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SARGENT & LUNDY ENGINEERS CHICAGO

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| Calcs. For: OPEN CIRCUIT OF CURRENT TRANSFORMER SECONDARY | | Calc. No. 19-BD-5 |
| X Safety-Related | Non-Safety-Related | Rev. 1 Date 10/17/83 |
| | | Page 1 of 8 |

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| Client: ILLINOIS POWER COMPANY | Prepared by: [illegible] FHD | Date: 10/17/83 |
| Project: CLINTON - UNIT 1 | Reviewed by: FD Ensel EPED | Date: 10/17/83 |
| Proj. No.: 4536-00 Equip. No. | Approved by: Mark H. Zac EPED | Date: 10/17/83 |

FILE NO. 1950 RESP. DIV. EPED

I. REVISION STATUS

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|---|---|---|
| Rev. 0 | 1/4/83 | First issue all pages. |
| Rev. 1 | 10/17/83 | Second issue all pages. The revised material is denoted by \| in left margin. This revision deletes information from two referenced Q.A. calculations which have been voided, and includes two more pieces of equipment into the analysis. |



II. PURPOSE

The purpose of this calculation is to determine if the open circuiting of the secondary of the non-Class 1E metering or bus duct differential relaying CTs at the main and reserve feed to the 4.16 kV ESF switchgear would cause a condition adverse to safety-related circuits, since the non-Class 1E CT secondary wiring is bundled and/or in close proximity to Class 1E wiring internal to the switchgears. The open circuiting of the non-Class 1E CTs analyzed are identified in Section IV.B of this calculation.



REVIEW METHOD

Detailed Review of Rev. 1 changes
FD Ensel

Form GD 308 1 Rev 2

## III. REFERENCES

1. "Peak Voltages Induced by Accelerated Flux Reversal in Reactor Cores Operating Above Saturation Density" by Theodore Specht and E. C. Wentz in AIEE Transactions, May 1946.

2. Insulation of Electrical Apparatus book by D. F. Miner, 1941, Chapter III, "Factors Affecting Dielectric Behavior".

3. "Overvoltages in Saturable Series Devices" by A. Boyajian and G. Camilli in AIEE Transactions, 1951, pp. 1845-1853.

4. ANSI Standard C57.13-1978.

5. ICEA-NEMA Standard S-66-524.

6. Q.A. Calculation 4536-EAD-1, Rev. 2, dated 8/12/81.

7. S&L single line drawing: E02-1AP01, Sht. 004, Rev. C, 4/29/83.

8. S&L Relay and Metering Diagrams:
   E02-1AP12, Sheet 011, Rev. P, dated 4-7-83.
   E02-1AP12, Sheet 013, Rev. M, dated 4-7-83.
   E02-1AP12, Sheet 016, Rev. J, dated 7-22-83.

9. S&L CT excitation curves:
   Westinghouse 459341, Rev. A, for 5000:5A CT
   Westinghouse 536932-A, Rev. A, for 800:5A CT
   Westinghouse 622004, Rev. A, for 4000:5A CT
   Westinghouse 666818, for 2500:2.5A CT.

10. Memo of telephone conversation between Ed Horn of Westinghouse and G. A. Poletto of S&L, dated 12/30/82.

11. NCRs 5426, Rev. 1, dated 8-9-82
    5425, Rev. 1, dated 8-9-82.
    5453, Rev. 1, dated 8-9-82.

III. REFERENCES (Cont'd.)

12. ANSI/IEEE C37.90-1978, "Relays and Relay Systems Associated with Electric Power Apparatus".

13. "The Effects of Electric Discharges Between Electrodes Across Insulation Surfaces", by Lyon Mandelcorn, AIEE Transaction on Power Apparatus and System, August 1961, pp. 481-494.

14. Buchanan "Electrolog" January 1971.

IV. DATA

A. Test Data on Some Typical CTs

1.(Reference 1, dated 1946)

a. 2500/5A CT Voltage Class 5000V Westinghouse Type H-5
Accuracy Class 0.3B-0.1, 0.5, 2
Peak secondary open circuit voltage with rated current in the primary: $V_{oc}$ = 11,000V

b. 5/5-600/5A CT Voltage Class 5000V Westinghouse Type CT-5
Accuracy Class 0.3B-0.1, 0.5, 2
Peak secondary open circuit voltage with rated current in the primary: $V_{oc}$ = 1800V

2. (Reference 10, dated 12/30/82)

a. 1200/5A CT Westinghouse Type RCT for medium voltage swgr.
Peak secondary open circuit voltage with rated current in the primary: $V_{oc}$ = 25,000V

b. 600/5A CT Westinghouse Type RCT for medium voltage swgr.
Peak secondary open circuit voltage with rated current in the primary: $V_{oc}$ = 12,000V

c. 400/5A CT Westinghouse Type RCT for medium voltage swgr.
Peak secondary open circuit voltage with rated current in the primary: $V_{oc}$ = 4000V

IV. DATA (Cont'd.)

B. Rating of Existing Non-Class 1E CTs Whose Open Circuiting is Analyzed

1. On the Main Feed to 4.16 kV Buses 1A1 and 1B1 (Ref. 9 )

   a. 2500-2.5A CT with accuracy class C-400 for bus duct differential relay.

   b. 800-5A metering CT with accuracy class 10H50.

2. On the Reserve Feed to 4.16 kV Buses 1A1 and 1B1 (Ref. 9 )

   4000-5A CT accuracy class C-200 for bus duct differential relay.

3. On the Main Feed to 4.16 kV Bus 1C1

   5000-5A CT for bus duct differential relay.

4. On the Reserve Feed to 4.16 kV Bus 1C1

   4000-5A CT for bus duct differential relay.

C. Insulation Requirements for the CTs, Cables and Other Devices

1. A current transformer is required to withstand a secondary voltage of 3500V peak for 60 seconds (per ANSI C57.13 - Ref. 4 ).

2. 600V class cables are required to withstand 3500V rms for 5 minutes (per ICEA-NEMA Std S-66-524 - Ref. 5 ).

3. Terminal blocks and test switches are required to withstand twice rated voltage plus 1000V rms for 60 seconds.

   Terminal block rated 750V (Ref. 12, p. 42)

   $750 \times 2 + 1000 = 2500V$ rms

   Test switch rated 600V

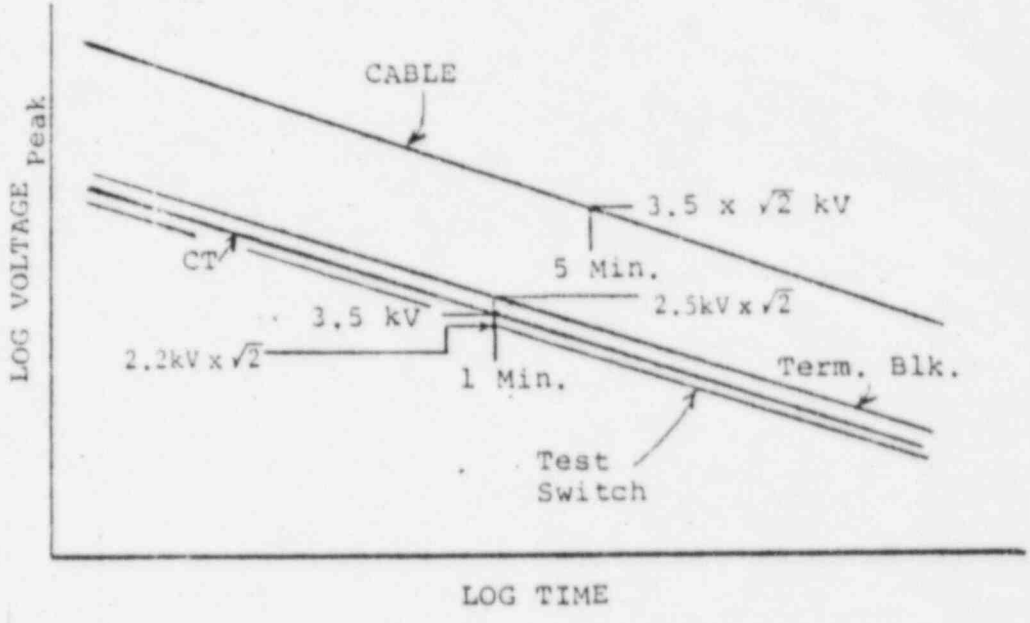
   $600 \times 2 + 1000 = 2200V$ rms

## V. ANALYSIS OF EFFECTIVE OPEN CIRCUITED CT SECONDARY

Determination of the peak voltage that would occur if the secondary of any of these CTs in question were to become open circuited with full load current flowing in the primary with any degree of accuracy is difficult without actually performing a test on each CT. This peak voltage is a function of the turns ratio and the design of the core of the transformer. Even with the same turns ratio, the peak voltage may vary greatly from one CT to another due to differences in the core design. Since the manufacturers are reluctant to perform tests on CTs with secondaries open circuited, there is very limited test data available to compare with the CTs in question. However, it can be seen from the available test data that the peak voltages may range from 2 kV to 25 kV. If the open circuit of the secondary goes undetected for an extended period of time, these peak voltages will most likely cause an insulation failure.

From the industry requirement for the insulation of the devices given in Section IV.C, and that breakdown voltage for insulation materials is an inverse exponential function of time (Ref. 2), we may draw a typical curve for each of the four insulations involved in the CT circuitry as shown below.

V. ANALYSIS OF EFFECTIVE OPEN CIRCUITED CT SECONDARY (Cont'd.)




From this figure we can expect either the CT insulation, the terminal block or the test switch to fail before the cable insulation. If the CT fails, it would occur near the ungrounded CT terminal which is exposed to the full peak open circuit voltage and would most probably involve a sparkover between terminals or to ground. The arc will quickly form a carbon track (Ref.13) which will provide a low resistance path to ground. Having both terminals grounded will short circuit the secondary of the CT and alleviate the high peak voltage. The secondary current will only be a few amperes and will not cause damage to the ground path.

The safety and non-safety terminal blocks or test switches are physically separated (not touching) from each other. If the terminal block or test switch fail, it will involve an arc from

V. ANALYSIS OF EFFECTIVE OPEN CIRCUITED CT SECONDARY (Cont'd.)

the terminal connected to the ungrounded CT lead to the grounded terminal. This arc will quickly form a carbon track (Ref. 13) which will act as a low resistance path for the CT secondary current. This short circuits the secondary of the CT and alleviates the high peak voltage. The secondary current will only be a few amperes and will not cause damage in the ground path.

For the metering CTs the open circuit condition would be detected during the next meter logging operation and corrected.

For the main (RAT) feed differential relay CT to any of the ESF buses, the differential relay will trip immediately and transfer the ESF buses to the reserve source or the diesel generator if the current through the open circuited CT is greater than the minimum sensitivity of the relay. However, if the current is less than the minimum relay sensitivity, open circuiting of the CT will not cause the breaker to trip but the relay will still be able to detect and trip for any fault occurring within its zone of protection.

For the reserve feed differential relay CT to any of the ESF buses, the differential relay will trip immediately and transfer the ESF buses to the main source or the diesel generator if the current through the open circuited CT is greater than the minimum sensitivity of the relay. If the current is less than the minimum relay sensitivity, open circuiting of the CT will not cause the breaker to trip, but the relay will still be able to detect and trip for any fault within its zone of protection.

## VI. CONCLUSIONS

We conclude that open circuiting of the metering or differential relaying CTs is not expected to result in a condition adverse to safety-related circuits.