BANGLADESH RURAL ELECTRIFICATION BOARD

PBS INSTRUCTION 100-22

ADEQUATE GROUNDING ON PBS DISTRIBUTION SYSTEM

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SUBJECT: ADEQUATE GROUNDING ON PBS DISTRIBUTION SYSTEM

I. PURPOSE:

To provide technical guidance for adequate grounding of PBS distribution system.

II. GENERAL:

Grounds are provided in PBS distribution systems to relieve the system of abnormal voltages and currents, to stabilize the neutral at or near earth potential, and to provide a low impedance return circuit for a maximum degree of safety to operating personnel and the public.

For safety, it shall be ensured that in both normal and abnormal situations, no undesirable voltage appear on equipment or lines for which accident may occur. To comply this all metallic items and neutral of equipment and lines are to be connected to earth.

III. SYSTEM GROUNDING:

System grounding for PBS distribution system must conform to the requirements of the Electricity Safety Code.

(1) Grounding of Sub-station:

An effective sub-station ground system consists of driven ground rods, buried inter-connecting grounding cables or grid, equipment ground mats, connecting cables from grounding grid to metallic parts of structures and equipment, connections to grounded systems neutral. The specification of Sub-Station grounding rod is mentioned below-

Ground rod will be Copper weld (Clad) ideal driven electrode. It will be protected against corrosion by a 3 (three) mm thick exterior of copper tube, permanently welded/bounded to a high strength steel core.

The maximum resistance to earth in a sub-station shall be less than 0.5 (zero point five) ohm. The 33/11 KV transformer neutral shall be solidly grounded by connection to the sub-station ground mat.

(2) Grounding of Distribution Line:

A driven ground rod shall be installed at each equipment location, individual service and secondary dead end. The primary neutral shall have a ground connection at least every 402 m (1320 ft.) or less, in addition to the ground connection at the individual services. More ground connections may be needed to limit the voltage rise on the system neutral. The number will depend upon the resistance-to-earth of the individual electrode, earth resistivity, and magnitude of neutral and earth return current.

(3) Grounding of 11 KV network/ secondary dead end and services.

Maximum resistance to earth in line or secondary dead end and service shall be 10 (ten) ohm but it is desirable within 3 Kilometer from sub-station less than 5(five) ohm. All equipment cover in 11 KV line or secondary or service dead end are to be grounded.

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Where buried bare concentric neutral in contact with the earth is employed, the concentric neutral need not be grounded every 402 m (1320 ft.)

Table-I describes the BREB accepted grounding assemblies and gives recommendations for their use.

If grounding is stolen, it must be reinstalled immediately of occurrence. If it can not be reinstalled then power supply will be switched off in that section of line and will not be re-energized till replacement of neutral. Senior General Manager/ General Manager and AGM (O&M/E&C/P&M) must adhere to this instruction.

IV. MAGNITUDE OF GROUND RESISTANCE:

50 (fifty) Hertz system ground resistance requirements are usually met by the inherent low resistance of the multi-grounded neutral.

Resistance to earth of the individual grounding electrodes is significant, principally when considering the effects of lightning. Low resistance grounds drain to earth much of the energy in lightning surges. Much of this energy is dissipated close to the point of the lightning stroke. Where high resistance grounds exist, lightning surges may travel over many miles of line before the energy is finally dissipated.

Though low resistance grounds are always desirable, they are not essential for primary equipment protection. Failures of primary equipment protected by gaps or arresters commonly occur because of conditions other than high resistance grounds. Failures are often the result of excessive voltage produced by surge current flowing through unnecessarily long arrester leads. Because primary equipment failures are seldom due to ground resistance problems, system grounding improvement programs for the sole purpose of reducing primary equipment losses are seldom justified.

On the other hand, resistance to earth of individual grounding electrodes is a factor where lightning repeatedly causes damage to secondary equipment and wiring. Often this difficulty is due to failure to interconnect to the primary system neutral with grounded objects on the secondary; such as metallic water piping systems, well casing and grounding electrodes. This lack of interconnection will have far more effect in high resistivity soil areas than in low resistivity soil areas. To improve protection of secondary equipment and wiring, the first and usually only action necessary is to interconnect all secondary grounds with the primary system neutral. If this is ineffective, the resistance to earth of the existing secondary grounding electrodes should be lowered or additional grounding electrodes should be installed. If this measure is unsuccessful, a secondary surge arrester placed close to the entrance may prove helpful.

The resistance to earth of an individual grounding electrode is dependent upon its depth in the earth, contact area, chemical makeup and moisture content of the surrounding soil. The ground rods should be driven at least 2.8 M (9 ft.) into the earth and deeper into the permanent moisture level, if conditions permit. Rods in the permanent moisture level will lend to minimize the variation of ground resistance due to the seasonal fluctuation of moisture content in the soil. At locations where one ground rod does not provide sufficiently low resistance, the resistance may be lowered by installing two or more ground rods in parallel. If two or more ground rods are used, they should be at least 2 m (6 ft.) apart for optimum benefit. Spacing of less than 6 ft. will result in overlapping of the ground rod currents being dispersed into the earth and increase the resistance to earth of the parallel ground rods. Where enough space is not available and one ground rod of 8 ft long 5/8" diameter does not provide sufficient low resistance, the resistance may be lowered by doubling the diameter of the electrode. This will reduce resistance about 10%

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approximately.

Another method used to lower the resistance to earth of a grounding electrode is chemical treatment. This consists of treating the soil surrounding as the grounding electrode with chemicals such as sodium nitrate, ammonium sulphate, calcium chloride, sodium chloride or any other suitable chemical. Three main disadvantages of this approach are:

1. Chemicals could promote or add to the corrosion rate of the grounding electrode.
2. Chemicals could contaminate nearby water supplies and be harmful to deeply rooted vegetation.
3. Chemicals may dissipate and periodic chemical treatment may be needed. It is, therefore, recommended that chemical treatment be considered only when multiple grounding fails to provide sufficiently low ground resistance or when existing conditions make multiple electrode grounding impractical.

V. GROUNDING SYSTEM ARRANGEMENT IN SUB-STATION

The system function is served by providing the lowest practical resistance between circuit neutral and true earth. When a sub-station bus or transmission or distribution line is faulted to ground, the flow of ground current may be between portions of a sub-station ground grid, between the ground grid and surrounding earth, along connected overhead ground wires, or along a combination of all these paths. The fault current flowing between a sub-station ground grid and the surrounding earth will result in potential gradients within and around the sub-station, which can result potential hazard to a person on or near the sub-station.

Therefore to relieve system abnormal voltage and currents, following matters are to be done carefully.

(a) The ground system grid consisting of bare conductors buried in the earth are to be connected to grounded neutrals, equipment ground terminals, structures and fences at specified intervals.

(b) The ground grid encompasses all of the area within the sub-station fence and extends at least 0.61 meters (2.0 feet) is recommended, outside the sub-station fence. A perimeter grid conductor should be placed at 0.61 meter minimum (0.91 meter is recommended) outside and around the entire sub-station fence including the gates in any position. Perimeter grid should surround all the equipment and structures, if the fence is located far from the cluster.

(c) The ground grid should be buried at minimum 45 cm (18 inch) below final earth grade excluding crushed rock covering of 10 cm. For dried area deeper burial may be required to obtain desired value of ground resistance.

(d) Ground grid's main conductor spacing should be equal and not less than 2 meters (6.6 feet) and not more than 9 meters (29.5 feet) passing in one direction. The ground grid secondary conductor running transversely to the main conductor and spaced approximately twice to the main conductors. Main conductors and secondary conductors should be bonded at points of cross over where a bonding symbol is indicated on the drawing by thermiwelet process. Connections to equipment and structures shall occur at junctions between the main and secondary conductors.

(e) Operator's platform or mat connected to the operating handle shall be connected to the grid at least at two places and the operator must stand on this platform to operate the device.

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(f) Surge arrester must be grounded to ensure protection of the equipment they are protecting and to minimize high potential gradients during operation.

The surge arrester grounds should be connected as close as possible to the ground terminals of the apparatus to be protected and have as short and directed a path to earth as practical. Arrester lead should be as free from sharp bends as practical. It is recommended that a separate copper conductor(s) be used between the arrester ground terminal and the sub-station grounding grid.

(g) If the earth resistivity is too high, deep electrode may be required to be placed to achieve a satisfactory resistance. High resistivity may be seasonal because of dry seasons. Rods are most commonly used electrodes.

(h) The size of the ground grid conductor should be 1.5 times the present fault current with 3 seconds duration. On this basis, the following sizes of copper cable are minimum requirement against fault currents mentioned.

Copper Size (AWG)	Nominal Diameter (Inch)	Fault Current (Amperes)	Cross-Sectional Area	
			Circular mill	$Inch^2$
# 3	0.2294	10,000	62620	0.04133
# 1	0.2893	15,000	83690	0.06573
# 1/0	0.3249	20,000	150600	0/08291
# 3/0	0.4096	30,000	167800	0.1318
# 4/0	0.4600	40,000	211600	0.1662

(i) Ground rods, copper or steel rod of at least 1.6 cm (5/8 inch) in diameter and 2.5 meter (8.0 feet) in length, should be installed as per drawing with tops 5 cm (12 inch) minimum below the ground grid connections. Those rods should be installed where large ground currents may be expected, such as surge arrester's connections and transformer neutrals.

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VI. GROUNDING SYSTEM ARRANGEMENT IN DISTRIBUTION LINE

To have better grounding system in distribution line the primary neutral shall have a ground connection at least every 402 M (1320 ft) or less through poles in addition to the ground connection at the individual services. More ground connections may also be needed to limit the voltage rise on the system neutral. All equipment are also to be grounded according to the requirement of Electricity Safety Code. A pole can be protected from lightning damage by grounding the pole and extending the ground wire the length of the pole. Either a butt plate or butt wrap ground may be used if a driven ground rod is not required for system or equipment grounding. The pole protection assemblies do not satisfy the requirements for a system or equipment ground, but do provide some additional neutral grounding.

In the past, the ground wire extension above the neutral on 11/6.35 KV assemblies has resulted in pole top damage and radio noise. The ground wire extension should be located 100 mm (4 inch) directly below the pole top pin. A gap larger than 100 mm may result in gouging of the pole's surface from lightning surges near the top of the ground wire. A gap of less than 50 mm (2 inch) may result in radio and TV interference. The potential for pole top damage and radio noise can be minimized by careful installation of present designs and use of ground wire clips, rather than staples above the neutral. On a guyed 11/6.35 KV pole, the anchor may serve as the pole protection ground with the M2-9 pole top extension and the guy strand completing the assembly.

Pole protection assemblies should not be used at railroad crossings or over telephone lines of more than two circuits. At these poles, a higher insulation level is desirable to minimize line flash-overs and possible conductor or pole damage.

Ground wire extensions above the neutral are not needed at poles where a primary lightning arrester is connected to single-phase lines or the center phase of three-phase lines. An exception to this occurs on three-phase lines when the equipment and arrester are connected to the center phase and may be moved to an outer phase at a future date for load balancing or other reasons. In these cases, the ground wire extension to the pole top may be needed.

On new pole installations, system pole damage experience and local lightning conditions will determine whether pole protection grounds should be installed. Where system experience is not conclusive, the following recommendations may be used as a guide:

(1) In areas where thunderstorm days per year average 50 or more, a ground and pole protection assembly should be installed on each primary line pole.

(2) In areas where thunderstorm days average from 30 to 50 days per year, a ground and pole protection assembly should be installed on each multi-phase primary pole.

In these latter areas, the importance of single-phase primary lines and future plans for such lines will determine the extent of grounding necessary.

VII. INFLUENCE OF GROUNDING ON ANCHOR ROD CORROSION

The combination of copper grounding electrodes and steel anchor rods connected to the system neutral sets up a galvanic action which could lead to corrosion and failure of the anchor rods. The rate of anchor rod corrosion is dependent upon the soil characteristics, earth resistivity, and the ratio of buried steel to buried copper connected to the system neutral. Anchor rod corrosion problems tend to appear in areas that have low soil resistivity and a low ratio of buried steel to buried copper. Corrosion can be significantly reduced by increasing the ratio of buried steel to buried copper connected to the system neutral. This may be accomplished by installing more galvanized steel ground rods. If anchor rod corrosion problems are severe, installation of cathodic corrosion protection may be needed.

As a general recommendation, anchor rods and grounding electrodes should be made out of the same metal, preferably galvanized steel.

VIII. GROUNDING CONDUCTOR

BREB requires the grounding conductor shall be not less than No. 6 copper or equivalent, and it must provide at least one-fifth the conductivity of the neutral of which it is attached. For example, No. 6 AWG copper ground wire can be attached to no larger than 4/0 ACSR neutral.

On system grounding assemblies, either copper or aluminum ground wire may be used above ground, galvanized steel or copper (bare or covered) wire is permitted underground only. Aluminum wire should not be used below ground.

Stranded wire is recommended for jumper wire because of its greater resistance to damage from repeated bending and flexing. Solid wire should be used for the pole top extension because of its resistance to damage from lightning surges. The ground wire on the pole above ground can be either solid or stranded. However, stranded wire is more susceptible to mechanical damage by driving of staples or climbing. If aluminum ground wire is used on the pole, a solid wire is preferred. The aluminum and copper or iron wire must be joined by an aluminum compression connector to prevent corrosion.

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Short pieces of ACSR conductor, not suitable for other purposes, may be used for grounding wire only in areas relatively free from contamination.

It is recommended that similar metals be used as much as possible, such as copper covered staples with copper wire. Where dissimilar conductors are to be connected, a suitable corrosion resistant compression connector should be used.

IX. TEMPORARY GROUNDING

Personal Protective grounding for Lineman at the Work Location

The objective of personal protective grounds are to limit current flowing through the lineman's body to a safe value. Personal protective grounds also limit any voltage rise on the de-energized line which may occur due to induction and capacitance of nearby energized lines or thunders.

The safety of lineman working on de-energized electric lines requires personal protective grounding set for their safety. The linemen are to be trained to install the personal protective grounding set for maximum protection. The personal protective grounding set have to have the capacity of handling the fault current available.

If the lineman is in contact with conductor and his feet are contacting the ground wire on the pole, and if the line is accidentally energized, then the current will flow through the lineman's body. The only resistance to flow current is the resistance of the lineman's body and the ground resistance. The same thing will happen, if it is steel pole or tower.

If there are no grounds on the pole and the pole is dry, we would have much different condition, the resistance of the man's body would be in series with the resistance of the wood pole and earth. If there is a flow of current due to accidental energization of the line. In this situation the current flow through the man would be much less than in the pole where ground wire exists.

Selection of Personal Protective Grounding Cable

To select the size of the personal protective grounding cable, the fault current developing at the working place are to be known or determined afterwards clearing time of circuit protective device are also to be known. Using the above data, select grounding cables and clamps which are adequate for the duty. It is recommended that the total resistance of the cable and clamps should not be more than 0.005 ohm. Number 2 copper cable is capable of handling approximately 13000 A for 0.5 sec. The resistance of # 2 copper cable is 0.000162 ohm per feet. For about 30 ft it is 0.005 ohm.

Tolerable Limits of Body Current

If the line is accidentally energized, the current will pass through the body. Effect on of body will depend on the amount of current passing, duration of current flow and the weight of the body. Considering frequencies at 50 Hz., 110 lb weight and duration 0.03 to 3.0 seconds, effect on a human body can be summarized as follows.

Sl No.	Effect on Human Body	Amount of Current
1	No sensation	less than 0.5 mA
2	Slight sensation	0.5 mA to 2.0 mA
3	Muscular contraction	2 to 10 mA
4	Painful shock, inability to walk	5 to 25 mA
5	Violent muscular contraction	Over 25 mA
6	Ventricular fibrillation	50 to 200 mA
7	Paralysis of breathing	Over 200 mA

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So the current flowing through the body must have to be limited to an amount which can be safely tolerated.

Temporary Grounding Procedure

1. A critical factor in applying personal protective grounds for protection of lineman is to absolutely control the maximum voltage stress across the work area. This control is best accomplished by installing Personal Protective Grounding Set at the work site and in parallel with the workman. In no circumstances, linemen shall work on line without installing the Personal Protective Grounding Set.
2. There may be situation where it is neither practical nor possible to ground at the work location, then it will be necessary to ground both side of the work site at the nearest poles. But installation of personal protective grounding at the work location i.e on the same pole provides best margin of safety.
3. Before placing grounds, "fuzz" the line with a hot stick to make sure it is de-energized.
4. Grounding cables in any case must not be less than the conductor size.
5. Grounding Procedure:

   Use Hot Stick for fastening ground cables.

   Step-1: Securely fasten ground cable hot-line clamp to the neutral with Hot-stick.

   Step-2: Fasten the other end of the cable to the phase-wise nearest to the neutral.

   Step-3: Progressively ground other phases by Hot Line Clamp by fastening to phase-wise grounded in Step-2. The same procedure shall be followed to ground other phase-wise.

   Step-4: Fasten the Hold Card.
6. Use a clean dry hot stick and rubber gloves when applying and removing ground cables.
7. Remove cables in reverse order - remove the clamp from the grounded neutral last.

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TABLE-1

11/6, 35 KV SYSTEM GROUNDING AND POLE PROTECTION ASSEMBLIES

UNIT	DESCRIPTION	PURPOSE	RECOMMENDED FOR USE AT
M2-1	Driven ground with pole top extension.	To provide system and equipment grounding and lightning protection of poles except at Grade B crossing (For the purpose of this table Grade B crossing are railroad crossings & crossings over telephone lines of more than two circuits.)	(a) 402 M (1320 ft.) intervals along primary line; (b) Secondary dead ends. (c) Single-phase or V-phase installations connected to outer phases of multi-phase lines. (d) Do not Use at Grade B crossings
M2-11	Driven ground without pole top extension.	To provide system and equipment grounding. It does not provide pole top lightning protection by itself.	(a) Grade B Crossings. (b) Equipment connected to single - phase lines. (c) Three-phase power banks, three-phase re-closer, sectionalizer regulator and capacitor installation. (d) Same locations as M2-1 where lightning is not a factor.
M2-2A2	Galvanized steel but plate ground with pole protection.	To provide lightning protection of poles. This is not a system grounding assembly.	(a) All primary poles where thunder storm days exceeds 50 per year. (b) Do not use at grade B crossing & at Guy pole where M2-9 has been used.
M2-3	Trench type ground with pole top	To provide system and equipment grounding and lightning protection of	(a) Substitute for M2-1 in rock location. (b) Don not use at grade B

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	extension.	poles where rock conditions make driven grounds impractical.	Crossings.
M2-13	Trench type ground without pole top extension.	To provide system and equipment grounding where rock conditions make driven grounds impractical. It doesn't provide pole top lightning protection.	(a) Grade B crossing in rock locations. (b) Substitute for M2-11 in rock locations.
M2-9	Pole top extension from neutral	To provide protection from lightning.	(a) At guyed poles in primary lines where driven grounds is not required. (b) Do not use at grade B crossing.
M2-12A2	Galvanized steel butt plate	This is not a system grounding assembly.	(a) All primary poles where thunder storm days more than 50 per year. (b) Do not use at grade B crossing & at guy pole where M2-9 has been used.
M30-1	Pole top extension on guyed poles	To provide pole top protection from lightning.	(a) At guyed poles in primary lines where driven ground is not required. (b) Do not use at Grade B crossings
M30-2	Pole top extension on V-phase and three phase grounding or pole protection assemblies.	To provide pole top protection from lightning. This is not a grounding assembly but is intended for use with butt plate, butt wrap or driven ground assemblies.	(a) At three and V-phase poles where thunder storm days are more than 30 per year. (b) Do not use at grade B crossings.

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Note:-

The following standard shall be followed for grounding purpose at distribution transformer-

Sl No.	Transformer Size	Ground Rod Size	Remarks
(a)	Up to 25 KVA	16′×⅝″ Hot Dip galvanized MS rod	Red oxide shall be used at welding for rust protection
(b)	Above 25 KVA	32′×⅝″ Hot Dip galvanized MS rod	

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