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Guide for Safe Operating Procedures At High Voltage Substations By NBS and Utility Staff During the Field Calibration of Coupling Capacitor Voltage Transformers (CCVTs)

David L. Hillhouse

Electrosystems Division
Center for Electronics and
Electrical Engineering
U.S. Department of Commerce
National Bureau of Standards
Washington, DC 20234

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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Field Calibration of Coupling Capacitor Voltage Transformers (CCVTs)

David L. Hillhouse

Applied Electrical Measurements Group
Electrosystems Division
Center for Electronics and Electrical Engineering

This guide contains a checklist of safe operating procedures to be used by NBS staff in specific calibrations involving high voltages (arbitrarily, >600 V). Although these procedures are believed to conform with relevant national standards and codes, this guide is not to be construed as either a standard or code. In addition, the contents do not represent the results of NBS research. Use of this guide is restricted to the purpose stated in the title.

November 1980

Guide for Safe Operating Procedures at High-Voltage Substations

by

NBS and Utility Staff

during

Field Calibration of Coupling Capacitor Voltage Transformers (CCVTs)

ABSTRACT

A guide for safe operating procedures during the field calibration of CCVTs at high-voltage substations is presented in eight major steps, as follows: (1) Offload and Set up; (2) Pre-calibrate System Using Truck-Mounted Resonant Power Supply; (3) Connect Standard Divider to High-Voltage Bus; (4) Calibrate CCVTs; (5) Disconnect the Standard Divider from the High-Voltage Bus; (6) Calibrate CCVTs on Next Phase; (7) Recalibrate Standard Divider using Truck-Mounted Resonant Power Supply and; (8) Dismantle Divider and Reload on Truck. Scope and general considerations, including NBS staff responsibilities, are also discussed.

SCOPE

This guide documents certain minimum operating procedures for carrying out safe calibrations in high-voltage substations[A]. It is presented in the form of a checklist designed to ensure a systematic approach to safe calibration. The guide intentionally does not address specific, detailed measurement procedures having no bearing on safety. The complete calibration procedure for CCVTs is described in references 1 and 2 (see footnote B below).

In using this guide, it must be recognized that no procedure, no matter how carefully followed, can by itself assure safe operation. In other words, there is no substitute for experience and the development of safe work methods and habits. Each substation is to some extent unique in the specific hazards it presents; so that this guide is to be regarded as one tool for promoting safe operation.

Since this guide does not constitute a description of any research carried out by NBS and has been prepared primarily for use by NBS staff, it is not available for general distribution. However, interested parties, particularly clients of NBS high-voltage calibrations, may request copies from the Electrosystems Division, Building 220, Room B166, National Bureau of Standards, Washington, D.C. 20234.

A. High voltage is arbitrarily defined per the National Electrical Code, Article 710, as >600 V.

B. References

1. "A Prototype Field Calibration System for Coupling Capacitor Voltage Transformers (CCVTs)," D. L. Hillhouse, O. Petersons, and W. C. Sze, EPRI Report No. EL-690, April 1978.

2. "A Prototype System for On-Site Calibration of Coupling Capacitor Voltage Transformers (CCVTs)," D. L. Hillhouse, O. Petersons, and W. C. Sze, IEEE Transactions on Power Apparatus and Systems, Vol. PAS-98, No. 3, May/June 1979.

GENERAL CONSIDERATIONS

The specific steps and precautions outlined herein are to be supplemented and reinforced by continuous mutual observation and warning of potential danger between and among NBS and utility personnel. Some utilities assign a single person to be responsible for safety alone.

In addition, this is a FAIR-WEATHER SYSTEM. It should not be operated in rain, or if rain (especially thunderstorms) is known to be near the substation.

NBS staff in the field consists of a project engineer, a second professional*, and a senior technician experienced** in high-voltage measurements. The project engineer has overall responsibility for execution of the NBS portion of the calibration procedure, including the detailed steps of this guide. The engineer is also responsible for liaison and coordination with utility personnel regarding all aspects of safety. In addition, the engineer functions where appropriate as an active crew member in the actual performance of detailed safety steps, and may carry out or assist in carrying out any of those procedures for which NBS is responsible.

The technician carries out, in conjunction and in coordination with the project engineer and/or utility personnel, the detailed steps of this guide. The technician is encouraged to suggest modifications of these procedures in the interest of improved safety, but may not bypass safety steps without on-the-spot approval. If the technician perceives what said technician believes to be an unsafe practice occurring (or about to occur), the technician shall without prejudice take immediate corrective action no matter where the offender stands in the normal chain of command.

*Exceptions - one qualified technician, who must be thoroughly experienced in operating the system, may offload and set up the system before the project engineer arrives (section 1), and with the assistance of utility personnel deemed by the technician to be qualified, run an abbreviated precalibration (section 2) to ascertain that the system is functioning properly this will normally occur only on long trips, where the truck is on the road more than one day, so that the professional staff travels to the site only after the truck has arrived).

**The training consists primarily of "apprenticeship" to experienced high-voltage personnel. In addition, safety procedures such as this guide are issued, periodically updated, and periodically reviewed with participating staff (especially immediately before a field calibration trip). Personnel are also encouraged to take CPR (cardio-pulmonary resuscitation) and first aid courses, plus periodic refreshers.

PROCEDURE

1. Offload and Set up

At a pre-calibration site inside the substation but well away from energized high-voltage buses, the modular standard divider is off-loaded and set up, using a truck crane operated by a utility crew.

2. Pre-calibrate System Using Truck-Mounted Resonant Power Supply

2.1 Short out the standard divider (against "static" pickup).

2.2 Connect heavy grounding cables from:

2.2.1 Standard divider to substation ground;

2.2.2 Truck to substation ground.

2.3 Enclose standard divider with portable bright yellow and black safety fence sections.

2.4 Place safety-orange flags on safety fence corners.

2.5 Place battery-powered flashing red lights on safety fence perimeter.

2.6 Place "DANGER - HIGH VOLTAGE" signs on standard divider base.

2.7 Connect an external grounding lead, attached to truck ground, to the standard divider's high-voltage lead before that lead is connected to the truck's high-voltage bushing.

2.7.1 A similar lead inside the truck's high-voltage power compartment grounds the system's high-voltage resonant power supply.

2.8 Place rubber mats on the ground where personnel normally step on and off the truck, and where they kneel to connect signal cables from the test piece and standard divider.

2.9 Plug the 60-Hz, single-phase power cable (208 - 276 V, depending on the substation) into the truck input panel. UTILITY PERSONNEL will first have connected the power cable into their source. In a three-wire system, NBS personnel must make certain the proper wire is grounded at the source. Also, this power cable should never pass beneath the high-voltage buses (large transient voltages can be induced in the power cable during switching or a fault).

2.10 Apply the truck's high voltage to the standard divider to perform the pre-calibration, as follows:

2.10.1 Have at least two people present and in close communication:

2.10.1.1 Operator (on board truck);

2.10.1.2 Data taker and observer (outside truck).

2.10.2 Operator removes internal grounding lead from resonant power supply.

2.10.3 Outside worker removes the outside grounding lead from the divider before each operation, and replaces it afterward, but does so only after

2.10.3.1 Receiving and acknowledging verbal "voltage-off" assurance from inside worker (operator) and receiving operator's clearance to do so.

2.10.3.2 Observing the "power-off" green light on the power supply control console.

2.10.4 Operator not only monitors the outside worker's performance of the above, but also

2.10.4.1 Is constantly aware of the outside worker's whereabouts.

2.10.4.2 Turns voltage on only when the outside worker is in view and has assured the inside worker that the grounding lead is off and the area is clear.

2.10.5 Both operator and outside worker (but especially the outside worker) make sure the area is clear and warn any nearby people that the system is "hot" before applying power.

NOTE: The following interlocks and safety features protect on-board personnel:

a. An interlocked door isolates the operator from the truck's high-voltage power compartment. Power cannot be applied unless this door is closed, and shuts off if this door is opened.

b. The high-voltage power supply contol console has the following safety features:

1. If the high voltage is shut down for any reason, the power supply cannot be re-energized until the voltage control is returned to zero.

2. High voltage arc-over is automatically detected, the system is shut down, and an arc-over warning light is lit. A further measure of safety against high current and prolonged high voltage is provided by the immediate de-tuning of the resonant power supply by any substantial load change.

3. Connect Standard Divider to High-Voltage Bus

3.1 Move standard divider under high-voltage bus:

3.1.1 Making sure the standard divider top remains grounded, disconnect the divider lead from the truck (see also 2.7).

3.1.2 Place standard divider low-side grounding switch in the GROUND position.

3.1.3 Place standard divider low-side output switch in the OPEN position, and the range switch in the appropriate position for the first calibration.

3.1.4 Disconnect signal cables and 60 Hz power cable from the truck and

3.1.4.1 Place their open ends on the rubber mats (item 2.8), or other insulating surfaces.

3.1.4.2 Make sure these cables do not cross each other or a grounding lead. DANGER: Do not touch or remain within one or two feet of these cables during high voltage switching.

3.1.5 Establish and maintain continuous contact with utility personnel who are to perform the high-voltage switching, either by sight and voice or by two-way voice radio (walkie-talkies).

3.1.6 From this time until the line has been de-energized (see 3.1.8, below) all personnel must

3.1.6.1 Remain totally clear of the truck, or remain totally on the truck. NEVER, for example, should the feet be on the ground and the hands on the truck, because a switching surge can result in very large potential differences between "grounded" objects. It is in fact good practice to remain totally clear or totally

on the truck at ALL times. A line fault somewhere could cause unexpected switching.

3.1.7 Give the utility crew specific clearance to de-energize the high-voltage bus. NOTE: This is of course relative only to NBS readiness. Actual clearance is given by utility operating personnel, often in a control center many miles away.

3.1.8 UTILITY CREW WILL de-energize high-voltage bus.

3.1.8.1 Open circuit breakers.

3.1.8.2 Open motor-driven bus disconnecting switches ("disconnects").

3.1.8.3 Close hand-cranked bus grounding switches, lock closed.

3.1.9 UTILITY CREW remove heavy substation grounding cable from divider.

3.1.10 UTILITY CREW move standard divider under high-voltage bus.

3.2 Connect divider to bus:

3.2.1 Reconnect heavy grounding cable from standard divider base to substation ground
CAUTION: double check this.

3.2.2 Set up safety fence, etc., around divider once more, i.e., repeat steps 2.3 through 2.6.

3.2.3 UTILITY CREW will bolt divider high-voltage lead to bus.

3.2.4 Make sure the divider low-side grounding switch (see 3.1.2) is still in GROUND position, and the output switch (see 3.1.3) is still in the OPEN position.

3.2.5 Re-ascertain continuous contact with utility switching personnel (see 3.1.5).

3.2.6 Make certain all personnel are

3.2.6.1 Totally clear of truck, or (see 3.1.6 and CAUTION);

3.2.6.2 Totally on the truck, AND

3.2.6.3 At least 100 feet (30 meters) from the standard divider (there is a remote but real chance of module rupture during switching).

3.2.7 Give clearance for re-energizing the bus (see NOTE with 3.1.7).

3.2.8 UTILITY CREW will re-energize the high-voltage bus.

3.2.8.1 Unlock and open hand-cranked bus grounding switches, lock open.

3.2.8.2 Close motor-driven disconnects.

4. Calibrate CCVTs

4.1 Reconnect power and signal cables to calibration truck.

4.2 From behind the safety fence, and using electrical gloves and regulation insulated "hot stick" for the bus voltage involved (e.g., 230, 345, 500 kV) UTILITY CREW will

4.2.1 Place divider low-side grounding switch in OPERATE position.

4.2.2 Place low-side output switch in RATIO position, and ascertain that the range switch is still in the appropriate position.

4.3 At the option of the utility: close off an even larger area around the divider with safety rope or tape, as a further precaution against casual intruders.

4.4 Connect test piece low side to calibrate system (UTILITY CREW), proceed with calibration.

4.5 If divider range change is required during calibration, UTILITY CREW, equipped and proceeding as in 4.2 above, will place the RANGE switch in the new position.

5. Disconnect the Standard Divider from the High-Voltage Bus

5.1 UTILITY CREW, once again equipped as in 4.2, above, will

5.1.1 Place standard divider low-side output switch in the OPEN position.

5.1.2 Place standard divider low-side grounding switch in GROUND position.

5.2 NBS and UTILITY CREW now repeat steps 3.1.4 through 3.1.8 for de-energizing the high-voltage bus. CAUTION: continue to emphasize especially 3.1.5 through 3.1.7. If at this point the CCVTs on all three phases have been calibrated, proceed to section 7. If not:

6. Calibrate CCVTs on Next Phase

6.1 UTILITY CREW will disconnect divider from bus, and ground its top.

6.2 Move divider to next phase (UTILITY CREW - see also 3.1.9 and 3.1.10).

6.3 Repeat procedure outlined in 3.2.

6.4 Repeat sections 4 and 5 above.

7. Recalibrate Standard Divider using Truck-Mounted Resonant Power Supply

7.1 Move the standard divider back to its "pre-calibrate" location (UTILITY CREW).

7.2 Repeat section 2, all steps.

8. Dismantle Divider and Reload on Truck

8.1 Follow the procedures and precautions outlined in section 1.

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D. L. Hillhouse

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This summary documents minimum procedures and operations necessary to provide for a safe calibration in a high voltage substation. The summary is in the form of a checklist so that it outlines a formal, systematic approach to safe calibrations.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Calibration; coupling capacitors; high voltage measurements; safety; substations; voltage transformers.

13. AVAILABILITY

☐ Unlimited

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