Wind Project Interconnections: Protection and Control Expectations

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INTRODUCTION

There are many entities involved in the development and interconnection of a wind project. Each of these entities has certain project expectations. As protection and control engineers, we need to know the protection and control expectations of each entity so that we may provide them with the proper deliverables.

This paper is written from a protection and control consultant's perspective and is based on experience with over 60 utility scale wind projects throughout the U.S. since 2002. The general objectives of each entity drive their protection and control expectations. These entities include owners, operators, developers, construction contractors, designers, turbine manufacturers, commissioning teams, power purchasers, qualified schedulers, transmission providers, and system operators.

Modern relays and associated equipment coupled with modern design concepts and applications provide answers to the challenges of meeting these expectations.

Wind farms are interconnected in many different ways with the point-of-interconnection located in different places, but in general, Figure 1 shows a basic configuration and some definitions.

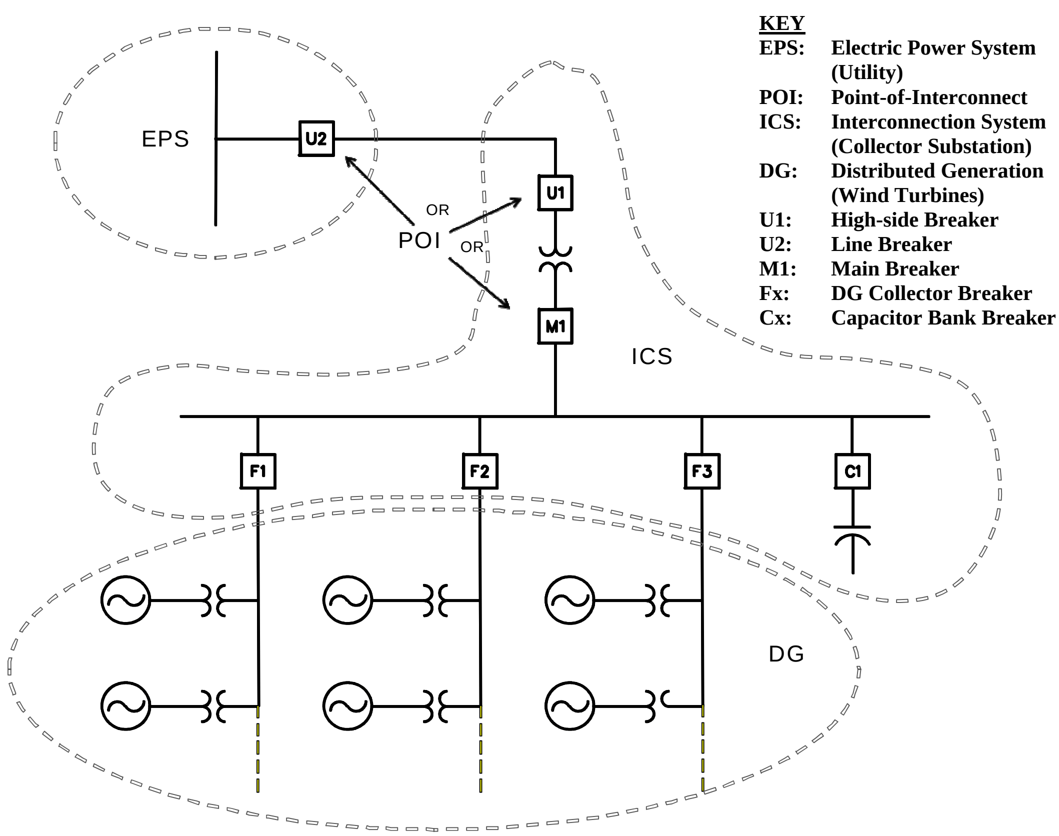


Figure 1: Basic Wind Farm Interconnection and Terminology.

WIND ENERGY GROWTH

The growth of electrical wind energy in the United States has been remarkable. In 1999 the installed capacity of wind derived generation in the United States was less than 2.5 gigawatts in 15 states.

One decade later the installed capacity has increased ten-fold to over 28.6 gigawatts in 35 states (see Figure 2). The American Wind Energy Association (AWEA) has stated that at the end of 2008 the United States surpassed Germany as the world leader in both installed capacity and wind energy production [1]. The United States is now poised under the national renewable electrical standard (RES) to target 10% of U.S. electrical supply from wind by 2012 and as much as 20% by 2030 [2]. The National Renewable Energy Laboratory under the auspices of the Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) has evaluated the impact of the proposed 20% national renewable portfolio standard (RPS) as of February 2009 and has concluded that the United States can reliably accommodate 20% wind energy penetration under the assumption that wind capacity in 2030 will expand to 129 gigawatts, a 450% increase over 2009 [3].

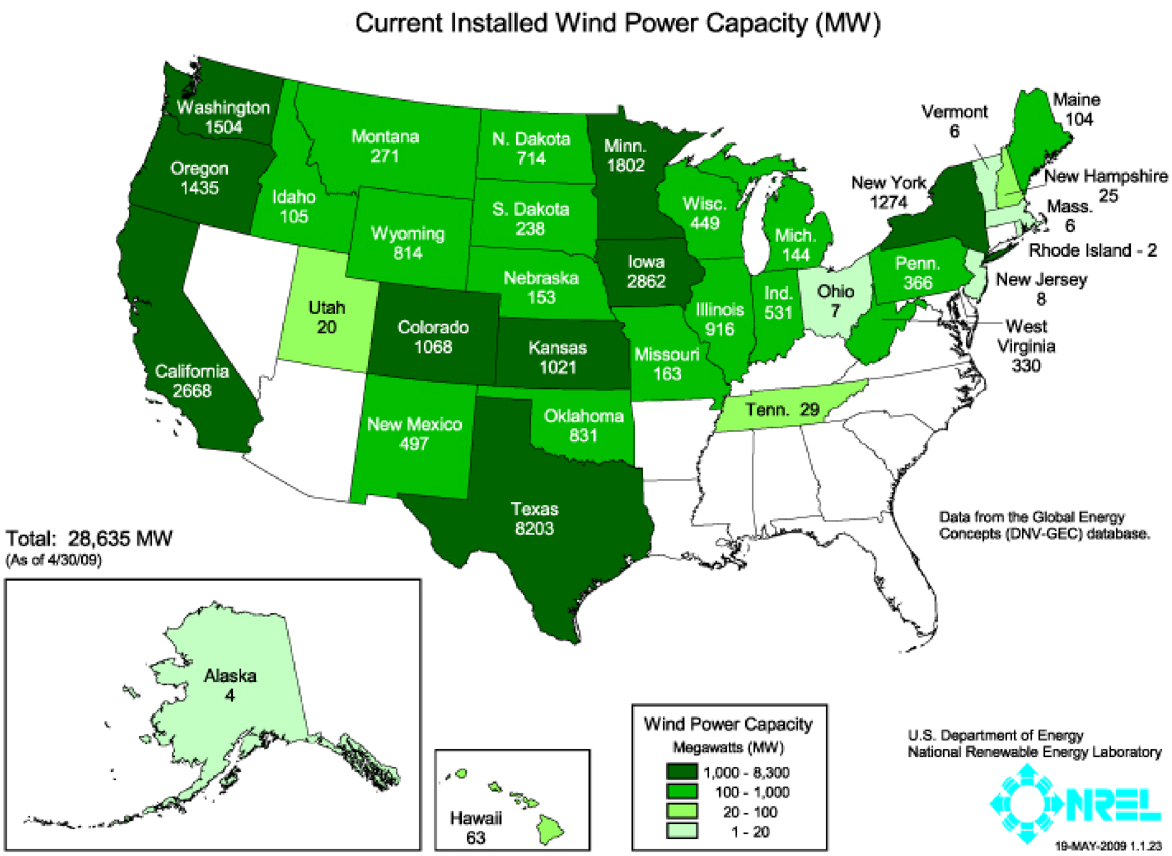


Figure 2: Installed Wind Energy Generation in the United States as of April 30, 2009 U.S. DOE web site: http://www.windpoweringamerica.gov/wind_installed_capacity.asp

Project Entity Objectives

Each entity has a set of objectives for each wind farm project. These general objectives drive the protection and control expectations. These expectations lead to specific deliverables that the protection and control (P&C) engineer should provide to the entity for review or reference. The following discusses each entity and their objectives. Table 1 summarizes the P&C deliverables that meet the P&C expectations of their objectives.

Owners

A utility or a private generation company may be the owner. They want to minimize damage during fault conditions, limit outages to the necessary equipment, maintain personnel safety, minimize construction costs, begin producing power as quickly as possible, and maximize "up" time once the project is completed. The owner will want to monitor the operation and have access to general information about power output and "up" time. When considering the deliverables for the owner they have a direct interest in several items during the design and construction phases, but at the conclusion of the project will need delivery of a complete package of all deliverables.

Operators

Most wind farm on-site operators do not have a utility background. Typically, the operators require skills that include the mechanics of the turbines, turbine maintenance, and knowledge of the turbine control system. Substation and interconnection protection knowledge is desired, but is not used regularly by the on-site operators. On-site operators typically maintain operations from a site operation and maintenance facility that is often only staffed during the day. 24/7 operations are often managed from remote, central locations by the owner or by a third party service.

Because of this, the operators need simple visibility of the substation and interconnection. They need to be able to quickly troubleshoot an operation and have remote control. To operate the wind farm over the long term, the operators need access to basic trend data, system up-time statistics, and easy access for gathering additional data if needed. To maximize the facility "up" time, the operators need to minimize maintenance outages and system event outages, and be able to rely on protection systems for isolating a faulted zone without impacting other zones of protection.

Developers/Construction Management

The developers of a project may plan to own the project or they may plan to sell the project. In some cases an owner may hire an experienced developer to provide construction management for the project and turn it over to the owner when complete. In all of these cases, the developer wants a project without surprises, a safe working environment, and a short time-to-production schedule.

Based on experience there have been a few recurring issues that extend the project timeline.

Items that are more likely to increase project timelines include:

- Easements
- Transformer delivery
- Turbine erection
- Telecom service
- Electrical design staffing
- Responsibility matrix

The last two items in the previous list are directly related to the P&C engineer as mentioned in the following discussion about the contractors and the design team. The bottom line is that the design team needs a P&C engineer and all project entities need to know the responsibility assignments for all aspects of the project including the P&C items.

Construction Contractors

Construction contractors typically develop a price and schedule based on a set of preliminary design documents. They expect that the “For Construction” design will be very close to the “Preliminary” design. Once the design is issued for construction, the contractors want to keep the design changes to a minimum. During the construction phase the contractor expects that the design team is available for consultation should questions or changes arise. The responsibility matrix for all work, but in particular the P&C work, are critical to keeping the project on schedule. Design decisions and construction decisions are often different depending on the owner of particular tasks. For example, if the utility is responsible for the line protection, the design team and construction contractors will rely on the utility to design and place their relay panels. This will require the utility to identify the schedule requirements to facilitate the design and panel installation.

Designers

The design team should include the P&C engineer that will be providing the relay settings. Some utilities break up the role of the P&C design versus the relay settings. This works well when standard designs are implemented. Often, a utility that designs a wind farm realizes that their typical design standards will not apply, so it is recommended that the P&C engineer providing the settings be involved in the design. The design team expects the P&C engineer to specify the appropriate relays and the I/O assignments. They need a specification for the design and they expect the specification will not change. This includes requirements from the interconnect agreement, system operator, and any NERC requirements. It is becoming more common for a wind farm to include a curtailment scheme or other special protection schemes. These details need to be part of the initial design considerations.

Turbine Manufacturers

The turbine manufacturers take on different roles depending on the project. They may do one or more of the following:

- Supply turbines
- Erect turbines
- Provide a turbine control system
- Provide a plant wide turbine control system
- Provide substation VAr control
- Provide a curtailment system

The expectations of the turbine manufacturer change depending on which of these items they provide. At a minimum they will expect a location for them to install their control system. This is usually installed in the substation or operation and maintenance building. For plant wide control they need to measure voltage and current in the substation. The location of the measurements may be on the high or low side of the transformer depending on the control requirements. If they are providing a substation VAr control system they need to know how other automated systems work in the area or locally in the substation. Typically, data for these systems or for general integration requirements require communication between the turbine SCADA system and the project SCADA system. The turbine manufacturer needs to know what the data exchange requirements are for control and integration.

Commissioning Teams

The commissioning teams expect to have the substation complete and ready for final testing. The design should include means for testing such as test switches or logic to isolate systems. They need all of the relay and integration device settings in a downloadable format and enough information to test them properly. This often includes a description of any automated systems, logic diagrams, and setting descriptions. The P&C engineer should provide commissioning team support during the commissioning.

Power Purchasers

Depending on the project, the power may be brokered by the owner, they may use the power themselves, or there may be a third party power purchaser. In all cases, this entity needs revenue data, trend data, "up" time statistics, and maximum generation from the project.

Qualified Schedulers

Depending on the project, the entity scheduling the power on the grid may be the owner or a third party scheduler. In both cases, this entity needs forecast data, real-time generation data, and scheduled "up" time.

Transmission Providers

The transmission provider is focused on the interconnection and needs clear lines for ownership of the design, testing, and maintenance. They want coordinated protection including the interconnection (line or bus), islanding protection and special protection schemes. Sometimes the transmission provider will request details of the transformer protection and other wind farm substation protection. This information should only be necessary to the degree that it impacts transmission operations. A P&C engineer can help determine the relevance. The transmission provider will also need wind farm substation status (interconnect and VAr support equipment), and real-time power values.

System Operators

Operators of the transmission system, often called dispatchers, need real-time power and generation availability. The availability data may include outage information, curtailment schedules, VAr resources, and/or fault operations. The operators need quick resolutions to problems. This is made possible by simple troubleshooting methods, proper protection zones, and an available protection engineer to assist in event analysis when needed.

Protection and Control Deliverables

Most of the protection and control deliverables are familiar to an experienced P&C engineer, but often we do not realize what each entity needs and why. The preceding objectives give us insight into the deliverables that a P&C engineer needs to provide to each entity. The following table may be used as a reference when identifying project deliverables and getting them to the correct entity. Each project may differ slightly, but this table will be a good starting point.

	Owners	Wind Farm Operators	Developers	Construction Contractors	Designers	Turbine Manufacturers	Commissioning Team	Power Purchasers	Qualified Schedulers	Transmission Provider	System Operators
Relay Specification					X					X	
Interconnection protection summary	X									X	X
Curtailment or Special Protection system	X				X	X					X
Relay I/O Assignments					X						
Wind Project Fault Study Model										X	
Settings Calculations	X										
Relay Settings	X						X				
Logic diagrams	X						X				
Downloadable settings							X				
Schedule for P&C activities including testing			X	X			X			X	
Pre-requisites for Testing				X			X				
Test plans or Settings with functional detail							X				
Design, testing, and maintenance ownership	X		X	X	X		X			X	
Energization Protection Requirements				X			X			X	
P&C Engineer Availability			X	X	X		X			X	
Protection System Component Level of Monitoring	X										
Substation HMI Screens		X									
Data Exchange Map (separate for each entity)	X	X				X		X	X	X	X
VAr control system objectives	X					X					
Capacitor Control System Overview	X					X				X	X
Capacitor Control System Description		X					X				
Substation Restoration Overview	X									X	X
Substation Restoration Description		X					X				
Operation Manual		X									
Operations Training		X									
Overview of all control systems in the area	X	X				X					
Event Analysis Contact		X	X	X							X

Table 1: Protection and Control Engineer Deliverables Checklist for Each Entity

SOLUTIONS USING ADVANCED APPLICATIONS

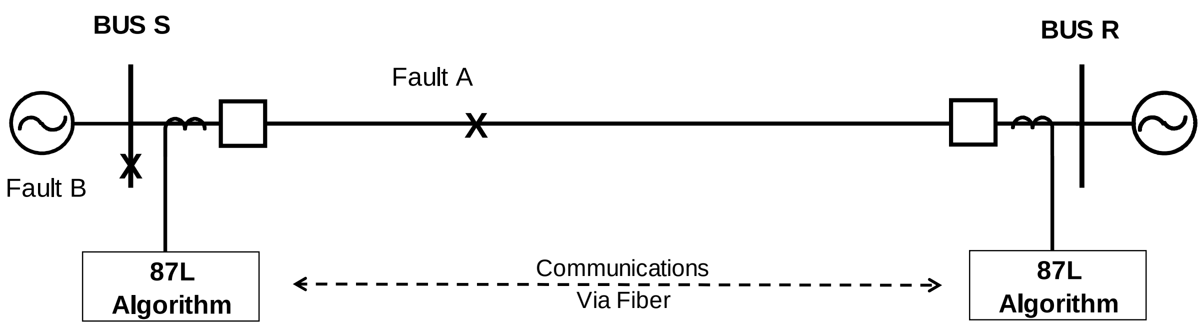
As identified above, each entity has different expectations. In some cases the expectations may conflict with one another. Using modern substation equipment, advanced applications provide solutions for the many expectations, including those that are in conflict. The following are solutions for some of the more challenging expectations.

Weak source protection

Transmission protection engineers have been challenged by weak source conditions since power systems were designed using looped and multi-source architecture. One early example includes the design of the distance relay. In general, distance relays do not need to be adjusted when the source behind the relay is reduced. As transmission systems have required faster fault isolation to maintain system stability or minimize system damage, communication schemes were introduced to accelerate the protection while maintaining isolated zones of protection. These schemes added new concerns when at least one end of a transmission line was considered a “weak source” or interchangeably a “weak feed” condition. The most common communication systems are the Current Differential Scheme (87L), the Directional Comparison Blocking Scheme (DCB) and the Permissive Overreaching Transfer Tripping Scheme (POTT). The details of these schemes are beyond the scope of this paper, but an understanding of each scheme is needed to fully understand the implications when applying these to a wind farm interconnection. For further details of these schemes, refer to the technical references [5], [6].

87L

A current differential scheme communicates local current flow information with the remote end. Using this data, each end determines if the fault is internal or external. If one relay trips locally it typically also sends a trip to the remote end. The other relay then typically trips its breaker based on the remote relay’s trip signal. This scheme is by far the most secure and the most dependable, and it is immune to weak source conditions if set correctly. The only drawback to the current differential scheme is that it does not work during a failed communication channel. This scheme is typically only applied on systems that have fiber communication between the stations. Refer to Figure 3 for the various fault conditions and resulting breaker operations.



IF $I_{LOCAL} + I_{REMOTE}$ > Trip Setting THEN Trip Local and Transfer Trip Remote

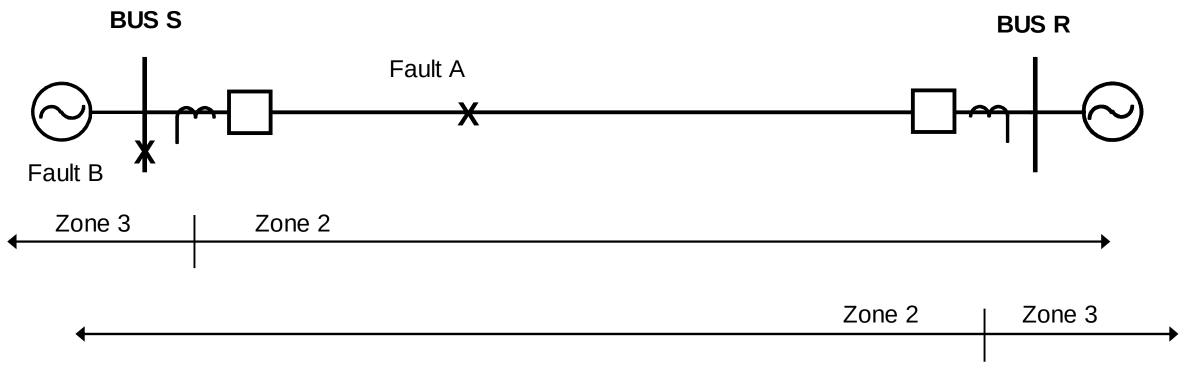
	BUS S	BUS R
Fault A, Normal:	$I_S = 1$ pu	$I_R = 1$ pu
	$1 + 1 > 0.1 \longrightarrow$ Trip Local and Remote	$1 + 1 > 0.1 \longrightarrow$ Trip Local and Remote
Fault B, Normal:	$I_S = -1$ pu	$I_R = 1$ pu
	$-1 + 1 \ngtr 0.1 \longrightarrow$ No Trip	$1 + -1 \ngtr 0.1 \longrightarrow$ No Trip
Fault A, Weak Source at Bus R:	$I_S = 1$ pu	$I_R = 0$ pu
	$1 + 0 > 0.1 \longrightarrow$ Trip Local and Remote	$0 + 1 > 0.1 \longrightarrow$ Trip Local and Remote
Fault B, Weak Source at Bus R:	$I_S = -1$ pu	$I_R = 0$ pu
	$-1 + 0 \ngtr 0.1 \longrightarrow$ No Trip	$0 + -1 \ngtr 0.1 \longrightarrow$ No Trip

I_{LOCAL} = Current via the Current Transformer
I_{REMOTE} = Current of the remote end via fiber
I_S = Current at Bus S as seen by the $87L_S$ Relay
I_R = Current at Bus R as seen by the $87L_R$ Relay

Figure 3: 87L Internal/External Fault Scenarios With/Without a Weak Source Condition.

DCB

A DCB scheme uses overreaching elements to trip after a short coordination delay. This coordination delay needs to allow time for the remote end to "block" the tripping. If the block (reverse fault) is received, the relay does not trip. If the block is not received by the expiration of the coordination delay, the relay will trip. Coordination delays are in the 0.5 to 3 cycle range. This scheme has been used throughout the industry because it may be applied on systems having poor communication channel availability. The local end will trip even if the channel fails. It has also been thought to be immune to weak feed conditions. On most transmission systems this is the case, but with wind farms the fault current for phase faults is dependent on the amount of generation at the time of the fault and the fault contribution characteristics of the machines. Some machines will only contribute about 1.1 pu (110% of full generation) after a few cycles into the fault. This can produce a very weak source and ultimately the source can be zero if no generation exists. Refer to Figure 4 for the various fault conditions and resulting breaker operations.

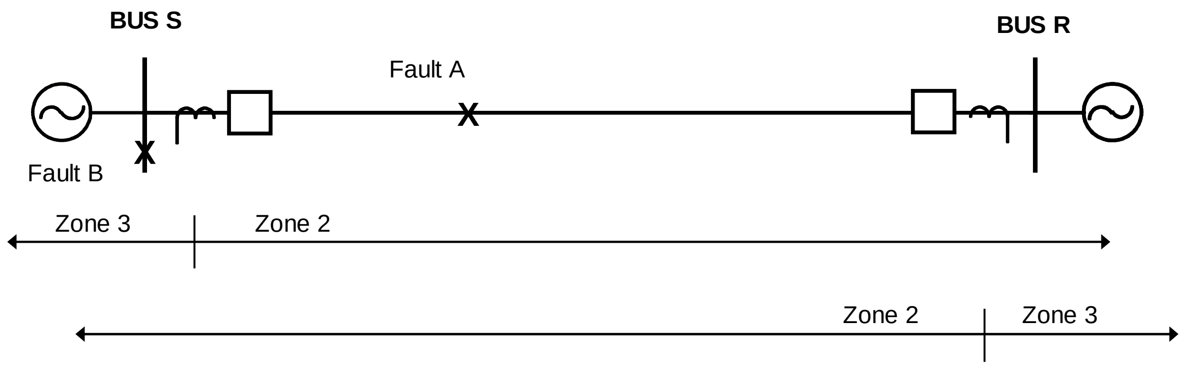


	BUS S	BUS R
	$Zone2_S$ AND NOT $Zone3_R$ = $Trip_S$	$Zone2_R$ AND NOT $Zone3_S$ = $Trip_R$
Fault A, Normal:	True AND True = $Trip_S$	True AND True = $Trip_R$
Fault B, Normal:	False AND False = No $Trip_S$	True AND False = No $Trip_R$
Fault A, Weak Source at Bus R:	True AND True = $Trip_S$	False AND True = No $Trip_R$
Fault B, Weak Source at Bus R:	False AND False = No $Trip_S$	False AND False = No $Trip_R$

Figure 4: DCB Internal/External Fault Scenarios With/Without a Weak Source Condition.

POTT

A POTT scheme uses overreaching elements to trip if permission is received from the remote end. The remote end sends permission if its overreaching elements pick up. Additional logic is added to handle current reversals and weak source conditions. For the weak source conditions the remote end will echo permission and can also trip locally. Modern relays include this logic in the POTT schemes. Refer to Figure 5 for the various fault conditions and resulting breaker operations.



BUS S	BUS R
$Zone2_S$ AND $Zone2_R$ = $Trip_S$	$Zone2_R$ AND $Zone2_S$ = $Trip_R$

Normal

Fault A:

True AND True = $Trip_S$ | True AND True = $Trip_R$

Fault B:

False AND True = No $Trip_S$ | False AND True = No $Trip_R$

Weak Source at Bus R

Logic includes: Zone2 = Zone2 OR (Weak Source AND NOT Zone3)

Fault A:

True AND True = $Trip_S$ | True(Weak) AND True = $Trip_R$

Fault B:

False AND False = No $Trip_S$ | False AND False = No $Trip_R$

Figure 5: POTT Internal/External Fault Scenarios With/Without a Weak Source Condition.

Analysis

From the basic analysis of a wind farm as a weak source, the DCB scheme may leave the wind farm breaker closed for a fault and the individual turbines will shut down via islanding protection such as loss of grid voltage. From a protection standpoint, this is not a problem since the scheme will eventually trip the breaker(s). However, some utilities have developed their own weak feed logic to trip the local wind farm breaker using current supervised undervoltage elements. This method does provide tripping for more cases, but still does not address the case where generation is very low or zero.

The reason to trip the wind farm terminal faster than the islanding protection is the need to provide high speed reclosing on a line where energization impacts system operations or other customers. Most utilities require transfer tripping in these cases, but if a DCB scheme is being used, it is likely because the communication channel is not reliable (i.e. power line carrier) for internal faults. This means that the transfer trip over a similar channel may not be reliable either.

If reclosing also requires an open breaker status from the wind farm terminal prior to closing, then the reclosing scheme itself is dependent on the communication channel. What is gained by adding weak feed tripping logic is unavailable by the definition of needing the weak feed logic (i.e. loss of channel). The channel may recover after the fault is cleared and provide the necessary breaker status, but the zero generation level condition would still be a problem.

If high speed reclosing is very important then an alternate communication channel for transfer tripping should be required. If reclosing is not that important and on occasion, when the generation level is low, it is acceptable to reclose after about 3-5 seconds, then redundant channels are not necessary. In either case (additional communication channel or slower reclosing on occasion) the weak feed logic is not needed in the DCB scheme. Having the additional logic is acceptable, but it adds complexity to the coordination (voltage element tripping at remote ends of the lines) without adding any value. Because DCB schemes do not address a weak source for the local breaker, it is recommended that a DTT signal be sent to the weak terminal for all DCB trips.

Recommendations

The following is a summary of proposed tripping schemes for various combinations of communication channels and required tripping schemes. In all cases, backup relaying is also recommend (step distance and ground overcurrent) but is not included in the table.

Although solutions are presented for almost every case, some cases have coordination and protection zone isolation problems. These schemes are noted by an asterisk *. The following table applies to two and three terminal lines. Most notations are self explanatory, but some may not be. Note the following definitions:

- Z2: Overreaching phase distance element trips locally
- Z2G: Overreaching ground distance element trips locally
- 67: Overreaching directional phase overcurrent element trips locally
- 67G: Overreaching directional ground overcurrent element trips locally
- OPGW: Optical Ground Wire (multi-strand fiber inside transmission line static wire)

	System Requirements			
Comm Path 1 Comm Path 2	High Speed Tripping (HST)	HST with Separate Com Paths	HST with Separate Algorithms	HST with Separate Com Paths and Separate Algorithms
None None	Z2* 67G*	NA NA	Z2/Z2G* 67/67G*	NA NA
OPGW None	87L, 87L None	87L Z2/67 w/Com fail*	87L, POTT None	87L, POTT Z2/67G w/Com fail*
OPGW Multiplexer	87L 87L	87L 87L	87L POTT	87L POTT
OPGW PLC	87L, 87L None	87L DCB with DTT	87L, POTT None	87L DCB with DTT
OPGW Microwave	87L, 87L None	87L POTT	87L, POTT None	87L POTT
OPGW OPGW	87L 87L	87L 87L	87L POTT	87L POTT
Multiplexer None	87L, 87L None	87L, 87L Z2/67G w/Com fail*	87L, POTT None	87L, POTT Z2/67G w/Com fail*
Multiplexer PLC	87L, 87L None	87L DCB with DTT	87L, POTT None	87L DCB with DTT
Multiplexer Microwave	87L, 87L None	87L POTT	87L, POTT None	87L POTT
Multiplexer Multiplexer	87L 87L	87L 87L	87L POTT	87L POTT
PLC None	DCB with DTT None	Not recommended Not recommended	Not Recommended Not Recommended	Not Recommended Not Recommended
PLC Microwave	None POTT on Microwave	DCB POTT	DCB with DTT POTT	DCB with DTT POTT
PLC PLC	DCB with DTT DCB with DTT	DCB with DTT DCB with DTT	Not Recommended Not Recommended	Not Recommended Not Recommended
Microwave None	POTT, POTT	POTT Z2/67G w/Com fail	POTT, DCB with DTT None	POTT, DCB with DTT Z2/67G w/Com fail
Microwave Microwave	POTT POTT	POTT POTT	POTT DCB with DTT	POTT DCB with DTT

Table 2: Best Choice Schemes Given Certain System Requirements and Communication Channels for Wind Projects. These are Applicable to Two and Three Terminal Line Applications. Non-communication Backup Relaying is not Identified but Expected in all Cases

System Restoration

One of the conflicting sets of expectations includes the need to remove the wind farm from the system for curtailment, line loss, or other system conditions versus the desire to keep the wind farm producing as much power as possible. If a utility has an outage from a fault, or needs to reduce system generation for stability or overload conditions, they will trip the interconnecting breaker or transfer trip the wind farm high-side breaker. To restore generation the wind farm operators typically have to first determine why the breakers tripped and then manually restore the wind farm.

As discussed in a recent American Wind Energy Association Technical Paper [4] there are alternatives when there is an outage caused by a system condition. The entire substation may be automatically restored. As the reference discusses, the savings in one operation can pay for the added cost of the scheme.

VALUE FOR AUTO-RESTORATION

Energy Rate	ER	0.075	$/KWHr
Generation Capacity	RC	100	MW
Capacity Factor	CF	33	%
Generation to Grid Time	GTG	70	%
Hours Per Year	HPY	8760	Hrs/Yr
Yearly Gross Revenue	YGR	$21,681,000 *	$/Year
Value per Available Hour	HV	$3,536 **	$/Op Hr
Average Manual Restoration Time	MRT	12	Hrs
Auto-Restoration Time	ART	0.1	Hr
Value of Auto-Restoration Per Event	**VAR**	**$42,075 ***	**$/Event**

* =ER*RC*1000*(CF/100)*HPY
** =YGR/(HPY)/(GTG/100)
*** =(MRT-ART)*HV

Figure 6: Cost Benefit of One Successful Operation of an Automated Restoration System after a Grid Event.

A restoration scheme is a logic function that walks through the collection system substation and closes each breaker one at a time after the grid power becomes available. Figure 7 shows a typical state-flow diagram.

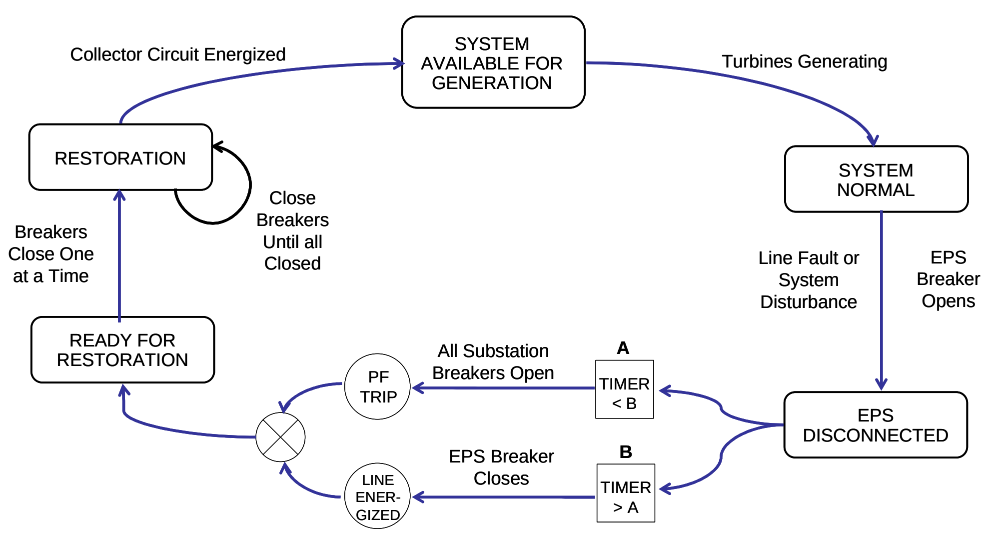


Figure 7: State-flow Diagram of an Automated Substation Restoration System.

For conditions requiring tripping due to overload, it is recommended that a curtailment signal be supplied by the utility and the wind turbine control system be used to reduce generation in the desired amount of time. If the reduction is needed immediately (less than the turbine control system ramp rate) then individual collector breakers may be tripped to quickly reduce generation without tripping the entire wind farm.

Islanding protection

If the wind farm is tripped offline for any reason, the turbines will continue to try and generate based on their low voltage/fault ride through capability. Different turbines respond differently, but it's most conservative to assume the turbines are synchronous machines with shorter time constants and reduced fault duty. Because of this, it is recommended that when the wind farm is isolated from the system, it should be segregated into smaller systems so that the various turbines are not acting as one large system. The best place to do this is at the collector breaker. If the wind farm is separated from the system (i.e. high side breaker is opened) for whatever reason, it is recommended to simultaneously trip the collector breakers. This will minimize any negative effects of islanding by segregating the system into several smaller systems. On one particular project, the high side breaker was opened to take the wind farm offline. A fault did not exist, so the turbines saw the event as a low voltage condition and began to try to "ride-through" the fault. The resulting 34.5 kV voltage and frequency is shown in Figure 8. The frequency reached 64.8 Hz in 15 cycles and the voltage reached 150% of nominal in 20 cycles. This resulted in a failed voltage arrester causing a ground fault, which the turbines detected and shut down quickly. Segregating the system would not have stopped the increased frequency or voltage but would have minimized it as there would have been a smaller amount of VAr capability per segregated system.

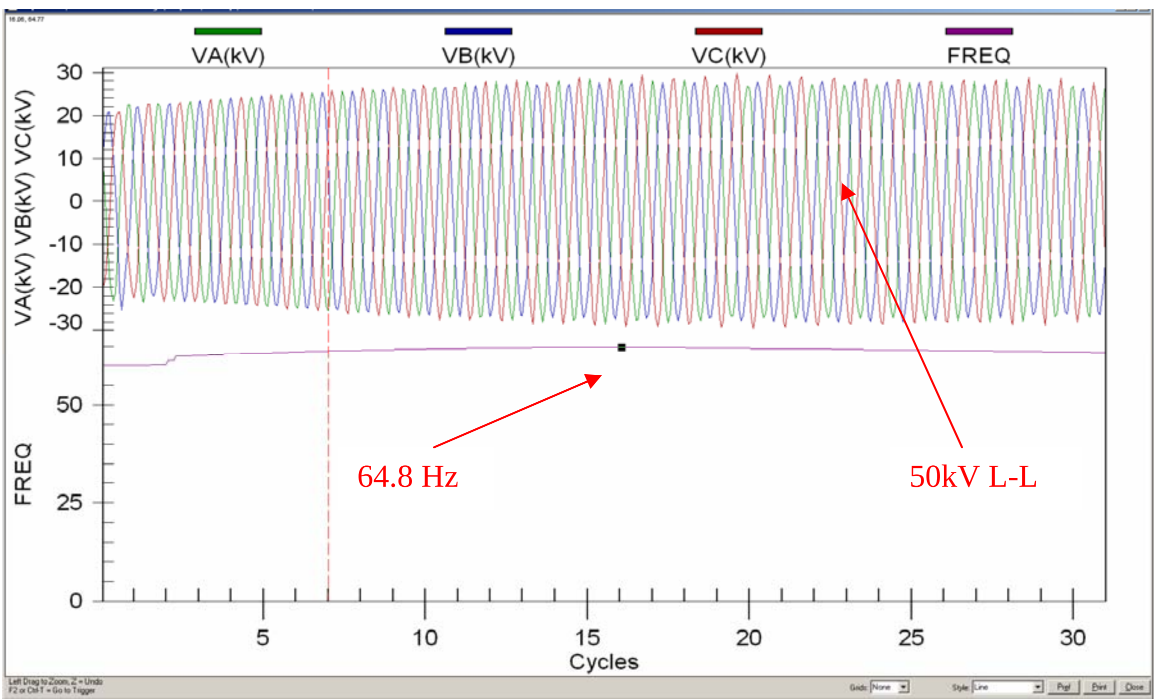


Figure 8: Waveform Capture of the Overvoltage and Overfrequency Event on the 34.5 kV Bus of a Collector Substation when the High Side Breaker was Manually Opened During Generation.

This segregation may be implemented with only a logic change if the devices are all communicating via an advanced logic processor. Figure 9 represents the two different methods of a substation restoration system. The advanced method would allow minor logic changes to implement the segregation scheme.

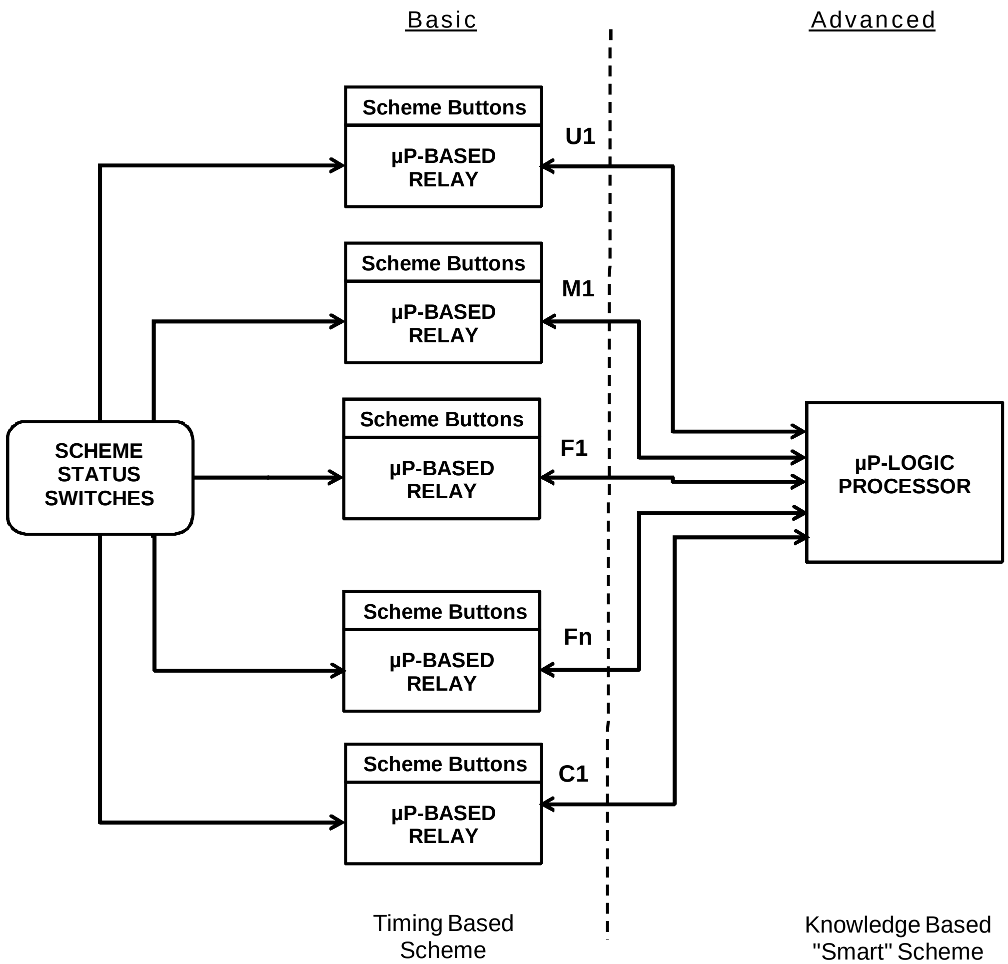


Figure 9: Topology of the Hardware of a Substation Auto-restoration Scheme. The Advanced, Knowledge Based Scheme may be Used to Implement a Segregation Scheme.

Recommended Data for Data Exchange Maps

Wind Farm Operator (includes HMI)

- Breaker Statuses
- Real-time power flow per substation breaker
- Relay trip target
- Station alarms (i.e. transformer, device failures, battery)
- Automation system statuses (i.e. auto vs. manual)
- Remote controls
- Communication alarms
- Meteorological data
- Power flow counters at point of interconnect (revenue meter and check meter)
- Aggregate turbine data

Turbine manufacturer

- Curtailment setpoints
- Real-time power flow at the point of interconnect

Power Purchaser and/or Qualified Scheduler

- Interconnect breaker status
- VAr control system breaker/switch statuses
- Curtailment values or signals
- Power flow counters at point of interconnect (revenue meter and check meter)
- Real time power flow
- Meteorological data
- Number of available turbines

Transmission System Operator (Dispatcher or ISO)

- Real-time power flow at the point of interconnect
- Interconnect breaker status
- Line relay alarms
- Power flow counters at point of interconnect (revenue meter and check meter)
- Curtailment control

SUMMARY

1. Protection and control (P&C) expectations are different for various project entites.
2. Some P&C expectations are in conflict with each other.
3. The provided checklist may be used to determine the deliverables for each project entity.
4. Advanced applications using modern substation equipment provide solutions to conflicting expectations.
5. Automated substation restoration provides maximum "up-time" for wind farm projects.
6. DCB schemes are not designed to handle weak feed conditions that can occur on wind farm interconnections.
7. When DCB schemes are used, DTT should be applied.
8. If wind farm trip timing is critical to the transmission system operation then an alternate communication path should be used for DTT.
9. Islanding protection should be supplemented with a segregation tripping scheme to segregate the wind farm into smaller systems when disconnected from the grid.

REFERENCES

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