PP&L	ENGINEERING STUDIES, ANALYSES, AND EVALUATIONS COVERSHEET	QUALITY LEVEL	ER/CTN NO. 743153
		■ SAFETY	SEA NO. SEA-EE-182
		☐ ASME	DCP NO.
		☐ OTHER	
		☐ NON QUALITY	PAGE 1 OF 12

EVALUATION OF POTENTIAL

TRANSFORMERS USED TO

DEVELOP UNIT 1 & 2

COMPUTER INPUTS

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REVISION NO.	DATE	PREPARED BY	REVIEWED BY	APPROVED BY

DC015.0-A REV. 1

EVALUATION OF POTENTIAL TRANSFORMERS USED TO DEVELOP UNIT 1 AND 2 COMPUTER INPUTS

TABLE OF CONTENTS

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1.0 SCOPE

The purpose of this SEA is to evaluate the failure modes of potential transformers and determine if these failures could result in high secondary voltages. The basis for this concern is that the high voltages could perhaps migrate through the plant process computer to other safety related equipment and prevent these other safety systems from meeting their minimum performance requirements.

2.0 PROBLEM STATEMENT

At Susquehanna SES, non-Class 1E low energy level instrumentation computer inputs are tapped directly from Class 1E circuits without the installation of nuclear qualified electrical isolation devices. This exception to Regulatory Guide 1.75 is discussed in FSAR Section 8.1.6.1q(7). Since some computer inputs are developed from potential transformer (PT's) circuits, high voltages produced by failures of these PT's must be addressed. The concern is that high voltages could perhaps prevent other Class 1E circuits which are connected directly to the computer from meeting their performance requirements. If the PT's fail in such a manner as to impress high voltages on their secondary circuits, the transducers used to develop the computer inputs may fail and high voltage may then migrate through the computer to Class 1E circuits. This concern must be analyzed to demonstrate that either 1) this problem is not credible or, 2) other Class 1E circuits are not degraded for the above failures. If either 1 or 2 cannot be demonstrated, then appropriate electrical isolation must be installed for these Class 1E circuits.

The PT circuits that are connected to the computer are listed below. These circuits provide computer inputs through General Electric Type 4701 and Type 4721 series transducers and Westinghouse Type VP-840 transducers. There are no PT's connected directly to the computer.

EQUIP	PT TYPE	RATIO	MFR	COMPUTER POINTS
1A101-05	PTM-110	14400-120	W	EBE01
1A102-05	PTM-110	14400 120	W	EBE02
0A103-03	PTM-110	14400-120	W	EBE11
0A103-04	PTM-110	14400-120	W	EBE31
1A202-05	PC-60	4200-120	W	EBE42
1A203-05	PC-60	4200-120	W	EBE43
1A204-05	PC-60	4200-120	W	EBE44
2A101-05	PTM-110	14400-120	W	EBE51
2A102-05	PTM-110	14400-120	W	EBE52
2A102-05	PTM-110	14400-120	W	EBE61
0A104-04	PTM-110	14400-120	W	EBE81

EQUIP	PT TYPE	RATIO	MFR	COMPUTER POINTS
2A201-05	PC-60	4200-120	W	EBE91
2A202-05	PC-60	4200-120	W	EBE92
2A203-05	PC-60	4200-120	W	EBE93
2A204-05	PC-60	4200-120	W	EBE94
1A201-05	PC-60	4200-120	W	EBE41
0C520A	JVM-3	4200-120	GE	EGE01
0C520B	JVM-3	4200-120	GE	EGE02
0C520C	JVM-3	4200-120	GE	EGE03
0C520D	JVM-3	4200-120	GE	EGE04
0C520A	JVM-3	4200-120	GE	EGJ01
0C520B	JVM-3	4200-120	GE	EGJ02
0C520C	JVM-3	4200-120	GE	EGJ03
0C520D	JVM-3	4200-120	GE	EGJ04
0C520A	JVM-3	4200-120	GE	EGJ05
0C520B	JVM-3	4200-120	GE	EGJ06
0C520C	JVM-3	4200-120	GE	EGJ07
0C520D	JVM-3	4200-120	GE	EGJ08
1A101-01	PTM-110	14400-120	W	ETE01
0A103-01	PTM-110	14400-120	W	ETE31
1A201-02	PC-60	4200-120	W	ETE41
1A203-02	PC-60	4200-120	W	ETE42
2A101-01	PTM-110	14400-120	W	ETE51
0A104-02	PTM-110	14400-120	W	ETE81
1A201-10	PC-60	4200-120	W	ETE91
1A203-10	PC-60	4200-120	W	ETE92
1G107	JVT-150	24000-120	GE	ETJ01
0A103-01	PTM-110	14400-120	W	ETJ10
2G107	JVT-150	24000-120	GE	ETJ51
0A104-02	PTM-110	14400-120	W	ETJ60
1G107	JVT-150	24000-120	GE	ETU02
0A10301	PTM-110	14400-120	W	ETU11
2G107	JVT-150	24000-120	GE	ETU52
0A104-02	PTM-110	14400-120	W	ETU61
1G107	JVT-150	24000-120	GE	GNE02
1G107	JVT-150	24000-120	GE	GNE03
1G107	JVT-150	24000-120	GE	GNE04
1G107	JVT-150	24000-120	GE	GNJ01
1G107	JVT-150	24000-120	GE	GNJ02
1G107	JVT-150	24000-120	GE	GNU02
1G107	JVT-150	24000-120	GE	GNU03
1R104	CD	132800-115	GE	YBE01(U1)
500KV SWYD	CD51	288000-120	GE	YBE01(U2)

3.0 CONCLUSION

The analysis in Section 5 of this SEA shows that the PT's, listed in the problem statement, will not fail in such a manner as to apply high voltage on the PT secondary circuits. These PT's are not high voltage sources to the computer, therefore the Class 1E circuits connected to the computer do not require further consideration. This conclusion is based upon the inherent physical construction features which provide separation and isolation between the PT primary and secondary terminals, PT construction/insulation systems, the installed configuration and the low probability of a PT primary turn to turn fault.

4.0 RECOMMENDATION

The present practice of using butyl rubber molded or epoxy resin cast potential transformers should be continued. These transformers provide a minimum of four levels of insulation between the primary and secondary windings.

If different types of potential transformers are used to develop computer inputs, an analysis as discussed in this SEA must be completed to evaluate the failure modes of the potential transformers and determine if these failures could result in high secondary voltages.

This recommendation will be included in the design descriptions for the AC electrical systems.

5.0 DISCUSSION

The potential transformers identified in the problem statement are installed in:

- Emergency Diesel Generator 4KV High Voltage Cabinets
- Main Generator Potential Transformer Cabinets (24KV)
- Engineering Safeguard Systems 4KV Switchgear
- Startup and Auxiliary 13KV Switchgear
- 500KV and 230KV Coupling Capacitor Voltage Transformers (CCVT's)

These potential transformers consist of either epoxy casting or epoxy casting and butyl rubber mold construction. These types of construction provide a minimum of four (4) levels of insulation between the primary and secondary windings. The butyl rubber mold construction insulation levels consist of:

1) Insulated wire for the secondary winding.

2) Butyl Rubber between secondary and primary windings.

3) Epoxy encapsulation of the primary winding.

4) Insulated wire for the primary winding.

The epoxy casting construction insulation levels consist of:

1) Insulated wire for the secondary winding.

2) Epoxy encapsulation of the secondary winding.

3) Epoxy resin between primary and secondary windings.

4) Epoxy encapsulation of primary winding.

5) Insulated wire for the primary winding.

Before analyzing the affects of the potential high voltages on Class 1E circuits, it is necessary to evaluate the failure modes of the PT's, identified in the problem statement, to determine if failure modes exist that could apply high voltages to the PT secondary circuits.

The potential transformer fault analysis in Attachment 1 shows that open circuit and short circuit faults do not increase the PT secondary voltage. However a hot short could apply the primary system voltage across the PT secondary. For this to occur, the PT failure modes are:

1 - Primary leads hot short to secondary leads.

2 - Internal PT faults (Primary Winding Hot Short to Secondary Winding).

5.1 <u>Primary Lead Hot Short To Secondary Leads</u>

Primary and secondary leads could short together for:

1 - Seismic event which breaks the leads.

2 - Electrically generated fire which burns insulation and allows the leads to short.

5.1.1 <u>Emergency Diesel Generator High Voltage Cabinets</u>

The potential transformers in the Emergency Diesel Generator 4KV High Voltage Cabinets are seismically qualified and seismically mounted in a separate compartment within this equipment. These PT's are connected phase to phase to the solid 4KV buses in these high voltage cabinets. The primary of these PT's are connected to the 4KV buses through fuses mounted on the PT's. The PT primary leads are bolted to the 4KV buses and the PT's. The secondary leads are also bolted to the PT's.

The primary terminal connections are at the top and opposite side of the PT from the secondary terminal connections which are located on the bottom of the PT. This provides a minimum calculated separation distance of 12 inches between the PT primary and secondary terminals. Also the PT secondary terminals are equipped with plastic covers.

The PT terminal separation, the secondary terminal cover, and the separate compartment for the PT's, preclude the primary leads from shorting, to the PT secondary. This is based upon the fact if primary phase lead broke loose from the 4KV Bus it would short to ground by contacting the PT compartment housing before contacting the PT secondary. In the event the Primary lead broke loose at the PT, the separation between the primary and secondary terminals and the PT secondary terminal covers would prevent the primary lead from contacting the PT secondary. Also this separation distance prevents the secondary leads from contacting the PT primary terminal in the event the secondary lead breaks loose at the PT.

Since the Emergency Diesel Generator 4KV High Voltage Cabinets and PT's are seismically qualified, the PT's and their connection will maintain their integrity, during and after a seismic event. Therefore the PT primary and secondary leads will not short together for a seismic event.

In the unlikely event that an electrical fault generates a fire in the PT primary or secondary leads, the separation distance between the PT primary and secondary terminal will prevent these leads from shorting together. The PT secondary leads are physically separated from the primary leads. The closest the leads come to each other is at the PT.

Based upon the PT physical characteristics, qualification, and installation, as discussed above, it is concluded that PT primary to secondary faults will not occur due to the primary and secondary leads shorting together in the Emergency Diesel Generator High Voltage Cabinets.

5.1.2 Main Generator Potential Transformer Cabinets

The potential transformers in the Main Generator Potential Transformer Cabinets are connected to the 24KV Main Generator Isolated Phase Buses through solid bus bars. The PT primary leads are bolted to these bus bars through primary fuses. The PT secondary wiring connections are made to the screw type terminals which are located in the totally enclosed metallic conduit box provided on the PT's. The PT cabinets are located under the isolated phase buses, with vertical bus bars dropping down to the PT's. The PT secondary wiring, which is approximately 12 inches, is routed along the PT base to the secondary fuses.

The PT primary terminals are located on the top of the bushings while the secondary terminal conduit box is located on the PT base. This provides a minimum 23 inch physical separation between the PT primary and secondary.

In the event the Main Generator potential transformers break loose from their mountings, the primary or secondary leads break loose, a primary to secondary short would not occur. This is based upon physical

separation of the PT terminals, the totally enclosed secondary terminal conduit box and the installation of the PT leads. The breaking loose of the PT disconnects the PT from the bus, while the conduit box prevents secondary terminal contact with the bus. The physical separation of the PT terminals precludes the secondary leads from contacting the bus taps.

In the unlikely event that an electrical fault generates a fire in the PT secondary wiring, the physical separation between the wiring and the primary terminals prevents the PT leads from shorting together. The solid bus bars will not burn.

Based upon PT's physical construction and installation, it is concluded that PT primary to secondary faults will not occur due to the primary and secondary leads shorting together in the Main Generator Potential Transformer Cabinets.

5.1.3 <u>4KV And 13KV Switchgear</u>

The PT's in the 4KV and 13KV Switchgear are mounted in a separate compartment within this equipment. The connection to the primary and secondary buses are made through sliding contacts to the Primary solid bus bars and the secondary cables. The secondary cables are connected to the sliding contact in a different compartment than the PT location. The PT's and Primary fuses are mounted upon a cradle which is linked to the compartment side-hinged door.

For this factory supplied PT fuse cradle assembly and disconnecting contact arrangement, there is no failure mode that could cause the PT primary and secondary loads to short together for a broken connection.

The 4KV switchgear, including the PT's are seismically qualified. These PT's and their connections will maintain their integrity during and after a seismic event. Therefore the PT primary and secondary leads will not short together for a seismic event.

The 13KV Switchgear is not seismically qualified, however the construction of the PT and fuse cradle assembly is similar to the 4KV. Even if the PT's break loose in a seismic event, this would not cause PT primary to secondary short, since the PT would be disconnected from the main buses.

Likewise if the secondary leads break loose during a seismic event, a PT Primary to secondary short would not occur since the secondary leads are located in a different compartment from the PT's and main buses. Therefore the PT primary and secondary leads will not short together for a seismic event or a broken primary or secondary connection.

In the unlikely event that an electrical fault generates a fire in the PT primary or secondary leads, the physical separation provided by the construction of the transformer cradle and disconnecting contact arrangement, the compartmentization of the PT's and the separation of the secondary leads in a different compartment than the PT's will prevent the PT primary and secondary leads from shorting together for this fault.

Based upon the PT assemblies physical construction, qualification (4KV switchgear) and installation, as discussed above, it is concluded that PT primary to secondary faults will not occur due to the primary and secondary lead shorting together in the 4KV and 13KV switchgear.

5.1.4 230 KV AND 500KV CCVT's

The 230 KV and 500 KV coupling capacitor voltage transformers (CCVT'S) are connected line to ground to the Generator 1 and 2 transmission systems. These devices consist of epoxy resin cast potential transformer and series capacitor used for coupling the PT to the transmission line. The capacitor stack forms a voltage division network stepping the line to ground voltage down to approximately 5000V at the PT primary taps.

The PT's are located in the CCVT metal base compartment which is separated from the capacitor stacks. The PT primary leads are bolted to PT terminals located on top of the PT while the secondary connections are made through screw type terminals on the side of the PT. This provides an estimated 10 inch separation distance between the primary and secondary terminals. The secondary wiring is approximately 8 inches and is routed along the bottom of the CCVT base compartments.

In the event the PT's in the 230 KV and 500 KV CCVT's break loose from their mountings, the primary or secondary leads break loose, a primary to secondary short would not occur. This is based upon physical separation of the PT terminals and the installation of the PT leads. The breaking loose of the PT disconnects the PT from the capacitor tap. The physical separation of the PT terminals precludes the secondary and primary leads from contacting.

In the unlikely event that an electrical fault generates a fire in the PT secondary wiring, the physical separation between the wiring and the primary terminal prevents the PT leads from shorting together.

Based upon PT's physical construction and installation, it is concluded that PT primary to secondary faults will not occur due to the primary and secondary leads shorting together in the 230KV and 500KV CCVT's.

5.2 Internal PT Faults

Internal potential transformer faults could impress higher than normal voltages on the PT secondary circuits. These faults could occur if the PT insulation between the windings or between turns of the same winding electrically breakdown. The magnitude of the secondary voltage depends upon the number of turns shorted.

Typically internal PT faults occur due to:

1 - Moisture degrading the insulation.

2 - Dust/dirt degrading the insulation.

5.2.1 Emergency Diesel Generator High Voltage Cabinets

The potential transformers mounted in this equipment are General Electric Type JVM-3 PT's. The primary and secondary windings of these PT's are constructed of enamel insulated wire. The primary winding is wound and cast in an epoxy resin. The secondary winding is inside the primary next to the core. The entire transformer assembly is molded in Butyl Rubber to provide further insulation.

The molding of the transformer in Butyl Rubber substantially reduces the probability of moisture and dirt affecting the insulation. Also this compound provides further insulation of the transformer. The casting of the primary winding in epoxy resin virtually eliminates the possibility of a PT failure from the primary to secondary winding due to the encapsulation of the winding. This provides a physical barrier between the primary and secondary winding and additional insulation for the primary winding.

A primary turn to turn fault is not expected since the insulation system on two turns would have to break down for this to occur. The Butyl Rubber transformer moldings makes these transformers relatively impervious to moisture and dirt which is the primary cause of insulation breakdown.

Based upon the PT internal insulation system, construction and the Butyl Rubber molding of the transformers, it is concluded that the probability of an internal fault increasing the voltage on the PT secondary is very low and no further action is required.

5.2.2 Main Generator Potential Transformer Cabinets

The potential transformers mounted in this equipment are General Electric Type JVT-150 PT's. The construction of these PT's contain all the features of the Type JVM-3 PT's. Therefore the analysis and conclusions for the Type JVM-3 PT's apply to the Type JVT-150 PT's.

5.2.3 4KV and 13KV Switchgear

The potential transformers mounted in the 4KV and 13KV Switchgear are Westinghouse Type PC-60 and Type PTM-110 respectively. These PT's contain all the features of the Type JVM-3 except the Type PC-60 uses a cast epoxy resin insulation for the primary and secondary without the Butyl Rubber molding. This provides the same insulation performance as the Type JVM-3 PT's. Therefore the analysis and conclusions for the Type JVM-3 PT's apply to the Type PC-60 and Type PTM-110 PT's.

5.2.4 230 KV and 500 KV CCVT's

The potential transformers in the 230 KV and 500 KV CCVT's are epoxy cast constructed. These PT's contain all the features of the type JVM-3 except these PT's use the cast epoxy insulation without the butyl rubber molding. This construction provides the same insulation performance as the type JVM-3 PT's. Therefore the analysis and conclusions for the type JVM-3 PT's apply to the 230 KV and 500 KV CCVT's.

6.0 REFERENCES

IOM 125 - Isolate Phase Bus
IOM 187 - 13KV Switchgear
IOM 211 - 4KV Switchgear
TD 44-060 - Westinghouse Technical Data for Instrument Transformer
GET 97D - General Electric Manual of Instrument Transformers
7920 - General Electric Catalog Instrument Transformers
7940 - General Electric Catalog Instrument Transformers
7907 - General Electric Catalog Instrument Transformers
PD 42-801 - Westinghouse Style Number Index - Instrument Transformers
NCR 87-0021

ATTACHMENT 1

POTENTIAL TRANSFORMER FAULT ANALYSIS

FAULT	CONSEQUENCES
Primary Open CKT	Loss of Computer Signal. No increase in secondary voltage.
Secondary Open CKT	Possible loss of Computer Signal depending where open CKT occurs. No increase in Secondary Voltage.
Primary Short CKT	Loss of Computer Signal. No increase in Secondary Voltage.
Secondary Short CKT	Loss of Computer Signal. No increase in Secondary Voltage.
Primary to Secondary Hot Short	Applies up to system voltage across load.
Primary Turn to Turn Shorts	Increases secondary voltage to core saturation voltage of estimated 150% rated. Many primary turns must fail to increase voltages since N1 is much greater than N2.
Secondary Turn to Turn Shorts	Decrease in Secondary Voltage

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