Testing Personal Protective Grounds

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Abstract - This paper is not intended to discourage low current testing, however it is intended to point out that in and of itself low current testing of protective grounds is not a sufficient method to qualify grounds as safe, adequate or good.

Personal Protective Grounds, Ground Sets or "Ground Chains" are intended to provide protection to the electrical worker by maintaining a sufficiently low voltage across an individual in the event of unexpected line energization. Energization can occur from numerous sources including lightning, falling conductors and operational errors such as closing the wrong switch or breaker. Generally 50 volts is the accepted level (although some organizations may allow 75 volts) that must not be exceeded across the worker and thus the protective ground set during such conditions.

Although the electrical industry has worked diligently to eliminate accidental energization, they still occur, mandating the use of personal protective grounds. Usually the most severe case results from the unexpected energization of the line or system from its normal or alternate energy source. It is this condition that typically allows the largest available current to flow.

Some system available fault currents exceed 100,000 amperes and 20 - 30,000 amperes available is common place. If we use a resistive value of 1000 ohms to represent a worker in parallel (IEEE Standard 1048 - 1990 indicates that a worker can be represented as having 500 ohms internally), and if the maximum allowable voltage across the worker is 50 volts, the current flowing through the worker will be (0.050 amperes) 50 milliamperes. Based on research done by Charles F. Dalziel and Abdul M. Mouse, the generally accepted values for "Let Go" current is 9 - 15 milliamperes with ventricular fibrillation occurring at 67 - 100 milliamperes for 0.5% of the persons exposed. Therefore, 50 milliamperes is dangerously close to respiratory tetanus and approaches ventricular fibrillation. At 20,000 amperes, the ground set must withstand 19,999.95 amperes till the circuit is opened by system over current protection devices. To achieve these small numbers the maximum allowable resistance (impedance) for the ground set is 0.003 ohms. (At 50,000 amperes the ground set resistance (impedance) cannot exceed 0.001 ohms or 1 milliohm. Although we are actually dealing with AC values the above information is sufficient to make the point. Ground sets must be maintained in the best of working order and cannot be installed without cleaning connections. Coiling grounds of excessive length creates an inductive coil which increases the ground sets impedance reducing their effectiveness. Further, they must not be installed over galvanizing, paint, dirt, rust or other materials that are poor conductors. Obviously frayed conductors, improperly crimped, loose connections or dirty clamp jaws will not provide the required worker protection.

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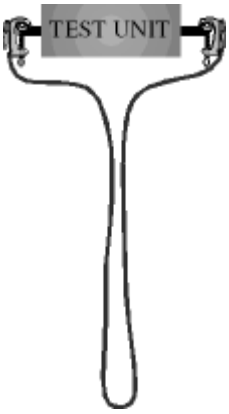
Large fault currents require the use of heavy conductors and large clamps capable of withstanding huge electromagnetic (mechanical) forces. Cable reaction to large currents is sudden and violent, creating tremendous stress on the connections. In order to practically apply these cables they must be flexible, durable, and capable of maintaining their electrical integrity during the time required for relaying and breakers to clear the line.

Accepted, essentially throughout the industry is the use of "welding cables" or grounding cables, a flexible multi-stranded cable that is inherently susceptible to strand damage. These cables are used because of their flexibility and versatility and probably are the current "best choice" of all cables available. Cables used for personal protective grounds should meet IEEE Standard F 855 - 90. There are three Types "I", "II", and "III". Table 5 of this standard establishes conductivity at 60 Hertz for cables used as protective grounds. Additionally, cable insulation and insulation flexibility are addressed for appropriate temperature ranges..

In an effort to assure themselves of a ground sets integrity it is becoming common place for companies to test personal protective ground sets. Testing of cables at tens of thousands of amperes changes conductor annealing and the conductors rated ampacity. Equipment necessary to perform such tests is not only expensive but it requires employee training to be used properly, not to mention that it requires a system capable of providing large currents without interfering with normal system use.

Since many organizations do not have high current test facilities that can be used to test at such elevated currents, low current testing and extrapolation of low current test results may be desirable, especially if numerous ground sets are to be tested. Additionally manufactures have developed and sold equipment specifically designed to test ground sets. As with any test where human life is involved caution and prudent judgment must be used.

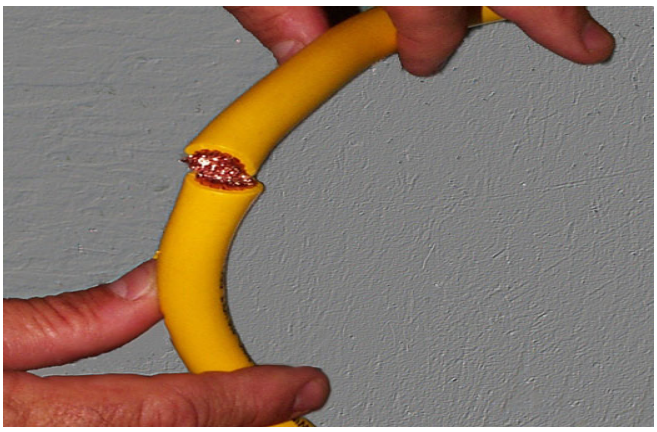
Test validity must be determined before test data is depended on to protect human lives. In keeping with this philosophy tests were conducted in Bangor Hydro Electric's Safety Test Laboratory in May, 1997 and again in September, 1997. Low current tests were conducted on a twenty foot length of 2/0 copper welding cable (Coleman Cable and Wire Company) attached to Salisbury #21030 Ground clamps and elevated on a wooden work bench to reduce any magnetic induction problems. (The Salisbury 21030 clamp is an Aluminum Duck Bill Ground Clamp using a threaded ferrule that screws into the clamp body and is locked in place with a locking nut. This clamp is designated as a grade 5 clamp) Test layout is shown in Figure #1.

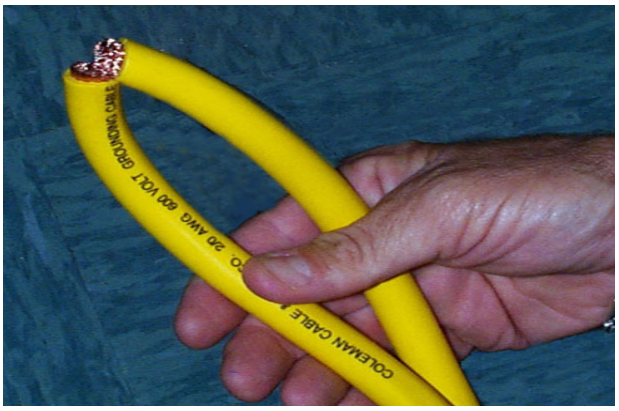


Four tests were made using a high current test set delivering 300 amperes at 120 volts. Test, were conducted using four cable conditions. Voltage drop across the tested cable were read using the testers voltmeter.

Test Conditions	Amperes AC	Volt Drop AC
Undamaged Cable	300	0.72
25% Strand Damage (Approx.)	300	0.72
50% Strand Damage (Approx.)	300	0.75
75% Strand Damage (Approx.)	300	0.78

As can be determined from the above table massive strand damage will go undetected if low current testing is the only criteria used to determine the condition of a ground set. Obviously large ground sets that have 25 - 50% strand damage cannot be depended on to function as designed. Certainly damaged ground sets cannot be expected to limit the voltage across a worker to safe level.





Inadequate or improper connections resulting from dirty clamp jaws or loose connections between the clamp and cable ferrule could also go undetected at lower currents. Experience has shown that elevated voltage drops are read and clamp jaws on the tester may heat up when dirty clamps are tested. However, dirty clamp jaws can also be detected by a through visual inspection and eliminated by proper cleaning before using a ground set.

Personnel depending on grounds must understand the information determined from low current testing of protective grounds is not sufficient to establish that a set of grounds are adequate to withstand full rated currents and maintain a voltage of less than or equal to fifty volts. A complete visual inspection, tightening to the proper torque of all connections and cleaning will probably provide as good a result as low current testing.

It is imperative that ground sets be maintained, inspected for damage and discarded if damaged or subjected to large currents. It is recommended that protective grounds be inspected, cleaned and checked for tight connections before each usage.

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