ANALYSIS OF FLEXIBLE CONDUIT
USED AS AN ELECTRICAL FAULT
SEPARATION BARRIER WITHIN PGCC

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INTRODUCTION

The NRC has stated in the Clinton Safety Evaluation Report that it takes exception to Amendment 8 of the Clinton FSAR, which states that "Fire detection, intercom, and utility service wiring may be run in conduit in any divisional floor duct." The same is true for the Reactor Protection System and Main Steam Isolation Valve solenoid wiring.

The NRC believes that the above installations do not meet the separation requirements of IEEE 384-1974 and R.G. 1.75, and needs verification that safety is not compromised.

DISCUSSION

The presence of flexible conduits in PGCC cable ducts is acceptable under Reg. Guide 1.75 if it carries a circuit of the same division and the same essentiality as other conductors in that duct. However, some divisional ducts contain conduits that are non-essential. It is postulated that a fault from an internal conductor to the inside of a flexible conduit could cause heating of the conduit, which in turn could cause damage to safety-related cables outside of the conduit. This possibility is analyzed below on a generic basis, and conditions specific to Clinton are shown to be enveloped by the analysis.

By providing redundant, non-1E circuit protection to the non-essential cables within the conduit, and by grounding the conduit at least every 30 feet, we conclude that damaging faults will be cleared without degrading the adjacent essential circuits.

A normal low impedance short circuit in the conduit will cause a fuse or a breaker to operate quickly to clear the fault, and it will not cause significant heating. The chances of having a medium impedance fault are remote at 125 volts and below, since the shorted conductor will either weld itself to ground or clear itself. Nevertheless, the worst case medium impedance fault has been investigated and found to present no threat to divisional circuits.

Measurements of temperature rise of conductors within a conduit caused by the overheating of external conductors show that the heating effects are minimal. Thus, the Reactor Protection and MSIV solenoid circuits are well protected by flexible conduit.

Redundant, testable, non-1E circuit protection will be added where necessary to utility power circuits at Clinton to insure

that faults in these on-essential circuits will have a high probability of clearing. Other circuits mentioned above are already protected by redundant fusing or are of low energy and are incapable of causing damage.

ANALYSIS

CONDUIT RESISTANCE

Flexible conduit is constructed of interlocking, galvanized steel strip wound in a helix. If adjacent coils of the strip are in good contact, the conduit electrically will appear to be a tube. If the coils are not in good contact, it will appear to be a helix of higher resistance. The helix case results in higher resistance to ground and greater heating when faulted. It is used in this analysis. The calculated helix resistance is 0.016 ohms at 20^{o}C per linear foot of conduit.

CONDUIT GROUNDING

The flexible conduit in PGCC is grounded every 30 feet. The maximum resistance of 30 feet of conduit is 0.48 ohms. This value is used below to determine the maximum clearing time for low impedance faults.

CONDUIT HEATING EFFECTS

Ampacity calculations were performed for PGCC floor section cable ducts to determine the maximum long term current required to raise the conduit temperature to the maximum fault temperature rating of the insulation. The calculation was based upon a Du Pont Chemical Company paper titled, "Calculation of Ampacity, Multi-Conductor Cable in Tray" by Dr. J. R. Perkins, and on IEEE paper 70TP537-PWR, "Ampacities for Cables in Closely Filled Trays" by J. Stolpe. This current is 57 amps.

The maximum long term current value was used to establish the maximum allowable rating of redundant circuit protection devices.

Solid line to ground (or line to neutral) faults will be cleared quickly and are shown below to be non-damaging.

FOR UTILITY CIRCUITS

a. Assume largest size redundant circuit protection device is a 30 A breaker. (The maximum size breaker used at Clinton Station is 30 amps.)

b. Assume utility power source is a 40 KVA 120/240 V 1Ø distribution transformer with 5% impedance.

The calculated line to ground fault current through 30 ft. conduit ground length (I_1) is approximately 240 amps.

The calculated line to ground fault current at ground point (I_2) is approximately 1800 amps.

Time to trip breaker @ I_1 = <u>3.6 secs</u>.

Time to trip breaker @ I_2 = <u>instantaneous</u>

Heat rise of conduit during the first few seconds at 240 amps is 13°C/sec or 47°C in 3.6 seconds. This temperature rise is well below the temperature rating of the cable insulation. Therefore, adjacent class 1E cables would not be degraded by normal, low impedance faults.

c. A prolonged, medium impedance fault was considered using Dr. J. R. Perkins' analysis of a single overloaded conductor in a cable tray. The limiting temperature of the conduit was taken to be the maximum fault current temperature rating of Tefzel or Vulkene (250°C). The calculated current in the conduit is 57 amps. If an internal fault which produces a current of 57 amps is cleared by the protective devices, no damage will occur to the adjacent cables.

At 57 amps, a 30 amp breaker will clear a fault in approximately 120 seconds and a 30 amp fuse will melt in approximately 3 seconds. Therefore, faults within conduits protected by 30 amp breakers or fuses do not pose a threat to essential cabling in the same duct.

As confirmation of the long term heat flow calculations, the temperature rise was also calculated assuming no heat is transferred to anything. This can be done from the definition of specific heat. The method is widely used for short term (3 or 4 seconds) fault heating calculation. It is ultra conservative for the 120 second opening time of the breaker. Calculating the temperature rise with no heat transfer from the conduit gives a final temperature of 125°C, which is far below the maximum overload temperature rating of Tefzel or Vulkene insulation.

REACTOR PROTECTION SYSTEM AND MAIN STEAM ISOLATION VALVE SOLENOIDS*

These circuits are deenergize-to-operate and are protected from external hot shorts by encasing them in grounded flexible

*Illinois Power Company has elected to run this wiring in compliance with Reg. Guide 1.75.

conduit. They are powered from non-essential supplies since they are fail safe. In most PGCC's, they are run with essential cables. These circuits are protected by 30 amp breakers in series with 15 amp fuses and are covered by the utility wiring case analyzed above.

The opposite situation has also been considered. In this case, the effect of faulting and heating of a cable external to an RPS or MSIV conduit was tested. Since PGCC power wiring is 10 AWG in flexible conduit, this was chosen as a heat source. A conduit was instrumented and strapped tightly to the heat source. Current in the 10 AWG wires was gradually increased to 140 amps. Failure of the circuit occurred in six minutes. The conduit adjacent to the overloaded conduit showed only a $12^{O}F$ temperature rise. It was concluded that faults in adjacent power wiring does not pose a threat to RPS and MSIV cables.

FIRE PROTECTION CIRCUITS

Fire detection wiring is supplied from a fused, limited source, 24 volt dc power supply. It is operated ungrounded and has an audible ground fault alarm. A ground fault sounds the alarm, but causes no fault current to flow. Redundant fault protection will be provided for 120 volt power to the fire protection cabinet as covered under utility wiring.

COMMUNICATIONS

Most of the communications wiring is low energy. In those cases where 120 volt power is supplied, it is run in non-divisional ducts or will have redundant fusing as in the case of utility wiring.

SUMMARY

Flexible conduit is used in PGCC for fire protection, communication, and utility wiring to separate it from essential wiring. It is also used in MSIV and Reactor Protection solenoid wiring to prevent hot shorts.

The results of this analysis show that internal faults will be cleared without overheating adjacent essential cables if redundant circuit protection is used. The redundant protective devices can be non-1E (but must be testable), since they are used in non-essential circuits.

Heating from external overloads will not damage reactor protection and main steam isolation valve circuits run in flexible conduit. This has been confirmed by tests.

Circuit protection for Clinton will conform to this analysis after redundant devices are added where necessary.

ATTACHMENT TWO

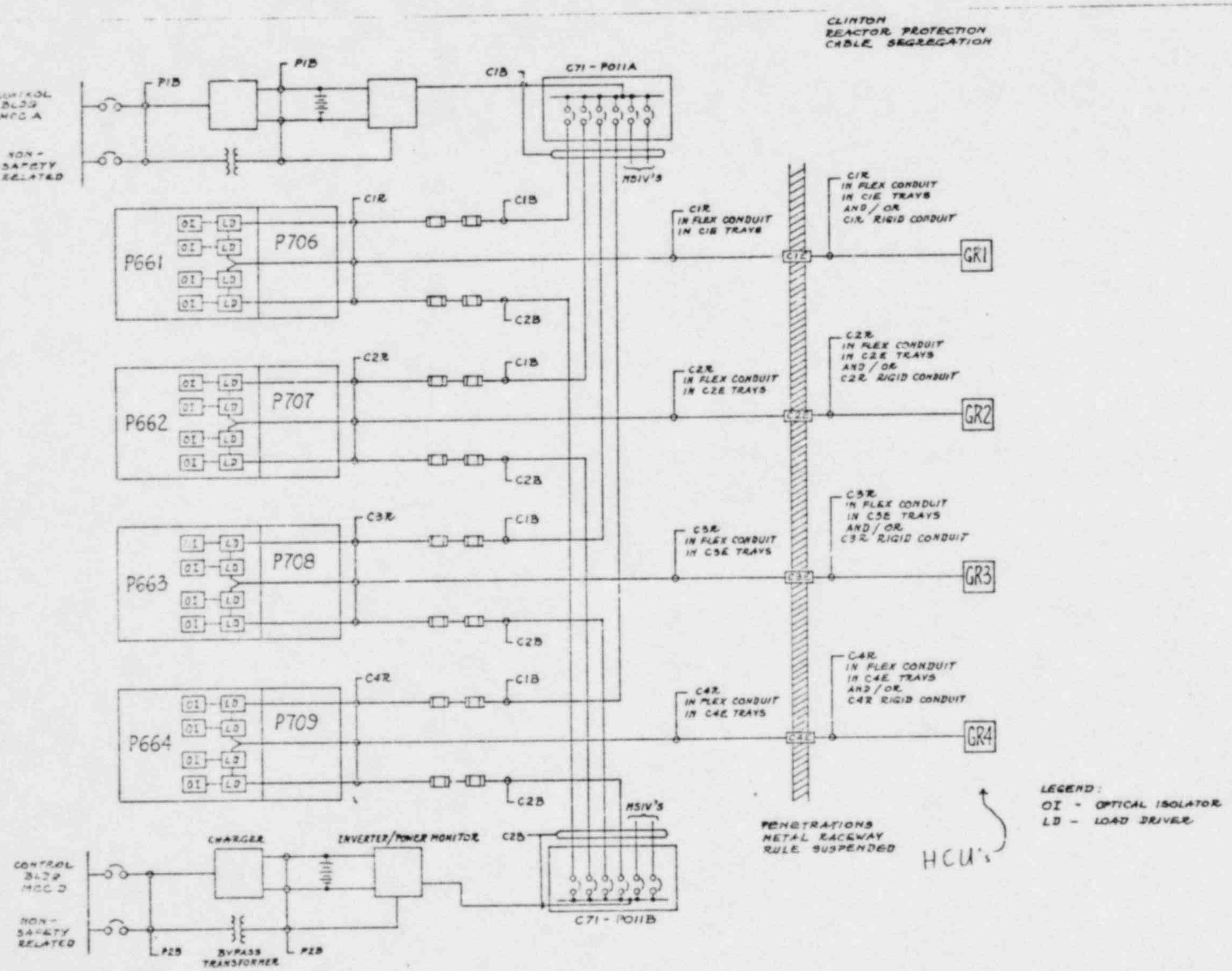
A sketch showing the power distribution and cable segregation for the solenoid circuits of the Reactor Protection Systems (RPS) and Main Steam Isolation Valves (MSIV).

The "A" solenoids are supplied power from a motor control center (MCC), charger, battery, inverter/power monitor, and power distribution panel P011A. The "B" solenoids are supplied power from a different MCC, charger, battery, inverter/power monitor, and P011B.

Each non-1E (C1B or C2B cable segregation code), solenoid power circuit exiting P011A or P011B is isolated from the class 1E RPS logic panels P661, P662, P663, and P664 by two fuses in series. These fuses are located in a junction box in the Control Building.

The solenoid circuits after the fuses have an "R" segregation code, which as defined on page 8.3-32 of the CPS FSAR, is allowed to occupy raceways with 1E cable of the same division.

The circuits from the RPS logic panels all the way to the scram solenoids on the Hydraulic Control Units (HCU's) are placed in rigid or flexible conduit, then routed in appropriate 1E cable trays or PGCC floor section ducts. This rigid or flexible conduit provides added protection against "hot shorts" defeating the RPS' decision to scram.


CLINTON
REACTOR PROTECTION
CABLE SEGREGATION
CONTROL BLDG MCC A
NON-SAFETY RELATED
P1B
C1B
C71 - P011A
MSIV'S
P661
P706
P662
P707
P663
P708
P664
P709
OI
LD
C1R
C2R
C3R
C4R
C2B
C1R IN FLEX CONDUIT IN C1E TRAYS
C1R IN FLEX CONDUIT IN C1E TRAYS AND / OR C1R RIGID CONDUIT
C2R IN FLEX CONDUIT IN C2E TRAYS
C2R IN FLEX CONDUIT IN C2E TRAYS AND / OR C2R RIGID CONDUIT
C3R IN FLEX CONDUIT IN C3E TRAYS
C3R IN FLEX CONDUIT IN C3E TRAYS AND / OR C3R RIGID CONDUIT
C4R IN FLEX CONDUIT IN C4E TRAYS
C4R IN FLEX CONDUIT IN C4E TRAYS AND / OR C4R RIGID CONDUIT
GR1
GR2
GR3
GR4
CHARGER
INVERTER/POWER MONITOR
CONTROL BLDG MCC D
NON-SAFETY RELATED
P2B
BYPASS TRANSFORMER
C71 - P011B
PENETRATIONS METAL RACEWAY RULE SUSPENDED
HCU's
LEGEND:
OI - OPTICAL ISOLATOR
LD - LOAD DRIVER