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# PROBLEMS OF MEDIUM VOLTAGE EARTHING PRACTICE IN A DEVELOPING POWER SYSTEM

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## Safety and Earthing

There are power systems in the world where loss of human lives on account of electrical accidents has not been much less than those due to social crimes. According to a U.N. publication of 1967, there have been about 900 electrocutions in a year in an Asian country. Situation in some other power systems is not happy either. In Pakistan, there were about 250 electrocutions in West Wing of Pakistan during the year 1970. This is not only a challenge to the engineers in general but also a moral obligation on humanity to devise more fool proof working standards for ensuring greater safety. This essentially calls for an appraisal of the existing earthing practices in power network especially the medium voltage system, so as to make grounding system more efficient.

A medium voltage power system can be operated as ungrounded but the many advantages of an earthed system establish its almost universal application. Grounding serves the following purposes :—

(*i*) Neutral is prevented from floating and consequently dangerous overvoltages are avoided. This saves the insulation from failures. System voltage is also stabilized more. Another advantage is that a saving is effected in insulation.

(*ii*) Earth faults can be conveniently utilized to operate system protection.

(*iii*) Dangerous voltages are avoided in nominally earthed metal parts.

## Types of Grounding Practices

Before considering the problems of a developing system, various grounding, practices for overhead lines and equipment are briefly reviewed. Mainly, there are three ways :—

(*a*) **Direct Earthing.**—In this method, ground contact is established by earthing each pole, the substation and at consumer premises.

Reliance is placed on the general mass of earth to act as continuous conductor for the fault power flow. In cases of poor ground contact or in soils of high specific resistance, the earthing system may not operate efficiently, thus resulting in dangerous consequences.

(*b*) **Use of Earth Wire.**—In this method, earthing is established through a continuously run conductor, which is fully earthed at the substation, consumer's end and at one or more points in between. This is a more reliable method to ensure effective operation of earthed loop in the event of fault. The fault power mainly flows through this conductor instead of the mass of earth, thus bypassing the danger involved in cases of poor contact of high specific resistance of soil. However, the provision of continuous earthing conductor sometimes may serve as a general fault hazard in systems where workmanship standards may not be satisfactory. The hazard may be more marked in the overhead lines having multiple circuits. Further, if the earth wire breaks, the earthing system will not function.

(*c*) **Grounding through the Neutral Conductor.**—In this method, the earth contact is achieved by earthing the neutral conductor at the substation, at a number of points in between and at the consumer's end. This is multiple grounded neutral system. Number of points to be earthed in between, is prescribed by Regulations. The fault power flows through the neutral conductor. If, however, the neutral breaks, either due to heavy out of balance currents affecting weak points or some mechanical cause, the earthing system is likely to be ineffective. A separate earth wire is usually not used when the neutral conductor is multiple earthed.

In Pakistan, this system was introduced a few years back and the relevant Regulations of 1937 made under the Electricity Act of 1910 were amended. The method is presently adopted in most countries including U.K. It is interesting to depict the trend of electric shock in Pakistan before and after the introduction of multigrounded neutral system. (See Fig. 1).

In the above methods of earthing the overhead system, the primary object is to get low impedence loop in the event of an earth fault for proper operation of protection.

**Earth Electrodes**

Earthing of lines or equipment is achieved with low resistance plates buried in soil near the water table. The conventional method of using coke,

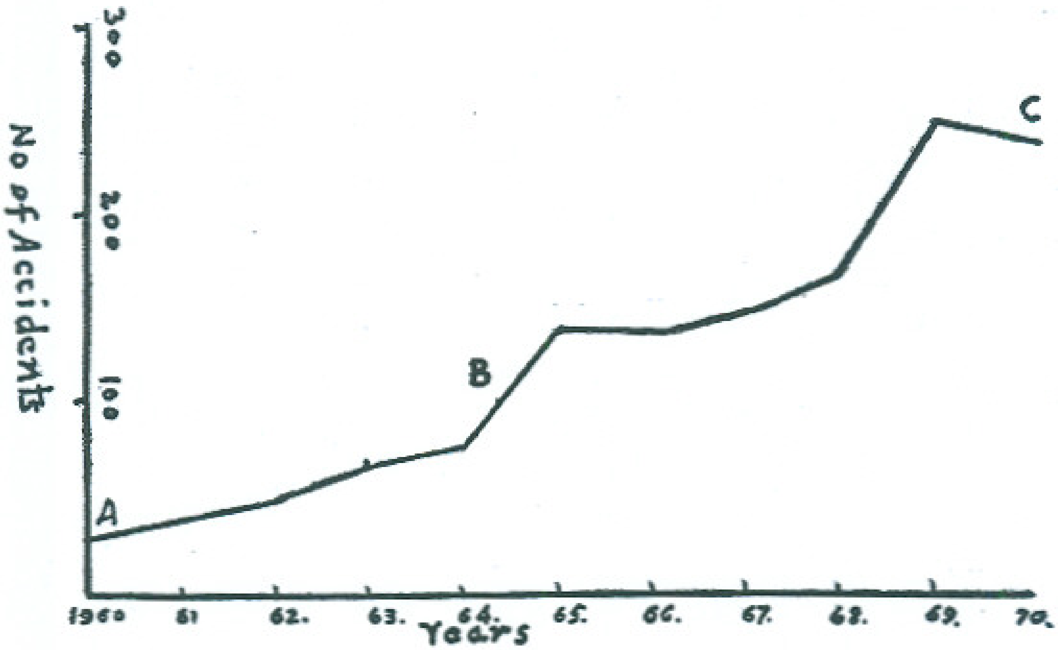


Fig. 1. Electricity accidents in West Pakistan

salt around the plate ensures lessening of resistivity of the adjoining soil. The latest trend of earth contact through driven rods or tubes is proving more convenient and effective. It is also more economical in labour and material costs. The rods are copper coated to resist corrosion in the soil. These are driven into the soil by means of electric or pneumatic hammers. In high resistivity soils, longer rods or tubes have to be used. The size of the rods should be able to withstand the fault power. If the earthing rod or plate is of copper, it will corrode less and last longer. In that case, however, salt or coke may not be used, being corrosive for copper. In Pakistan we are mostly using copper plates buried at suitable depths. Experience has shown that they are severely attacked by corrosion in almost violent soils of certain areas. Efforts are made to give special artificial treatment to the soils at such places. The use of driven rods is also becoming common. Further, the earth leads should also be of proper size to ensure minimum resistance. The connection at the points should be tight and must not be allowed to give rise to any galvanic corrosion. The earthleads or driven rods may be of sufficient size, capable to withstand the fault currents according to the derivation in terms of symmetrical components, where the letters denote the usual meaning:

$$I_f = \frac{3 E_{ph}}{Z_1 + Z_2 + Z_0}$$

In this connection, however, research needs to be carried to find more economical material for earthing conductor or rod. It should at the same time be more anticorrosive, less resistive and capable of withstanding more mechanical strains.

**Developing Power Systems**

There are certain essential prerequisites for an efficient operation of a MV earthing system, especially in a fast developing power distribution system which poses a number of problems of techno-managerial nature. Broadly, there are the following important factors by virtue of the developing nature of the system.

(*a*) Organizational efficiency.

(*b*) Design Standards of Earthing System.

(*c*) Workmanship/Testing Routines.

(*d*) Training potential.

(*e*) Legislation and Educational measures.

Each of the above points is discussed below.

(*a*) **Organizational.**—Need for an overall efficient organizational set-up in a power utility hardly requires emphasis. The organisation must be capable to ensure implementation of the technical policies, working procedures and standards. For that matter, the general requisites laid by established management principles have to be fulfilled. Although this factor is important for all activities in a power system, yet its contribution in the case of earthing practices, even small cannot be ignored either.

(*b*) **Design Standards.**—The design standards to be laid for earthing practice are pivotal for efficient operation of grounding system. This involves choice of various factors, *viz* :—

(*i*) Whether multiearthed neutral system is to be adopted or any other form according to the condition peculiar to the system.

(*ii*) Adequate fusing practice adopted for the substations and L.T. mains.

The multiearthed neutral system is at present widely practised in most of the developing power systems. In West Pakistan, this was adopted a few years back and the relevant regulations were amended. The new system provided for earthing the neutral of 3 phase 4 wire AC system at the source and at one or more points along the run of the circuit and at each consumer's premises. At the same time, the use of cradle guards on low tension lines was rendered unnecessary. The old system as laid down in Indian Electricity Rules of 1937 providing for cradle guards and continuous earth wire grounding system was abandoned. Fusing practice on secondary side of distribution transformers was also discarded for transformer up to 100 KVA.

Similarly, another change which West Pakistan experienced was from cooper to aluminium conductors in the medium voltage system. With this change, the incidence of electrocutions increased in alarming proportions. The earthing system did not operate satisfactorily in many cases. An investigation revealed that the maloperation of earthing was due to the following factors which are more relevant to design practice:—

(*a*) In areas of high resistivity, the ground contact was poor, thus introducing high impedence in the fault loop. Such cases are about 40% on average. These were however much less with continuous earth wire and cradle guards. Thus cradle guarding arose as a necessity to ensure proper operation of protection particularly in medium voltage. In case of 11,000 Volts and above, guarding can however be dispensed with, in view of sufficient driving force.

(*b*) In 70% cases, the electrocutions were due to broken conductors remaining live on the ground. This happened even in areas where the specific resistance was low. This can be briefly explained; Let us take the case of a pole mounted three phase distribution transformer feeding on L.T. overhead line without secondary fuses. The HV side of the transformer is protected by ungauged drop out fuses. When there is a conductor breakdown on one phase on the line, corresponding 11 KV. single fuse blows. The two 11 KV phases cause induction on the secondary side of the transformer; thus fault power flows through the broken conductor, the ground and neutral of the transformer. If any living body comes in contact with the broken wire at a point which is some feet above the broken ends of the conductor, it will experience a flow of current through the body giving electric shock. In cases of animals having more sensitive nerves, the shock is more likely to prove fatal. As a matter of fact, there will be gradient of protential along the broken conductor up to the transformer, with zero at the broken end (provided the grounding contact is good). If, however, there is fuse on the secondary side of each phase, the portion of the broken conductor on transformer side will be isolated, while that of load side might remain live as a result of back-feed. This will, however, minimize incidence of shock. Another measure to reduce electrocutions from broken conductor can be to use insulated conductors, but that will be costlier.

(*c*) With the rapid introduction of aluminium conductor without wide spread adoption of proper working techniques, it resulted in tremendous rate of conductor breakdowns on account of galvanic corrosion/oxidation etc., thus endangering safety as explained in paras (a) and (b) above.

(*d*) In some cases, the unnecessary long length of L.T. lines rendered greater fault impedences thus creating difficulties in isolation of faulty portions.

(*e*) In a number of cases, electric shock took place on leakage of insulated service lines energizing the pole or stay wire. In such cases, provision of pole fuses might help. However, if the pole being energized is not duly earthed, the resistance of pole/structure will increase the impedence of the fault loop and the energized metal parts may not be isolated.

Thus, in view of the above, it may be concluded that straight adoption of multiple earthing of neutral for all areas (including those with high resistivity) without ensuring minimum incidence of conductor breakage is not fool proof. In Pakistan, we have hilly areas, marshy soils, soils hit by salinity and waterlogged and normal compact soils of urban areas. Thus in areas where there are more possibilities of poor grounding contact or high specific resistance of soil, the chances of breakdowns are more, the provision of continuous earth with cradle grounds is desirable for efficient operation of earthing system. The design standards should, therefore, account for these points. While providing cradle guards, efforts have to be made to ensure proper clearance so that these do not become fault hazards.

Further, proper fusing practice on L.T. mains as well as service T-points is considered desirable to ensure greater safety. In this case, however, increased number of outages due to more fuse blowing is another aspect of the extensive fusing practice; but this can be controlled with a proper organization.

(3) **Workmanship/Testing Routines** An important cause for the maloperation of grounding system may be poor workmanship at any point in the earthing circuit. This deserves attention at many important positions viz :—

(*a*) Joints especially of bimetallic type.

(*b*) Connections being loose.

(*c*) Earth electrodes/rods not of standard.

(*d*) Absence of anticorrosive and other low impedence measures.

(*e*) Insulation failures of service lines be minimized

Considering each of these points, the first one relates to the Al/cu connections on the network. If these points are not duly prevented from oxide formation or the galvanic corrosion, it may result in increased impedence in the circuit and even cause incidence of breakages, thus endangering safety. Next, the connections of the earthing leads and other junctions need to be secure preferably under compression. The electrode has also to be buried deep enough and treated artificially keeping in view the considerations of low resistance and avoiding soil corrosion.

The most important step to be taken to ensure good earthing system is the evolution of a proper cell for regular comprehensive testing the earthing resistances at fixed intervals. This is imperative in developing systems where the rapid rate of development may not ensure proper workmanship in laying earthing system. Need for regular testing is also necessitated from the fact that the earths are likely to be deteriorated in varying soil resistivity around the buried electrode as well as the corrosive effects of soil. Regular inspection of earths may also enable detection of loose and corroded points. In this connection, it may be of interest to see the resistivity test results carried in Lahore (Fig. 2).

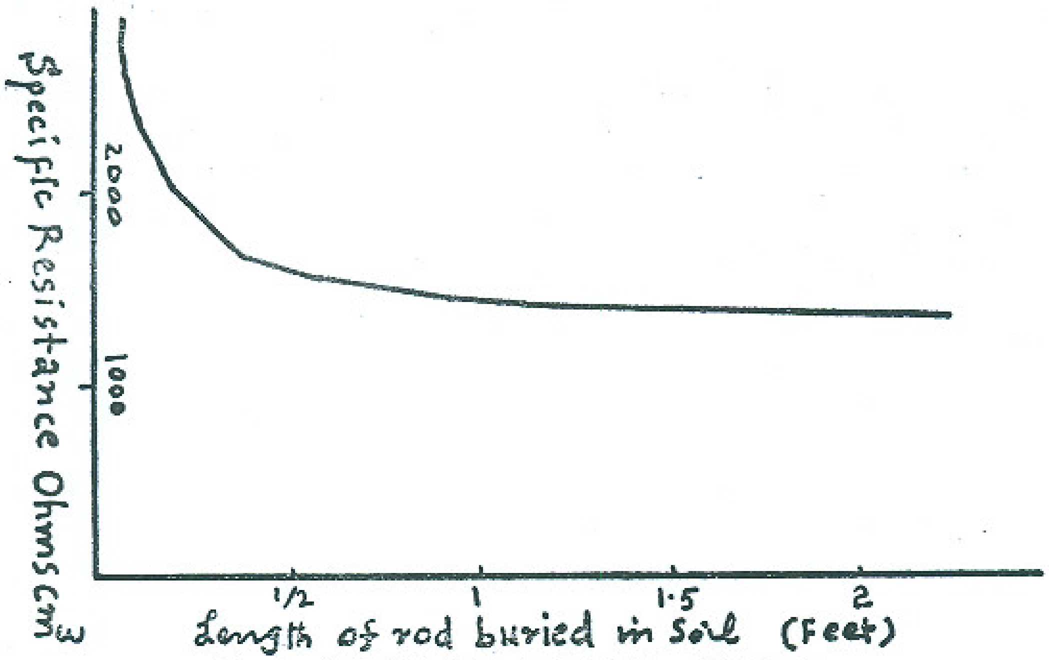


Fig. 2. A Soil Resistivity test at Lahore (Pakistan)

(*d*) **Training Potential.**—The developing systems usually face the problems of finding trained personnel at the pace of development. Consequently, it affects the workmanship standards as explained above. The wide-spread introduction of Aluminimum conductor, mainly for economic considerations, poses specific challenge of workmanship and requires trained workmen to handle it. In Pakistan, such a problem did arise and the rate of development has almost out-stepped the speed of training personnel. This, however, is being streamlined now. Thus it is imperative for a power utility to introduce extensive on-the-job training opportunities as well as the regular training institutes for the growing training needs.

(*e*) **Legislative and Educative Measures.**—Legislation is meant to help regulate efficient earthing system both by the Licensee of the power supply undertaking as well as the consumers. In Pakistan, the Electricity rules were amended once a few years ago as briefly stated earlier. Still need is felt to augment these rules to meet the new challenges of endangered safety. Generally, the usual approach in Electricity rules is to specify the earthing procedures. This may not be enough in modern socio-economic trends peculiar to a developing system and law may also lay the following where necessitated :—

(*i*) Testing schedules for the earths both at the supply and the consumer's end.

(*ii*) Machinery to control the workmanship of electrical gadgets in the market to avoid leakages etc.

(*iii*) Adoption of educative measures for the general public to apprise them of safety rules and precautions.

In developing systems where literacy percentage is low, special measures may be adopted to educate consumers *viz* : (1) Slides in Cinemas/T.V. be frequently shown. (2) Suitable literature in simple language be produced and adequately circulated. (3) Articles in the general press be published. Symposia and lectures may also be arranged from time to time.