

Root Cause Analysis and Recommendations

Investigation of July-29th Incident on Washington State Ferry - Tacoma

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Summary

This report investigates possible root causes of the blackout incident that occurred on Tacoma on July 29th, 2014 and provides our recommendations to prevent future blackouts.

Whenever the ferry approaches a dock, a third generator is put online as a backup in case the two generators that are already online fail. On July 29th, 2014 Generator-4 was put online while approaching Seattle-Dock and it was taken offline after the ferry docked. When it was taken offline, overvoltage alarm was reported by the Alarm and Monitoring System. Later, when the ferry was approaching Bainbridge-Dock, Generator-4 was put back online. This was followed by a series of alarms and finally the blackout.

Based on data from the IBA/PDA data acquisition system and damage done to Generator-4 cubicle, probable sequence of events that led to the blackout have been established. While at Seattle-Dock, Tacoma's Generator-4 was taken offline and there was voltage surge due to opening of the breaker that connects Generator-4 to the rest of the system. This voltage surge damaged all three surge limiters and phases 1 and 3 high side PT fuses of Generator-4. High voltage alarm was reported on Generator-4 by the Alarm and Monitor System and it was acknowledged by the system operator. After about thirty minutes, while the vessel was approaching Bainbridge-Dock, Generator-4 was put online. Because of lost fuses and actions of Generator-4 AVR (automatic voltage regulator), there was a severe voltage mismatch between Generator-4 and the rest of the 4.16KV system. This severe voltage mismatch created voltage dip on the 4.16KV system and Generator-1 and Generator-3 that were online became out of synchronization and blackout occurred.

Voltage surges occur during switching because the generator and the mainly inductive load system try to adjust to a new power flow condition. Surge limiters put on all feeders and generators suppress this voltage surge by channeling the energy to ground. Because of the frequency of switching over long years of operation, surge limiters can wear out and get damaged. The surge limiters put on the vessel are rated for 3.6KV continuous operating voltage (U_c) but the ferry's power generation system is an isolated or ungrounded system and the surge arresters needed to be rated (U_c) for at least the line-to-line voltage of the ferry (4.16KV).



When Generator-4 voltage transformers lost phases 1 and 3 fuses, phase loss relay in Generator-4 cubicle should have detected the phase loss and should have locked-out the breaker preventing it from closing. Because of the logic used in wiring the voltage transformers, the phase loss relay in Generator-4 is unable to detect phase loss when two of the three fuses get damaged. It can detect phase loss when one of the three fuses or when all of the fuses get damaged but when two out of three fuses get damaged, it is unable to detect phase loss. This was proven on the ferry by pulling out two fuses from Generator-1 voltage transformers and measuring line-to-neutral voltage at the phase loss relay. It is also proved by modeling the phase loss relay in MATLAB/Simulink simulation software.

When an offline generator is put online, a synchronizer relay compares generator's phase angle and voltage magnitude against the rest of the system and if the difference is within the set tolerance value, it commands the PLC to close the breaker and make the generator part of the system. The SPM relay model on the vessel has the capacity to check only phase match but not voltage magnitude match (redundant but needed as back up). If the SPM relay had voltage match capability, it would not have allowed the Generator-4 breaker from closing at Bainbridge-Dock. This redundant voltage check could have prevented the Generator-4 breaker from closing even if the phase loss relay didn't detect the phase loss.

Cable entries in all cubicles in both switchboards are not sealed. Flashover from Generator-4 cubicle went to Generator-3 cubicle and damaged it. This could have been prevented if all cable entries were sealed and proper pressure relief mechanism installed in the cubicles.

Siemens recommends rewiring the phase loss relay by removing the neutral conductor from its terminal. This was proven on the ferry using Generator-1 voltage transformers, removing neutral conductor from phase loss relay, and measuring line-to-line voltage at the phase loss relay. It is also proven using the model built in MATLAB/Simulink software. Siemens recommends replacing the SPM relay with a synchronizer relay that has the capacity to check both phase and voltage magnitudes. We further recommend sealing all cable entries with proper pressure relief mechanism.

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1 Introduction

There are four identical diesel generators and two similar 4.16KV switchboards on the ferry. Generators 1 and 2 energize Switchboard 1 while generators 3 and 4 energize Switchboard 2. The two switchboards are connected to each other by high voltage cables with a tie breaker at each end. The two switchboards are made up of two types of cubicles connected into a uniform line-up. The two cubicle types are:

1. Cubicles equipped with SIEMENS TYPE 3AF vacuum circuit breakers. These are used in generator, propulsion transformer, and tie cubicles.
2. Cubicles equipped with SIEMENS TYPE 81000 vacuum contact starters. These are used in the ship service transformers, motor/generator sets, and propulsion motors excitation transformers (i.e. in lower power applications).

Each generator connected to the switchboards is a synchronous generator rated at 3000KW, 3750KVA, 4160V, 60Hz and 900RPM. The generators are protected using the following:

1. Differential protection (ANSI/IEC 87G) – SIEMENS TYPE 7UT512 relay
2. Winding temperature protection (ANSI/IEC 49) – BASLER TYPE BE4-49
3. Over-current time delay protection (ANSI/IEC 50/51) – SIEMENS TYPE 7SJ511
4. Reverse power protection (ANSI/IEC 32) – BASLER TYPE BE4-32
5. Over-voltage protection (ANSI/IEC 59) – BASLER TYPE BE4-59
6. Under-voltage protection (ANSI/IEC 27) – BASLER TYPE BE4-27
7. Under-voltage protection(i.e. phase loss) – SIEMENS TYPE 7TU9914
8. Under/over frequency protection (ANSI/IEC 81) – BASLER TYPE BE4-81 U/O

Some of the generator protection relays listed above trip the circuit breaker isolating the generator from the rest of the system in case of faults while some of them just send alarm signals to the Alarm and Monitoring system. Table 1 summarizes actions of the generator protection relays.

Table 1: Outputs of generator protection relays

Disturbance	Alarm & Monitoring	Trip Circuit Breaker
Generator winding temperature alarm (if temperature in the windings reaches 130°C)	X	
Generator winding temperature trip (if temperature in the windings reaches 145°C)		X
Differential relay function	X	X
Over-current relay function	X	X
Over-voltage relay function (if voltage at the terminals of the generator reaches 115% of its rated value)	X	
Under-voltage relay function (if voltage at the terminals of the generator reaches 75% of its rated value)		X
Under-frequency function	X	
Over-frequency function	X	
Reverse power function	X	X
Under-voltage – phase loss (if fuses at the high side of PTs are blown)		X

The 4.16KV system on the ferry is a floating or isolated system (i.e. the neutral conductors of the generators are not grounded). This is done to assure a high continuity of service even in the event of a single line-to-ground fault. There are ground voltage relays (ANSI/IEC device number 59G) in each switchboard that monitor ground faults. The outputs of these relays are connected to the Alarm and Monitoring System.



In case of under-voltage on the 4.15KV buses, under-voltage relays in Tie-1 and Tie-2 cubicles will trip all the breakers and contactors on the bus the under-voltage occurred (i.e. if under-voltage occurs on 4.15KV switchboard 1, under-voltage relay in Tie-1 cubicle will trip all breakers and contactors in switchboard 1. Hence, removing load or generator that caused the under-voltage and the rest of the system can continue to operate). Ground fault relays in Tie-1 and Tie-2 cubicles monitor ground fault in the 4.16KV system.

Besides under-voltage and ground fault relays, there exists overcurrent time delay relay in Tie-2 cubicle that trips both tie breakers in case of short-circuit on either of the switchboards and thus save the other switchboard from a blackout. Table 2 summarizes actions of under-voltage, ground fault and over-current time delay relays in Tie-1 and Tie-2 cubicles.

Table 2: Outputs of relays in Tie-1 and Tie-2 cubicles

Disturbance	Alarm and monitoring	Trip breakers and contactors
Ground fault on the 4.16KV system	X	
Under-voltage trip		X
Over-current trip (on Tie-2 only)		Trip Tie-1 and Tie-2 breakers

2 Sequence of Events that Occurred on July 29th, 2014

Based on data from the IBA/PDA data acquisition system, substantial damage caused to HV-cubicles of Generator-3 and Generator-4, and minor damage caused to Excitation-Transformer AC1, the following probable sequence of events are established. Some of the transducer-signals are filtered (up to 200 msec) and various communication channels are configured at different scan rates (up to 500 msec) at the IBA/PDA data acquisition system. Therefore, some of the actual signal values may have looked different than depicted on the chart-recordings [1]. Data recorded from IBA/PDA data acquisition system is attached as Appendix B.

2.1 At Seattle-Dock

While the ferry was at Seattle-Dock on July 29th at 11:51:56 PDT, Generator-4 was taken offline. It was injecting current at 0.29 per unit (i.e. ~151A or ~630KW). At 11:51:58, overvoltage alarm for Generator-4 was reported. It is assumed that this voltage surge damaged the three surge limiters of Generator-4 and phases 1 and 3 high side fuses of Generator-4 PTs (voltage/potential transformers). At 11:53:15, overvoltage alarm for Generator-4 was acknowledged. Figure 1 shows the sequence of events that occurred on July 29th while Tacoma was at Seattle Dock.

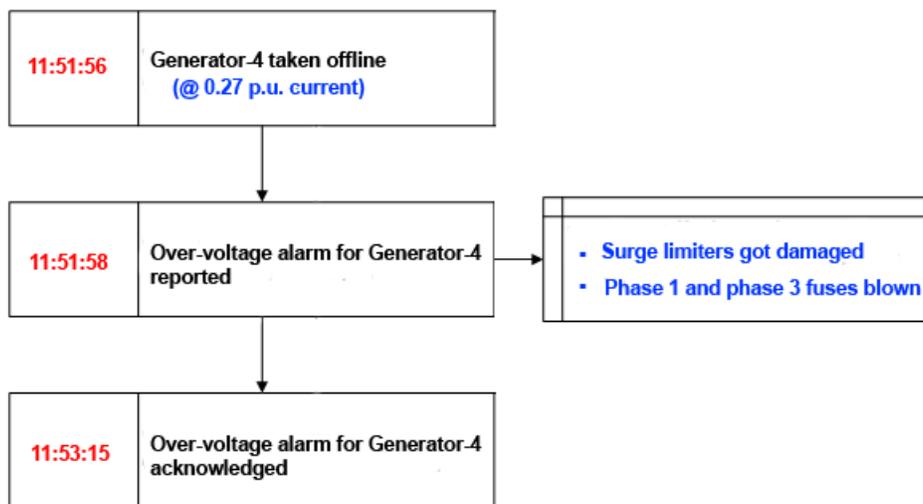


Figure 1: Sequence of events that occurred on Tacoma while at Seattle-Dock
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2.2 Arriving at Bainbridge-Dock

Approaching Bainbridge-Dock, Generator-4 was started. The high side breaker that connects Generator-4 to the bus was closed at 12:31:00 but immediately opened due to an under-voltage trip signal from the under-voltage relay (F11). Several under-voltage alarms were reported at switchboards 1 and 2. The high side breaker of Generator-3 was tripped and differential trip signals were triggered by differential relays of Generator-3 and Generator-4. Over-current time delay relays of Generator-3 and Generator-4 registered over-current condition but since the time delay of 6 seconds didn't expire, they didn't issue trip commands.

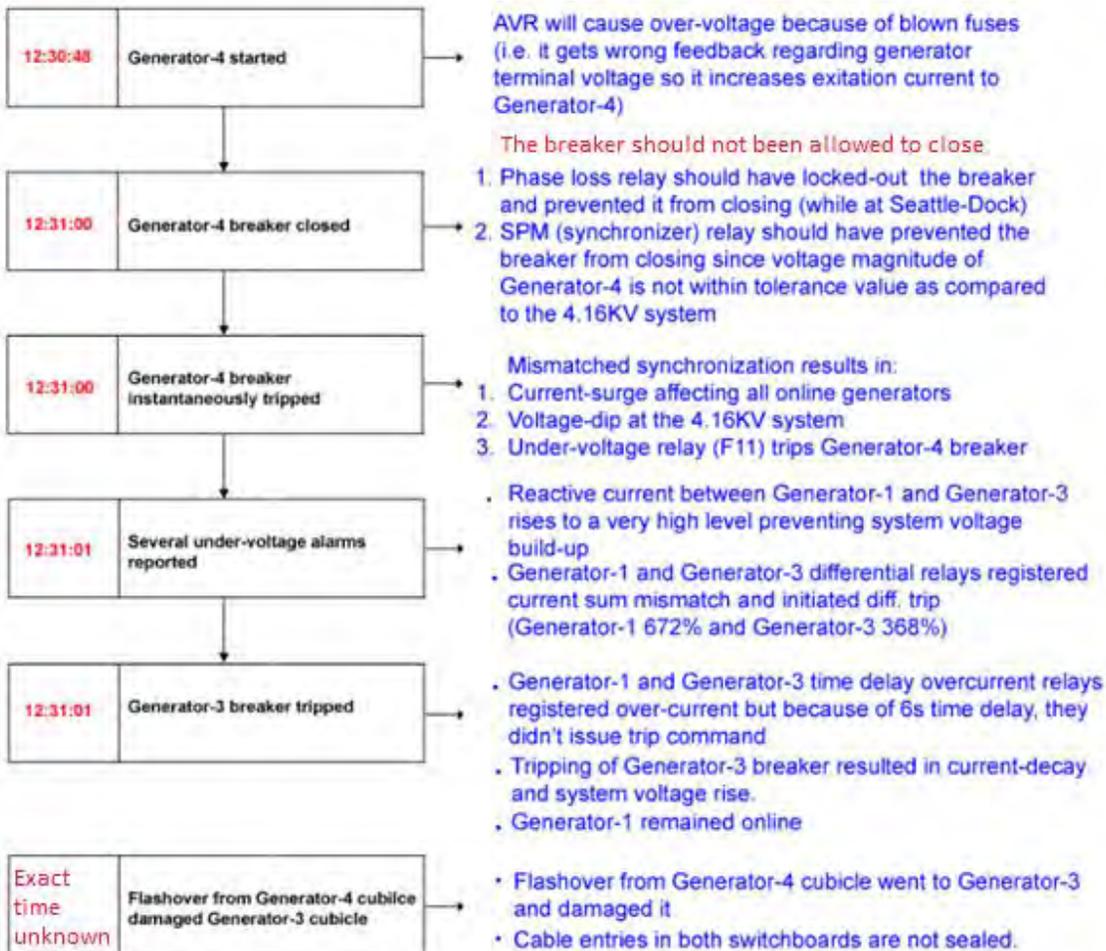


Figure 2: Sequence of events that occurred while Tacoma was approaching Bainbridge-Dock

3 Root Cause Analysis

In order to understand the root cause of the blackout, the three most important questions that need to be answered are:

1. When Generator-4 was made offline at Seattle-Dock, there was a voltage surge and three of the surge limiters along with two fuses of Generator-4 PTs got damaged. Why did this occur after 17 years of operation? What caused and/or contributed to the voltage surge?
2. When two of the three high side fuses of Generator-4 PTs got blown, why did the phase loss relay not detect it? The phase loss relay is put there specifically for this purpose.
3. While arriving at Bainbridge-Dock, Generator-4 was put online. Why the HV breaker of Generator-4 was allowed to close when its terminal voltage and frequency didn't match that of the rest of the system? The phase loss relay and the synchronizer relay should have prevented the breaker from closing.

3.1 Voltage-Surge during Switching

According to IEEE.C62.48 [2], temporary over-voltage can be caused when a distribution generator and part of the distribution network are separated. To limit over-voltage in the 4.16KV system, surge limiters are installed on all generator and feeder cubicles. These surge limiters are designed to have an average life span equivalent to that of the electrical installation they protect, but they progressively deteriorate over time due to the successive over-voltage they eliminate. The exact cause of damage to the surge limiters could not be determined due to the extensive compartment damage and limited data available but deterioration due to high frequency of switching of the HV breaker over 17 years of operation is a plausible reason. From tests performed on the Generator-4 breaker (on-site), the number of breaker operations recorded is 9106.

The existing surge limiters on the ferry are of SIEMENS TYPE 3EF1048-0 (4.8KV level) and have the following ratings:

- voltage $U_r = 4.8KV$

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- continuous operating voltage $U_c = 3.6KV$
- energy absorption capacity = $\frac{0.8KJ}{KV}$

Based on the ratings of the surge arresters and the 4.16KV system (isolated system):

1. The continuous operating voltage of the surge arresters (U_c) needs to be at least 4.16KV. During ground fault, the surge arresters at the unfaulted lines could see line-to-line voltage level across their terminals. Thus, their continuous operating voltage rating must be at least equal to the line-to-line voltage rating of the system so they do not get damaged for ground faults. The existing surge limiters on the ferry have continuous operating voltage ratings of 3.6KV, while the line-to-line rating of the ferry is 4.16KV.
2. The energy discharge capacity of the surge arresters ($\frac{0.8KJ}{KV}$) is not high enough for generation type application. During faults, generators keep injecting power into the system and the arresters on generators need higher energy discharge capacity.

3.2 Blown Fuses and Phase Loss Detection

When Generator-4 was put offline at Seattle-Dock, the voltage surge damaged two of the three high side fuses of Generator-4 PTs but the phase loss relay (SIEMENS TYPE 7TU9914) didn't detect it.

The phase loss relay (F14 relay) in Generator-4 cubicle is an under-voltage relay that measures line-to-neutral voltage and compares it to a set point (threshold value) to determine if a phase is lost. It takes stepped down voltages from the Generator-4 PTs and if phase loss is detected (i.e. if measured voltage is below the set threshold value), it sends a signal to the Alarm and Monitoring System instantaneously, and sends a trip command to the Generator-4 breaker after a time delay of six seconds.

The way the PTs are grounded, the burden on them, and the fact that the 4.16KV system is an isolated system, causes the line-to-neutral voltage measured by the F14 relay to be above the threshold value

when two of the three fuses burn out. Thus, the F14 relay in its current configuration can detect phase loss when any one of the fuses or all of the fuses blow out, but it is unable to detect phase loss if two of the three fuses burn out. Figure 3 shows connections of PTs on Generator-4, and figure 4 shows the connection diagram of F14 relay.

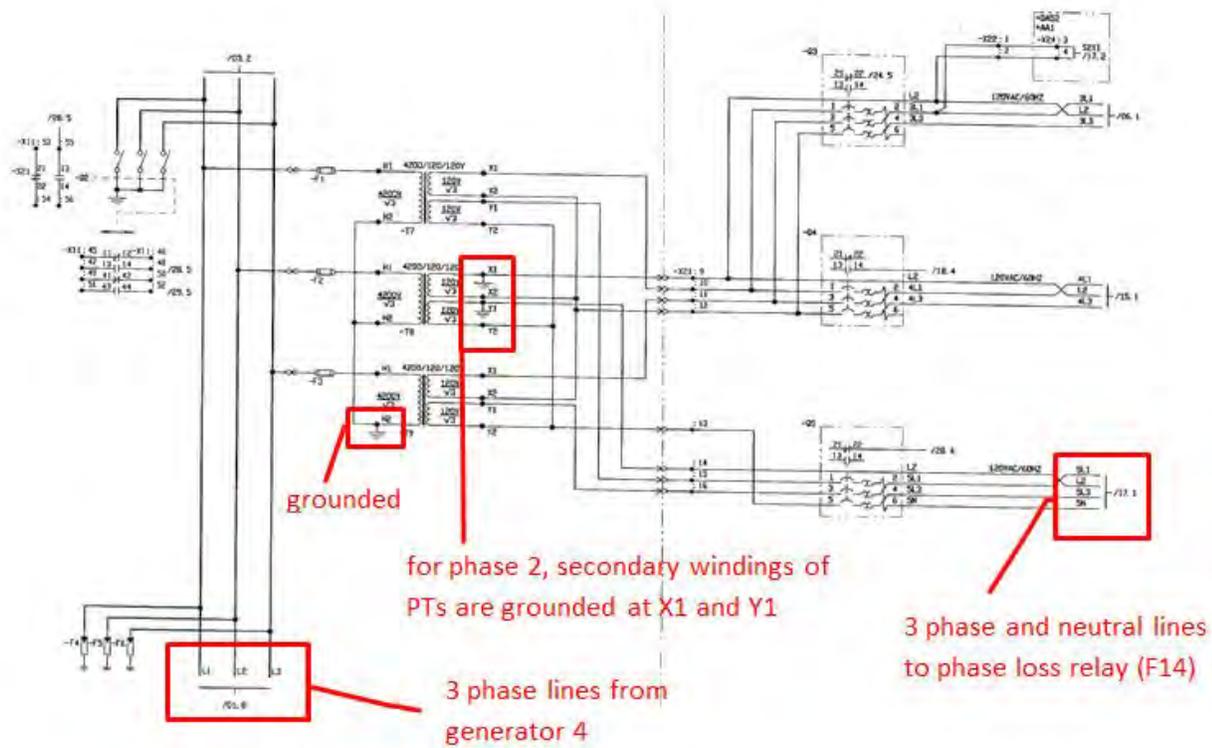


Figure 3: Generator-4 PT connection

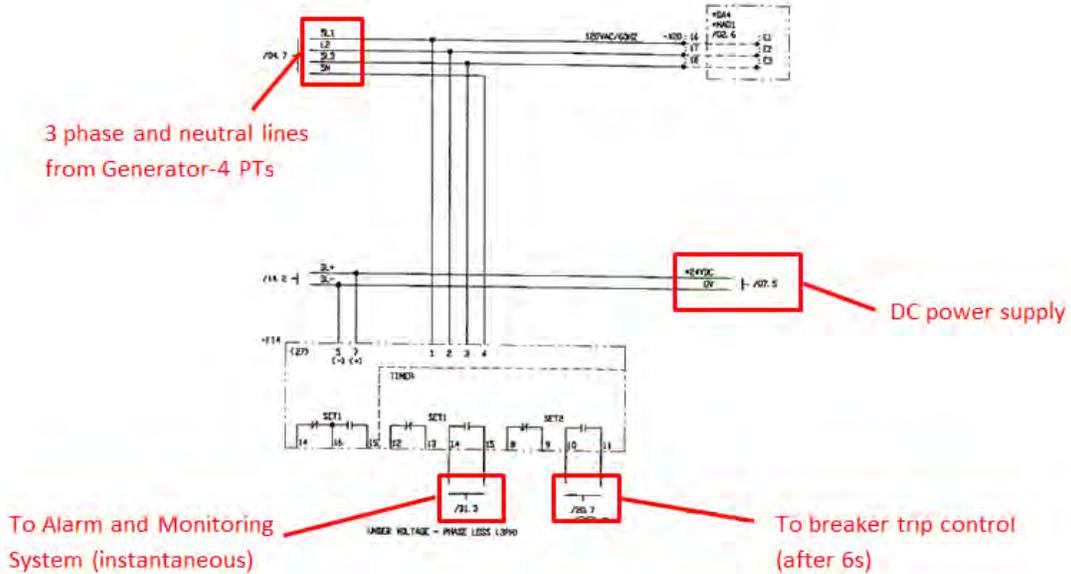


Figure 4: Connection diagram of the phase loss relay (F14)

As seen from figure 4, F14 relay is powered by a 24VDC power supply and it accepts phase voltages and the neutral as inputs. It compares each of the phase voltages (line-to-neutral) to a threshold voltage value of $42V_{rms}$ (voltage set value) and if the result is lower, it sends an instantaneous alarm signal, and after six seconds, it sends a signal to trip the breaker and isolate the generator.

Currently, two normally open contacts (N.O. or A contacts) from F14 are used to send alarm and trip signals. As shown in figure 5, the trip contact from F14 is tied in series with a normally closed contact (N.C. or B contact) from ground-fault relay in tie-breaker 2 cubicle. Therefore, F14 will only trip the breaker after six seconds and if there is no ground fault detected by the ground-fault relay (59G) initially. This is done for reliability purposes (i.e. to make the generator stay online as long as possible). In case of ground fault, the phase loss relay (which is an under-voltage relay) detects under-voltage and interprets it as phase loss and will try to trip the breaker.

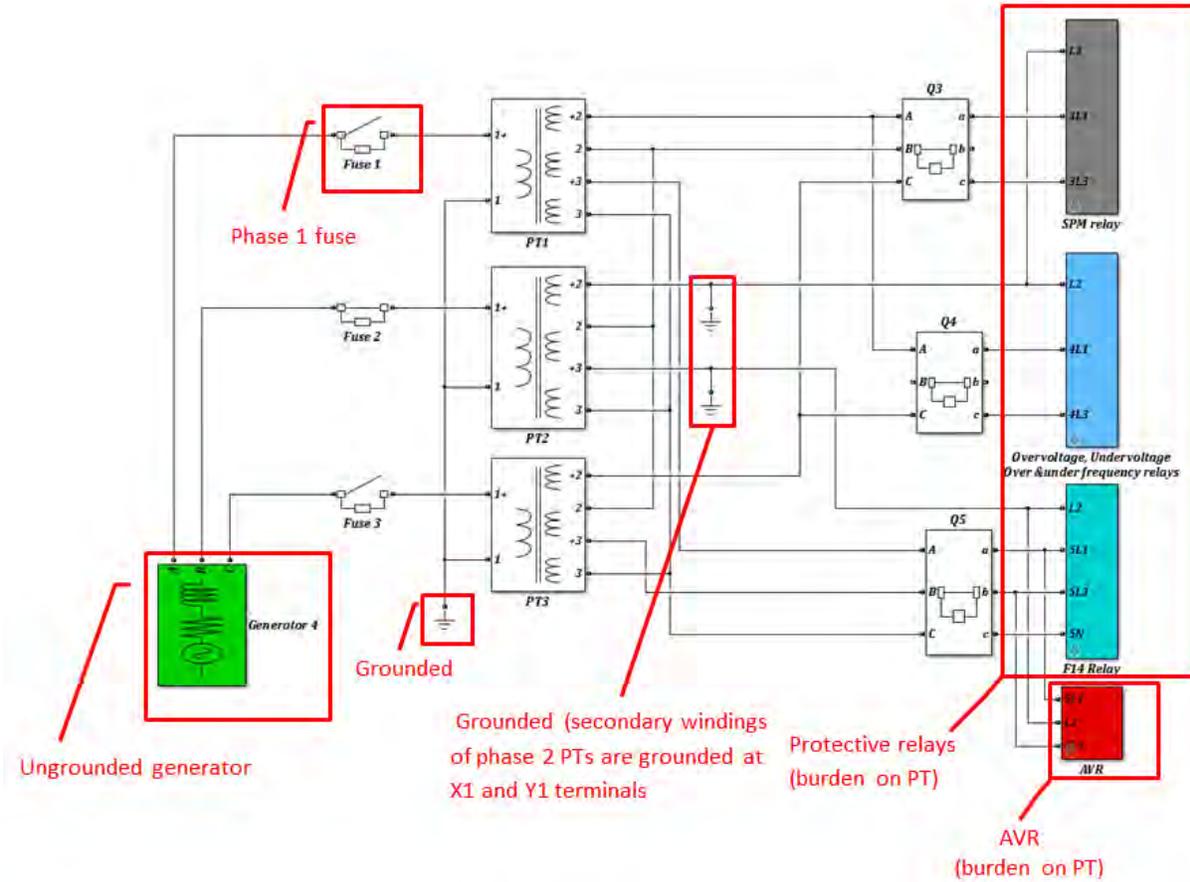


Figure 6: Simulink model of Generator-4 protection scheme

As shown in figure 6, three three-winding transformers are used to model the three PTs. To model Generator-4, a three-phase voltage source model is selected from SIMULINK's library and the neutral is left floating. Since most burden (load) on PTs are mainly resistive, 0.05VA/phase burden is assumed on each relay and a resistance value of $\sim 95K\Omega$ is calculated (the calculated impedance accounts for impedance from conductors connecting the PTs to the protective relays). The fuses are modeled by low impedance single phase breakers (i.e. low voltage drop across the breakers). Fuse loss does not mean the voltage on that line is going to be zero.

The F14 Relay block consists of voltage measurement blocks and comparison blocks. A scope is connected to visually display the voltage measured by the F14 measurement blocks. Double clicking the F14 Relay block reveals the inside connection diagram of the F14 relay. Figure 7 shows the inside connection diagram of the F14 Relay block.

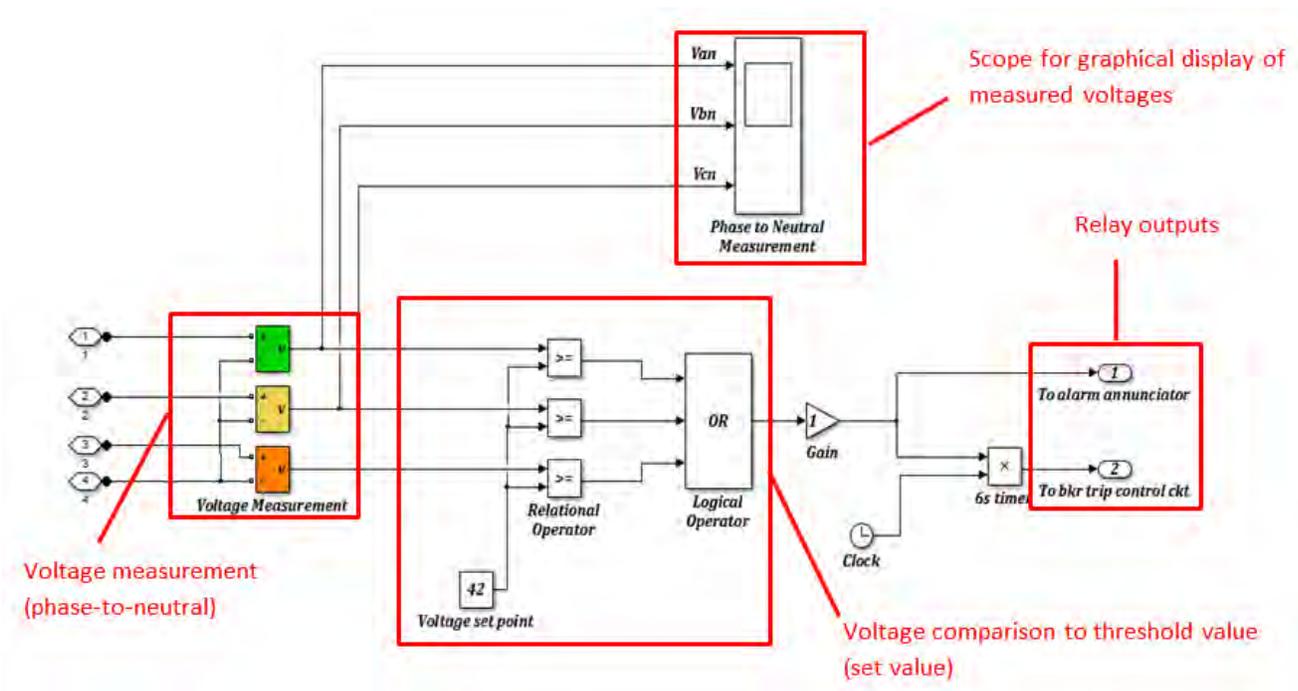


Figure 7: Connections inside F14 Relay block

3.2.1.1 Simulation and Result When No Fuse Is Blown

When the model is run with all fuses working, the expected voltage at terminals of the F14 relay is $\frac{120}{\sqrt{3}} = 69.282V_{rms}$ (line-to-neutral) and it is well above the voltage set point (i.e. $42V_{rms}$). Figure 8 shows scope capture of voltages measured at the terminals of F14 relay when all fuses are working. It can be seen from the figure that the measured line-to-neutral voltage of each phase is about $\sim 98V_{pk}$ ($\sim 69V_{rms}$).

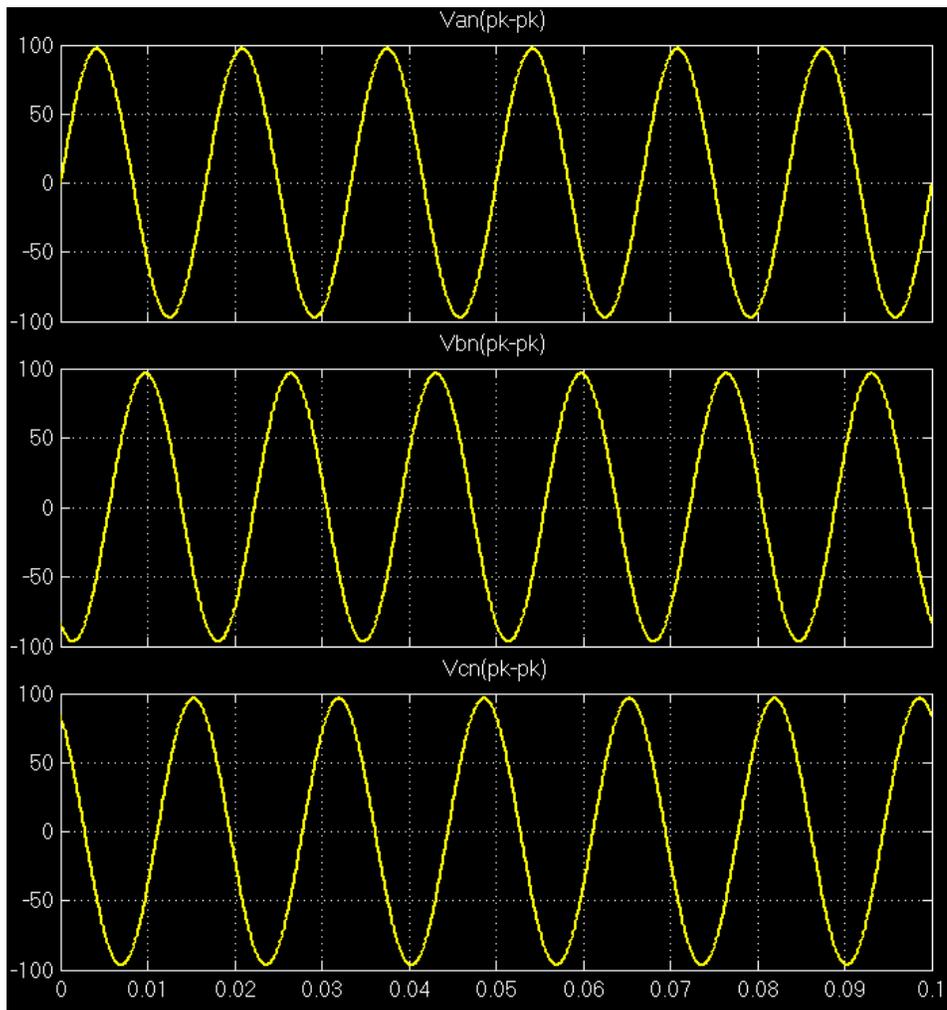


Figure 8: Line-to-neutral voltages measured by F14 relay when all fuses are working

3.2.1.2 Simulation and Result When One Fuse Is Blown

For this simulation, phase 1 fuse is opened and line-to-neutral voltages measured by F14 relay are captured by the scope.

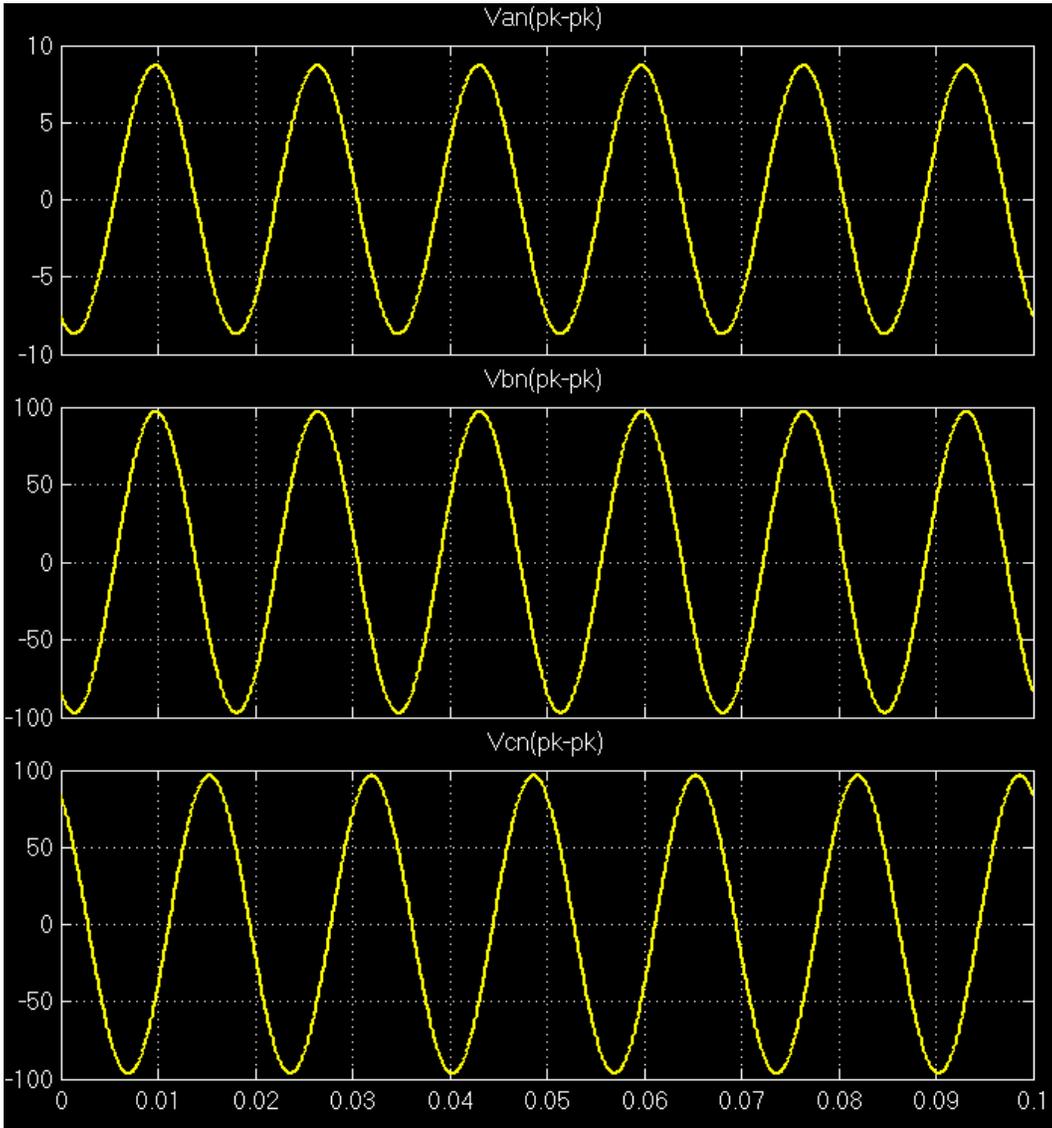


Figure 9: Line-to-neutral voltages measured by F14 relay when phase 1 fuse is blown

As seen from figure 9, the line-to-neutral voltage measured by the F14 relay is almost $\sim 98V_{pk}$ ($\sim 69V_{rms}$) for phases 2 and 3, but it is about $\sim 9V_{pk}$ ($\sim 6V_{rms}$) for phase 1. Phase 1 voltage measured is well below the set threshold value of $42V_{rms}$ and the relay will trip the breaker after six seconds.

3.2.1.3 Simulation and Result When Two Fuses are Blown

For this simulation, phases 1 and 3 fuses are opened and line-to-neutral voltages measured by F14 relay are captured by the scope.

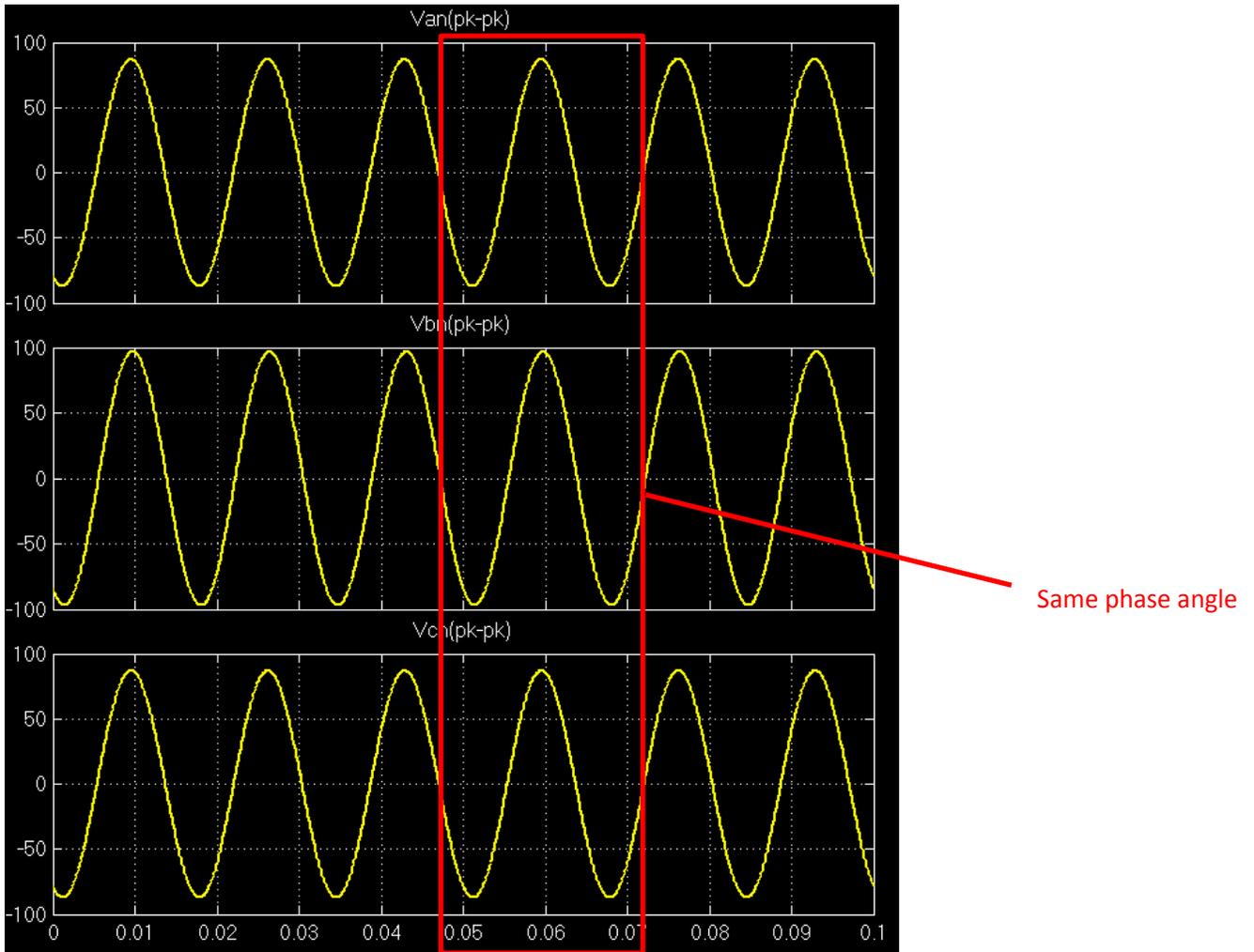


Figure 10: Line-to-neutral voltages measured by F14 relay when phases 1 and 3 fuses are blown

As seen from figure 10, the line-to-neutral voltages measured by F14 relay are almost $\sim 85V_{pk}$ ($\sim 60V_{rms}$) for all phases. In this particular case, the F14 relay will not trip the breaker since all measured voltages

are above the threshold value of $42 V_{rms}$. It is also observed that all measured voltages have identical phase angles (i.e. all of them have the same phase shift as phase 2).

3.2.1.4 Simulation and Result When Two Fuses are Blown and The Neutral Conductor Removed

For this simulation, phases 1 and 3 fuses are opened and the neutral conductor is removed from terminals of F14 relay. As shown by the scope capture, line-to-neutral measured voltages by F14 relay when two fuses are blown and when neutral conductor removed are all less than $10 V_{rms}$

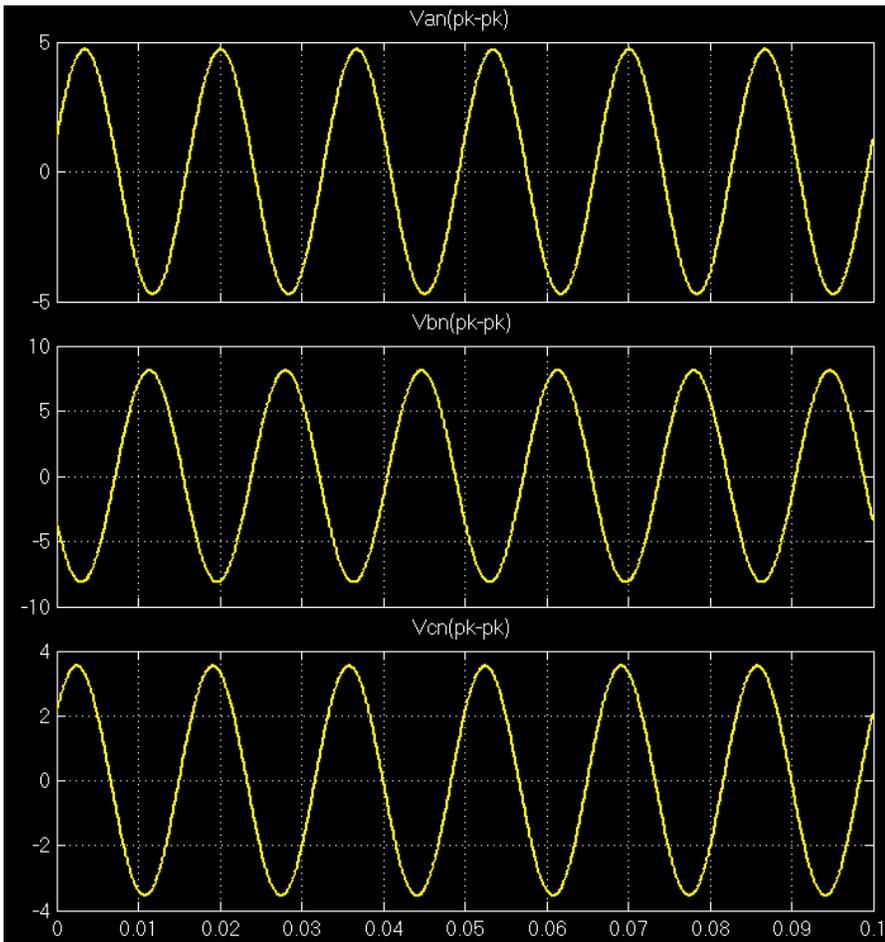


Figure 11: Line-to-line voltages measured when two phases and neutral cable are not connected

3.2.1.5 Validation and Verification of Simulation Results

Using Generator-1's F14 relay, line-to-neutral voltages at the terminals of F14 are measured on site [1]. By supplying $47V_{rms}$ between X_1 to X_2 terminals of the PTs, and by pulling out phases 1 and 3 fuses, voltages at the terminals of F14 are measured and recorded. Table 3 summarizes the result obtained.

Table 3: Voltage measurement at the terminals of Generator-1's F14 relay

Applied voltage X_1 to X_2	F14 (line-to-neutral)			Connected devices
	Phase A	Phase B	Phase C	
47	48.6V	46.8V	48.2V	F14+AVR+Q3+Q4
47	20.6V	47.4	34.3	F14+Q3+Q4
47	0V	47.2V	0V	Only F14
	F14 (line-to-line)			
47	7.67V	6.95V	0.73V	F14+AVR+Q3+Q4

As shown in table 3, when 47V is supplied between X_1 to X_2 terminals of the PTs and phases 1 and 3 fuses are pulled out, the line-to-neutral voltages measured by F14 relay are almost the same as the supplied voltage (i.e. above the threshold value). When the neutral conductor is removed from the terminals of F14 relay and the test is repeated, the line-to-line voltages measured at the terminals of F14 relay are all well below the threshold value.

The reason why 47V is supplied between X_1 to X_2 terminals of the PTs instead of the full line-to-line voltage of 120V is for safety purposes (to avoid using higher voltage) and it is selected to be above the threshold value. As seen from table 3, the voltages measured at terminals of F14 relay are different depending on the secondary side PT breakers and whether AVR are connected or not (i.e. whether Q3 and Q4 are closed and AVR is connected or not). Under normal operations, the secondary side breakers are closed and AVR is connected and the PTs see full burden.

Based on the results of the simulation and on-site tests performed on the F14 relay, the F14 relay is unable detect phase loss when two of the three fuses get damaged.

3.3 Putting Generator-4 Online With Voltage Mismatch

When an offline generator is about to be put online, the synchronizer (WOODWARD TYPE SPM 9905-001) relay compares the generator's phase 1 phase angle against phase 1 of the 4.16KV bus and if they don't match within $\pm 10^\circ$ tolerance, it either speeds up or slows down the generator through the Load Sharing and Speed Control relay. If there is phase angle match, the SPM relay sends signal to the PLC (E200) to close the generator breaker. Figure 12 shows the connection diagram of Generator-4 SPM relay.

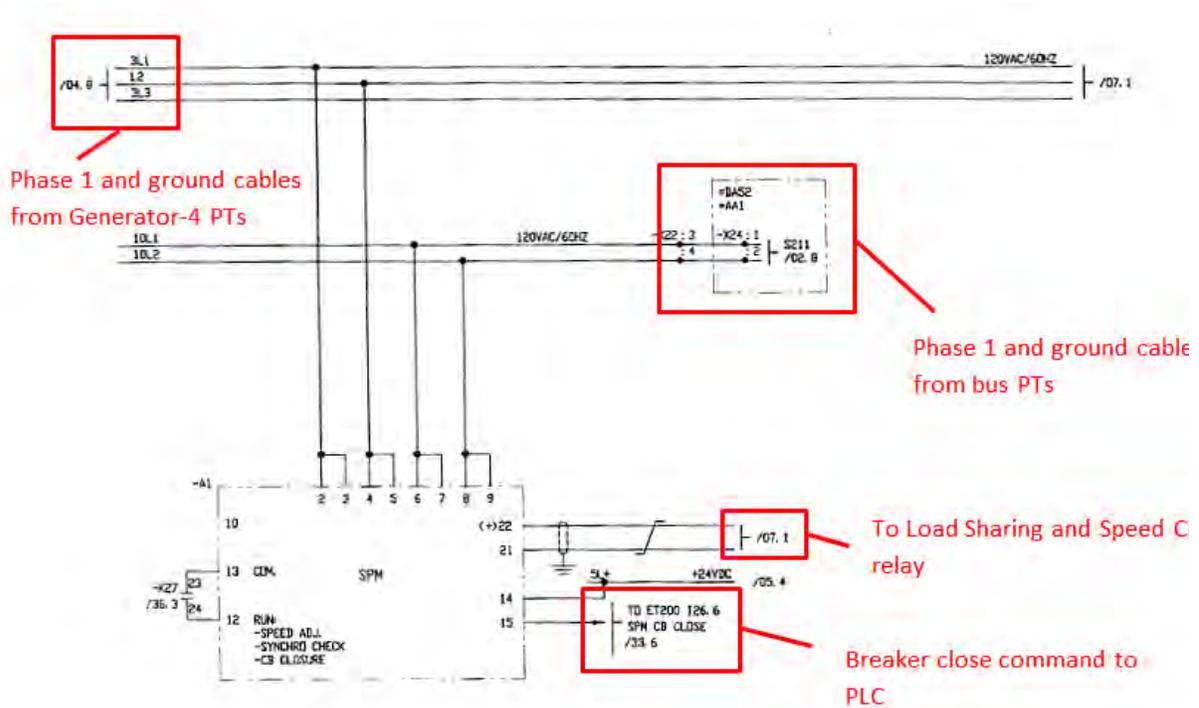


Figure 12: Generator-4 SPM connection diagram

As shown and discussed in section 3.2.1.3, the phase loss relay (F14) does not detect phase loss when two of the three fuses get damaged (i.e. the line-to-neutral voltages measured at the terminals of the

F14 relay are above the threshold value of $42V_{rms}$). To investigate the line-to-ground voltage value at the terminals of the SPM relay when two of the three fuses are blown, voltage measurement block is added inside the SPM Relay block and the model is run. Figure 13 shows the scope capture of the voltages measured at the terminals of the F14 and SPM relays when two fuses are blown.

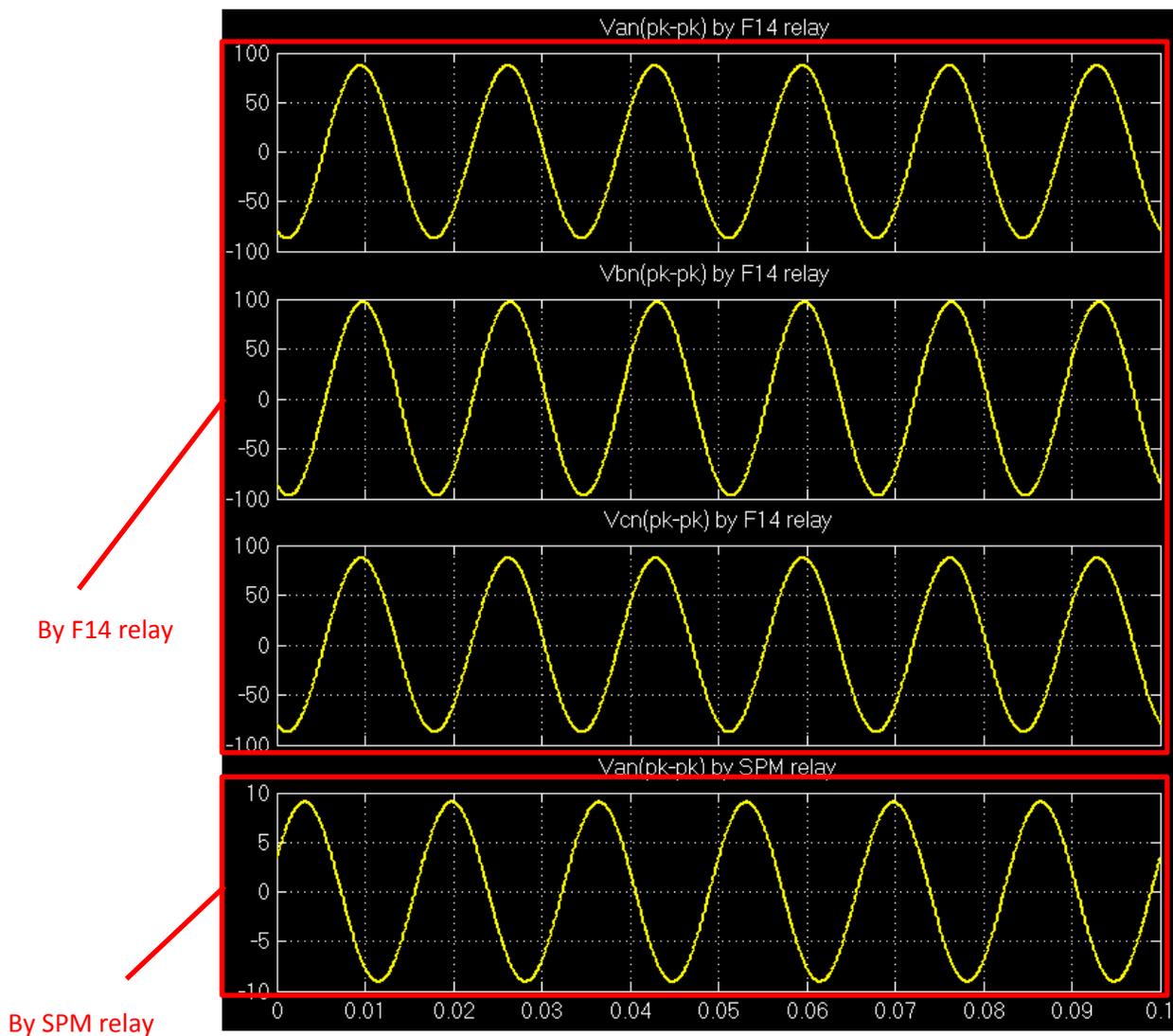


Figure 13: Voltages measured by F14 and SPM relays when two fuses are blown



The magnitude of voltage measured by the SPM relay is well below the line-to-neutral voltage value of $\sim 70V_{rms}$ (as shown in figure 13) when two of the three fuses burn out. If the SPM relay model installed on the ferry had a capability to compare voltage magnitudes besides phases, it would have caught the voltage magnitude difference between Generator-4 PTs and PTs on the 4.16KV bus 2. It would not have sent the “close” command to the PLC and the PLC in turn wouldn’t have closed Generator-4 breaker with such severe voltage mismatch.

4 Recommendations

4.1 Surge Limiters

When the blackout occurred, both 4.16KV switchboards were tied together and the surge limiters on all feeders might be stressed out. They have to be tested according to IEEE recommended practice for surge arrester test procedures. The existing surge limiters on the feeders do not have a maximum continuous operating voltage rating of 4.16KV (i.e. they are rated for $U_c = 3.6KV$) Therefore, Siemens recommends replacing the surge arresters on all feeders. The surge arresters on generators do not have the right energy discharge ratings and they need to be replaced with surge arresters recommended for generation type application. The following surge arrester types are recommended:

- For feeders, ABB TYPE POLIM-C 4.8 LB ($U_r = 6KV$, $U_c = 4.8KV$, and $5.5 \frac{KJ}{KV}$)
- For generators, SIEMENS TYPE 3EL2 006-2PC31-4NH5 ($U_r = 6KV$, $U_c = 5.1KV$, and $10 \frac{KJ}{KV}$)

4.2 Phase Loss Relay (F14)

The phase loss relay (SIEMENS TYPE 7TU9914) can be configured to measure line-to-line voltages [3]. As seen from the simulation result and from the on-site test, the phase loss relay can detect any kind of phase loss if it is configured to measure line-to-line instead of line-to-neutral voltages. Figure 14 shows front and back side views of F14 relay in Generator-4 cubicle (low voltage cubicle).



Siemens Industry, Inc. **Figure 14: Front and back side views of F14 relay in a cubicle**

The preferred solution is replacing the F14 relay with a modern relay that has both phase and voltage magnitude comparison capabilities. However, if the F14 relay were to be replaced, there is no space on the doors of the generator cubicles (figure 14) and it would need lots of rewiring. Therefore, Siemens recommends reconfiguring the F14 relay by removing the neutral conductor from its terminal and changing the voltage set value (threshold value) to 64V. This was verified at Siemens Alpharetta facility as follows:

1. Power the F14 relay by supplying $\pm 24 V_{DC}$
2. Adjust the voltage set to 64V by opening all the switches on the dip switch except for switch number 3 and 7 (i.e. $30V + \sum(2V + 32V) = 64V$)
3. Connect three phase $120 V_{AC}$ voltage supply to F14 terminal no. 1,2 and 3
4. Supply $+24 V_{DC}$ to F14 terminal no. 10 and 14
5. Remove phase 1 supply from F14 terminal no. 1
6. Check for instantaneous voltage change between F14 terminal no. 14 and 15
7. Check voltage change between F14 terminal no. 10 and 11 after 6s time delay
8. Repeat steps 5 to 7 for single phase loss detection
9. Repeat steps 5 to 7 for two phase loss detection
10. Repeat steps 5 to 7 for three phase loss detection

Because of the impedance of the cables connecting PTs to F14 on the ferry, the set voltage value of 64V has to be field adjusted.

4.3 Synchronizer Relay (SPM)

The SPM relay model installed on Tacoma (WOODWARD 9905-001) checks only phase match between two lines but does not check voltage magnitude match. If this relay had the capability to check voltage mismatch, the Generator-4 breaker would not have been allowed to close with severe voltage mismatch with the 4.16KV system while Tacoma was approaching Bainbridge-Dock. Therefore, Siemens



recommends replacing the SPM relay with a WOODWARD SPM 9905-003 model that has the capability of checking both phase and voltage match (5% tolerance) between two lines.

4.4 Sealing Cable Entry

Cable entry cover plates are missing in both switchboards. According to current ANSI/IEEE C37.20.7 [4] and IEC 61641 [5] testing guides for internal arc faults:

1. Cubicles should have correctly secured doors and their covers should not open
2. Internal arc should not migrate to other compartments

Siemens recommends sealing these cable entries and verifying proper pressure venting.

5 Items Damaged

The following table summarizes the items that got damaged during the July 29th incident.

Table 4: Items damaged during July 19th incident

Generator-4	Generator-3	Excitation-transformer AC1
Two PT fuses (phase 1 and phase 3)	Three PT fuses	One surge limiter (phase 1)
Three surge limiters	Three surge limiters	One HV fuse (phase 1)
Insulators, copper-bars, and metal parts	Insulators, copper-bars, and metal parts	
High voltage cables	Three PTs	
Cubicle partitions	High voltage cables	
Control-wire harness	Cubicle partitions	
	Control-wire harness	

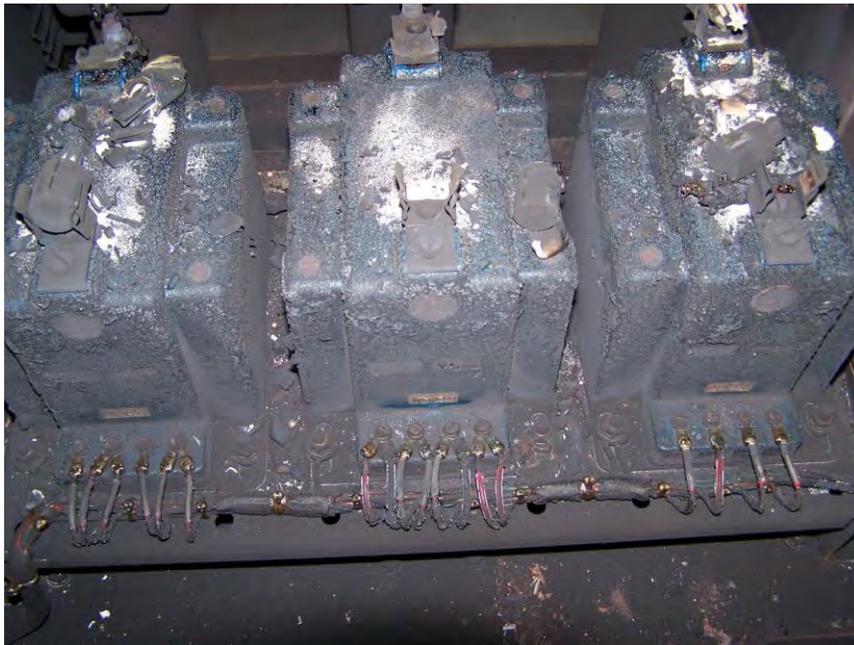


Figure 15: Generator-3 PTs and fuses got damaged



Figure 16: Surge limiters on Generator-4 and Generator-3 got damaged



Figure 17: 5KV insulators, PT connection fingers and CT connectors got damaged



Figure 18: Single phase shutters and glastic board got damaged



Figure 19: High voltage cubicles of Generator-3 and Generator-4 got damaged



Figure 20: Control-wire harness damaged

6 References

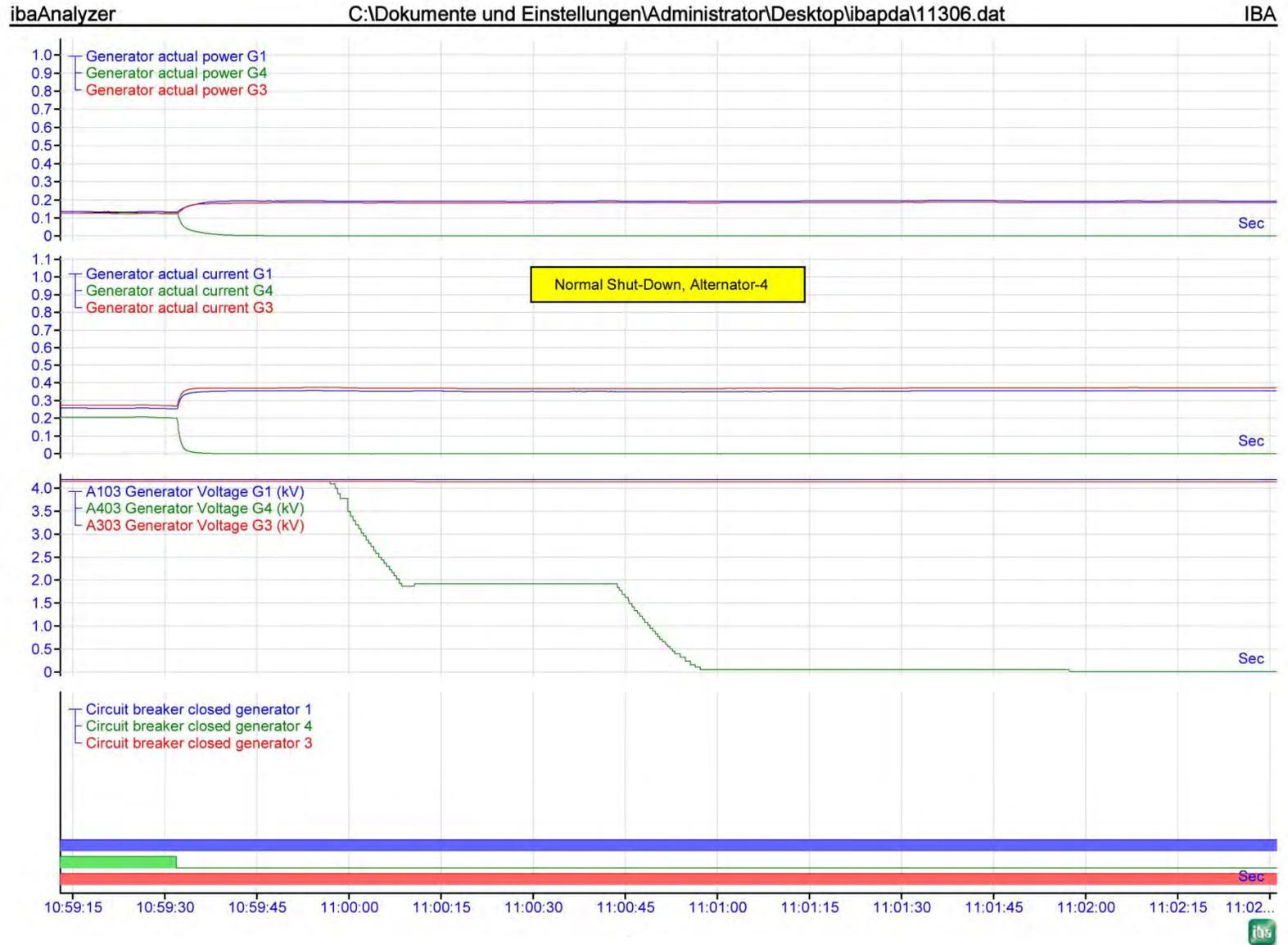
- [1]. Schuckert, Fritz, "Washington-State-Ferry, WSF "Tacoma" Investigation of "July-29th" Incident, Report No. 1914, August 08, 2014
- [2]. IEEE Std C62.48, IEEE Guide for Interactions Between Power System Disturbances and Surge- Protective Devices
- [3]. Siemens Relay Manual, "Solid-state AC Over/Undervoltage Relay 7TU99", R 1.3, 1994
- [4]. IEEE Std C37.20.7, IEEE Guide for Testing Metal-Enclosed Switchgear Rated Up To 38KV For Internal Arcing Faults
- [5]. IEC TR 61641:2014, Enclosed Low-Voltage Switchgear and Assemblies – Guide for Testing Under Conditions of Arcing due to Internal Fault

7 Appendix A: Bill of Materials

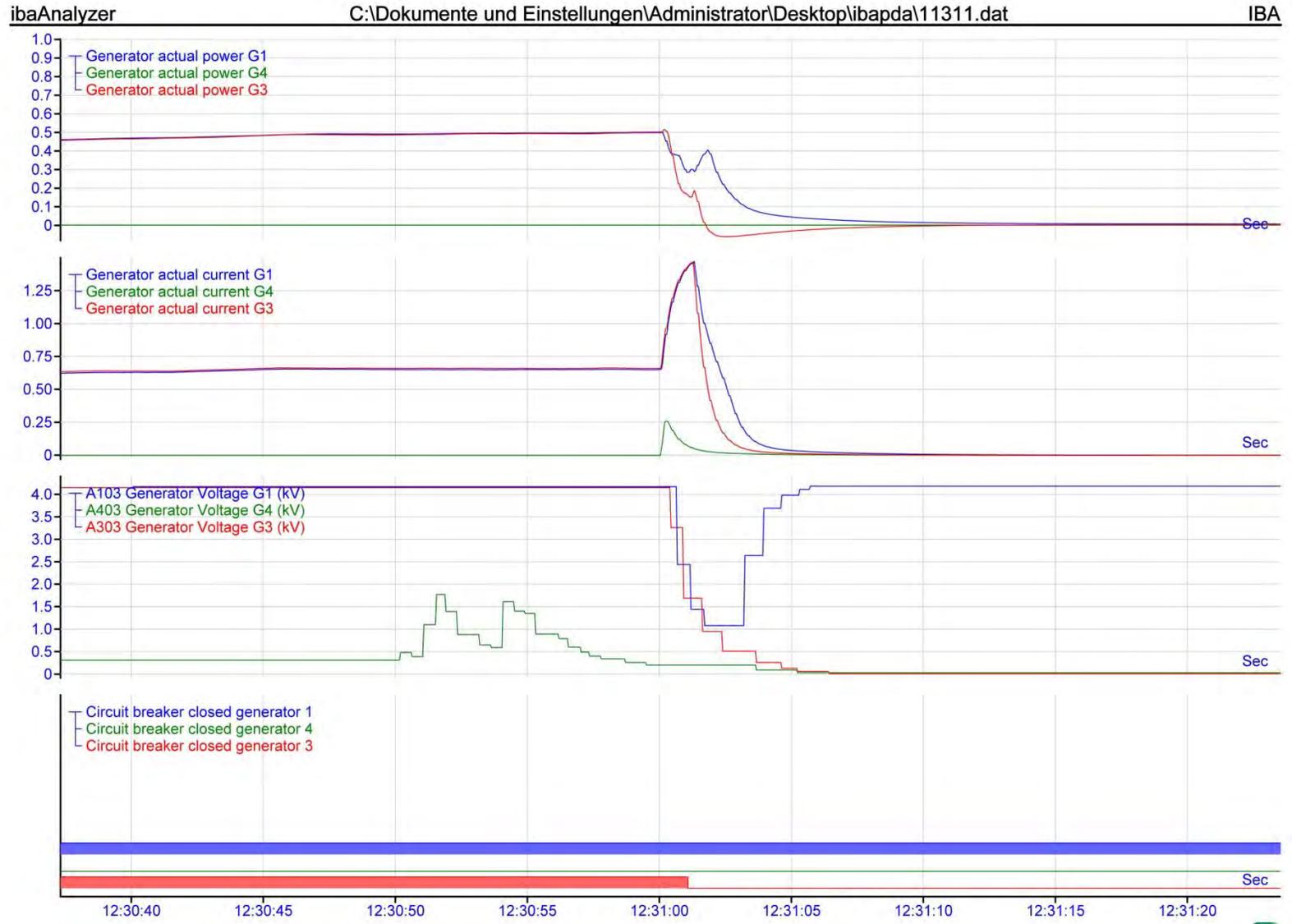
Table 5: Bill of Materials

No.	Item
1	Disconnect fingers
2	5KV red insulators
3	Connecting frame
4	6KV surge arresters (generator application)
5	6KV surge arresters (non-generator application)
6	Surge arrester mounting brackets
7	Voltage transformers
8	High voltage fuse
9	Fuse clips
10	Synchronizer (SPM relay)
11	Red glastic board
12	Red glastic board
13	Single phase shutters
14	Rear panel cover brackets
15	Braded uninsulated copper wire
16	Uninsulated wire lugs
17	Clean tubing

8 Appendix B: IBA/PDA Charts and Alarm Log Print Outs









Active Alarms	S...	Alarm Point	Description	Start Time	End Time	Acknowledge Time	Alarm Status	Worst Value	End date	Current Value	Start Date	Acknowledge D...	Alar...
		I804	PASSENGER ELEVATOR TROUBLE	11:45:58 AM:420	11:45:58 AM:820		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		I804	PASSENGER ELEVATOR TROUBLE	11:45:59 AM:430	11:46:00 AM:460	11:46:50 AM:030	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		A404	ALT4 V HIGH	11:51:58 AM:180	11:51:59 AM:100	11:53:25 AM:820	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		E425	ME4 - FO PRESS	11:55:23 AM:420	11:55:23 AM:820	11:55:56 AM:590	ALARM	20	7/29/2014	0	7/29/2014	7/29/2014	2002
		E435	ME4-DIESEL CTRL PNL SUM ALARM	12:30:42 PM:670	12:31:09 PM:800	1:20:30 PM:240	ALARM	ALARM	7/29/2014	Blocked	7/29/2014	7/29/2014	961
		A311	ALT3 FREQ	12:31:00 PM:870	12:31:02 PM:270	1:20:30 PM:180	H.W.ERROR	60	7/29/2014	60	7/29/2014	7/29/2014	2004
		A509	END2 TIE BKR BUS FREQ	12:31:00 PM:870	12:31:02 PM:270	1:20:30 PM:230	H.W.ERROR	60	7/29/2014	57	7/29/2014	7/29/2014	2004
		Y146	ST GEAR 1- FU STEERING FAILURE	12:31:00 PM:990	12:31:13 PM:070		ALARM	ALARM	7/29/2014	ALARM	7/29/2014	7/29/2014	961
		Y246	ST.GEAR 2- FU STEERING FAILURE	12:31:00 PM:990	12:31:13 PM:070		ALARM	ALARM	7/29/2014	ALARM	7/29/2014	7/29/2014	961
		A111	ALT1 FREQ	12:31:01 PM:130	12:31:02 PM:530	1:20:30 PM:270	H.W.ERROR	60	7/29/2014	56	7/29/2014	7/29/2014	2004
		A504	END1 BUS FREQUENCY	12:31:01 PM:130	12:31:02 PM:530	1:20:03 PM:930	H.W.ERROR	60	7/29/2014	57	7/29/2014	7/29/2014	2004
		A508	END2 TIE BKR BUS V	12:31:01 PM:270	12:31:02 PM:270	1:20:30 PM:180	ALARM	3.67	7/29/2014	0.00	7/29/2014	7/29/2014	2002
		S205	PM BRG 2.1 HTR & OIL LVL 30%	12:31:01 PM:270	12:31:01 PM:770	1:20:30 PM:180	ALARM	ALARM	7/29/2014	Blocked	7/29/2014	7/29/2014	961
		S212	PM BRG 2.2 HTR & OIL LVL 30%	12:31:01 PM:270	12:31:01 PM:770	1:20:30 PM:180	ALARM	ALARM	7/29/2014	Blocked	7/29/2014	7/29/2014	961
		D242	END2 A&M 24V CHARGER FAULT	12:31:01 PM:390	12:31:27 PM:730		ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		T218	EXFMR 2 MAIN CONTACTOR TRIP	12:31:01 PM:470		1:20:30 PM:360	TRIPPED	TRIPPED		TRIPPED	7/29/2014	7/29/2014	965
		A503	END1 BUS VOLTAGE	12:31:01 PM:530	12:31:03 PM:430	1:20:30 PM:270	ALARM	2.84	7/29/2014	0.06	7/29/2014	7/29/2014	2002
		S105	PM BRG 1.1 HTR & OIL LVL 30%	12:31:01 PM:530	12:31:02 PM:470	1:20:21 PM:450	ALARM	ALARM	7/29/2014	Blocked	7/29/2014	7/29/2014	961
		S112	PM BRG 1.2 HTR & OIL LVL 30%	12:31:01 PM:530	12:31:02 PM:470	1:20:21 PM:450	ALARM	ALARM	7/29/2014	Blocked	7/29/2014	7/29/2014	961
		S126	PM BRG 1.3 HTR & OIL LVL 30%	12:31:01 PM:600	12:31:02 PM:550	1:20:21 PM:130	ALARM	ALARM	7/29/2014	Blocked	7/29/2014	7/29/2014	961
		E135	ME1-DIESEL CTRL PNL SUM ALARM	12:31:01 PM:630	12:45:41 PM:320	1:20:21 PM:130	ALARM	ALARM	7/29/2014	Blocked	7/29/2014	7/29/2014	961
		D142	END1 A&M 24V CHARGER FAULT	12:31:01 PM:660	12:31:27 PM:280		ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		X313	PM3 SITDR 1 UNDERVOLTAGE	12:31:01 PM:670	12:34:27 PM:880	1:20:20 PM:990	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		X413	PM4 SITDR 1 UNDERVOLTAGE	12:31:01 PM:670	12:34:27 PM:880	1:20:20 PM:990	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		L117	END1 MTR/ALT FAW LOW FLOW	12:31:01 PM:730	1:43:32 PM:430	1:20:21 PM:230	ALARM	ALARM	7/29/2014	ALARM	7/29/2014	7/29/2014	961
		L211	END2 SCR/BRG FAW FLOW LOW	12:31:01 PM:730	1:44:14 PM:840	1:20:21 PM:030	ALARM	ALARM	7/29/2014	ALARM	7/29/2014	7/29/2014	961
		A307	ALT3 CURRENT	12:31:01 PM:770	12:31:02 PM:270	1:20:21 PM:030	H.W.ERROR	685	7/29/2014	0	7/29/2014	7/29/2014	2004
		P212	PM3 DRIVE NOT READY	12:31:01 PM:770	1:51:36 PM:970	1:20:21 PM:030	ALARM	ALARM	7/29/2014	ALARM	7/29/2014	7/29/2014	961
		P179	PM3 EXCITATION 1 FAULT	12:31:01 PM:770	12:31:03 PM:670	1:20:21 PM:030	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P213	PM4 DRIVE NOT READY	12:31:01 PM:770		1:20:21 PM:030	ALARM	ALARM	7/29/2014	ALARM	7/29/2014	7/29/2014	961
		P183	PM4 EXCITATION 1 FAULT	12:31:01 PM:770	12:31:03 PM:670	1:20:21 PM:030	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P201	PM3 EXCITATION SWITCHED OVER	12:31:01 PM:810	12:31:03 PM:270	1:20:21 PM:090	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P209	PM4 EXCITATION SWITCHED OVER	12:31:01 PM:890	12:31:03 PM:340	1:20:21 PM:150	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		I701	No1 M/G SET MOTOR PWR (KW)	12:31:01 PM:930	12:31:02 PM:430	1:20:21 PM:430	H.W.ERROR	72	7/29/2014	2	7/29/2014	7/29/2014	2004
		I003	TEP CHRGR FAULT	12:31:01 PM:940	12:31:21 PM:160		ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		A107	ALT1 CURRENT	12:31:01 PM:970	12:31:02 PM:530	1:20:21 PM:450	H.W.ERROR	686	7/29/2014	3	7/29/2014	7/29/2014	2004
		L111	END1 SCR/BRG FAW FLOW LOW	12:31:01 PM:970	1:43:44 PM:550	1:20:21 PM:450	ALARM	ALARM	7/29/2014	ALARM	7/29/2014	7/29/2014	961
		L217	END2 MTR/ALT FAW LOW FLOW	12:31:01 PM:970	1:44:09 PM:110	1:20:21 PM:210	ALARM	ALARM	7/29/2014	ALARM	7/29/2014	7/29/2014	961
		P172	PM3 INTERNAL DRIVE FAULT	12:31:02 PM:030	12:31:03 PM:480	1:20:21 PM:290	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P173	PM4 INTERNAL DRIVE FAULT	12:31:02 PM:030	12:31:03 PM:480	1:20:21 PM:290	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		I461	END2 HR SW COOL 3A PMP FAULT	12:31:02 PM:170	12:31:03 PM:600	1:20:20 PM:990	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		I109	END1 MCHRY SW/BLIMP 1A FAULT	12:31:02 PM:190	12:31:03 PM:590	1:20:21 PM:230	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965



Active Alarms	S...	Alarm Point	Description	Start Time	End Time	Acknowledge Time	Alarm Status	Worst Value	End date	Current Value	Start Date	Acknowledge D...	Alar...
		P173	PM4 INTERNAL DRIVE FAULT	12:31:02 PM:030	12:31:03 PM:480	1:20:21 PM:290	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		I461	END2 HR SW COOL 2A PMP FAULT	12:31:02 PM:170	12:31:03 PM:600	1:20:20 PM:990	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		L109	END1 MCHRY S/W PUMP 1A FAULT	12:31:02 PM:190	12:31:03 PM:590	1:20:21 PM:230	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		L120	END1 MTR/ALT F/W PUMP 1A FAULT	12:31:02 PM:190	12:31:02 PM:690	1:20:21 PM:230	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		L107	END1 SCR/BRG F/W PUMP 1A FAULT	12:31:02 PM:190	12:31:03 PM:590	1:20:21 PM:230	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		M109	PM1 FAN 1B TRIP	12:31:02 PM:190	12:31:03 PM:590	1:20:21 PM:230	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		M110	PM1 FAN 1C TRIP	12:31:02 PM:190	12:31:03 PM:590	1:20:21 PM:230	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		M209	PM2 FAN 2B TRIP	12:31:02 PM:190	12:31:03 PM:590	1:20:21 PM:230	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		M210	PM2 FAN 2C TRIP	12:31:02 PM:190	12:31:03 PM:590	1:20:21 PM:230	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		A309	ALT3 DIFF PROTECTION	12:31:02 PM:270	12:31:17 PM:810	1:20:12 PM:250	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		A409	ALT4 DIFF PROTECTION	12:31:02 PM:270	12:31:17 PM:380	1:20:12 PM:250	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		S235	END2 S/TUBE LUBD PUMP FAULT	12:31:02 PM:320	12:31:03 PM:740	1:20:12 PM:310	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		I416	ME1 - HT/REC PMP FAULT SUM ALM	12:31:02 PM:430	12:31:14 PM:290		ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		I426	ME2 - HT/REC PMP FAULT SUM ALM	12:31:02 PM:430	12:31:14 PM:290		ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		X116	PM1 SITDR 2 UNDERVOLTAGE	12:31:02 PM:430	12:34:27 PM:840	1:20:11 PM:930	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		X213	PM2 SITDR 1 UNDERVOLTAGE	12:31:02 PM:430	12:34:27 PM:840	1:20:11 PM:930	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P214	END1 FREQUENCY LIMITER ACTIVE	12:31:02 PM:470	12:31:04 PM:280	1:20:12 PM:000	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		L209	END2 MCHRY S/W PUMP 2A FAULT	12:31:02 PM:470	12:31:03 PM:870	1:20:12 PM:030	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		L207	END2 SCR/BRG F/W PUMP 2A FAULT	12:31:02 PM:470	12:31:03 PM:870	1:20:12 PM:010	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		T418	EXFMR 4 MAIN CONTACTOR TRIP	12:31:02 PM:470	12:31:04 PM:320		TRIPPED	TRIPPED	7/29/2014	TRIPPED	7/29/2014	7/29/2014	965
		P210	PM1 DRIVE NOT READY	12:31:02 PM:470	1:49:36 PM:590	1:20:12 PM:000	ALARM	ALARM	7/29/2014	ALARM	7/29/2014	7/29/2014	961
		P180	PM1 EXCITATION 2 FAULT	12:31:02 PM:470	12:31:04 PM:280	1:20:12 PM:000	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P211	PM2 DRIVE NOT READY	12:31:02 PM:470		1:20:12 PM:000	ALARM	ALARM	7/29/2014	ALARM	7/29/2014	7/29/2014	961
		M308	PM3 FAN 3A TRIP	12:31:02 PM:470	12:31:03 PM:870	1:20:12 PM:030	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		M310	PM3 FAN 3C TRIP	12:31:02 PM:470	12:31:03 PM:870	1:20:12 PM:030	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		M408	PM4 FAN 4A TRIP	12:31:02 PM:470	12:31:03 PM:870	1:20:12 PM:030	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		M410	PM4 FAN 4C TRIP	12:31:02 PM:470	12:31:03 PM:870	1:20:12 PM:030	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		T412	EXFMR 4 MAIN CB TRIP	12:31:02 PM:470	12:31:04 PM:320		TRIPPED	TRIPPED	7/29/2014	TRIPPED	7/29/2014	7/29/2014	965
		S135	END1 S/TUBE LUBD PUMP FAULT	12:31:02 PM:550	12:31:03 PM:890		ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P200	PM1 EXCITATION SWITCHED OVER	12:31:02 PM:550	12:31:04 PM:350	1:20:12 PM:050	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P202	PM2 PHASE A SWITCHED OVER	12:31:02 PM:550	12:31:03 PM:030	1:20:12 PM:050	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		X108	PM1 SITDR 1 AIR FLOW LOW	12:31:02 PM:630	12:31:03 PM:130	1:20:12 PM:110	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		X109	PM1 SITDR 2 AIR FLOW LOW	12:31:02 PM:630	12:31:03 PM:130	1:20:12 PM:110	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P204	PM2 PHASE B SWITCHED OVER	12:31:02 PM:630	12:31:03 PM:090	1:20:12 PM:110	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P206	PM2 PHASE C SWITCHED OVER	12:31:02 PM:630	12:31:03 PM:090	1:20:12 PM:110	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		I462	END2 HR SW COOL 2B PMP FAULT	12:31:02 PM:670	12:31:04 PM:070		ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		I436	ME3 - HT/REC PMP FAULT SUM ALM	12:31:02 PM:670	12:31:14 PM:300		ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		I446	ME4 - HT/REC PMP FAULT SUM ALM	12:31:02 PM:670	12:31:14 PM:300		ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P187	PM3 TRIP BY SIMADYN D	12:31:02 PM:670	12:31:04 PM:510		ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P189	PM4 TRIP BY SIMADYN D	12:31:02 PM:670	12:31:04 PM:510		ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		T318	EXFMR 3 MAIN CONTACTOR TRIP	12:31:02 PM:690	12:31:04 PM:030		TRIPPED	TRIPPED	7/29/2014	TRIPPED	7/29/2014	7/29/2014	965
		T312	EXFMR 3 MAIN CB TRIP	12:31:02 PM:690	12:31:04 PM:030		TRIPPED	TRIPPED	7/29/2014	TRIPPED	7/29/2014	7/29/2014	965



Active Alarms	S...	Alarm Point	Description	Start Time	End Time	Acknowledge Time	Alarm Status	Worst Value	End date	Current Value	Start Date	Acknowledge D...	Alar...
		P189	PM4 TRIP BY SIMADYN D	12:31:02 PM:670	12:31:04 PM:510		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		T318	EXFMR 3 MAIN CONTACTOR TRIP	12:31:02 PM:690	12:31:04 PM:030		TRIPPED	TRIPPED	7/29/2014	TRIPPED	7/29/2014		965
		T312	EXFMR 3 MAIN CB TRIP	12:31:02 PM:690	12:31:04 PM:030		TRIPPED	TRIPPED	7/29/2014	TRIPPED	7/29/2014		965
		P170	PM1 INTERNAL DRIVE FAULT	12:31:02 PM:760	12:31:04 PM:130	1:20:12 PM:230	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P171	PM2 INTERNAL DRIVE FAULT	12:31:02 PM:760	12:31:04 PM:130	1:20:12 PM:230	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P215	END2 FREQUENCY LIMITER ACTIVE	12:31:02 PM:770	12:31:03 PM:670	1:20:12 PM:250	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P195	PM3 PHASE A SWITCHED OVER	12:31:02 PM:820	12:31:03 PM:270	1:20:12 PM:330	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P197	PM3 PHASE B SWITCHED OVER	12:31:02 PM:820	12:31:03 PM:270	1:20:12 PM:330	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P199	PM3 PHASE C SWITCHED OVER	12:31:02 PM:820	12:31:03 PM:270	1:20:11 PM:890	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P203	PM4 PHASE A SWITCHED OVER	12:31:02 PM:820	12:31:03 PM:270	1:20:11 PM:890	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		C318	TC3.B.1 ZERO CURR MONITOR FLT	12:31:02 PM:820	12:31:04 PM:670	1:20:12 PM:330	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P205	PM4 PHASE B SWITCHED OVER	12:31:02 PM:890	12:31:03 PM:340	1:20:04 PM:040	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P207	PM4 PHASE C SWITCHED OVER	12:31:02 PM:890	12:31:03 PM:340	1:20:04 PM:040	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		C327	TC3.C.1 ZERO CURR MONITOR FLT	12:31:02 PM:890	12:31:04 PM:700	1:20:04 PM:040	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		C409	TC4.A.1 ZERO CURR MONITOR FLT	12:31:02 PM:890	12:31:04 PM:700	1:20:04 PM:040	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		L210	END2 MCHRY S/W PUMP 2B FAULT	12:31:02 PM:970	12:31:04 PM:320	1:20:04 PM:100	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		L208	END2 SCR/BRG F/W PUMP 2B FAULT	12:31:02 PM:970	12:31:04 PM:320	1:20:04 PM:100	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		M309	PM3 FAN 3B TRIP	12:31:02 PM:970	12:31:04 PM:320	1:20:04 PM:100	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		M409	PM4 FAN 4B TRIP	12:31:02 PM:970	12:31:04 PM:320	1:20:04 PM:100	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		Y013	ST GEAR 1 - CONTROL PWR FAILURE - 1A	12:31:03 PM:070	12:31:13 PM:470		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y014	ST GEAR 1 - CONTROL PWR FAILURE - 1B	12:31:03 PM:070	12:31:12 PM:380	1:20:03 PM:760	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		Y011	ST GEAR 1 - PWR FAILURE - 1A	12:31:03 PM:070	12:31:13 PM:020		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y012	ST GEAR 1 - PWR FAILURE - 1B	12:31:03 PM:070	12:31:11 PM:770	1:20:03 PM:760	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		Y023	ST GEAR 2 - CONTROL PWR FAILURE - 2A	12:31:03 PM:070	12:31:13 PM:470		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y024	ST GEAR 2 - CONTROL PWR FAILURE - 2B	12:31:03 PM:070	12:31:11 PM:970	1:20:03 PM:760	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		Y021	ST GEAR 2 - PWR FAILURE - 2A	12:31:03 PM:070	12:31:13 PM:020		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y022	ST GEAR 2 - PWR FAILURE - 2B	12:31:03 PM:070	12:31:11 PM:770	1:20:03 PM:760	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		L110	END1 MCHRY S/W PUMP 1B FAULT	12:31:03 PM:160	12:31:04 PM:470	1:20:04 PM:070	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		L108	END1 SCR/BRG F/W PUMP 1B FAULT	12:31:03 PM:160	12:31:04 PM:470	1:20:04 PM:070	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		M108	PM1 FAN 1A TRIP	12:31:03 PM:160	12:31:04 PM:470	1:20:04 PM:070	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		M208	PM2 FAN 2A TRIP	12:31:03 PM:160	12:31:04 PM:470	1:20:04 PM:070	TRIPPED	TRIPPED	7/29/2014	Normal	7/29/2014	7/29/2014	965
		T212	EXFMR 2 MAIN CB TRIP	12:31:03 PM:420	12:31:05 PM:190		TRIPPED	TRIPPED	7/29/2014	TRIPPED	7/29/2014		965
		I113	PH1 24VDC CHARGER FAULT	12:31:03 PM:470	12:31:05 PM:010		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		I213	PH2 24VDC CHARGER FAULT	12:31:03 PM:470	12:31:05 PM:010		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		T118	EXFMR 1 MAIN CONTACTOR TRIP	12:31:03 PM:590	12:31:05 PM:330		TRIPPED	TRIPPED	7/29/2014	TRIPPED	7/29/2014		965
		T112	EXFMR 1 MAIN CB TRIP	12:31:03 PM:590	12:31:05 PM:330		TRIPPED	TRIPPED	7/29/2014	TRIPPED	7/29/2014		965
		P167	PM3 SYNCHR. VOLT. FAILED	12:31:03 PM:970	12:31:04 PM:390	1:20:04 PM:170	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P168	PM4 SYNCHR. VOLT. FAILED	12:31:03 PM:970	12:31:04 PM:390	1:20:04 PM:170	ALARM	ALARM	7/29/2014	Normal	7/29/2014	7/29/2014	961
		P186	PM1 TRIP BY SIMADYN D	12:31:04 PM:660	12:31:05 PM:070		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		P188	PM2 TRIP BY SIMADYN D	12:31:04 PM:660	12:31:05 PM:070		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		I113	PH1 24VDC CHARGER FAULT	12:31:06 PM:770	12:31:12 PM:810		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		I213	PH2 24VDC CHARGER FAULT	12:31:06 PM:770	12:31:12 PM:810		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961



Active Alarms	S...	Alarm Point	Description	Start Time	End Time	Acknowledge Time	Alarm Status	Worst Value	End date	Current Value	Start Date	Acknowledge D...	Alar...
		P188	PM2 TRIP BY SIMADYN D	12:31:04 PM:660	12:31:05 PM:070		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		I113	PH1 24VDC CHARGER FAULT	12:31:06 PM:770	12:31:12 PM:810		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		I213	PH2 24VDC CHARGER FAULT	12:31:06 PM:770	12:31:12 PM:810		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		I205	E GEN START BAT CUR&DIR OF CUR	12:31:07 PM:900	12:31:08 PM:580	1:20:03 PM:620	H.W.ERROR	11	7/29/2014	2	7/29/2014	7/29/2014	2004
		I002	TEP BAT CUR & DIR OF CUR	12:31:09 PM:980	12:31:19 PM:910	1:19:36 PM:900	ALARM	-43	7/29/2014	0	7/29/2014	7/29/2014	2002
		E321	ME3 - LUBD PRESS	12:31:11 PM:340	12:31:16 PM:900	1:20:04 PM:290	ALARM	28	7/29/2014	0	7/29/2014	7/29/2014	2002
		I424	ME2 - HT/REC PMP MTR RPM	12:31:11 PM:910	12:31:12 PM:300		H.W.ERROR	0	7/29/2014	0	7/29/2014		2004
		E319	ME3 - TURBO OIL PRESS	12:31:12 PM:240	12:31:16 PM:970	1:20:03 PM:920	ALARM	20	7/29/2014	0	7/29/2014	7/29/2014	2002
		I415	ME1 - HT/REC PMP MTR AMP	12:31:12 PM:300	12:31:12 PM:710		H.W.ERROR	0	7/29/2014	0	7/29/2014		2004
		I414	ME1 - HT/REC PMP MTR RPM	12:31:12 PM:300	12:31:12 PM:710		H.W.ERROR	0	7/29/2014	0	7/29/2014		2004
		I425	ME2 - HT/REC PMP MTR AMP	12:31:12 PM:300	12:31:12 PM:710		H.W.ERROR	0	7/29/2014	0	7/29/2014		2004
		I445	ME4 - HT/REC PMP MTR AMP	12:31:12 PM:700	12:31:13 PM:100		H.W.ERROR	1	7/29/2014	1	7/29/2014		2004
		I444	ME4 - HT/REC PMP MTR RPM	12:31:12 PM:700	12:31:13 PM:100		H.W.ERROR	0	7/29/2014	0	7/29/2014		2004
		I435	ME3 - HT/REC PMP MTR AMP	12:31:13 PM:100	12:31:16 PM:970		H.W.ERROR	1	7/29/2014	1	7/29/2014		2004
		I434	ME3 - HT/REC PMP MTR RPM	12:31:13 PM:100	12:31:16 PM:970		H.W.ERROR	0	7/29/2014	0	7/29/2014		2004
		I415	ME1 - HT/REC PMP MTR AMP	12:31:13 PM:110	12:31:16 PM:200		H.W.ERROR	1	7/29/2014	0	7/29/2014		2004
		I414	ME1 - HT/REC PMP MTR RPM	12:31:13 PM:110	12:31:16 PM:200		H.W.ERROR	0	7/29/2014	0	7/29/2014		2004
		I425	ME2 - HT/REC PMP MTR AMP	12:31:13 PM:110	12:31:17 PM:010		H.W.ERROR	0	7/29/2014	0	7/29/2014		2004
		I424	ME2 - HT/REC PMP MTR RPM	12:31:13 PM:110	12:31:17 PM:010		H.W.ERROR	0	7/29/2014	0	7/29/2014		2004
		I001	TEP BAT V (120V)	12:31:13 PM:370	12:31:21 PM:210	1:20:03 PM:620	ALARM	116	7/29/2014	127	7/29/2014	7/29/2014	2002
		I445	ME4 - HT/REC PMP MTR AMP	12:31:13 PM:510	12:31:16 PM:110		H.W.ERROR	2	7/29/2014	1	7/29/2014		2004
		I444	ME4 - HT/REC PMP MTR RPM	12:31:13 PM:510	12:31:16 PM:110		H.W.ERROR	0	7/29/2014	0	7/29/2014		2004
		E335	ME3-DIESEL CTRL PNL SUM ALARM	12:31:14 PM:840	12:31:17 PM:020	1:20:03 PM:980	ALARM	ALARM	7/29/2014	Blocked	7/29/2014	7/29/2014	961
		Y013	ST GEAR 1 - CONTROL PWR FAILURE - 1A	12:31:20 PM:420	12:31:22 PM:510		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y023	ST GEAR 2 - CONTROL PWR FAILURE - 2A	12:31:20 PM:420	12:33:26 PM:140		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		I002	TEP BAT CUR & DIR OF CUR	12:31:21 PM:580	12:31:22 PM:880		H.W.ERROR	171	7/29/2014	0	7/29/2014		2004
		Y013	ST GEAR 1 - CONTROL PWR FAILURE - 1A	12:31:25 PM:040	12:31:27 PM:190		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y013	ST GEAR 1 - CONTROL PWR FAILURE - 1A	12:31:30 PM:150	12:31:31 PM:570		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y013	ST GEAR 1 - CONTROL PWR FAILURE - 1A	12:31:34 PM:450	12:31:35 PM:680		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y013	ST GEAR 1 - CONTROL PWR FAILURE - 1A	12:31:38 PM:960	12:31:39 PM:780		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y013	ST GEAR 1 - CONTROL PWR FAILURE - 1A	12:31:43 PM:050	12:31:43 PM:870		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y013	ST GEAR 1 - CONTROL PWR FAILURE - 1A	12:31:46 PM:940	12:31:47 PM:560		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y013	ST GEAR 1 - CONTROL PWR FAILURE - 1A	12:31:50 PM:770	12:31:50 PM:970		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y013	ST GEAR 1 - CONTROL PWR FAILURE - 1A	12:31:54 PM:430	12:31:54 PM:640		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y246	ST.GEAR 2 - FU STEERING FAILURE	12:32:27 PM:830	12:32:31 PM:010		ALARM	ALARM	7/29/2014	ALARM	7/29/2014		961
		Y146	ST GEAR 1 - FU STEERING FAILURE	12:32:28 PM:080	12:32:31 PM:010		ALARM	ALARM	7/29/2014	ALARM	7/29/2014		961
		D242	END2 A&M 24V CHARGER FAULT	12:32:28 PM:360	12:32:44 PM:700		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		I113	PH1 24VDC CHARGER FAULT	12:32:28 PM:430	12:32:30 PM:520		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		I213	PH2 24VDC CHARGER FAULT	12:32:28 PM:430	12:32:30 PM:520		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		D142	END1 A&M 24V CHARGER FAULT	12:32:28 PM:520	12:32:44 PM:010		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		I003	TEP CHR6 FAULT	12:32:28 PM:600	12:32:29 PM:590		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961
		Y013	ST GEAR 1 - CONTROL PWR FAILURE - 1A	12:32:30 PM:220	12:32:31 PM:180		ALARM	ALARM	7/29/2014	Normal	7/29/2014		961



DEI Electrical Consultants, Inc.

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Spokane Valley, WA 99206*

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October 21, 2014

Ray Kemink
Intermountain Electric
415 N Fancher Rd
Spokane Valley, WA 99212

Re: MV Tacoma - "Root Cause Analysis"

Dear Ray:

As you requested I met you on the MV Tacoma on September 16, 2014. You and I visually inspected the damage the arcing fault caused to the 4.16 kV Switchgear serving Alternators #3 & #4. The cubicle containing the breaker for Alternator #4 had significantly more black soot inside the cubicle than did Alternator #3 cubicle. The cables feeding Alternator #4 breaker were damaged more than the corresponding cables in Alternator #3 cubicle. It was apparent that a major arc flash had occurred and significant damage was done to both Alternator #3 & #4 vacuum breaker cubicles and a little less damage to the adjacent cubicles. The breakers were not present on site at the time of our observation. We were able to review the Siemens as-built drawings for the installation.

When reviewing the as-built drawings I noted the voltage sensing in the system was being done in a phase to ground mode. I thought that was odd because the 4.16 kV power system is not grounded at the generator or the switchgear. I would have expected to see the voltage sensing to be in a phase to phase configuration. The 4.16 kV power system floats without a solid ground reference. The neutral spades on the alternators are not bonded to ground nor impedance grounded through a grounding resistor.

Most 4.16 kV systems on land are impedance grounded through a grounding resistor to limit the available fault current and to give a reliable fault return path to be able to easily sense whenever a single phase fault event occurs. We normally install CTs in the neutral to ground path to sense when there is excessive single phase fault current. Even with the fault current reduced we are able to quickly sense and act on a single phase fault because of the neutral to ground bond.

While looking into this I kept asking myself why is the system ungrounded? I am not a marine expert. I discovered most marine applications look for reliability over and above system protection. With the system ungrounded if a single power cable shorts to the hull the system keeps operating. In a solidly grounded or impedance grounded system the feeder would fault and the protection system would take it offline.

After looking further into the design of the system I was able to learn the 4200/120V PTs are grounded on all phases on the 4200 volt side and on B phase on the 120 volt secondary. This creates a ground reference for the protective devices on the 120 Volt based protection system. Also there is a correlation between the apparent ground in the 4.16 kV system and the 120 volt system. The apparent ground in the 4.16 kV system is dependent on the PT fuses being intact. If one or more PT fuses are blown there is no proper sensing of 4.16 kV voltage in the system.

I have been able to review the three Siemens reports regarding the damage to the equipment. I have read Fritz Schuckert's report of the "July-29th" incident. I agree in general with his assessment of the cause of the failure. I am not an expert at reading the Siemens event logs and must rely on his interpretation of the data.

To me the root cause of the failure was the design included an F14 Phase Loss Relay that was configured in a phase to ground voltage sensing when it should have been sensing phase to phase due to the minimal ground reference in the 4.16 kV system. Phase loss is always hard to detect. Sometimes the other phases feedback through loads and fool a phase loss relay. That is why we usually put a fairly tight allowable voltage range on phase loss relays. I have seen inexpensive phase loss relays be fooled in a 480 volt system with lots of small motors running. The F14 Phase Loss Relay deficiency in the control system allowed Alternator #4 to be closed in out of phase and out of voltage compatibility with the live bus. Had

that not occurred this incident would not have occurred. A new phase loss relay needs to be installed that requires all three phases be within a tight tolerance before a breaker close command can be given.

I currently have a project with the Department of Corrections where we designed new paralleling controls for Airway Heights Corrections Center. Their system consists of four 1000 KW generators that parallel to provide standby power to the facility. The new controls have an SEL 700 generator protector that must agree with a separate 25 Relay (Sync Relay) before the 4.16 kV vacuum breaker is allowed to close. Both use different voltage inputs to determine the generator is in sync and within voltage range and both must agree before the breaker can be closed. This is the general type of protection design changes that should be implemented to make the MV Tacoma system more bulletproof.

I hope this meets with your approval. If you have any questions, comments or concerns please do not hesitate to contact me.

Sincerely,

DEI ELECTRICAL CONSULTANTS, INC.

A handwritten signature in cursive script that reads "Stephen Helms".

Stephen Helms, PE
SH/kd

Breaker #	Serial #	Bottle Count	Issues	Recommendation
1	CAN-0541	5276	Missing Barriers	We need to make the new barriers & we recommend, while it's in the shop, cleaning, lubricating, & re-testing the breaker.
2	CAN-0536	8027	Broken Barriers	We need to make the new barriers & we recommend, while it's in the shop, cleaning, lubricating, & re-testing the breaker.
3	CAN-0539	21036	Broken Barrier, Missing Barrier, Breaker will not electrically operate. The racking mechanism is jammed into the operator.	We recommend replacing the breaker because the racking mechanism is not working. We would have to replace the racking mech to even see if the breaker would work. Also, since these bottles are 30K operation bottles, they are already at 70% of their life. It would be more cost efficient to buy the replacement breaker.
4	CAN-0538	1094	No issues	We recommend, while it's in the shop, cleaning, lubricating, & re-testing the breaker.
5	CAN-0535	8531	No issues	We recommend, while it's in the shop, cleaning, lubricating, & re-testing the breaker.
6	CAN-0958	3002	No issues	We recommend, while it's in the shop, cleaning, lubricating, & re-testing the breaker.
7	CAN-0534	1060	Needs new charging motor	We recommend replacing the charging motor, cleaning, lubricating, & re-testing the breaker.
8	CAN-0533	19276	Broken Counter, Broken racking linkage, Close Coil needs replaced, Corona on A&B-Phase Barrier.	We recommend replacing the breaker because the racking mechanism is broken. We would have to replace the racking mech to even see if the breaker would work. Also, since these bottles are 30K operation bottles, they are already at 64% of their life. It would be more cost efficient to buy the replacement breaker.
9	CAN-0542	8023	High Contact Resistance on A-Phase, 34.7ms of bounce. B & C-Phase is .10ms. This means that A-Phase is taking a lot longer to close, which can cause a possible bottle failure.	We recommend replacing the breaker because we cannot get replacement bottles.
10	Missing Nameplate	9110	Heavy Carbon on the bottom stabs. The unit appears to have been in a fault & is extremely dirty.	We recommend replacing the breaker because we would normally replace the bottles after a fault. Since we cannot buy replacement bottles, it's going to need replaced.
11	CAN-0540	7950	No issues	We recommend, while it's in the shop, cleaning, lubricating, & re-testing the breaker.

Description	Serial Number	Cycle Counter
❖ Generator Number One	CAN0539	21,034
❖ Generator Number Two	CAN0533	19,276
❖ Generator Number Three	CAN0535	8,531
❖ Generator Number Four	CAN? (Label missing)	9,110
❖ Drive Motor Number One	CAN0542	8,022
❖ Drive Motor Number Two	CAN0540	7,949
❖ Drive Motor Number Three	CAN0536	8,026
❖ Drive Motor Number Four	CAN0958	2,999
❖ Tie Breaker Number One	CAN0534	1,059
❖ Tie Breaker Number Two	CAN0538	1,093
❖ Spare 3AF Circuit Breaker	CAN0541	5,276
❖ Contactor, Excitation Motor One	RAL92877-B1-010397	
❖ Contactor, Excitation Motor Two	RAL99554-A1-050694	
❖ Contactor, Excitation Motor Three	RAL90133-A2-111194	
❖ Contactor, Excitation Motor Four	RAL99554-A2-050694	
❖ Contactor, HT Number One	RAL90133-B1-010397	
❖ Contactor, HT Number Two	RAL90133-B2-111194	
❖ Contactor, MG Number One	RAL90133-C1-111194	
❖ Contactor, MG Number Two	RAL90133-C2-111194	
❖ Contactor, Spare Number One	RAL92877-A3-010397	
❖ Contactor, Spare Number Two	RAL92877-C3-010397	
❖ Contactor, Spare Number Three	RAL90133-A1-111194	

S

Siemens Industry Inc.

MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER TEST REPORT

Customer: WASHINGTON STATE FERRY Location: _____
 Substation: _____ Feeder/Cubicle: _____ Unique ID: 1 OF 11

Nameplate Data

Manufacturer:	SIEMENS	Voltage Rating:	4.76
Type / Style:	3AF1052-4	Current Rating:	1200
YR / Serial Number:	94/11 CAN-0541	Interrupting Rating:	31.5KA
IB Number:		Trip Coil / Close Coil:	24 VDC

Inspection

Primary Fingers:	B	Charging Motor Operation:	B
Vac. Contact Wear Indicators:	B	Clean and Lubricate Mechanism:	
Vac. Contact Wipe Indicators:	B	Racking and Shutter Mechanism:	
Clean Bottles and Insulation:		Mechanical Interlocks:	B
Auxiliary Contacts:	B	Electrical Charge Test:	B
Control Circuit Wiring:	B	Electrical Close and Trip Test:	B
		Relay Trip Test:	N/A
Operation As Found:	05276		
Operation As Left:			

CODE LEGEND
A= Like New Condition
B= Good Condition
C= Poor Condition Requires Correction
D= Corrections Made
E= Unacceptable Condition Do Not Use!
NA= Not Applicable

A Phase	B Phase	C Phase
B	B	B

Contact Gap / Wear Indication:

Electrical Tests

Environmental Conditions

Insulation Resistance									
Readings in Mega-Ohms @ 2500 VDC									
As Found					As Left				
A-G	A-B	A-A'	B-G	66M	A-B	238M	A-A'	200G	
B-G	B-C	B-B'	C-G	177M	B-C	148M	B-B'	200G	
C-G	C-A	C-C'	C-G	33M	C-A	58M	C-C'	200G	

Selection
Indoor/Outdoor
Clean / Dirty
Wet / Damp / Dry
Temp (Degree C)
Relative Humidity (%)

Control Wiring (Tested at 500 VDC) _____

Contact Resistance			
Readings in Micro-Ohms			
As Found		As Left	
A	27	A	
B	28	B	
C	26	C	

HIPOT Across Open VAC Contacts @ 10 kV AC AC or DC

Phase A (MA)	Phase B (MA)	Phase C (MA)
PASS	PASS	PASS

COMMENTS

Satisfactory for Continued Service	Requires Repair	X	Repairs Made During Maintenance
MISSING BARRIERS TIMING CLOSE: 3.86CY 3.86CY 3.83CY OPEN: 2.29CY 2.30CY 2.32CY 10K OPERATION BOTTLES			

Job No: 3005080799-5200405589 Tested By: WARRICK/PERTUSET Date Tested: 9-30-14 ID # _____

S

Siemens Industry Inc.

MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER TEST REPORT

Customer: WASHINGTON STATE FERRY Location:
 Substation: Feeder/Cubicle: Unique ID: 2 OF 11

Nameplate Data

Manufacturer: SIEMENS Voltage Rating: 4.76
 Type / Style: 3AF1052-4 Current Rating: 1200
 YR / Serial Number: 94/11 CAN-0536 Interrupting Rating: 31.5KA
 IB Number: Trip Coil / Close Coil: 24 VDC

Inspection

Primary Fingers:	B	Charging Motor Operation:	B	CODE LEGEND A= Like New Condition B= Good Condition C= Poor Condition Requires Correction D= Corrections Made E= Unacceptable Condition Do Not Use! NA= Not Applicable
Vac. Contact Wear Indicators:	B	Clean and Lubricate Mechanism:		
Vac. Contact Wipe Indicators:	B	Racking and Shutter Mechanism:		
Clean Bottles and Insulation:		Mechanical Interlocks:	B	
Auxiliary Contacts:	B	Electrical Charge Test:	B	
Control Circuit Wiring:	B	Electrical Close and Trip Test:	B	
Operation As Found:	08027	Relay Trip Test:	N/A	
Operation As Left:				

	A Phase	B Phase	C Phase
Contact Gap / Wear Indication:	B	B	B

Electrical Tests

Insulation Resistance									
Readings in Mega-Ohms @ 2500 VDC									
As Found					As Left				
A-G	25M	A-B	8M	A-A'	200G	A-G		A-B	A-A'
B-G	21M	B-C	9M	B-B'	200G	B-G		B-C	B-B'
C-G	29M	C-A	19M	C-C'	200G	C-G		C-A	C-C'

Control Wiring (Tested at 500 VDC)

Environmental Conditions

	Selection
Indoor/Outdoor	
Clean / Dirty	
Wet / Damp / Dry	
Temp (Degree C)	
Relative Humidity (%)	

Contact Resistance			
Readings in Micro-Ohms			
As Found		As Left	
A	29	A	
B	29	B	
C	29	C	

HIPOT Across Open VAC Contacts @ 10 kV AC AC or DC

Phase A (MA)	Phase B (MA)	Phase C (MA)
PASS	PASS	PASS

COMMENTS

Satisfactory for Continued Service	Requires Repair	X	Repairs Made During Maintenance
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BROKEN BARRIER.
 TIMING OPEN: 3.56CY 3.62CY 3.60CY
 CLOSE: 2.52CY 2.41CY 2.48CY
 10K OPERATION BOTTLES.

Job No: 3005080799-5200405589 Tested By: WARRICK/PERTUSET Date Tested: 9-30-14 ID #

S

Siemens Industry Inc.

MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER TEST REPORT

Customer: WASHINGTON STATE FERRY Location:
 Substation: Feeder/Cubicle: Unique ID: 3 OF 11

Nameplate Data
 Manufacturer: SIEMENS Voltage Rating: 4.76
 Type / Style: 3AF1052-4 Current Rating: 1200
 YR / Serial Number: 94/11 CAN-0539 Interrupting Rating: 31.5KA
 IB Number: Trip Coil / Close Coil: 24 VDC

Inspection

Primary Fingers:	B	Charging Motor Operation:	B
Vac. Contact Wear Indicators:		Clean and Lubricate Mechanism:	
Vac. Contact Wipe Indicators:		Racking and Shutter Mechanism:	C
Clean Bottles and Insulation:		Mechanical Interlocks:	
Auxiliary Contacts:	B	Electrical Charge Test:	B
Control Circuit Wiring:	B	Electrical Close and Trip Test:	C
		Relay Trip Test:	N/A

Operation As Found: 21036
 Operation As Left:

CODE LEGEND

A= Like New Condition
B= Good Condition
C= Poor Condition Requires Correction
D= Corrections Made
E= Unacceptable Condition Do Not Use!
NA= Not Applicable

Contact Gap / Wear Indication:

A Phase	B Phase	C Phase

Electrical Tests

Insulation Resistance
 Readings in Mega-Ohms @ 2500 VDC

As Found			As Left			VDC
A-G	A-B	A-A'	A-G	A-B	A-A'	200G
B-G	B-C	B-B'	B-G	B-C	B-B'	200G
C-G	C-A	C-C'	C-G	C-A	C-C'	200G

Environmental Conditions

Selection
Indoor/Outdoor
Clean / Dirty
Wet / Damp / Dry
Temp (Degree C)
Relative Humidity (%)

Control Wiring (Tested at 500 VDC)

Contact Resistance
 Readings in Micro-Ohms

As Found		As Left	
A		A	
B		B	
C		C	

HIPOT Across Open VAC Contacts @ 10 kV AC AC or DC

Phase A (MA)	Phase B (MA)	Phase C (MA)
PASS	PASS	PASS

COMMENTS

Satisfactory for Continued Service	Requires Repair	X	Repairs Made During Maintenance
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BROKEN BARRIER BRACKET.
 MISSING BARRIER SUPPORT.
 BREAKER WILL NOT ELECTRICALLY OPERATE. RACKING MECHANISM JAMMED THE OPERATOR.
 10K OPERATION BOTTLES
 *****RECOMMEND REPLACEMENT BREAKER*****

Job No: 3005080799-5200405589 Tested By: WARRICK/PERTUSET Date Tested: 9-30-14 ID #

K. Rolley

100 Technology Dr. Alpharetta, GA 30005
 770-740-3000

F1098AB-SW
 Rev 4

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Siemens Industry Inc.

MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER TEST REPORT

Customer: WASHINGTON STATE FERRY Location: _____
 Substation: _____ Feeder/Cubicle: _____ Unique ID: 4 OF 11

Nameplate Data

Manufacturer:	SIEMENS	Voltage Rating:	4.76
Type / Style:	3AF1052-4	Current Rating:	1200
YR / Serial Number:	94/11 CAN-0538	Interrupting Rating:	31.5KA
IB Number:		Trip Coil / Close Coil:	24 VDC

Inspection

Primary Fingers:	B	Charging Motor Operation:	B	CODE LEGEND A= Like New Condition B= Good Condition C= Poor Condition Requires Correction D= Corrections Made E= Unacceptable Condition Do Not Use! NA= Not Applicable
Vac. Contact Wear Indicators:	B	Clean and Lubricate Mechanism:		
Vac. Contact Wipe Indicators:	B	Racking and Shutter Mechanism:		
Clean Bottles and Insulation:		Mechanical Interlocks:	B	
Auxiliary Contacts:	B	Electrical Charge Test:	B	
Control Circuit Wiring:	B	Electrical Close and Trip Test:	B	
		Relay Trip Test:	N/A	
Operation As Found:	01094			
Operation As Left:				

	A Phase	B Phase	C Phase
Contact Gap / Wear Indication:	B	B	B

Electrical Tests

Environmental Conditions

Insulation Resistance								
Readings in Mega-Ohms @ 2500 VDC								
As Found			As Left					
A-G	A-B	A-A'	A-G	25M	A-B	32M	A-A'	200G
B-G	B-C	B-B'	B-G	62M	B-C	44M	B-B'	200G
C-G	C-A	C-C'	C-G	34M	C-A	18M	C-C'	200G

	Selection
Indoor/Outdoor	
Clean / Dirty	
Wet / Damp / Dry	
Temp (Degree C)	
Relative Humidity (%)	

Control Wiring (Tested at 500 VDC) _____

Contact Resistance			
Readings in Micro-Ohms			
As Found		As Left	
A	29	A	
B	30	B	
C	28	C	

HIPOT Across Open VAC Contacts @ 10 kV AC AC or DC

Phase A (MA)	Phase B (MA)	Phase C (MA)
PASS	PASS	PASS

COMMENTS

Satisfactory for Continued Service		Requires Repair	X	Repairs Made During Maintenance	
TIMING CLOSE: 3.79CY 3.79CY 3.75CY OPEN: 2.40CY 2.39CY 2.42CY 10K OPERATION BOTTLES					

Job No: 3005080799-5200405589 Tested By: WARRICK/PERTUSET Date Tested: 9-30-14 ID # _____

S

Siemens Industry Inc.

MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER TEST REPORT

Customer:	WASHINGTON STATE FERRY	Location:	
Substation:		Feeder/Cubicle:	
		Unique ID:	5 OF 11

Nameplate Data			
Manufacturer:	SIEMENS	Voltage Rating:	4.76
Type / Style:	3AF1052-4	Current Rating:	1200
YR / Serial Number:	94/11 CAN-0535	Interrupting Rating:	31.5KA
IB Number:		Trip Coil / Close Coil:	24 VDC

Inspection			
Primary Fingers:	B	Charging Motor Operation:	B
Vac. Contact Wear Indicators:	B	Clean and Lubricate Mechanism:	
Vac. Contact Wipe Indicators:	B	Racking and Shutter Mechanism:	
Clean Bottles and Insulation:		Mechanical Interlocks:	B
Auxiliary Contacts:	B	Electrical Charge Test:	B
Control Circuit Wiring:	B	Electrical Close and Trip Test:	B
		Relay Trip Test:	N/A
Operation As Found:	08531		
Operation As Left:			

CODE LEGEND
A= Like New Condition
B= Good Condition
C= Poor Condition Requires Correction
D= Corrections Made
E= Unacceptable Condition Do Not Use!
NA= Not Applicable

A Phase	B Phase	C Phase
B	B	B

Electrical Tests										
Insulation Resistance										
Readings in Mega-Ohms @ 2500 VDC										
As Found					As Left					
A-G	151M	A-B	400M	A-A'	200G	A-G		A-B		A-A'
B-G	88M	B-C	226M	B-B'	200G	B-G		B-C		B-B'
C-G	72M	C-A	274M	C-C'	200G	C-G		C-A		C-C'

Environmental Conditions	
Indoor/Outdoor	Selection
Clean / Dirty	
Wet / Damp / Dry	
Temp (Degree C)	
Relative Humidity (%)	

Control Wiring (Tested at 500 VDC)

Contact Resistance		
Readings in Micro-Ohms		
	As Found	As Left
A	29	A
B	33	B
C	30	C

HIPOT Across Open VAC Contacts @ kV AC DC

Phase A (MA)	Phase B (MA)	Phase C (MA)
PASS	PASS	PASS

COMMENTS

Satisfactory for Continued Service	<input type="checkbox"/>	Requires Repair	<input checked="" type="checkbox"/>	Repairs Made During Maintenance	<input type="checkbox"/>
<p>TIMING CLOSE: 3.79CY 3.78CY 3.82CY OPEN: 2.58CY 2.60CY 2.55CY</p> <p>10K OPERATION BOTTLES</p>					

Job No:	3005080799-5200405589	Tested By:	WARRICK/PERTUSET	Date Tested	9-30-14	ID #	
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Siemens Industry Inc.

MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER TEST REPORT

Customer: WASHINGTON STATE FERRY Location: _____
 Substation: _____ Feeder/Cubicle: _____ Unique ID: 6 OF 11

Nameplate Data

Manufacturer:	SIEMENS	Voltage Rating:	4.76
Type / Style:	3AF1052-4	Current Rating:	1200
YR / Serial Number:	97/03 CAN-0958	Interrupting Rating:	31.5KA
IB Number:		Trip Coil / Close Coil:	24 VDC

Inspection

Primary Fingers:	B	Charging Motor Operation:	B	CODE LEGEND A= Like New Condition B= Good Condition C= Poor Condition Requires Correction D= Corrections Made E= Unacceptable Condition Do Not Use! NA= Not Applicable
Vac. Contact Wear Indicators:	B	Clean and Lubricate Mechanism:		
Vac. Contact Wipe Indicators:	B	Racking and Shutter Mechanism:		
Clean Bottles and Insulation:		Mechanical Interlocks:	B	
Auxiliary Contacts:	B	Electrical Charge Test:	B	
Control Circuit Wiring:	B	Electrical Close and Trip Test:	B	
		Relay Trip Test:	N/A	
Operation As Found:	03002			
Operation As Left:				

	A Phase	B Phase	C Phase
Contact Gap / Wear Indication:	B	B	B

Electrical Tests

Insulation Resistance											
Readings in Mega-Ohms @ 2500 VDC											
As Found					As Left						
A-G	200K+	A-B	200K+	A-A'	200K+	A-G		A-B		A-A'	
B-G	200K+	B-C	200K+	B-B'	200K+	B-G		B-C		B-B'	
C-G	200K+	C-A	200K+	C-C'	200K+	C-G		C-A		C-C'	

Control Wiring (Tested at 500 VDC) _____

HIPOT Across Open VAC Contacts @ 10 kV AC AC or DC

Phase A (MA)	Phase B (MA)	Phase C (MA)
PASS	PASS	PASS

Contact Resistance		
Readings in Micro-Ohms		
	As Found	As Left
A	29	A
B	32	B
C	32	C

Environmental Conditions

	Selection
Indoor/Outdoor	
Clean / Dirty	
Wet / Damp / Dry	
Temp (Degree C)	
Relative Humidity (%)	

COMMENTS

Satisfactory for Continued Service		Requires Repair	X	Repairs Made During Maintenance	
TIMING CLOSE: 4.12CY 4.11CY 4.09CY OPEN: 2.75CY 2.74CY 2.77CY 10K OPERATION BOTTLES					

Job No: 3005080799-5200405589 Tested By: WARRICK/PERTUSET Date Tested: 9-30-14 ID #: _____

K. Rolley

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Siemens Industry Inc.

MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER TEST REPORT

Customer:	WASHINGTON STATE FERRY	Location:	
Substation:		Feeder/Cubicle:	Unique ID: 7 OF 11

Nameplate Data

Manufacturer:	SIEMENS	Voltage Rating:	4.76
Type / Style:	3AF1052-4	Current Rating:	1200
YR / Serial Number:	94/11 CAN-0534	Interrupting Rating:	31.5KA
IB Number:		Trip Coil / Close Coil:	24 VDC

Inspection

Primary Fingers:	B	Charging Motor Operation:	C	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">CODE LEGEND</th> </tr> </thead> <tbody> <tr><td>A= Like New Condition</td></tr> <tr><td>B= Good Condition</td></tr> <tr><td>C= Poor Condition Requires Correction</td></tr> <tr><td>D= Corrections Made</td></tr> <tr><td>E= Unacceptable Condition Do Not Use!</td></tr> <tr><td>NA= Not Applicable</td></tr> </tbody> </table>	CODE LEGEND	A= Like New Condition	B= Good Condition	C= Poor Condition Requires Correction	D= Corrections Made	E= Unacceptable Condition Do Not Use!	NA= Not Applicable
CODE LEGEND											
A= Like New Condition											
B= Good Condition											
C= Poor Condition Requires Correction											
D= Corrections Made											
E= Unacceptable Condition Do Not Use!											
NA= Not Applicable											
Vac. Contact Wear Indicators:	B	Clean and Lubricate Mechanism:									
Vac. Contact Wipe Indicators:	B	Racking and Shutter Mechanism:									
Clean Bottles and Insulation:		Mechanical Interlocks:	B								
Auxiliary Contacts:	B	Electrical Charge Test:	B								
Control Circuit Wiring:	B	Electrical Close and Trip Test:	B								
		Relay Trip Test:	N/A								
Operation As Found:	01060										
Operation As Left:											

	A Phase	B Phase	C Phase
Contact Gap / Wear Indication:	B	B	B

Electrical Tests

Insulation Resistance											
Readings in Mega-Ohms @ 2500 VDC											
As Found					As Left						
A-G	980M	A-B	3.04M	A-A'	200G	A-G		A-B		A-A'	
B-G	580M	B-C	1.01G	B-B'	200G	B-G		B-C		B-B'	
C-G	286M	C-A	1.01G	C-C'	200K+	C-G		C-A		C-C'	

Control Wiring (Tested at 500 VDC)

Environmental Conditions

	Selection
Indoor/Outdoor	
Clean / Dirty	
Wet / Damp / Dry	
Temp (Degree C)	
Relative Humidity (%)	

HIPOT Across Open VAC Contacts @ kV AC or DC

Phase A (MA)	Phase B (MA)	Phase C (MA)
PASS	PASS	PASS

Contact Resistance		
Readings in Micro-Ohms		
	As Found	As Left
A	30	A
B	31	B
C	32	C

COMMENTS

Satisfactory for Continued Service		Requires Repair	X	Repairs Made During Maintenance
<p>NEED NEW CHARGING MOTOR.</p> <p>TIMING CLOSE: 4.09CY 4.07CY 4.08CY OPEN: 2.82CY 2.83CY 2.83CY</p> <p>10K OPERATION BOTTLES</p>				

Job No:	3005080799-5200405589	Tested By:	WARRICK/PERTUSET	Date Tested	9-30-14	ID #	
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Siemens Industry Inc.

MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER TEST REPORT

Customer:	WASHINGTON STATE FERRY	Location:	
Substation:		Feeder/Cubicle:	
		Unique ID:	8 OF 11

Nameplate Data			
Manufacturer:	SIEMENS	Voltage Rating:	4.76
Type / Style:	3AF1052-4	Current Rating:	1200
YR / Serial Number:	94/09 CAN-0533	Interrupting Rating:	31.5KA
IB Number:		Trip Coil / Close Coil:	24 VDC

Inspection			
Primary Fingers:	B	Charging Motor Operation:	B
Vac. Contact Wear Indicators:	B	Clean and Lubricate Mechanism:	
Vac. Contact Wipe Indicators:	B	Racking and Shutter Mechanism:	
Clean Bottles and Insulation:		Mechanical Interlocks:	B
Auxiliary Contacts:	B	Electrical Charge Test:	B
Control Circuit Wiring:	B	Electrical Close and Trip Test:	B
		Relay Trip Test:	N/A
Operation As Found:	19276		
Operation As Left:			

CODE LEGEND	
A=	Like New Condition
B=	Good Condition
C=	Poor Condition Requires Correction
D=	Corrections Made
E=	Unacceptable Condition Do Not Use!
NA=	Not Applicable

	A Phase	B Phase	C Phase
Contact Gap / Wear Indication:	B	B	B

Electrical Tests

Insulation Resistance											
Readings in Mega-Ohms @ 2500 VDC											
As Found					As Left						
A-G	192	A-B	426	A-A'	200G	A-G		A-B		A-A'	
B-G	244	B-C	645	B-B'	200G	B-G		B-C		B-B'	
C-G	268	C-A	460	C-C'	200K+	C-G		C-A		C-C'	

Control Wiring (Tested at 500 VDC)

HIPOT Across Open VAC Contacts @ 10 kV AC AC or DC

Phase A (MA)	Phase B (MA)	Phase C (MA)
PASS	PASS	PASS

Contact Resistance		
Readings in Micro-Ohms		
	As Found	As Left
A	29	A
B	30	B
C	29	C

Environmental Conditions

Indoor/Outdoor	Selection
Clean / Dirty	
Wet / Damp / Dry	
Temp (Degree C)	
Relative Humidity (%)	

COMMENTS

Satisfactory for Continued Service	<input type="checkbox"/>	Requires Repair	<input checked="" type="checkbox"/>	Repairs Made During Maintenance	<input type="checkbox"/>
<p>COUNTER BROKEN. RACKING LINKAGE TAPED TO TOP OF BREAKER. CLOSE COIL NEEDS REPLACED. CORONA ON A & B PHASE/BARRIER.</p> <p>TIMING CLOSE: 4.55CY 4.57CY 4.54CY OPEN: 2.47CY 2.41CY 2.48CY 10K OPERATION BOTTLES</p> <p>*****RECOMMEND REPLACEMENT BREAKER*****</p>					

Job No:	3005080799-5200405589	Tested By:	WARRICK/PERTUSET	Date Tested	9-30-14	ID #	
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S

Siemens Industry Inc.

MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER TEST REPORT

Customer: WASHINGTON STATE FERRY Location:
 Substation: Feeder/Cubicle: Unique ID: 9 OF 11

Nameplate Data

Manufacturer:	SIEMENS	Voltage Rating:	4.76
Type / Style:	3AF1052-4	Current Rating:	1200
YR / Serial Number:	94/11 CAN-0542	Interrupting Rating:	31.5KA
IB Number:		Trip Coil / Close Coil:	24 VDC

Inspection

Primary Fingers:	B	Charging Motor Operation:	C	CODE LEGEND A= Like New Condition B= Good Condition C= Poor Condition Requires Correction D= Corrections Made E= Unacceptable Condition Do Not Use! NA= Not Applicable
Vac. Contact Wear Indicators:	B	Clean and Lubricate Mechanism:		
Vac. Contact Wipe Indicators:	B	Racking and Shutter Mechanism:		
Clean Bottles and Insulation:		Mechanical Interlocks:	B	
Auxiliary Contacts:	B	Electrical Charge Test:	B	
Control Circuit Wiring:	B	Electrical Close and Trip Test:	B	
		Relay Trip Test:	N/A	
Operation As Found:	08023			
Operation As Left:				

	A Phase	B Phase	C Phase
Contact Gap / Wear Indication:	B	B	B

Electrical Tests

Insulation Resistance									
Readings in Mega-Ohms @ 2500 VDC									
As Found					As Left				
A-G	A-B	A-A'	B-G	72M	A-G	A-B	A-A'	B-G	200G
B-G	B-C	B-B'	C-G	75M	B-C	B-B'	C-G	75M	200G
C-G	C-A	C-C'	C-G	84M	C-A	C-C'	C-G	75M	200G

Environmental Conditions

Indoor/Outdoor	Selection
Clean / Dirty	
Wet / Damp / Dry	
Temp (Degree C)	
Relative Humidity (%)	

Control Wiring (Tested at 500 VDC)

Contact Resistance		
Readings in Micro-Ohms		
As Found	As Left	
A	61	A
B	29	B
C	30	C

HIPOT Across Open VAC Contacts @ 10 kV AC AC or DC

Phase A (MA)	Phase B (MA)	Phase C (MA)
PASS	PASS	PASS

COMMENTS

Satisfactory for Continued Service	Requires Repair	X	Repairs Made During Maintenance
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TIMING CLOSE: 4.44CY 4.28CY 4.27CY
 OPEN: 2.20CY 2.34CY 2.30CY

HIGH CONTACT RESISTANCE A PHASE & 34.7MS OF BOUNCE.

10K OPERATION BOTTLES

RECOMMEND REPLACEMENT BOTTLES OR BREAKER**

Job No: 3005080799-5200405589 Tested By: WARRICK/PERTUSET Date Tested: 9-30-14 ID #

S

Siemens Industry Inc.

MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER TEST REPORT

Customer: WASHINGTON STATE FERRY Location:
 Substation: Feeder/Cubicle: Unique ID: 11 OF 11

Nameplate Data

Manufacturer:	SIEMENS	Voltage Rating:	4.76
Type / Style:	3AF1052-4	Current Rating:	1200
YR / Serial Number:	9/11 CAN-0540	Interrupting Rating:	31.5KA
IB Number:		Trip Coil / Close Coil:	24 VDC

Inspection

Primary Fingers:	B	Charging Motor Operation:	B
Vac. Contact Wear Indicators:	B	Clean and Lubricate Mechanism:	
Vac. Contact Wipe Indicators:	B	Racking and Shutter Mechanism:	
Clean Bottles and Insulation:		Mechanical Interlocks:	B
Auxiliary Contacts:	B	Electrical Charge Test:	B
Control Circuit Wiring:	B	Electrical Close and Trip Test:	B
		Relay Trip Test:	N/A
Operation As Found:	07950		
Operation As Left:			

CODE LEGEND
A= Like New Condition
B= Good Condition
C= Poor Condition Requires Correction
D= Corrections Made
E= Unacceptable Condition Do Not Use!
NA= Not Applicable

A Phase	B Phase	C Phase
B	B	B

Contact Gap / Wear Indication:

Electrical Tests

Environmental Conditions

Insulation Resistance								
Readings in Mega-Ohms @ 2500 VDC								
As Found					As Left			
A-G	88	A-B	143	A-A'	200G	A-G		A-A'
B-G	108	B-C	150	B-B'	200G	B-G		B-B'
C-G	92	C-A	131	C-C'	200K+	C-G		C-C'

Selection
Indoor/Outdoor
Clean / Dirty
Wet / Damp / Dry
Temp (Degree C)
Relative Humidity (%)

Control Wiring (Tested at 500 VDC)

Contact Resistance			
Readings in Micro-Ohms			
As Found		As Left	
A	30	A	
B	32	B	
C	32	C	

HIPOT Across Open VAC Contacts @ 10 kV AC AC or DC

Phase A (MA)	Phase B (MA)	Phase C (MA)
PASS	PASS	PASS

COMMENTS

Satisfactory for Continued Service	Requires Repair	X	Repairs Made During Maintenance
TIMING CLOSE: 3.89CY 3.88CY 3.83CY OPEN: 2.46CY 2.48CY 2.50CY 10K OPERATION BOTTLES			

Job No: 3005080799-5200405589 Tested By: WARRICK/PERTUSET Date Tested: 9-30-14 ID #

