Ground-Fault Protection Systems and Electrical Inspections

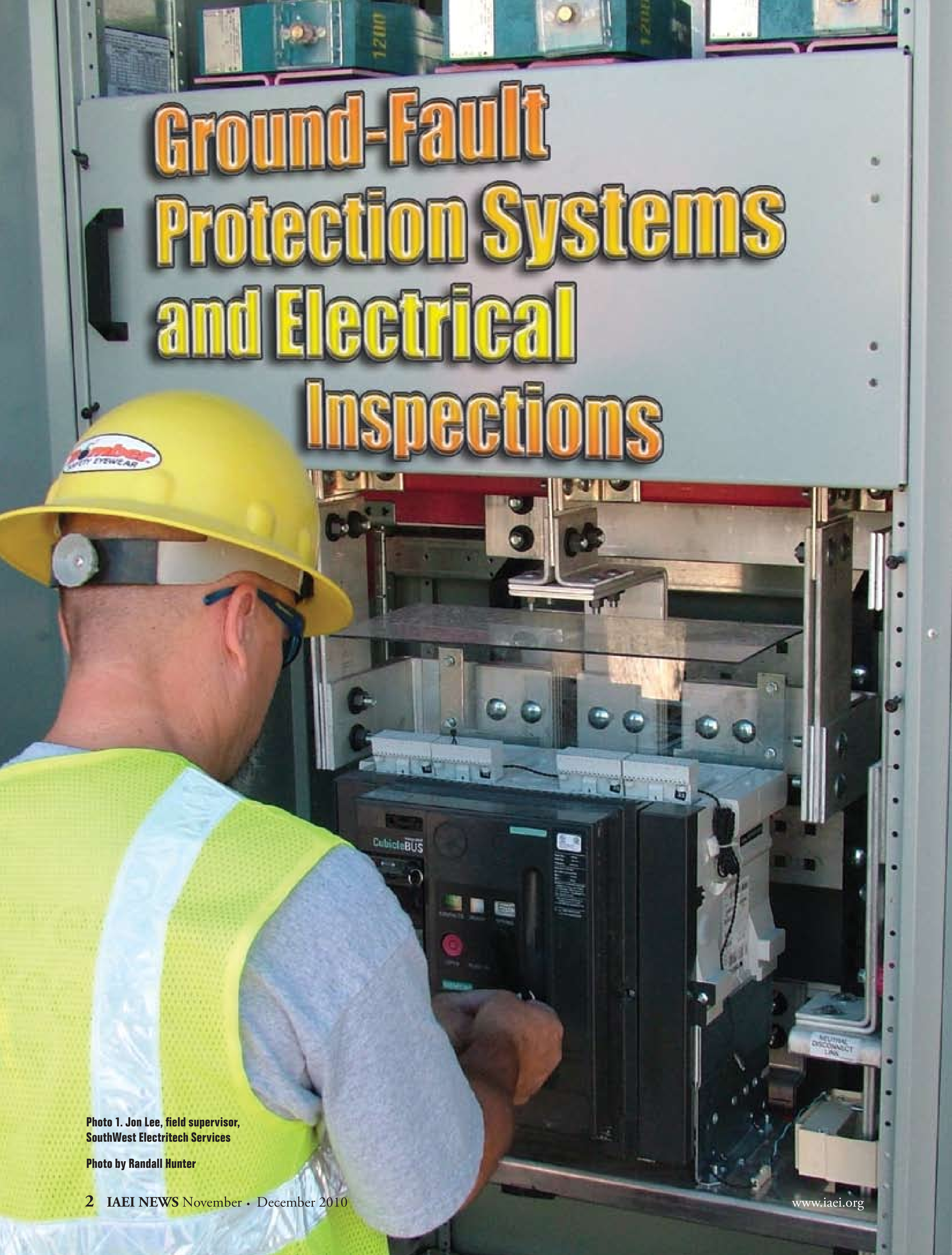

Photo 1. Jon Lee, field supervisor, SouthWest Electritech Services

Photo by Randall Hunter

by Howard Herndon

Don't just take a glance, see a testing sticker and approve it!

Ground-fault protection of electrical equipment is required by the *National Electrical Code* (*NEC*) in order to minimize the damage to the equipment in the case of a ground fault. *Ground-fault protection of equipment* is "a system intended to provide protection of equipment from damaging line-to-ground fault currents by operating to cause a disconnecting means to open all ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device." The minimum code requirement for ground-fault protection of equipment as outlined in *NEC* 230.95 is for "…solidly grounded wye electric services of more than 150 volts to ground but not exceeding 600 volts phase-to-phase for each service disconnect rated 1000 amperes or more."

Ground-Fault Protection System Types

The most common methods of providing ground-fault protection on low-voltage single source systems are:

Zero sequence: This is most commonly used in conjunction with molded-case circuit breakers and fused switches. These systems contain a large current transformer for all phase and neutral conductors or bus bars to pass through, a ground-fault relay, a control power transformer and a trip device for the circuit breaker or fused switch. This system utilizes a summation principle (exiting and entering currents must equal zero) to determine if there is a ground-fault condition.

Residual sensor: A residual system is provided with a separate current transformer (CT) on each phase and the neutral is also proved with a CT. This system can either utilize a ground-fault relay similar to the zero sequence system or be internally mounted within the overcurrent device and wired to the trip unit. This system utilizes a summation principle of all 4 CTs (on a 4-wire system) to determine if there is a ground-fault condition.

Internal ground-fault systems: These are used with solid-state circuit breakers and an external neutral sensor (current transformer) is added for the neutral conductors or bus bar. This sensor is used to measure the return current through the grounding electrode and the main bonding jumper.

In most cases, the ground-fault relay and current transformer used have been listed as a system by a nationally recognized testing laboratory (NRTL) and therefore are tested and meant to operate with each other. If a system is being repaired or added in the field, the manufacturer's relay or solid state breaker and current transformer must be compatible to insure proper operation of the device. Just because the devices are from the same manufacturer, does not necessarily mean they are compatible. Detail on the compatibility of the devices is listed in the instruction bulletins for the equipment, or the manufacturer should be consulted.

Testing and Approval

Now that we have identified the major system types and components of the system, what should be reviewed prior to authority having jurisdiction (AHJ) giving approval for energization of the system?

First, the system performance testing as required by *NEC* 230.95(C) is most often required by the AHJ to be completed by a third-party electrical testing company and not by the installing contractor or owner. All testing should be done prior to energizing the device. Testing the ground-fault system requires that both the line and the load on the device being tested be de-energized. The only test that can be done on energized devices is with a secondary injection test set. Use of a secondary injection test set will test the electronics of the relay or trip unit, but does not insure the CT installation and wiring are correct. Use of the test-trip button will test the circuit within the relay or trip unit, but again does not insure the CT installation and wiring are correct. This does not meet the intent of performance testing as outlined in *NEC* 230.95(C). Use of the secondary test set or push-to-test button is like performance testing

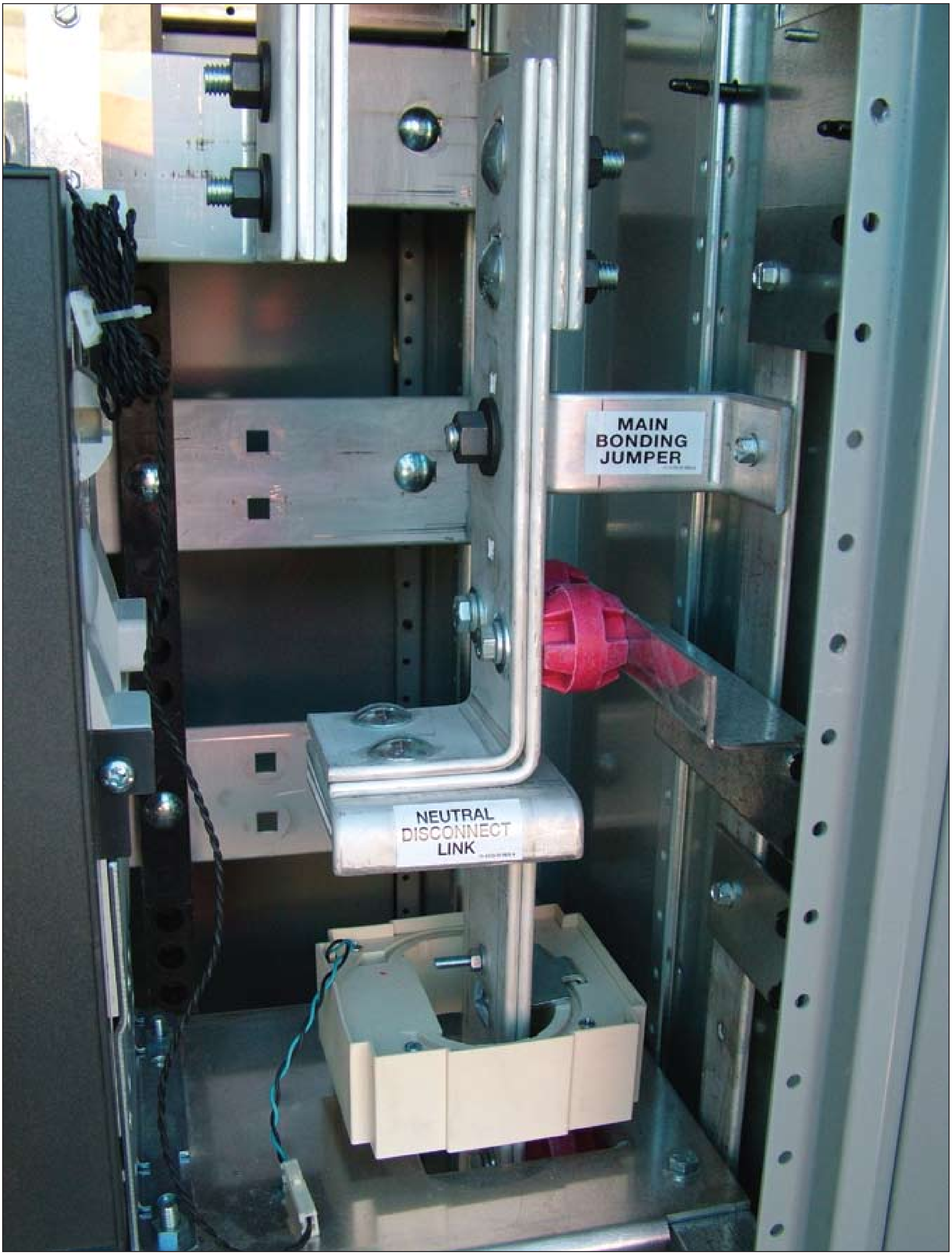

Photo 2. Neutral current transformer (CT), neutral disconnect, main bonding jumper

Photo by Randall Hunter

the safety features of a car while it is up on blocks — it may look good, but is not very effective.

Primary current injection by a qualified third-party testing agency using the procedure as outlined by the manufacturer is the only effective way to test the ground-fault protection systems. Testing with a primary injection test set tests the integrity of all the system components including the relay or trip unit, control power, wiring and the external CT. With primary injection testing, typically both trip and non-trip tests are used to prove the polarity of the CTs or sensors and the wiring of the system. When a system requiring control power is tested, a reduced voltage test is also done to insure the system will trip even if the supply power has lost a phase. Many ground-fault systems require particular attention to the wire that is

Photo 3. Main circuit breaker with ground fault **Photo by Randall Hunter**

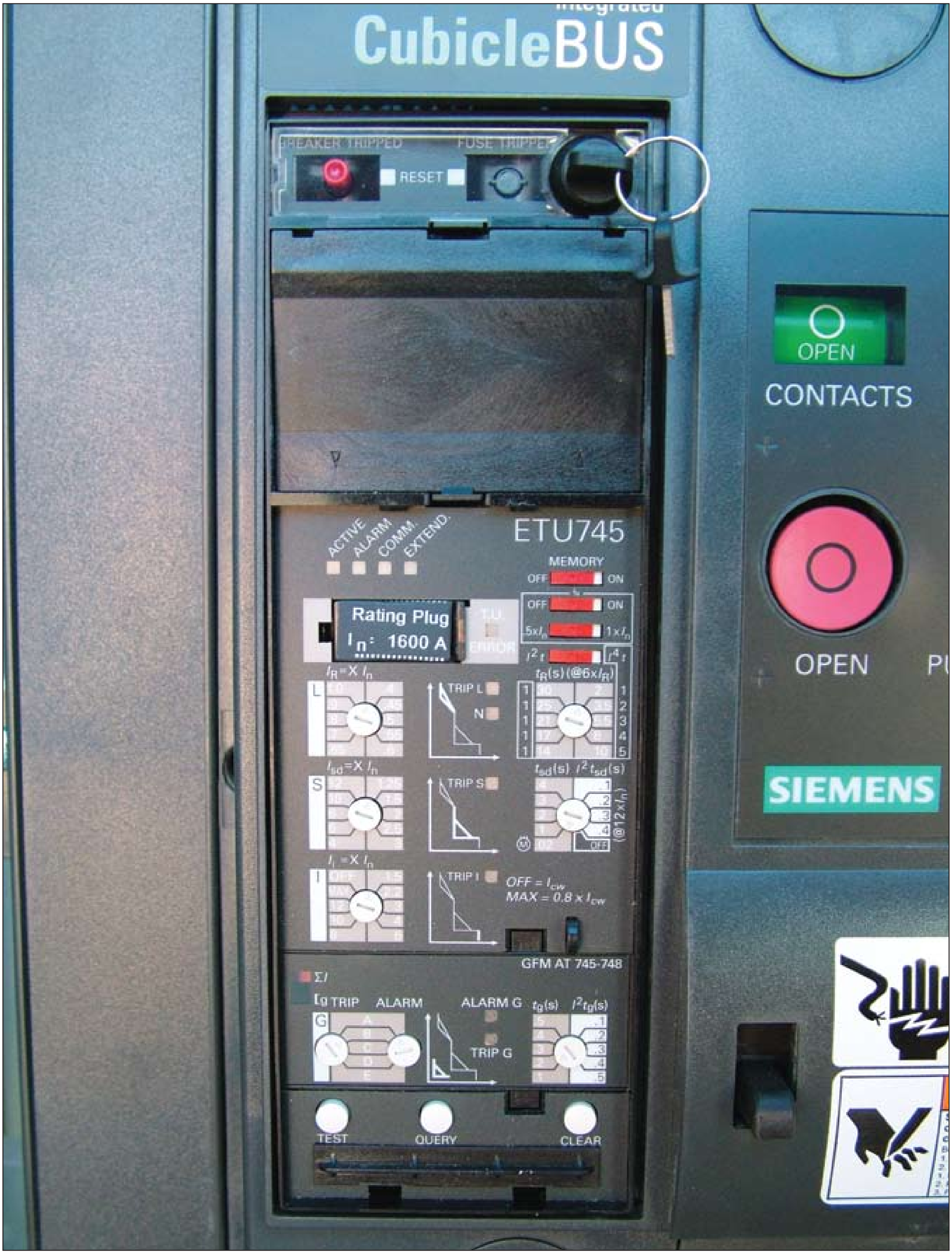

Photo 4. Main circuit breaker trip unit **Photo by Randall Hunter**

Primary Injection Testing

For primary injection testing, high current is injected through the primary side of the overcurrent device or current transformer. This testing can only be performed on a de-energized system. The entire system (current transformers, connection points, trip unit, and circuit breaker operation) is covered by the test.

Secondary Injection Testing

For secondary injection testing, current is injected through the trip unit at a test port in the trip device or a test plug provided by the manufacturer. Since trip units are proprietary to the manufacturer, so is each test kit and they often vary by the manufacturer's series of trip units. A secondary injection test may only be used on solid state or electronic trip overcurrent devices. This testing can be effective for maintenance testing because it tests the trip unit logic and the trip mechanism, but it should not be used for acceptance testing.

to be used. Some require minimum sizes of conductors, shield conductors or twisting together of the conductors when connecting to the CT. Verification that the polarity of the CT is correct is most often very difficult because of the location of the CT. The polarity marking on the current transformers varies from manufacturer to manufacturer. Polarity is determined by markings on the CT: some have an arrow for the direction of current flow; some have white dots, while others are based on the position of the terminal points. Nameplates or the instruction bulletin should be referred to for confirmation. The AHJ should ask for a copy of the test report and review any items noted by the testing agency, as there are often critical notes of items for correction or review placed on the test sheet. Don't just take a glance, see a testing sticker and approve it!

Second, since the control power for the ground-fault system is most often a tap conductor on the line side of the overcurrent device, this may commonly be some type of disconnect device with a fuse block. This device is the control power for the ground-fault relay and should be confirmed to be in the "on" or "energized" position. Our field personnel have opened control cabinets to several systems in operation and found them in the "off" position. At that point, there is no way to know if it was never turned on, or if it was turned off at some point to cover up nuisance tripping or some other issue in the electrical system. If the control power is not provided to an external system, there will be no ground-fault protection. If the ground-fault system is purposely disabled and someone is injured, there could certainly be grounds for litigation.

Third, because the third-party ground-fault protection performance testing is often done prior to the connection of the conductors, careful examination of the CT should be made once the conductors are pulled through the CT. Is there damage to the wiring or to the CT during installation of the conductors? Do all the conductors pass through the CT, and do they pass in the correct direction and all in the same direction? The grounding electrode conductor or equipment grounding conductor should not pass through the CT. This often causes nuisance tripping, and may prevent the device from accurately tripping at the device setting. If there are questions, the system should be reviewed, repaired and retested.

Fourth, verify that the grounding system is complete. The grounding system is the return path for a system fault. Is the grounding electrode conductor landed in the correct position and in the correct structure? Are the other systems properly grounded and bonded to provide a complete grounding system?

Lastly, review the connection of neutral conductors at each point in the system to insure they are not grounded downstream of the neutral bonding jumper. This is checked when the ground-fault performance test is conducted, but is most often done when the electrical distribution system is still incomplete, so careful attention must be made to insure the system will operate properly. Grounding of the neutral conductor most often makes the ground-fault protection system ineffective during a system ground fault condition.

With the greatest percentage of electrical faults being phase-to-ground, the properly operable ground-fault protection system cannot only minimize damage to electrical equipment, but can also help to minimize the danger to personnel. Careful inspection of the ground-fault system is critical, and requires far more attention than simply looking for a sticker.

Howard Herndon is principal of SouthWest Electritech Services, an independent electrical technical and testing services company based in Las Vegas, Nevada. Howard has over thirty years of experience in various fields in the electrical industry including electrical distribution equipment manufacturers, electrical systems designs, short circuit and coordination studies, electrical equipment field testing, and teaching electrically-based classes including electrical safety and code classes. Howard has served on the Board of Directors of the International Association of Electrical Inspectors, Southern Nevada Chapter since 2001, currently holding the position as secretary and treasurer of the chapter since 2005. He also serves on the Southern Nevada Electrical Code Committee as an industry member since 2005 for both the 2005 and 2008 NEC Southern Nevada Amendments.