would be undue reliance upon a switch to clear a line. We asked for their reasons for the switch. Their answers were that they were afraid they could not get into the control room to discuss the need with the operator in a timely manner when "something happened" which necessitated opening and locking out the generator breaker. They also mentioned they wanted to make sure the line was dead in the event they had to work on the line.

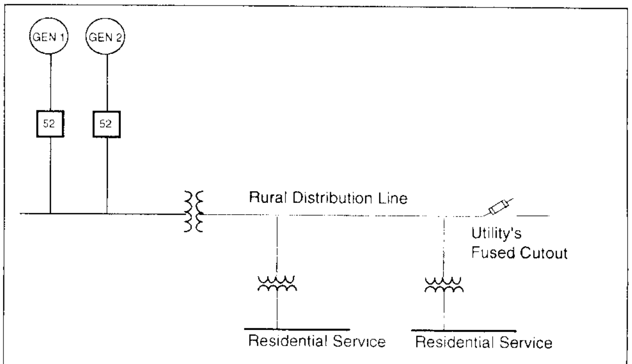
With regard to their first reason, a switch would be faster than walking into the control room and the equipment would be able to handle a full load trip and load rejection but there was no significant benefit in saving a few seconds or a minute. If the power system was in trouble, it would be picked up by the protective relays and the plant would be off line before any human could take action with any switch. Because of the high pressure boilers on site, an alert operator was always required to be present and the doors were never locked. Even if the doors were locked in the future, the utility had the operator's phone number or could knock on the door to get the operator's attention. Besides, it would be faster to call the operator from the dispatcher's office than to send a lineman to the facility to operate a switch.

After some lengthy discussions we finally agreed to leave the switch out and rely on an operator's fast action to open the line when requested by the utility without supervisory approval and we all agreed to use a padlock and tagging system on the racked out generator breaker for personnel safety. The plant controlled the lock and tagout procedure which allowed the utility to overlap with their lock and tagout procedures by putting the utility's lock on the same tagging point—both locks must be removed to rack in the breaker.

Equipment safety

Equipment safety is a common goal in the design of utility interconnections but there are different perspectives for the utility and the NUG because they each have their equipment to protect. Usually, there is good cooperation and agreement on equipment to be protected and how that equipment will be protected. Each is usually responsible for their own equipment so there are few disagreements—the NUG is responsible for protection of their generators, switchgear, transformers and other power equipment and the utility has the same responsibility for their equipment.

The utility had been very cooperative during the design and installation of the New York hydropower plant. The utility distribution system was a three wire system without a grounded neutral point. This meant that there could be one grounded phase on the utility side without fault current. The utility wanted us to have a ground fault detection relay to determine before the plant's breaker was closed that there were no ground faults on the utility system. We objected to this because of the cost (three pole-mount, 15 kV class PTs and a voltage sensitive relay) and because our equipment was all Delta facing the utility side providing no ground fault power source to the utility's lines. The utility insisted on the equipment and we reluctantly installed it.



Small Hydro Station

Here was another equipment safety issue on the same project: the fused cutout. The plant was at the end of a distribution line which fed residential areas. The fused cutout which fed the line section was well undersized for the conductors but provided plenty of capacity for the loads on that section. This arrangement was fine before the hydropower plant was commissioned and was a conservative fusing which probably provided easier coordination with upstream protective devices.

The utility delayed upgrading the fuses to accept the power flow into the utility system when the hydropower plant was at full power. Unfortunately, for those watching football that Monday night during startup, we found out the fuses had not been upgraded by blowing them! We called the utility service department and left the area before the neighbors figured out we were associated with the outage.

In the case of another hydropower station in Virginia, the utility insisted on a transfer trip scheme to allow fast tripping by the utility under certain system conditions. We determined that the need for the transfer trip scheme was not justified and asked the utility to waive the requirement. We were in the process of convincing them that the scheme was not needed when we passed a critical project deadline and had to proceed with the scheme as they demanded. A year after the plant started up we were able to convince them that the scheme was not needed and we were able to have it disabled. We still had to pay for the equipment but at least we were able to avoid the high monthly fees for the leased lines from the phone company.

The effects of power quality to other customers

Utilities often are forced to balance one objective against another. For instance, the decision to install a higher capacity transformer at a substation has the benefit of increased reliability over the existing overloaded transformer in exchange for the cost of the labor and capital for the new transformer and the cost of possibly stranding the remaining book value of the existing transformer.

The utility may require the NUG to pay for every possible additional cost associated with the additional capacity. For instance, examine the case of the NUG at a New Jersey college located on a 13.8 kV distribution line on which reclosers are upstream of the NUG interconnection point. The utility demanded that the cost of moving the recloser downstream of the NUG plant be borne by the NUG. We felt this was a reasonable request.

The utility did not demand the level of service to each of their existing customers be exactly the same as before. That demand could have required a new line installed to the substation and a new substation transformer. After moving the recloser, some of the customers who were formerly downstream of the recloser were now upstream of the recloser. Those customers might see less power interruptions but all customers on the distribution line would now have less recloser protected line than before. This would mean that a fault between the old recloser location and the new recloser location, which may have been cleared before, may result in an entire feeder outage in the new configuration.

There are subtle differences in service to the utility's customers which result from the NUG generator on that line such as reduction of line loading, smooth VAr production and additional fault power available. All these differences added together will make a difference in level of service to the utility's customers—better or worse than before. The important fact to remember is that service to the utility's customers is not perfect either before or after addition of a NUG's generator.

Non-technical issues (such as commercial, legal and political issues)

In a second New Jersey project, the utility stated that they would not reclose onto a dead line feeding our facility unless we went through a lengthy approval process which involved calling the plant operator and verifying that the generator was off-line. The plant would have utility-owned protective relays which would verify the line was dead before energization. In addition, the load on the island created when the line breaker was opened was many times the generator capacity and the sensitive NUG protective relays would detect abnormal voltage and frequency conditions and trip the utility breaker.

After further discussion and questions about what the utility would do if the NUG generator was a utility generator that the utility stated they would rely upon their relays but they were concerned about taking the same risk with another party's equipment when there was little to gain. We pointed out that the other customers on the line would have better service if they closed the breaker in the normal manner. We also pointed out that the protective relays would provide sufficient and reliable protection.

The utility would not agree until we treated the real issue: risk and liability accepted by the utility for the NUGs equipment. If the power plant had been the utility's equipment, the relays would have been used without concern. The NUG in this case, had to agree in writing to not blame the utility if the utility closed the breaker to energize a line based only upon relay supervision.

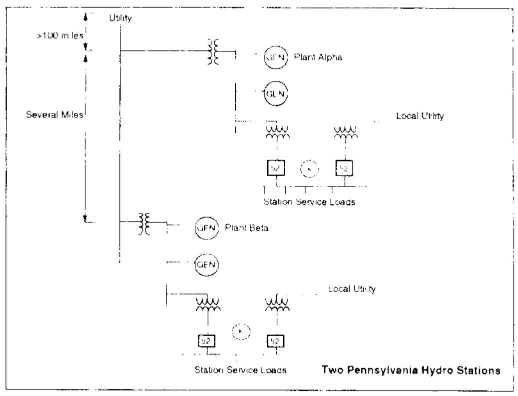
In this case the issue was a legal liability concern on the part of the utility. The lesson is to find out the real issue and treat that issue to achieve the goal.

Another legal issue and solution

At two large hydropower sites only a few miles apart in Pennsylvania there was a legal requirement that the utility not backfeed the plants because the plants were physically located in another utility's service territory. This caused a number of interconnect problems.

A second source of 480 volt station service power was supplied by the local utility. After startup, the power source could have been switched over to the station service transformer fed from the generator bus except that the loss of power during the key-interlocked open-transition transfer would cause too many problems with the control systems to allow the plant to continue running. Closed transition transfer could not be used because the two sources were from different utilities and they were at different phase angles.

Startup was complex because the dedicated 138 kV transmission line and the plant's power transformer would have to be energized from the utility side which meant feeding some power to magnetize the transformer and some kVA flow to absorb the VArs produced by the transmission line.



Two Pennsylvania Hydro Stations

The final version of the startup procedure was as follows:

- Start plant Alpha using local 480 volt power,
- Backfeed the transmission line with utility power (the utility allowed only a few

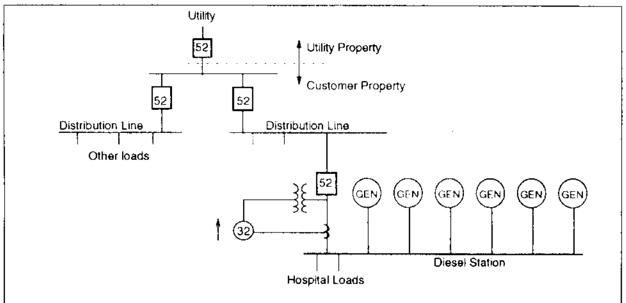
minutes in this backfeed condition to close on line and produce power),

- Close one of plant Alpha's generator's on line and generate sufficient power to backfeed and startup the other plant,
- Startup plant Beta using 480 volt station service power from the backfed generator bus and generate power, and finally,
- Shutdown plant Alpha, change the 480 volt power source to the generator bus and again startup plant Alpha.

Power quality to the host facility (including reliability and continuity of service) and **Cost of capacity, energy and backup power**

Costs are the driving force behind any NUG project. The costs are not always as simple as the cost per kWh for energy or the cost per kW-month for capacity charges. Sometimes the host facility has a large process loss when power is interrupted such as at a steel mill or a chemical processing facility. In these cases costs are still the driving force behind the project but they are hidden. It may be cost effective for an organization to pay more for electricity because of its reliability feature and importance to the reduction of process loss or other goal.

In other cases human life may depend upon reliable power sources such as at a six-unit prime power energy plant at a large hospital in the western USA. At this plant, the utility wanted a reverse power relay at the plant to keep from having power backfed to the other loads within the NUG facility's compound. The compound was large compared to the size of the power plant and the utility feeds were taken at a large NUG owned substation at the edge of the compound.



Hospital Power

The import-export controls had to be calibrated to have at least a little power import from the utility at all times to stay out of the way of the reverse power relay.

The ostensible reason for the relay was technical; the utility stated the reverse power relay was to keep from having power flow back to energize an otherwise dead line for safety reasons. However there were other ways of dealing with this problem. There could have been voltage relays and interlocks between the incoming breaker at the plant and the feeder breaker at the NUG's substation to keep from closing a breaker on a line already energized and the reverse power relay, if required for legal or commercial issues could have been located at the substation well upstream of the energy plant.

We suspect the utility wants the reverse power relay at the power plant to prevent the NUG from feeding other loads on the compound in addition to the hospital loads. In this case, the reverse power relay causes some nuisance tripping thus reducing the power quality to the NUG loads. A reverse power trip does not result in a loss of power to the loads but it does remove one of the two paralleled sources which reduces reliability for the power to NUG's hospital loads.

We feel the utility would allow removal of the reverse power relay if pressed. Other issues to which we are not exposed which would complicate the situation could include:

- Contractual agreements with the utility which specify limited power delivery from the power plant and require reverse power relays to enforce the clause in the contract,
- The desire on the part of the NUG to be a good neighbor to the utility and to avoid confrontation.

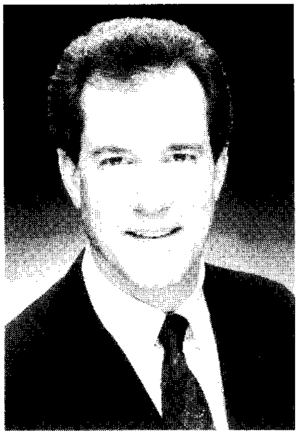
Other issues

At a number of power plant projects which have been proposed in New York, Pennsylvania and other states, the would be NUG is approached by the utility which wants to keep its market share and revenues and asked to stop the project. The utilities have offered cogeneration deferral rates and other financial incentives to postpone or cancel a planned inside-the-fence power plant project. These issues are beyond the scope of this paper, however, it is useful to recognize the perspectives of both parties in our evolving competitive marketplace and know that there is a lot more involved with utility interconnection than technical issues.

Conclusion

There are many problems which good engineering and cooperative relationships with the interconnected utility can solve. In the grand majority of cases, the utility and the NUG interests are similar so that with little compromise, all can agree on an interconnection which meets the needs of both parties.

About The Authors



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