GRADIENT CONTROL MAT INSTALLATIONS

Question:

Recently it was brought my attention that gradient control mats are being connected directly to ground grid systems. Please confirm for clarity and uniformity, that the grounding conductor for a pole top switch and handle must connect directly to the ground grid system and that the mat must be isolated from ground by crushed rock and connected to the switch handle by 2-2/0 conductors separately from the ground grid system. The handbook shows a picture of a typical installation. Some time ago a sketch was made, (possibly from BC Hydro), showing a mat with ground rods driven and connected to each corner of it. Also, should we be asking for a commissioning report for table 52 requirements for installations involving switches and mats only? (No sub station present)

Rule 36-308(2)(b)(ii) requires metal bases of switches to be grounded. This rule then refers us to rule 36-310 for switch handles.

Rule 36-310(1) requires the operating handle to be grounded to the station ground electrode.

Rule 36-310(2) requires touch voltage in the area where the operator of the switch would normally be standing to meet the requirements of table 52.

Rule 36-310(2)(a) requires a mat be installed for this purpose and that it be connected to the operating handle. (Not grounded)

Rule 36-310(2)(b) further requires that this mat must be placed on a minimum of 150 mm of crushed stone. (Isolation from ground)

The handbook (page 792) shows a picture of a station ground electrode connected to the metal switchgear at the top of the pole and to the operating rod of the switch. It also shows the gradient control mat connected to the operating handle. This picture is in accordance with the requirements of 36-310.

An amendment (which has not been renewed as of 1994) to this rule required a station ground electrode be installed to ground the switch even though a station was not present. It required the gradient control mat to be connected directly to it. (Grounded)

It has been common practice to accept these mats with rods attached to the corners and extending to the switch and the switch handle.

It was recently brought to my attention that we should reconsider approving gradient control mat installations that are connected to the station ground electrode directly as this practice appears to be in contravention of section 36. It was pointed out that fault current should be directed away from the area of the operator of these switches.

The intent of rule 36-310(2) appears to be to ensure that the operator is not subjected to a potentially hazardous touch voltage while standing on grade and operating the switch. By connecting the mat to the switch handle (thereby keeping the mat and the handle at the same potential) we are accomplishing this. By directing the fault current to the immediate vicinity of the operator we may be inviting a more potentially hazardous situation. Section 36 and the handbook appear to agree with this thinking.

It may be that the advantages of one method over the other are negligible, however the code instructs us to install these mats connected (bonded) to the switch handle and not grounded.

Answer:

Interpretation of rules governing the bonding and grounding of pole-mounted Highvoltage switches: (1) definition of station. (2) 36-302 (3) 36-308 (4) 36-310. Conductor sizes are not discussed since they are readily discernable in the s. 36.

Analysis

The pole mounted switch is deemed to be a station.

The station must be grounded by a station ground electrode.

A station ground electrode consists of 4 ground rods.

The rods are interconnected by a ground grid conductor.

The ground grid conductor is connected to all non-current carrying metal parts of equipment and structures. ie: switch and gradient control mat.

The ground grid conductor must form a loop around the equipment to be grounded. ie: pole, switch, and gradient control mat. For this discussion the exceptions are ignored.

The metal base of the switch must be connected to the station ground electrode.

The switch frame must be connected to the station ground electrode.

The neutral must be connected to the station ground electrode.

The switch operating handle must be connected to the station ground electrode by 1 of 2 means:

(a) a multi-revolution grounding device, or
(b) by connecting the operating shaft to the station ground electrode.

The gradient control mat must be connected to the handle grounding conductor.

The gradient mat must rest on 150 mm of crushed stone, which lies on the ground.

The gradient control mat cannot be isolated from ground.

Covering on top of the mat is optional.

Touch voltage calculation is not needed because if the mat is bonded to the switch as required, the mat and the switch are at the same voltage. The person on the mat will be raised to the voltage of the mat and switch. Operator and switch are at the same potential.

Step voltage in this circumstance is not mentioned in rule 36-310, eliminating the need for step voltage calculation.

Since we live in an imperfect world, things are not perfect. If the ground mat and gravel were a perfect resistance, the combination would act as total current-stopper. There is a finite resistance between switch, conductors, mat, gravel, and earth. Therefore a small current will flow. And if a person is holding the handle, a small current will flow through the noted items and the person, since the handle, the operator, the mat, the gravel and earth are in series. The gravel is the part of the series circuit with the highest resistance.

The following are in parallel with the operator:

(a) The handle, the two conductors to the mat, the mat, the gravel, and earth.
(b) The entire switch, the grounding conductor from the switch to the grounding electrode, the loop conductor, and the ground rods.
(c) And when present, the neutral.

The low impedance shunts in parallel with the operator, plus the high resistance in series with the operator, plus the likelihood that the operator will not step off the mat while operating the handle, and should the operator step off the switch, the operator will likely not be holding the handle. These elements combine to provide safety to an operator during a fault.

A danger exists during a fault should the operator step off the mat while holding the handle. The touch voltage magnitude would be directly proportional to the voltage imposed on the switch.

A step voltage would exist if the operator stepped off the mat after releasing hold of the handle. The voltage magnitude would be based on the length of the person's stride in parallel with the voltage drop in the earth under the person's feet. The resistance of the vertical portions of earth between the path of fault current in the earth and the person's feet help in limiting the current flowing into and out of the person's feet.
If the operator had one foot on the mat and one foot on the earth the series resistance of the gravel would enhance operator safety. The condition would be worse if both feet were on the earth.

Summary

All the exposed metal is bonded together and grounded. The rods and interconnecting conductor must form a loop around all the equipment. (Exceptions are not discussed here) Step voltage calculation is not required in respect of gang-operated switch handle grounds. Touch voltage is deemed acceptable if the installation meets the mechanical and electrical specifications of the rules and the operator does not have to step off the mat during operation of the handle.

If the above conditions prevail, the general objectives of rule 36-308 are met, namely, the prevention of the "build-up of dangerous potential differences between the equipment or structures and the nearby earth."