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Substation Preventive Maintenance Manual

Prepared By
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New Delhi-Washington, D C

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For
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SUBSTATION
PREVENTIVE MAINTENANCE MANUAL
(FINAL DRAFT)

HARYANA STATE ELECTRICITY BOARD

Prepared Under The

THE UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

Contract No OUT-PACE-I-804-96-0002-00

Prepared by The

IRg INTERNATIONAL RESOURCES GROUP

NEW DELHI -WASHINGTON,DC

PANCHKULA, HARYANA INDIA

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I INTRODUCTION

The International Resources Group (IRG) is providing technical assistance to the Haryana State Electricity Board (HSEB) under the United States Agency for International Development (USAID) Contract No OUT-PACE-I-804-96-00002-00 As the initial step, IRG was to examine the operating efficiency of the existing distribution system Upon the completion of this activity, IRg presented the results to the Chairman HSEB, Mr Ranjit Issar, and the Members of the board The Chairman HSEB, based on the results of IRg's investigations, requested an evaluation of the existing transmission and distribution substations

The IRG team visited a number of substations in an effort to identify the probable cause of the large number of HV substation power and distribution transformer failures A presentation was given to the Chairman and the Members of the Board on June 18, 1998 The results of the IRg investigations indicated the need to increase the maintenance quality, review and upgrade system protection practices used on the HV substations and on the distribution transformers

HSEB is procuring about US$ 60 million in equipment and material to upgrade portions of the heavily overloaded distribution system facilities utilizing funds available from the World Bank as part of a loan to the Central Government of India, World Bank Loan APL-1

HSEB Chairman requested that a substation preventive maintenance program be developed for implementation by HSEB This document is a substation preventive maintenance manual that provides basic guidelines to the Haryana State Electricity Board (HSEB) It includes the procedure to establish a computerized equipment preventive maintenance program primarily for substations

The manual also includes procedures for the performance of substation equipment maintenance These procedures are also applicable to distribution transformers This document is a complement to the existing maintenance manual of HSEB For completeness the HSEB Maintenance Manual has been included as Attachment 1

A procedure to develop the necessary equipment database that would permit computerization of the maintenance program is included The development and use of the computer program will ensure that the preventive maintenance activities are performed timely, that equipment failures are properly recorded, including downtimes, that spare parts are identified and procured timely and that individual equipment performance tracking is maintained

The computer program is to be developed by the Haryana State Electricity Board personnel using the procedures and guidelines included in the manual and the preventive maintenance Manuals that were provided by the manufacturers when the equipment was purchased It is essential that all guide lines and recommendations made within the body of the Manuals are followed to achieve their intended objective for a long-in-service life of the equipment

Installation and construction guide lines for workmanship, material, conductors sizes, fuses sizes, parallel groove and compression type connectors and use of proper tools must be observed if the program is to succeed At present HSEB is in need of having an intensive system upgrading and maintenance program to reduce the large number of transformer failures and equipment outages

This is a complementary manual to the existing HSEB Maintenance Manual Throughout this complementary manual emphasis is made on quality control of the various maintenance activities and on safety Implementation of the procedures stated herein will aid in the reduction of equipment downtime and frequency of occurrence of each of these outages

It is noted that out of the 31,000 distribution transformers that failed every year, about 20,000 transformers are cannibalized (used) to repair about 11,000 The replacement cost of the 20,000, assuming an average cost per transformer of Rs 30,000, and the financial annual impact to the HSEB is 30,000X20,000 is approximately Rs 620 million or about US $ 14 6 million, a rather significant amount

II HSEB SUBSTATIONS STATUS

A HSEB SUBSTATIONS

At the present time the Haryana Electricity Board (HSEB) operates and maintains all transmission lines and substations that transfer the electrical energy from the generation resources to the load centers of HSEB This temporary condition will be changing in the near future when the HSEB is divided into a Generation Company, a Transmission Company and about three Distribution Companies The operation and maintenance procedures presented herein are based on the assumption that each company will have access and be responsible for the operation and maintenance of their own substations

Table II 1 illustrates the system voltages and quantity of substations and distribution transformers that form part of the transmission and distribution systems There are approximately 53,159 circuit-kilometers of high-tension 11 kV (HT) feeders and 102,639 circuit-kilometers low-tension (LT) lines

TABLE II 1
SYSTEM VOLTAGE LEVELS AND QUANTITY
OF SUBSTATIONS AND DISTRIBUTION TRANSFORMERS

SYSTEM VOLTAGES (KV)	SUBSTATIONS
400	3
220	24
132	74
66	68
33	252
Distribution Transformers on 11 kV feeders	99,524
Totals	**99,942**

B IDENTIFY SOURCE OF LOSSES

The lack of adequate substation maintenance results in a low degree of equipment service reliability, loss of service to electric power consumers and in power losses that are not economically acceptable to HSEB

The main source of power losses at the substation is in the power transformer and auxiliary equipment However, there is another source of power losses in a substation which is usually the result of poor connections between the bus and line conductors, disconnect switches, circuit breakers, reclosers, and fuse cutouts There are at times poorly designed and/or deficient installations, and/or use of lengthy and undersized jumpers, use of non appropriate connectors to ensure a solid connection, and the making of connections between copper and aluminum and other material without the use of appropriate bimetal connectors The splicing of non-alike metals results in galvanic corrosion that eventually gives rise to a high power loss splice The continued use of non-essential equipment (fixed or rotating) also leads to power losses which are not acceptable to HSEB

A visual inspection of the substation may indicate some deficiencies to the experienced eye There are, however, many high resistance connections and, therefore, high power loss components, within the substation that can only be detected by the use of a special device called the Thermovision scanner

The Thermovision scanner is used to detect electric power system components that are operating at temperatures above their normal designed thermal capacity The use of a Thermovision scanner by substation maintenance personnel permits to determine the location of 'hot spots' or connections that are operating at abnormally high temperatures

C APPROACH TO LOCATE AND EVALUATE POWER LOSSES

The location of the source of power losses must be identified prior to the development of any action plan to reduce them The basic approach is as follows

1 Perform Thermovision scanning of all equipment, conductors, connectors and jumpers at the time of the substation peak load

2 Take measurements to determine contact resistance of equipment with scanned hot spot such as jumpers, connectors, transformers, etc **"before"** any corrective actions are implemented

3 Visually look for other sources of losses such as operation of non-essential, overloaded and/or undersized equipment

4 Develop and implement solutions to correct deficiencies and reduce power losses

Once the losses and their sources are identified from the above tests and corrective measures implemented to reduce these losses Perform the following evaluation to quantify the technical and economic benefits

5 Take measurements **"after"** the implementation of the corrective actions to evaluate the benefits, if any, of the changes made Ensure that the implemented measures are effective in reducing the energy losses

6 Repeat the Thermovisions canning of all the equipment, conductors and jumpers at the time of the substation peak load All previous 'hot spots' should now have been eliminated

7 Compute the reduction or savings in losses and perform an economic evaluation to determine the benefits which will then be used as input to the action plan matrix included at the end of this Chapter

D CONNECTORS

It appears to be a practice of the HSEB to utilize whatever material is available at the time of need This practice results in the use of wrong connectors for a given application or no connectors at all Connectors that are not correctly applied are a very common source of system power losses

To reduce the power losses at the substation, the correct connector for the application must be used

1 A specific application requires the correct connector to be selected and used The connector selected must match the configuration of the connected equipment Adding connectors in series will only add to the overall connector resistance, thus increasing the I^2R losses Select only one connector per connection

2 Connection of different metal types requires the selection of the correct bimetallic connector

3 The correct metallic bolts must be used with bolted connectors Application of the correct torque value must follow the manufacturer instructions

4 The correct size connectors must be used for the equipment termination being connected

5 The correct contact pressure must be reached by using either the correct bolt torque, or correct gun and cartridge for wedge connectors, or correct crimper and dies for crimped connectors

E TRANSFORMER COOLING

All substation transformers have an oil and air (OA) rating for a winding temperature rise of 65°C above the 30°C ambient with natural air-cooling Some transformers have an additional 25 per cent increase in thermal capacity over the OA rating through the use of forced cooling air fans The additional cooling capacity is derived from the use of cooling fans use to limit the winding temperature from rising above the 65 °C design temperature

If the transformer is carrying a load that is lower than the normal transformer OA rating, the operation of the fans is not required If fans are turned on manually and kept on running continuously, this is a waste of electrical energy and should be eliminated by turning off the fans

F TRANSFORMER TAP CHANGERS

It appears that in general, the HSEB has available at their substation transformers that were purchased with a variety of different tap changers to maintain bus voltage within the prescribed operating criteria

There are existing transformers with load tap changers which are defective and are either frozen on a particular tap position or which can not be operated onto a tap setting under no-load conditions

The optimum manual-tap position is determined by checking voltages on the primary feeders down the line at the time of the system peak load and during light load conditions Then, it is determined whether the voltage variation for that particular tap setting is within the acceptable operating criteria limit

It is necessary that load tap changers be maintained periodically to ensure that adequate voltage levels are maintained at the substation's 11 kV bus Incorrect tap settings may have detrimental effects on power factor, voltage and correspondingly on power losses

G CONDUCTOR SIZING

Jumper and bus conductors must be adequately sized for the main transformer loading Aluminum jumpers are used to connect equipment terminations that are almost always made of copper

Not using bimetallic connectors to connect the aluminum jumper to the copper termination pads of the equipment results in high power losses being generated due to incorrectly applied connectors

H CONTACT RESISTANCE

Breakers and reclosers have finite contact resistance internal to their tanks or enclosures With age and many interrupting operations with cumulative effects, this contact resistance could increase, thus generating I^2R losses under heavy load conditions

This contact resistance should be measured periodically and compared to the manufacturers designed values to ensure that they are within the tolerance allowed by the manufacturer If they are out of tolerance then the breaker/recloser should be taken out of service and the contacts cleaned in accordance with the manufacturers O & M procedures before putting the equipment back again into service

Typical resistances are of the order of 2 ~ 30 micro-ohms Similarly, fuse cut-outs and disconnect switches have mating parts and sliding contacts which, if allowed to deteriorate, can give rise to high resistance values

Checking for "Hot spots' with a scanner at the time of the substation peak load, alerts the users that the particular piece of equipment needs to have its contact surface cleaned since a higher than normal resistance is building up due to corrosion, oxidation, pitting, etc

I IMPROVISATION OF FITTINGS, CONNECTOR EQUIPMENT

Using equipment manufactured in accordance with a national standard (e g NEMA) is a guarantee that the equipment has been designed to operate within its ratings with no abnormal temperature rises

If, however, the equipment is modified or its connections are altered and not in accordance with the manufacturers recommendations, 'hot spots' are to be expected since the equipment is essentially put together without passing industry standards

Many times this improvisation has been found to be the source of hot spots A typical example is the replacement of fuse barrels and K type fuse links with wire hand wound across the terminals of the link connections Electrically this provides continuity to the system but from an economic standpoint **this** is a source of very high power losses, as hign contact resistances are created

It is an excellent engineering practice to use the manufacturers designed equipment for the application it was intended for Temporary solution or improvisation must not be allowed to become a permanent condition as these give rise to expensive power losses that must be avoided by HSEB

J PROTECTION COORDINATION

A visual inspection of the distribution system lines and distribution transformers that HSEB do not use them at all It appears that through time this has become an standard and expensive practice resulting in many feeder outages and transformer failures Usually the fuses on a distribution line have to be coordinated with the recloser, relay, or another fuse at the 11 kV substation side HSEB needs upgrade the entire protection system by utilizing fuses, lightning arresters, breakers at every substation and to perform coordination studies to determine relay settings and fuse types to provide coordinated protection to the HSEB system Proper system protection coordination will ensure that the operation of fuses, located downstream on a given feeder, will not take out the entire feeder and/or substation The benefit of adequate system coordination is that only the faulty section is out of service and only a few consumers are affected

Also, ground fault relaying of the substations should be set high enough so as not to cause tripping at the substation, for unbalanced loads due to incorrect balancing, or for tripping of single phase line transformers which would cause a dynamic unbalance Ground fault relaying at the substation is generally set above 100 amps

K GROUNDING

All equipment tanks, neutral conductors, etc should be adequately grounded in accordance with industry standard practices High ground resistance in neutral conductors could generate high losses when the unbalanced currents flow in the neutral conductor

Also disconnection of neutral grounds depending on where they occur could cause floating neutral voltages which could give rise to high over voltages during unbalanced loading conditions

L BASE LOSSES

It should be noted that good planning, design, or maintenance couldn't eliminate all losses in a substation Every piece of equipment, conductor and connector has its own inherent losses As an example, the main transformer has "No load losses" and "load losses" These are specified and predicted by the manufacturers during the development of transformer design drawings and specifications Transformers can be purchased with power losses that are lower by writing specifications with low loss limits that are still within design constrains although the HSEB may have to pay a higher initial price However, over the economic life of the transformer this higher price transformer is the best economic choice for the HSEB

III PREVENTIVE MAINTENANCE PROGRAM DEVELOPMENT

A GENERAL

The preventive maintenance program described herein must be computerized This will allow for easy equipment record keeping and for controlling the actual work performance of the maintenance personnel It is also, important that the times taken by different crews to perform the same maintenance activity be recorded and analyzed Bonus (monetary, time off, others) incentives are provided to crews whose equipment under their responsibility has the lowest failure rates In a similar manner those crews that fail to meet a maximum equipment failure rate would be penalized, transferred or dismissed out of the preventive maintenance group It is understood that at times equipment failures are beyond the control of the PM Each equipment case with high failure rates must be carefully analyzed for fairness on imposing penalties to PM crews

B DATA COLLECTION

The first consideration is to design the program to meet the needs of the Haryana State Electricity Board Develop a manual that is as simple as possible The starting point is to perform an evaluation of needs The following questions must be answered

1 How much equipment is involved?
2 How many people are available to maintain the equipment?

If it is found that the available staff is not sufficient to maintain the equipment or their qualifications are below requirements, then HSEB has to evaluate the economic benefits of adding qualified staff to meet PM objectives Once the answers to these questions have been obtained then the overall program development can begin

There will be need to spend only three to four hours per equipment item to compile all necessary data This includes reading the maintenance operator's manual, developing and writing the program, and ordering recommended spare parts The PM requirements remain the same and only the equipment data needs to be compiled to ensure an adequate PM program

1 Forms

Forms 1 through 3 have been designed to collect the equipment data necessary to establish the preventive maintenance program

FORM 1 This Form 1 is the Equipment Data Record It is used to collect information on the equipment that is to be maintained This includes power transformers, voltage regulators, capacitors, distribution transformers, lightning arresters, disconnect switches, current transformers, potential transformers, capacitor controllers, motors, pumps, relays, compressors, batteries, etc

Once all data has been accumulated, an equipment numbering system must be developed The system may use six-digit numbers (for example, 0021-21) The fist four digits indicate the equipment type, the fifth and sixth digits identify the items - motor, coil or relay - in each category Such a numbering system should be used throughout the program to identify and catalog materials In addition to the equipment data, information about spare parts and assembly listings is included on the lower half of Form 1

FORM 2 - List on this Form items that must be maintained or verified on each piece of equipment such as oil levels, counter readings, loose connections, oil leaks, breaker contacts, relay settings, lubricate motors, fans, compressors, check spare parts requirements, etc This Form 2 also will show PM personnel what tools and spare parts are required

FORM 3 This Form is an equipment-guide list that identifies each piece of equipment in the electrical or mechanical system by name, number, and location It simplifies the work for the new PM personnel of locating the equipment to be maintained showing the equipment name, number and actual physical location

FORM 1
EQUIPMENT DATA RECORD

Equipment ____________________ Equipment No ____________________

Cap Equip no ____________________ Location ____________________

Manufacturer ____________________ Model no ____________________

Mfg Serial no ____________________ Vendor ____________________

Date purchased ____________________ Initial start-up date ____________________

Size ____________________ Volts ____________________

Frame __________ Ratio __________ Capacity ____________________

Others ____________________

Item	Assembly listing	Part No	Manufacturer	Technical reference

Item	Spare parts	Symbol number	Stores number	Location

FORM 2
LISTS OF ITEMS THAT MUST BE MAINTAINED OR VERIFIED FOR EACH PIECE OF EQUIPMENT

Equipment ____________________ PM No ________________

Related PM No __________

Tools, Materials, and parts required

FORM 3
EQUIPMENT-GUIDE LIST
IDENTIFY EACH PIECE OF EQUIPMENT IN THE ELECTRICAL OR MECHANICAL SYSTEMS BY NAME, NUMBER AND LOCATION

Equipment ____________________ Equipment No ____________

Number	Location

C CREATING THE PREVENTIVE MAINTENANCE MANUAL

Upon the completion of the collection of all equipment data, a computerized database is built and use as the basis for the development of the various preventive maintenance activities The system lists what maintenance checks must be performed on the equipment It also indicates what tools and spare parts are required

FORM 4 – This Form 4 is the PM MANUAL It is the heart of the program It contains a one-line summary of each PM requirement for each piece of equipment The manual is arranged in numerical sequence This manual supplies all information necessary to schedule preventive maintenance, order replacement parts, record equipment history, and analyze equipment conditions

Included in each section are the PM summary sheets, equipment data records, and equipment history records In front, an index lists all equipment in numerical order All forms are filed in sequence under the equipment number, beginning with 0001

FORM 4
PREVENTIVE MAINTENANCE MANUAL

Equipment _____________ Equipment no _________ Location __________

Preventive maintenance assignments

Assignment Number		Assignment Number	

D EQUIPMENT HISTORY

FORM 5 The equipment history record, Form 5, is the last page of each section Entries on this Form should include all repairs, overhauls, modifications, and other non-PM-related functions performed on that piece of equipment Descriptions should include parts, labor, and dates This record serves as guide to accurately estimating the need for future repairs of overhauls It maintains the equipment historical records that give all information on repairs to equipment It can point out recurrent problems and warn of a serious breakdown Again, the data on these Forms is input to the computer to continue the data base development

FORM 5
EQUIPMENT HISTORY RECORD

Equipment ______________________ Equipment no ________________

Date	Worked Performed	Labor (hours)	Parts Used

E SCHEDULING

Once the basic information has been collected, maintenance schedules are developed for each piece of equipment instructing the staff as to when and what type of maintenance they are to perform The computerized printout of each schedule is issued and each maintenance crew can then transferred to larger forms designed so they may be placed on convenient bulleting boards alongside each other This arrangement allows reading horizontally across one line at a time, assuring ease in scheduling Suggested sizes of schedules are yearly, 20 x 28 in, quarterly, 44 x 28 in , weekly, 24 x 28 in Space is provided for 50 equipment items Additional schedules may be used if necessary

1 Five Year Schedule

FORM 6 The five year schedule, Form 6, should be filled out first, covering all requirements except weekly Once all equipment numbers and names have been filled, the scheduling should begin with the first item Refer to the PM manual and make the appropriate assignments in each of the four blocks, each block represents one quarter of the year Quarterly checks are entered first Semiannual requirements are next and will be scheduled in two of the blocks Annual requirements are scheduled last

2 Yearly Schedule

FORM 6 is also used to develop a yearly PM schedule In the yearly schedule, similar types of PM should be scheduled for the same quarter For example, if a transformer LTC is to be cleaned and the oil changed quarterly, scheduling an annual circuit breaker inspection for the same time may be advantageous With this method, only one major shutdown of the main feeders would be necessary Before the yearly schedule is completed, monthly assignments must be recorded in the last block The yearly schedule is completed first and then use to schedule quarterly PM All information is taken from the PM Manual

FORM 6
YEARLY SCHEDULE

Beginning Year ____________

Equipment no	Equipment	1st	2nd	3rd	4th	5th

3 Quarterly Schedule

FORM 7 This Form 7 allows the development of the quarterly schedule starting at the first block Each of the 13 blocks represents 1 week of the quarter At the top of each column, the date of each Monday of the quarter should be entered Information for the quarterly schedule is taken from the yearly schedule and the PM manual Each of the 13 blocks represents 1 week of the quarter

FORM 7
QUARTERLY SCHEDULE

Quarter ______ Year ______

Equipment Number	Equipment	2 Jan	9 Jan	16 Jan	23 Jan	30 Jan

4. Monthly Schedule

FORM 8 Form 8 is used beginning with the first week and the first equipment item, schedule all monthly assignments Each equipment item will be scheduled three times per quarter Because there are 13 weeks per quarter one segment will have a 4-week interval Scheduling will depend on how much time is available for preventive maintenance, but try to **schedule jobs evenly throughout the month Otherwise, the crews will be performing all the jobs in the first week of every month** The only time a problem may occur is if an assignment must be rescheduled, and there may not be sufficient time to accomplish it

After the monthly assignments have been scheduled, the quarterly, semi-annual, and annual assignments should be added Consult the yearly schedule for those assignments included in the quarter being scheduled Refer to PM manual and schedule similar types of assignments for the same week

FORM 8
MONTHLY SCHEDULE

Month ______________ Year ______

Equipment No	Equipment	Week-1	Week-2	Week-3	Week-4

5 Weekly Schedule

FORM 9 The weekly schedule, Form 9, is the working document for preventive maintenance An extra column of blocks may be added to include the name of the person responsible for a particular piece of equipment

The schedule should have all daily and weekly assignments, if required It can be covered with plastic so that additional scheduling can be done with a grease pencil From week to week, simply wipe it clean and, reschedule from the quarterly

To set up the schedule, transfer all assignments from the applicable week on the quarterly schedule and enter the date of Monday of the current week in the top space An X should be drawn through assignments as they are completed Assignments that are not completed should be circled At the end of the week, all completed assignments should be noted on the quarterly schedule Unfinished ones should be circled and entered in the next weekly block The weekly schedule is filled out after the yearly and quarterly has been completed It will serve as the working document for preventive maintenance

FORM 9
WEEKLY SCHEDULE

Week __________

Equipment No	Equipment	Mon	Tue	Wed	Thurs	Fri	Sat

F POINTS TO REMEMBER

It is important to remember that uncompleted monthly, quarterly, semi-annual, and annual assignments cannot be carried over in this manner These incomplete assignments are left circled

The quarterly schedule will become a permanent record of the preventive maintenance system Sometimes before the end of the current quarter, a new quarterly schedule should be filled out Unfinished semiannual and annual assignments should be transferred to it The last block in the quarterly schedule should include those assignments to be transferred All monthly and quarterly assignments not completed within the quarter should be circled

Shortly before the end of the year, a new yearly schedule should be generated Any improvements in scheduling, such as rearranging assignments and dates, should be incorporated at this time

G DISTRIBUTE WORK LOAD EVENLY

The PM is most effective when jobs are scheduled and completed on an evenly distributed basis Monthly assignments should be completed 4 weeks apart, and so on Completion of assignments on time is important in assuring uniformity of equipment upkeep

H FAILED-PART/ EQUIPMENT REPORT

The failed-part/equipment report, Form 9, provides details on work other than PM performed on the equipment This report is filled out immediately when repairs or overhauls are completed A brief summary of the repairs is placed in the equipment history record The completed forms are then filed

This form includes the equipment name and number, the failure, and its cause On the lower portion of the form, a description of the corrective action and a list of parts used for the repair should be included

I SPARE PARTS

To formulate a useful list of spare parts, consult original equipment maintenance manuals, manufacturer's information, and, most important, the individuals maintaining the equipment These sources can provide an accurate accounting of all necessary spares The list at the bottom of the equipment data record can be used as the inventory of spares, or a separate sheet may be drawn up

After the system has been in operation for a time, many recurrent problems will be noted and adequate parts support will be available A periodic review of the failed-part/equipment reports may define some potential problem areas

FORM 9
FAILED-PART/EQUIPMENT REPORT

Date ____________________ W O No ________________________

Equipment _______________ Equipment No ____________________

Failure ____

____

____

____

____

Action taken ____

____

____

____

Parts List

Part Name	Part No	Comments

Date Repaired __________________

IV TRANSFORMER IMPEDANCE TEST

Purpose

This procedure covers transformer impedance testing, one of the acceptances tests for new transformers, and a method for routine testing The results of this test should compare directly with the manufacturer's data sheet

Tools

RMS voltmeter
RMS ammeter, or two multifunction meters with 0 5% accuracy
0-105 Vac variable power supply
20 A, 120V, single- phase sources
Jumpers of various lengths

Application

Impedance test locates problems within transformer windings The tests in this task procedure apply to

- Single-phase transformers
- Three-phase two-winding transformers with and without buried tertiaries
- Three-phase three-winding transformers
- Three-phase autotransformers with and without buried tertiaries

The results of impedance tests performed in the field should be within 5% of manufacturer's data Values beyond this range should be investigated by further tests

Impedance Tests

This procedure covers single-phase transformers, three-phase two-winding transformers with and without buried tertiary windings, and three-phase two-winding autotransformers

1 Set the no-load tap changer to the nameplate voltage before proceeding with the test

2 Short-circuit the secondary terminals together and connect the voltmeters and ammeters to the high-side bushings

3 Connect the variable power supply and slowly increase the voltage to 120 volts Watch for the overcurrent range of the ammeter, change the scale if necessary

4 Record the voltage, current, and the combination of high-side bushings (e g H1-H2, H1-H3, or H2-H3)

5 Disconnect the variable power supply and move the power leads to the next high-side (or low-side) bushing combination Repeat Steps 3, 4, and 5 until all combinations have been recorded

6 Calculate the percentage impedance

Three-phase Three-Winding Transformers

The procedure for measurement of three-phase three-winding transformers and three-phase three-winding autotransformers is the same as for two-winding transformers, except that there is a total of nine sets of measurements instead of three

For 3-phase three-winding transformers, three measurements are made by the short circuit test

Zps = Leakage impedance measured in the primary with the secondary short circuited and the tertiary open

Zpt = Leakage impedance measured in the primary with the secondary open and the tertiary short circuited

Zst = Leakage impedance measured in the secondary with the primary open and the tertiary short circuited

1 Set the no-load tap changer to the nameplate voltage before proceeding with the test

2 Short-circuit the secondary terminals together and connect the voltmeters and ammeters to the high-side bushings

3 Connect the variable power supply and slowly increase the voltage to 120 volts Watch for the overcurrent range of the ammeter, change the scale if necessary

4 Record the voltage, current, and the combination of high-side

bushings (e g H1-H2, H1-H3, or H2-H3)

5 Disconnect the variable power supply and move the power leads to the next high-side (or low-side) bushing combination Repeat Steps 3, 4, and 5 until all combinations have been recorded

6 Calculate the percentage impedance The measurements must refer to the high side and the same MVA base

Calculation for Percentage Impedance (Z%)

Z% for single phase transformers

$$Z\% = \frac{V_{h1h2}}{I_{sc}} \times \frac{MVA}{(KV_{11})^2} \times 100$$

Z% for 3-phase two winding transformers and auto transformers

$$Z\% = \left(\frac{V_{h1h2}}{I_{sc\,h1h2}} + \frac{V_{h1h3}}{I_{sc\,h1h3}} + \frac{V_{h2h3}}{I_{sc\,h2h3}}\right) \times \frac{1}{6} \frac{MVA}{(KV_{11})^2} \times 100$$

Z% for 3-phase three-winding transformer and auto transformers

$$Zps\% = Zpt\% = \left(\frac{V_{h1h2}}{I_{sc\,h1h2}} + \frac{V_{h1h3}}{I_{sc\,h1h3}} + \frac{V_{h2h3}}{I_{sc\,h2h3}}\right) \times \frac{1}{6} \frac{MVA}{(KV_{11})^2} \times 100$$

$$Zst\% = \left(\frac{V_{x1x2}}{I_{sc\,x1x2}} + \frac{V_{x1x3}}{I_{sc\,x1x3}} + \frac{V_{x2x3}}{I_{sc\,x2x3}}\right) \times \frac{1}{6} \frac{MVA}{(KV_{11})^2} \times 100$$

NOTE MVA and KV_{11} refer to the primary side of transformers

V SWITCHGEAR INSPECTION AND TEST PROCEDURES

Purpose

This Procedure covers the inspection and testing of switchgear to ensure that equipment and connections are all in working order

Visual and Mechanical Inspection

1 Inspect for physical, electrical, and mechanical condition

2 Compare equipment nameplate information with latest one-line diagram and report discrepancies

3 Check for proper anchorage, required area clearances, physical damage, and proper alignment

4 Inspect all doors, panels, and sections for paint, dents, scratches, fit, and missing hardware

5 Verify if the fuse and/or circuit breaker sizes and types correspond to the drawings

6 Verify if the current and potential transformer ratios correspond to the drawings

7 Inspect all bus connections for high resistance by using a low-resistance ohmmeter Check the tightness of bolted bus joints

8 Test all electrical and mechanical interlock systems for proper operation and sequencing

9 Closure attempt shall be made on locked open devices Opening attempt shall be made on locked closed devices

10 Key exchange shall be made with devices operated in off-normal positions

11 Clean entire switchgear using manufacturer's approved methods and materials

12 Inspect insulators for evidence of physical damage or

contaminated surfaces

13 Verify proper barrier and shutter installations and operation

14 Verify appropriate contact lubrication on moving current carrying parts

15 Verify appropriate lubrication on moving and sliding surfaces

16 Exercise all active components

17 Inspect all mechanical indicating devices for proper operation

Test Values

Insulation-resistance test shall be performed in accordance with Table 4 1 Values of insulation resistance less than what this table prescribes should be investigated Over potential tests should not proceed until insulation-resistance levels are raised above minimum values

Overpotential test voltages shall be applied in accordance with Table 4 2 (derived from ANSI/IEEE C37 20 2)

Test results are evaluated on a pass/fail basis by slowly raising the test voltage to the required value The final test voltage shall be applied for one (1) minute

TABLE 4 1

SWITCHGEAR INSULATION-RESISTANCE TEST VOLTAGES

Voltage Rating	Maximum dc Test Voltage	Recommended Minimum Insulation Resistance in Megohms
0 - 250V	500V	50
251 - 600V	1000V	100
601 - 5000V	2500V	1000
5001 - 15000V	2500V	5000
15001 - 39000V	5000V	20000

TABLE 4 2

FIELD OVERPOTENTIAL TEST VOLTAGES*

Type of Apparatus	Rated kV	Maximum Test Voltage kV	
		ac	dc
MC (Metal-Clad Switchgear)	4 76	14 3	20 3
	8 25	27 0	37 5
	15 0	27 0	37 5
	38 0	60 0	+
SC (Station-type Cubicle Switchgear	15 5	37 5	+
	38 0	60 0	+
	72 5	120 0	+
MEI (Metal-Enclosed Interrupter Switchgear)	4 76	14 3	20 3
	8 25	19 5	27 8
	15 0	27 0	37 5
	15 5	37 5	52 5
	25 8	45 0	+
	38 0	60 0	+
MEB (Metal-Enclosed Bus)	0 76	1 6	2 3
	5 0	14 3	20 3
	15 0	27 0	37 5
	25 0	45 0	+
	35 0	60 0	+
+ Consult Manufacturer's Specifications			
*Derived from ANSI/IEEE C37 20 2 and C37 20 3			

VI THERMOVISION SCANNER TO IDENTIFY "HOT SPOTS"

Purpose

This Procedure outlines the steps in identifying "Hot Spots" on equipment at a substation utilizing the Thermovision camera The Thermovision camera is capable of identifying the heat generated by individual substation components operating at temperatures above their equipment design ratings Basically, the I^2R losses produce the heat that is observed by the camera as a "hot spot" The purpose of the scanning therefore is to identify where there are localized losses in the electrical systems

Procedure

Transmission and distribution lines, including substations can be tested with Thermovision equipment to locate hot spots on conductors and equipment caused by loose connections and hardware and other defects Thermovision equipment locates hot spots by using infrared scanning to thermally inspect the equipment and lines The scanning equipment can be operated from a helicopter, a van or by an operator carrying the equipment

Refer to the manufacturer instruction manual included with the scanner to be procured by HSEB

Assemble the Thermovision Camera, Battery Pack and all auxiliary equipment (Refer to Instruction Manual)

1 Calibrate the equipment (Refer to instruction manual)

2 Select temperature range from 20°C to 100°C

3 Check the substation load logs to determine the Peak load period All scanning should be done during peak load For residential loads, this occurs between 7 pm and 8 pm daily Confirm from load logs

4 Commence scanning from the highside of the transformer and follow the electrical path all the way through to each 11 kV feeder outgoing line Pointing the camera lens towards the item being scanned does scanning

5 Hot Spots show up as light blue, yellow, orange, red or white on

a dark blue background The temperature of the hot spot increases as the color goes from light blue to red to white White being the hottest, (Refer to scanner instruction manual)

6 When a hot spot in located, zero in on the hottest area, and set the record and its temperature in memory

7 Hot Spots should be checked from different camera angles Relying on a scanning from one location may give erroneous results due to shadow effects of other equipment Thoroughly check the electrical system circuitry from different angles

8 When all the scanning has been completed and checked from different angles and recorded in the memory turn the camera off Disassemble any assembled components, and return all components to their original cases for transportation back to the shop

9 Download data and images with all temperature readouts into a computer

10 Analyze the cause of the hot spots Perform additional resistance measurement checks, visual checks, and/or follow up tasks to determine the plan for repairing or replacing the equipment or item causing the abnormally high temperatures

Standards To Be Observed

1 The images and data must be sharp and clear, especially those reading high temperatures

2 The equipment or location where hot spots were recorded must be identified correctly

3 Check that at least 1 or 2 other readings were taken from different angles to confirm the accuracy of the results

Scanning must be repeated when,

1 Scanning Operator relies on only one shot

2 Readings were not taken from different angles as a check on the accuracy of temperature

3 There were possible reflections or interference from an auxiliary high temperature source such as light bulbs, space heaters, sun (if during daylight hours) or reflected sunlight

Deviation from Standards None

Necessary Knowledge and Skills

1 Scanning Operator must be fully conversant with the operating manual for the scanner being used and must know how to calibrate the scanner for the ambient conditions

2 Since the Scanning Operator will be working in high voltage substations, all safety work practices, clearances, etc must be known and observed A minimum of two operators working together for each scanner is recommended

3 Both operators should be fully conversant with the scanner operation, hot spot readings, and recordings

4 The operator must be fully knowledgeable with downloading the recorded data and scans onto a computer, transferring scans onto video tape, developing transparencies and hard copies (in color) for presentations and /or reports

VII INCORRECT CONNECTORS REPLACEMENT

Purpose

Every connector in a circuit is a potential source of resistance and therefore, the following should be noted

1 Number of connectors should be kept to a minimum

2 Resistance of connectors should be kept to a minimum to limit I^2R losses

3 Corrosion of connectors with time should be avoided to prevent high contact resistance over time and therefore high I^2R losses

The purpose is to limit the contact resistance of connectors in circuits so as to keep the I^2R losses as small as possible

Procedure

1 A Thermal vision scan of the electrical system at peak load will give an indication of the hot spots in the circuit Identify which of the hot spots is the result of wrong connector type

2 Survey each circuit to determine the connectors that are in place, not overheated, but are not necessary These connectors add series resistance and are a source of I^2R losses

3 At all connections between equipment and jumpers, determine the equipment material type such as the proper connector can be selected for use to connect to the jumper to the equipment

Usually equipment connection pads are Copper, and jumper wires are aluminum When dissimilar metals are connected, bimetallic connectors should be used

4 Determine what type of connector is required on the equipment pad to connect the jumper wire Determine the connector configuration, e g , connection of a 2-hole Copper pad on the equipment to a 2/0 Al cable connector In this case, a 2-hole pad to 2/0 cable bimetallic connector is required

Instead of using, as an example, a copper 2 hole pad with a 2/0 Cu barrel connector in series with a bimetallic wedge connector of 2/0 Cu barrel to a 2/0 Al cable is acceptable from a corrosion standpoint, but is unacceptable because two connectors in series are used to perform the work of one, since the correct connector was not selected to start with

In the above example, another alternative would have been to use a crimped 2-hole Al lug on the 2/0 Al jumper to connect direct to the copper 2-hole pad on the equipment The sandwiched insertion of the copper hinged material limits the corrosion of the copper-aluminum connection Thus, the minimum number of connectors have been used and also have provided the bimetallic feature required to prevent corrosion and high resistance from developing

Therefore when replacing connectors, select one connector that will

a Match the equipment terminal configurations that are to be connected Examples of configurations include

- 2-hole pad to 2/0 cable
- or, 4-hole pad to 2/0 cable
- or, stud to 4/0 cable
- or, 2-hole pad to 336 MCM cable at a right angle takeoff
- etc

b Match the sizes of both conductor and terminals to the connector

Match the bolt pattern on the pads, i e , either 2-hole pattern, or 4-hole pattern, to the connector

Match the materials being connected, i e , Aluminum to Aluminum requires an all Aluminum connector Al-Cu requires a bimetallic connector

e Use the bolts supplied for the connector Using galvanized steel bolts with Copper will badly corrode the galvanized bolt, thereby greatly increasing the contact resistance with time When in doubt, use stainless steel bolts A good test for stainless steel bolts is to prove a magnet does not attract them Galvanized bolts are magnetic

5 Good contact with low contact resistance in the connection must be maintained This can be achieved by observing if

- Any specific torque values are specified, these should be followed explicitly
- Crimped connectors are used, the correct crimping tool and correct dies must be used
- Wedge connectors are used, the correct gun and correct cartridges must be used
- Any corrosion inhibiting grease is specified, the correct application and quantity should be adhered to

6 Do not modify, cut or miss-apply the manufacturer's connectors as these have been designed and tested for the service and application specified Field modifications will render the connector invalid for adequacy of current carrying and designed temperature rises

7 Finally, follow the manufacturer's recommendations closely Manufacturer has designed and tested his connectors for the recommended application

Standards To Be Observed

1 Connectors must be judiciously chosen The manufacturer's representative should confirm correct selection and application from vendor's catalogs

2 Do not try to modify manufacturer's connectors to fit a different application

3 Select one connector to connect two pieces of equipment together

4 Consider always the materials to be connected and use the recommended connector Connection of dissimilar materials requires special bimetallic connectors, otherwise, corrosion develops in the presence of moisture due to their electrolytic incompatibility

5 Size connectors in accordance with the equipment to be connected Cutting the strands off a cable or cutting a connector to match the pad, or to obtain metal clearances is unacceptable

6 Use bolts furnished with the connectors Do not improvise, or use volts of a different material

Necessary

1 Be fully conversant with the manufacturer's product line and

Knowledge And Skills

catalog application/selection guide

2 Be familiar with the requirements of connectors and configurations

3 Have vendors' representative confirm the selection you have made for the application you need

4 Be familiar with cable and wire sizes, NEMA hole spacing, and bolt sizes, torque requirements

5 Be able to identify terminals of equipment whether they are copper (or anodized cooper), Aluminum, Galvanized steel or ACSR This can be done by performing the following tests

- Scratch test for copper - bright red when scratched
- Magnetic test for steel vs Non-magnetic for stainless steel
- Light weight, silver color for Aluminum & non-magnetic

6 Ensure that adequate supplies of routinely used connectors are stocked When stocks are depleted, and an emergency arises, it is then that compromises are made, and a series of connectors are used to match the end configuration, bimetallic requirements are ignored, configurations are modified, and non-compatible bolts are used Example of the effect on losses of an incorrect and corroded connector in a circuit

An incorrect corroded connector can have a resistance of 1 5 ohms This connector used in a loaded feeder carrying say 80 A develops an I^2R loss = 80 X 80 X 1 5 * 0 5(lf)

= 4 8 kW

Loss in KWhr per year = 4 8 X 365 X 24

= 42,048

At 2 Rs/KWhr, lost energy costs = 84,096 Rupees

A good contact resistance is of the order of say 0 05 ohms

Cost of lost energy = 2,803 Rupees

Therefore, cost saving in one connector for a year = 81,293 Rupees in improving one connector from 1 5 Ohms to 0 05 Ohms resistance

VIII REPLACEMENT OF FAULTY EQUIPMENT

Purpose

Substation equipment is scanned to determine equipment and components operating at temperatures above their designed temperature rise ratings These localized high temperature zones are referred to as "hot spots" The reasons for the "hot spots" are then determined and corrective actions identified and implemented to reduce the high I^2R losses Corrective actions may include the replacement of faulty equipment

Procedure

1 The thermal vision scan of the substation may indicate that specific equipment is the source of the hot spot on the scan

2 The causes of the hot spot must be determined first It could be one or more of the following

   a High current flow above thermal limits overloading circuits

   b Poor contact connectors

   c Incorrect connectors

      i Incorrect size and configuration

      ii Dissimilar materials with no bimetallic interface

      iii Incorrect bolts such as size or material

   d Corroded connectors

   e Poor contact resistances within the equipment

   f Undersized equipment for the growth of load with time

   g Field modified equipment due to the unavailability of replacement parts

   h Deterioration of current carrying parts with time due to oxidation, corrosion, pitting, etc

Once the causes of "hot spots" had been identified, corrective action must then be taken accordingly Solutions to causes (a) through (h) enumerated above could be as follows

- For (a) replace the equipment with adequately rated current circuits

- For (b) (c) and (d), replace the equipment connectors in accordance with standard industry practices stated elsewhere in this Manual
- For (e), clean the contacts causing high resistance For oil circuit breakers, air switches, and reclosers, follow the Manufacturer's O&M Manual Instructions

After cleaning contacts, make sure the contact resistance is within the manufacturers recommended tolerances For measurement of contact resistance, refer to the Procedure for measuring resistances across hot spots

- For (f), change out the equipment and size adequately for the higher current requirements
- For (g), remove the field modified equipment and replace with adequately rated manufactured equipment, e g, fused cut-outs with modified fuse holders, fuses, and fuse barrels should be replaced with fuse links, fuse barrels and fuse holders all standard manufactured equipment and do not use field innovations or improvisations
- For (h), damaged or deteriorated equipment needs to be replaced with new equipment Field modifications, oftentimes result in hot spots

Standards to be Achieved

Follow the appropriate Procedure for replacement, repair, or correction of the existing conditions

Deviation from Standard

Do not improvise on manufactured equipment due to shortages or unavailability of fittings Have complete replacement equipment on hand before the outage for change out Using incomplete equipment defeats the purpose of the replacement which caused the problem to begin with

Necessary Knowledge and Skills

1 Be familiar with construction practices and installation skills
2 Be familiar with all-component parts, fittings, and auxiliaries of the manufacturer's equipment and components
3 Be familiar with sizing and rating the equipment and component parts

4 Be familiar with the metals used in the connection of the equipment and with the type of connectors needed to include the replacement equipment in the circuits

IX REDUNDANT EQUIPMENT AND JUMPERS REMOVAL

Purpose

Non-essential equipment that may have been left in the circuit for a number of reasons generates hot spots at each corroded or high resistance connection Since these connections are not required because the equipment can already be removed from service, these additional I^2R losses can be eliminated For service continuity however, the removed equipment must be replaced with a jumper The jumper and its connectors must be suitably sized and selected so as to cause the minimum of I^2R losses

Procedure

Redundant equipment in the circuit if not actually contributing to the system operation must be removed from the circuit and replaced with a jumper for service continuity In selecting a suitable jumper, the following tasks need to be performed

1 Determine the ampacity of the jumper to be used

2 Select cross sectional area of jumper after deciding on the material of the jumpers, i e , check the ampacity tables for current rating in free air for either CU, AA, or ACSR jumpers, of the various cross-sectional areas

3 Select jumper material and cross section

4 Measure length of jumper required from terminal to terminal of the connecting equipment leaving enough slack for the "drip loops," if connections require a vertical jumper connection (See Procedure For Making Drip Loops)

5 Select the connectors required at either end of the jumper to connect to the equipment at either end The selection of the connectors will depend on the material of the jumper and material of the connecting equipment terminations, and also on the configuration of the terminating connections (See Task Procedure for selection of connectors)

6 Apply and install connectors properly and in accordance with the connector requirements, if

a When making bolted connections use the correct bolts (material & size) and apply required torque

b Compression type, use proper crimping tool and dies

c Wedge type, use proper gun and cartridge for type, size and metal of connectors

7 After installation, measure the true resistance of the jumper i e jumper including connectors at each end (Use the Procedure for measurement of Resistance) This resistance should be less than 0 05 ohms

8 The circuit continuity across the equipment removed and replaced with a jumper is now restored with a low loss, in line, through connection

Standards To Be Observed

1 Total resistance of jumper including connectors at each end must not be greater than 0 05 ohms

2 Not more than one connector is to be used at each end of the jumper

3 Connecting metals of the connecting equipment and the jumper must be compatible by judicious selection of the connectors, using bimetallic connectors if necessary

4 "Drip loops" must be configured in all jumpers where vertical jumpers connect to equipment connectors (See the Procedure for formation of "Drip Loops")

5 Free air amp ratings of the selected jumper must be above maximum expected/designed continuous current rating of the circuit

6 Manufacturers recommended limits for oil characteristics must be observed Oil must be changed when these quality assurance limits have increased above or below the manufacturers acceptable tolerances

Deviation from Standards

1 If there are time constraints on the replacement, and the correct connectors are not immediately available, the addition of another connector in the jumper circuit is allowable to achieve the necessary connector configuration However, this is only allowable if the overall resistance of 0 05 ohms is <u>not</u> exceeded

2 Due to time constraints and the unavailability of the bimitallic connectors, Copper may be connected to Aluminum by using liberal coatings of Penetrox grease in the connector where Copper comes into contact with Aluminum This reduces the possibility of the galvanic corrosion that occurs between Cu and Al when acidic moisture penetrates the joint
However, with time the grease washes out leading to corrosion at the joint The greased joint is a quick fix only and must be replaced with the proper bimetallic connector as soon as it becomes available

Necessary Knowledge and Skills

1 Be familiar with substation open wire construction

2 Be able to size conductors

3 Be able to select connectors and apply them correctly

4 Be familiar with ohms law and the methods for measuring resistance

5 Be familiar with oil quality procedures

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X CHANGING TRANSFORMER NO-LOAD TAPS MANUALLY

Purpose

The characteristics of transformers that directly affect losses are the impedance and secondary side voltages These determine the output voltage at no load, and the voltage drop attributable to the transformer when carrying load Higher transformer impedance could give rise to higher losses (depending on load current)

By using full winding, the maximum losses occur for the same load current The taps are adjusted to give the maximum permissible voltage limit on the bus for the available 66 kV side primary voltage

On a 66 kV – 11 kV transformer with 5 taps at ± 2 1/2%, ± 5% primary winding, Tap 5 gives a ratio of 61,050 11,000 = 5 5

On tap 1, turns ratio = 67,650 11,000 = 6 15

When on tap 1, more of the primary circuit is involved resulting in a higher impedance

Procedure

1 Remove transformer from all energized sources including the primary and secondary sources
2 Remove tap position locking bolt
3 Move tap changer to desired position
4 Secure locking bolt
5 Test transformer for proper ratio, and measure windings resistance using megger
6 If transformer test ratio (TTR) and Megger tests are successful, then energize transformer

Standards To Be Observed

1 Check that voltage ratio is equal to the nameplate ratio for the tap selected
2 Successful megger test results ensure that changing the tap position has not degraded the insulation of the windings and taps have changed correctly as designed

Deviation from Standards	1	Correct positioning on the desired tap must give the exact ratio for the TTR test based on nameplate ratios No tolerance is acceptable
	2	Megger readings must remain in the Megohm range
Necessary Knowledge and Skills	1	Be familiar with turns – ratio calculations for tapped transformer windings
	2	Be familiar with correct operation of insulation megger and be able to evaluate results

XI TRANSFORMERS COOLING SYSTEMS

Purpose

Transformer cooling fans that can be operated automatic or manually as a function of the loading on the transformer are furnished by the transformer manufacturer Their purpose is to increase the transformer thermal capacity when its loading reaches 100 percent of normal rating Unfortunately most fan automatic control circuits found in some HSEB are now defective and to get the maximum forced air (FA) rating out of the transformer, the fans, when operational, have to be switched on manually

The forced oil cooling system was also found defective with radiators leaking or dielectric strength below the limits established by manufacturers The potential for transformer failures increases when these conditions exist

Procedure

1 Fan cooled transformers have two ratings, OA/FA OA rating indicates the maximum current that can be loaded on the transformer with natural air cooling to give a 65 °C winding temperature rise over a 30 °C ambient

2 The FA rating indicates the maximum load current that can be supplied by the transformer (usually 125% of the OA rating) with fan cooling to give a 65°C rise over a 30°C ambient

3 When operating automatically, the fans are controlled by the winding temperature, and are turned on when the winding temperature attempts to rise over 95°C

4 Transformers are furnished with top oil temperature gages and when winding temperatures approach 95°C, the top oil temperature gage may approach about 65°C It is this feature which is utilized when trying to control the cooling fans manually

The following are the conditions that have been found during the substation performance evaluations conducted in the field

1 It was noted that some of the fans were damaged and therefore, the extra cooling capability was not available or transformers were loaded at the FA rating without all fans operational

2 Fans electrically disconnected from the transformers, again the FA rating was not available
3 Transformer oil was leaking through the radiator at one substation on all radiators
4 Oil dielectric strength test results were not within the limits stated by manufacturers
5 Insulation resistance also was found to exceed the limits established by transformer manufacturers

Sample cases

When the transformer is loaded below its OA current rating, and if the outside ambient temperature is 30°C, then the winding temperature will be below 65°C Therefore there is no need to turn the fans on See Table below

	Load Amps	Outside Temp	Winding Temp	(Observe) Oil Temp	Operate Fans
Case 1	<OA Rating	30°C	< 95°C	<65°C	OFF
Case 2a	<OA rating	40°C	<95°C	<65°C	OFF
Case 2b	Less than OA rating but higher than Case 2a	40°C	>95°C	>65°C	ON
Case 3	>OA Rating	30°C	>95°C	>65°C	ON
Case 4	>OA rating	40°C	>95°C	>65°C	ON

It can be seen from the above Table that the decision whether to turn the fans ON or OFF depends on whether the oil temperature is above or below 65°C To allow for inaccuracies, etc use 60°C oil temperature as the criteria instead of 65°C

If fans are to be manually operated the oil temperature gage must by observed every hour and the fans turned on or off in accordance with the oil temperature gage reading

Using this procedure the maximum FA rating of the transformer could be utilized even when the automatic fan cooling circuit is non-functional

Standards To Be Observed

The oil temperature gage should be functional and accurate to within about ± 2°C

Deviations from Standard

1 If load changes occur very rapidly in the one-hour period, around Peak time, it may be beneficial to check the oil temperature gage more frequently during this period and operate the fans accordingly

2 Also replace transformer oil when its dielectric characteristics have deteriorated beyond the limits established by manufacturers

Necessary Knowledge and Skills

1 Basic understanding of transformer cooling parameters

XII FORMATION OF "DRIP LOOPS" IN VERTICAL JUMPERS

Purpose

Jumpers, when in a vertical configuration and connected to equipment, provide a path for water to trickle down and flow into the connector joints Forming a "Drip Loop" at the bottom of the jumper eliminates this seepage action It also deters corrosion and electrolytic action and thus reduces the I^2R losses which occur as a result of the development of high contact resistance

Procedure

When vertical jumpers are changed, the measurement for the new jumpers should include an easy 'S' drip loop before connecting the terminal bushings of the equipment to the bottom of the jumper This type of "drip loop" is required on all vertical jumpers that terminate on outdoor circuit breakers, reclosers, automatic voltage regulator etc

When replacing jumpers in the substation, apply the following steps

1 Select the material and cross section of the new jumpers for the required current carrying capacity
2 Remove all sources of energy from the equipment to be worked on
3 Apply safety grounds, ground clusters and ground chains to safely isolate the equipment
4 Remove "old" jumpers
5 Measure length of "old" jumpers but add an extra length of 2 feet to form the "drip loop"
6 Prepare connection between jumper and the equipment and select the correct connector
7 Make the connection of the vertical jumper to the equipment at the bottom end Form a "drip loop" with the slack in the jumper so that rainwater will run down the jumper and run off the jumper at the lowest point preventing it from flowing into the equipment connector at the end of the jumper
8 Complete the top connection of the jumper
9 Check for continuity and proper connections
10 Remove safety grounds

11 Energize substation

Standards To Be Observed	1	Smooth S loops should be formed
	2	The lowest point in the loop must be below the connector at the bottom end of the jumper The difference in elevation must be at four inches
	3	Conductor loops in the two outer phases should fan out from the conductor loop in the center phase to provide maximum phase-phase clearance
	4	When forming the "S" loops be sure not to let the conductor strands of the jumper "flare" out Flaring leads to increase power losses
Deviations from Standards		None
Necessary Knowledge	1	Familiarity with making jumpers connections
	2	Familiar with open wire substation construction
	3	Appreciation of and knowledge of required phase-phase and phase-ground clearances at different voltages, in substations

XIII INSPECTING & TESTING LARGE TRANSFORMERS

Purpose

This Procedure covers the inspection and testing of switchgear to ensure that equipment and connections are all in working order When changing no-load taps or installing new large power and substation transformers, tests should be performed to determine if the transformer should be energized Transformer no load taps, if not properly set, can increase transformer losses and reduce revenue

Visual and Mechanical Inspection

1 Compare equipment nameplate information with single-line diagram

2 Inspect for physical damage, cracked insulators, leaks, tightness of connections, and general mechanical and electrical conditions

3 Inspect impact recorder prior to unloading transformer if applicable

4 Verify removal of any shipping bracing after final placement

5 Verify proper auxiliary device operations

6 Check tightness of accessible bolted electrical connections in accordance with the manufacturers recommendations

7 Verify proper liquid level in all tanks and bushings

8 Perform specific inspections and mechanical tests as recommended by manufacturer

9 Verify proper equipment grounding

Electrical Tests

1 Perform insulation-resistance tests, winding-to-winding, and windings-to-ground, utilizing a megohmmeter with test voltage output as shown in Table 13 3 Test duration shall be for 10 minutes with resistances tabulated at 30 seconds, 1 minute, and 10 minutes Compute dielectric absorption ratio and the polarization index by dividing the 10-minute megohm value by

the 1 minute megohm value

2 Perform a turns-ratio test between windings at all tap positions The turns ratio is computed by dividing the secondary voltage into the primary voltage the tap voltage(s) shown on the nameplate

3 Sample insulating liquid in accordance with ASTM D-923 Perform insulation power-factor tests or dissipation-factor tests on all windings and bushings Determine overall dielectric-loss and power factor (C_H, C_L, C_{HL}) Test voltages should be limited to the line-to-ground voltage rating of the transformer winding

4 Perform winding-resistance tests on each winding in final tap position

5 Perform tests and adjustments on fan and pump controls and alarm functions

6 Verify proper core grounding if accessible

7 Perform percent oxygen test on the nitrogen gas blanket, if applicable

Test Values

1 Insulation-resistance and absorption test Test voltages shall be in accordance with Table 13 3 Resistance values shall be temperature corrected in accordance with Table 13 4

2 Polarization index should be greater than 1 05 The polarization index should be used for future reference

3 Turns-ratio test results shall not deviate more than one-half percent (0 5%) from either the adjacent coils or the calculated ratio

4 Maximum power factor of liquid-filled transformers corrected to 20°C shall be in accordance with manufacturer's specification Representative values are indicated in Table 13 1

5 Bushing power factors and capacitance that vary from nameplate values by more than ten percent (10%) should

be investigated

6 Excitation current test data pattern Two similar current readings for outside coils and a dissimilar current reading for the center coil of a three-phase unit

7 Dielectric fluid should comply with Table 13 2

8 Winding-resistance test results should compare within one percent (1%) of adjacent windings

TABLE 13 1

LIQUID-FILLED TRANSFORMER INSULATION POWER FACTOR VALUES

	Oil	Silicone	Tetrachlor-ethylene	High Fire Point Hydrocarbon
New Power Transformers	0 5%	0 5%	3 0%	0 5%
New Distribution Transformers	1 0%	0 5%	3 0%	1 0%
Remanufactured Power Transformers	1 0%	1 0%	----	----
Remanufactured Distribution Transformers	1 5%	1 0%	----	----

TABLE 13 2
INSULATING LIQUID TEST VALUES

	Oil	High Molecular Weight Hydrocarbon	Silicone	Tetrachlor-ethylene
Dielectric Breakdown ASTM D-877	30 kV Minimum	30 kV <Minimum	30 kV Minimum	30 kV Minimum
Dielectric Breakdown ASTM D-1816 @ 0 04' gap				
34 5 kV and below	20 kV Minimum	----	----	26 kV Minimum
above 34 5 kV	25 kV Minimum	----	----	----
Neutralization Number ASTM D-974	04 mgKOH/g Maximum	0 03 mgKOH/g Maximum	0 1 mgKOH/g Maximum	0 25 mgKOH/g Maximum
Interfacial Tension ASTM D-974 or D-2285	35 dynes/cm Minimum	33 dynes/cm Minimum	----	----
Color ASTM D-1500	1 0 Maximum	N/A	0 05 Maximum (D-2129)	
Visual Condition ASTM D-1524	Clear Bright Pale Straw	N/A	Crystal Clear (D-2129)	Clear, Slight Pink Iridescent
Power Factor ASTM D-924 @ 25°C	0 1%\ Maximum	0 1% Maximum	0 1% Maximum	2 0% Maximum
Water Content ASTM D-1533 15 kV and below	35 PPM Maximum	35 PPM Maximum	80 PPM Maximum	25 PPM Maximum
above 15 kV - below 115 kV [2]	5 PPM Maximum	----	----	----
115 kV - 230 kV	20 PPM Maximum	----	----	----
above 230 kV	15 PPM Maximum	----	----	----

Or in accordance with manufacturer's requirements Some manufacturers recommend 15 PPM maximum for all transformers

TABLE 13 3

TRANSFORMER INSULATION-RESISTANCE TEST VOLTAGES

Transformer Coil Rating	Minimum dc Test Voltage	Recommended Minimum Insulation Resistance in Megohms	
		Liquid-Filled	Dry-Type
0 - 600 Volts	1000 Volts	100	500
601 - 5000 Volts	2500 Volts	100	5000
5001 - 15000 Volts	5,000 Volts	800	25000
15001 - 39000 Volts	10,000 Volts	--	--
Over 39000 Volts	15,000 Volts	--	--

TABLE 13 4

TRANSFORMER INSULATION RESISTANCE

TEMPERATURE CORRECTION FACTORS TO 20c

Temperature		Transformer	
°C	°F	Oil	Dry
0	32	25	40
5	41	36	45
10	50	50	50
15	59	75	75
20	68	1 00	1 00
25	77	1 40	1 30
30	86	1 98	1 60
35	95	2 80	2 05
40	104	3 95	2 50
45	113	5 60	3 25
50	122	7 85	4 00
55	131	11 20	5 20
60	140	15 85	6 40
65	149	22 40	8 70
70	158	31 75	10 00
75	167	44 70	13 00
80	176	63 50	16 00

XIV UTILIZATION OF FUSES, CUTOUTS AND LIGHTNING ARRESTERS

Purpose

The purpose of this procedure is to illustrate the benefit to equipment derived from using properly sized fuses, cutouts and surge arresters on the distribution transformers and capacitors

Current HSEB Practice on Fuses

In the HSEB distribution system, over the years it has become a standard practice to "protect" the distribution transformers by replacing the fuses and cutouts with whatever piece of wire size and material is available at the time of need The purpose of this action is to get the transformer back on line with complete disregard for transformer protection

The use of the various wire sizes in place of a properly sized fuse has resulted in the large number of distribution transformer failures On an annual basis the distribution transformers failures have exceeded 31 percent Based on Table I 1 this percentage is equivalent to about 31,000 transformers per year

This practice is also extended to capacitors wherever they are used It is noted that capacitors are found only at substations

The cost of this practice is significant in terms of transformer repairs, procurement of new transformers and loss of revenue due to consumers out of service

Current HSEB Practice on Lightning Arresters

At present lightning arrersters are not used on distribution transformers and/or capacitors and at some substations large power transformers This equipment is not protected against system surges or lightning

The continuous sudden changes in system configuration resulting from the number outages caused by overloaded feeders, transformer failures, and other causes, create large over voltages This high over voltage travels along the high and/or low side of overhead lines connected to transformers or capacitors The effect upon the equipment is to puncture or damage the internal insulation of the equipment that may failed immediately or that eventually will fail

Chapter XIV – Utilization of Fuses Distribution Cutouts and Lightning Arresters

Fuses Purpose	Fuses are relative inexpensive protection devices connected between transformers, capacitors or other equipment and the high and low-tension distribution systems Fuses are used to prevent or limit the damage to equipment due to overloads or short circuits The fuses remove the transformer or capacitor out of service before the occurrence of damage to the equipment
Fuse Operation	When the current through the fuse is excessive the resistance offered by the fuse metal to the flow of current develops enough heat to melt the metal, thereby opening the circuit before any current flow above the equipment thermal capacity is reached
Time-Current Curve	A time-current curve is a curve that is plotted between the magnitude of a fault current and the time required for the fuse link to open the circuit The greater the current, the faster the fuse melts and the shorter the time for it to blow
Distribution Cutouts	Distribution cutouts provide a high-voltage mounting for the fuse element used to protect the distribution system or the equipment connected to it Distribution cutouts are used with installation of transformers, capacitors, cable circuits and sectionalizing points on overhead lines There are various types of cutouts, enclosed, open and open link to name a few Cutouts normally use an expulsion fuse that operates to isolate the fault or overload from circuit as a result of the arc from the fault current The current erodes the tube of the fuse holder producing a gas that blasts the arc out through the fuse tube vents
Lightning Arresters	Lightning or surge arresters are devices **that prevent high voltages from building up on a circuit by providing a low-impedance path to ground for the current from lightning or transient voltages**, and then restore normal circuit conditions

ATTACHMENT I

HSEB PREVENTIVE MAINTENANCE MANUAL

HARYANA STATE ELECTRICITY BOARD

MAINTENANCE AND INSPECTION SCHEDULES FOR TRANSFORMERS, ALLIED SUB STATION EQUIPMENT AND LINES

Office of the

Secretary [Technical Section]

HARYANA STATE ELECTRICITY BOARD

Shakti Bhawan, Panchkula

FOREWARD

There is a well-known saying,

"A stitch in time, saves nine" This applies correctly to t power system also

In today's world, when the electricity has attained a position one of the most important necessities of life, a great responsibili comes on the Power Utilities, to ensure reliable and un-interrupte power supply to various consumers While a small interruption power supply causes inconvenience to the consumers, it can lea to huge financial loss by way of the interrupted industri production

Basically, the power failures are caused due to mal-operation the electrical equipment If due care is taken to keep the powe supply system well maintained, a large number of power suppl failures could be avoided That is why, preventive maintenanc attains the highest priority for the Power Engineers controlling th Power Supply Network

With th s end in view, the instant 'Maintenance and Inspectio Schedule for Transformers, Allied Sub-Station Equipment an Lines' has been got published for circulation amongst all th Power Engineers and Technical Supervisory Staff I am sure, th guidelines given for the maintenance of various equipments woul be quite useful for achieving the ultimate goal of maintaining good quality power supply to the consumers

I appreciate the efforts made by the Technical Cell of the Boar in compiling this Maintenance Schedule and to get it published for the use of Techical staff

Place, Panchkula
Dated September 16, 1991

L R RAJPAL,
MEMBER/TECH (OP)

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INSPECTION AND MAINTENANCE SCHEDULES FOR TRANSFORMERS, LINES AND SUBSTATION EQUIPMENT

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BEST AVAILABLE COPY

ANNEXURE 'A'

INSPECTION & MAINTENANCE SCHEDULE FOR DISTRIBUTION TRANSFORMERS

Sr No	Inspection Frequency	Item to be inspected	Inspection Note	Action required Remarks
1	Monthly	Connection	i) Check for tightening of connections	Replace and re-fill worn out thimbles
			ii) Provision of PVC sleeves, insulating beeds on the connectors	Replace, where necessary
2	Monthly	Oil level	Check for proper oil level against the gauge glass	Top-up, if necessary with tested oil
			Check for leakage of oil from drain oft valve, gaskets and tank leaks etc	Stop any leaks
3	Monthly	Breather	Check for colour of silica gel and reactivating, if necessary	Recondition or replace, as necessary
4	Monthly	Lightning arrestors	Check L As and jumpers for tightness	
5	Monthly	Fuses (HT & LT)	Check for continuity, tightness and correct ratings	Replace old fuses with new ones of right capacity
6	Monthly	G O Switch	Check for position/sparking of G O switch blades	
7	Monthly	—	Check diaphragm for cracks	

1	2	3	4	5
8	Monthly	Insulation Reistance	Compare with values at the time of commissioning	Process if required
9	Quarterly	Bushings & arcing herns	i) Check for chipped and broken bushings ii) Examine & replace the damaged gaskets iii) Adjust the arcing horns for allignment and proper gaps between them	Replace these if necessary Clean off all dirt, paint & other deposits
10	Quarterly	Voltage	Measurement of voltage during max load period at the transformers and at the tail end of feeders	
11	Quarterly	Load	Measurement of load under maximum load conditions, against its rated capacity,	In case of overload T/F, reduce the load by transfer of load or augment the T/F, if necessary
12	Quarterly	Barbed wire, danger plate etc	i) Check for proper and sufficient provision of Barbed wire ii) Check for proper supporting of danger plate at suitable height	Recondition or replace barbed wire, as necessary Paint & reprint the danger plate if defected,
13.	Half yearly	Oil testing	i) Observe colour of the oil to have idea of its condition,	Perform crackle test on the oil samples drawn from drain-off

1	2	3	4	
			ii) Check water content in the oil iii) In case crackle test shows deterioration, perform di-electric strength test iv) Keep record of test results	valves to water cont In case of contaminat the T/F wi itself shou put to de ation and out by mea oil de-hydr set, till prop sults are obta
14	Half yearly	Load balancing on phases	Check load on three phases under max load conditions and secure between the 3 phases balanced loading	
15	Quarterly	Earth testing (to be done during driest part of the year)	i) tighten the earth connections ii) Examine and replace broken earth leads/conductors with proper size iii) Measure the earth resistence during driest part of the year of (a) Neutral of T/F (b) T/F body and other metal parts (c) lightning arrestors iv) Keep record of test results	i) ensure that val of earth resister are not more tl 2 ohms ii) In case of high values, recondion the rods deeer into ground by addition of water through pipe

2	3	4	5
Two yearly	Conservator Tank	i) Check for proper comunication of the conservator with T/F tank by draining some oil through drain off valve and watching the oil in the gauge glass to drop ii) In case the oil does not drop, investigate and remove the sludge or other obstructions after disassembling the tank iii) Check for leakage of oil from glass side	Clean the inspection glass so that oil lovel is properly visible
Two yearly	Acidity & sludge testing of oil,	Check and test for acidity and sludge formation	i) In case acidity is more than 0 5 gm KOH/gm recondition the same ii) In case acidity is more than 1 0 gm KOH/gm restore the quality of oil by reclaiming with Fullers earth or action of inhibitors
Once in every five years		Complete overhaul of the transformer	

Note, These charts should be displayed in the office room of the Xen and SDO concerned

ANNEXURE 'B'

HOURLY/DAILY SCHEDULE

INSPECTION AND MAINTENANCE SCHEDULE FOR POWER T/F

Sr No	Inspection Frequency	Item to be inspected	Inspection notes	Remarks
1	Hourly	Ambient Temp	Note down the temperature and record the maximum daily ambient temperature	
2	—do—	Winding Temp	Check that temp. rise is reasonable	Shut down the T/F and investigate if either is persistently higher than normal
3	—do—	Oil Temp		
4	—do—	Load (Amperes)	Check against rated figures	Note : An improper tap position can cause excessive core loss
5	—do—	Voltage		
6	Daily each Shift	Oil level in transformer	Check against transformer oil temperature.	If low, top up with dry oil, examine T/F for leaks
7	—do—	Oil level in bushings	Check for any leakage	If low, bring it to the correct oil level
8	—do—	Relief vent diaphragm	Check for cracked or broken	Replace if cracked or broken

1	2	3	4	5
9	Daily each Shift	For internal unusual noise	Check for any sound or excessive chattering	
10	—do—	Heaters in Junction Box	For proper working, if provided	
11	—do—	External connection (Leads/ Jumpers)	Check visually for tightness and sparking on jumpers Bushings etc on complete darkness	
12,	—do—	Bus bar & Cable Boxes & Cables	Check for any damage & signs of overheating at their joints	

Note These Charts should be displayed in the substations

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ANNEXURE

MONTHLY SCHEDULE

INSPECTION AND MAINTENANCE SCHEDULE FOR POWER

Sr No	Inspection Frequency	Items to be inspected	Inspection Notes	Remarks
1	Monthly	Dehydrating breather	i) Check for condition/ colour of Silica Gel	i) Recondition/ place, as necessary
			ii) Ensure that air passage is free	ii) Make up oil required
			iii) Tight lid of the breather for air tightness to avoid entry of moist air	iii) Do cleaning the breather
			iv) Check oil level in oilcup	
			v) Remove oil from dash pot & pour in fresh oil where required	
2	Monthly	Bushing and gaskets	Examine for cracks, Paint and dirt deposits and gap settings Check gasket for leakage	Clean or replace
3	—do—	Cooler fan and pump bearings motors and operating mechanism	Lubricate bearings, check gear box Examine contacts Check manual control and interlocks	Replace burnt or worn out contacts or other parts
4	—do—	On–load tap changer driving mechanism	Lubricate bearings, check gear box oil level and examine contacts	Replace burnt or worn out contacts or other parts

1	2	3	4	4
ɔ	Monthly	On-load tap changer automatic control	Check all circuits independently Check step by step operation including limit switches	If faulty, take suitable action to set it right
,	—do—	Insulation resistence	Campare with values at the time of commissioning	Process, if required
	—do—	Relay alarms, temperature alarm & their circuits	Examine relays and alarm contacts and their operation, fuses etc Check relays accuracy etc	Clean the components or replace contacts and fuses If necessary change the setting
	—do—	Arcing Horns	Set the rods for allignment and for proper gap adjustment	
	—do—	Measuring/ Protection CT's	Check for sparking and tightness of connections and oil level	
	—do—	Remote/ Manual Switch	Check for proper functioning	
	—do—	Fire fighting equipments	Examine them and ensure that these are in order	
	—do—	Buchholz's relay	Note the oil in the inspection glass of buchhloz's relay	

Note, These Charts should be displayed in the substation

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ANNEXURE 'B' (2)

QUARTERLY/HALF YEARLY/YEARLY SCHEDULE INSPECTION & MAINTENANCE SCHEDULE FOR POWER TRANSFORMERS

Sr No	Inspection Frequency	Items to be inspected	Inspection Notes	Remarks
1	Quarterly	Oil in T/F and tap changer	i) Check for dielectric strength and acidity	i Filter the oil or take suitable action to restore quality of oil
			ii) Keep continuous record of test results	ii) In case of very severe contamination the,T/F winding itself should be dehydrated with the dehydration set till satisfactory results are obtained
2	—do—	Ventilaters	Check that air passages are free	
3	—do—	Buchholz's Relay	Check for any gas collection and testing the gas collected	
4	—do—	Forced Cooling Systen	i) Megger testing of motors (Pumps) ii) Checking transformer ground connections for tightness iii) Cleaning of water Jacket	

1	2	3	4	5
5	Quarterly	Thermo Syphon Filters	Check for its normal working order	
6	—do— (Earth testing to be done during driest part of the season)	Earth Resistence	i) Check for tightness of earth connections ii) Measure earth resistance of the (a) T/F body neutral and other metal parts, (b) Keep proper record of test results	i) Recondition or replace where necessary ii) Ensure that test results are not more than 2 ohms In case of higher values, recondition the rods deeper into ground or by addition of water through pipe
7	Half yearly	Oil cooler	Test for pressure	
8	—do—	On-load tap changer driving mechanism	Inspect all moiving parts, contacts, brake shoes, Motor etc	Clean, adjust or replace as requred
9	Yearly (or earlier if transformer can conventently be taken out for	Oil in T/F	Check acidity, PPM, Tan delta,Sp resistivity sludge	Filter or replace Acceptable values as per ISS 1865-1978 are as under -

i) Water contents -
For equipment Voltage>170 KV=<20 PPM

1	2	3	4	5
			For equipment Voltage<170 KV=<30 P[illegible] ii) Tan delta at 90°C -- 0 01 or less iii) Specific Resistivity= Above 10×10^{12} ohm at 27°C iv) Neutralization value =0 5 or less mg KOH/gm of oil (Acidity) v) Sludge=Non-detectable for details of maintenance of oil ISS 1866-1978 may be referred to	
10	Yearly (or earlier if transformer can conveniently be taken out for checking)	Oil filled Bushings	Test oil for dielectric strength	Filter or rep as necessary
11	—do—	Cable Boxes	Check for sealing arrangements for filling holes Examine compound for cracks	Replace gask if leaking
12	—do—	Surge diverter and gaps	Examine for cracks and dirt deposits	Clean or replac
13	Yearly	Gasket Joints	Check for tightness of bolts to avoid uneven pressure	Replace damage gaskets
14	—do—	Pipe Connections	Check oil pipes, valves and plugs for tightness and proper functioning	

1	2	3	4	5
15	Yearly	Foundation	Check for cracks if any and settling,	
16	--do -	Bushings	Test the bushings with a hipot bushing tester and comparing with previous figures	
17	—do—	Temperature indication	Pockets holding thermometers should be checked,	Oil to be replenished, if required
18	—do—	Dial type oil gauge	Check pointer for freedom	Adjust, if required
19	—do—	Paint work	Should be inspected	Any painting or retouching should be done, if necessary
20	—do—	Conservator Tank	i) Check for proper communication of the conservator with T/F tank by draining some oil through drain off valve and watching the oil in gauge glass to drop ii) In case the oil does not drop, investigate and remove the sludge or other obstructions after dis-assembling the tank iii) Check for leakage of oil from glass side	Clean the inspection gass so that so that oil level is properly visible

1	2	3	4	5
21	Yearly or after 10,000 operations	Diverter switches for tap-changer having non-arcing selector switch	Check for worn out contacts, Filter oil irrespective of oil test	Replace worn out parts.
22,	Two years	Oil conservator	Internal inspection,	Should be thoroughly cleaned,
23	—do—	Buchholz relay	Mecehanical inspection	Adjust float, switches, etc, as required.
24	Three years or after 15,000 operations	Non-arcing selector switch of On load tap changer	General inspection	Replace worn out parts Filter oil
25	7 to 10 years		Overall inspection including lifting of core and coils Major overhaul (complete) of transformers.	wash by hosing down with clean dry oil Tighten all bolts, nuts coil clamping screws.
26	i) Once in 7 years ii) Once in 10 years:		3000 KVA and below Above 3000 KVA.	

Note. These Charts should be displayed in the substations

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ANNEXURE 'C'

INSPECTION AND MAINTENANCE SCHEDULE OF ISOLATORS/EARTH SWITCHES

Sr No	Inspection Frequency	Items to be inspected	Details of Inspection	Remarks
1.	Weekly	Insulator	Check for chipped or broken porcelain and excessive dirt film & to undertake repair of chipped spots by painting with Lacquer such as glyptal	
2	—do—	Blades and Contacts	Check that blades are properly seated in the contacts	
3	—do—	Blades latches and stops	Check that blade latches where provided are engaged.	
4	—do—	Locks & inter locks	Check that switches are properly locked in the open or closed position as required by padlocks or other key type locks or interlocks.	
5.	Monthly	Bolts, Nuts & Jumpers	Check bolts, nuts and jumpers for tightness	
6	Half yearly	I R Value & earth resistence.	Check I R Value and earth resistence see that double earthing is provided.	
7.	—do—	Auxiliary & limit switches	Check condition of contacts and refinish with fine file if burned or corroded Check	

1	2	3	4	5
			contact spring, operating rod and lever Check closing and opening position with respect to main switch contacts or travel or motor mechanism.	
8.	—do—	Manual operating Rod	To check for proper engagement of emergency operating handle & further its operation is smooth and satisfactory	
9	Annually	Line and Ground connections	Check and tighten line and bus terminals and operating handle ground connections See that ground cable is not broken	
10	—do—	Blade & contacts	Operate the isolator several times and see that the blades are properly aligned to engage contacts Clean contact surface if corroded Tighten bolts & Nuts	
11.	—do—	Contacts & hinge springs and shunts	Check pressure spring in contact and hinge and replace if not adequate. Replace flexible shunts, if frayed	
12	—do—	Arcing horns	Check arcing horns to see that they are not bent out of shape. clean up if burnt	
13	—do—	Blade latches & stops	Check latches for proper engaging and holding against opening force See that stops are in place and tight.	

1	2	3	4	5
14	Annual	Operating rods Levers and cranks	Check and tighten bolts, screws locknut. See that rods, levers and cranks are in serviceable condition and repair as necessary Lubricate pivots and bearings.	
15	—do—	Gear Boxes	Check gears and bearings Flush out oil grease and relubricate.	
16	—do—	Operating motor and mechanish	Check working of motor and mechanism.	
17	—do—	Locks & inter-locks	Check out locks and keys operate as intended Check mechanical interlocks, such as between main disconnecting switches and ground switch for fool proof operation.	
18,	—do—	Switch sticks (where applicable)	Inspect wooden operating sticks for cracks, splinters, loose heads etc	

Note . These Charts should be displayed in the substation

ANNEXURE 'D'

INSPECTION & MAINTENANCE SCHEDULE OF CT/PT

Sr No	Inspection Frequency	Items to be inspected	Details of Inspection	Remarks
1	Monthly	Insulator	Check for any crack or damage to porcelain insulater	
2	—do—	Oil	Check for oil leakage and when excessive the level be also checked	
3	—do—	Earth connection	Check that Earth connections are properly made	
4	—do—	Jumpers Nut Bolts etc	Check that jumpers, nuts, bolts, clamps are properly tight and are of proper size	
5,	—do—	Secondary wiring	Check that secondary wiring is properly made and routing is not disturbed. The connections in the panel are intact	
6,	Half yearly,	I R Value	Check I R values of primary and secondary windings,	
7	—do—	Earth resistance	Check earth resistance.	
8,	—do—	Secndary taps,	Check secondary taps for tightness to avoid overheating.	
9	yearly	Oil test	Check dielectric strength of oil and toping of oil,	
10	—do—	Tap setting	Check tap setting and adjustment at terminal board to see that they agree with diagrams,	

Note . These charts should be displayed in the substation

ANNEXURE 'E'

INSPECTION & MAINTENANCE SCHEDULE FOR LIGHT NING ARRESTORS

Sr No	Frequency of Inspection	Items to be inspected	Details of Inspection	Remarks
1.	Weekly or at the time of line/transformer tripping	Surge Counter	Note and record operation indicator reading	
2	Monthly	Base & Support	Usual inspection to detect cracking settling or shifting of base or supports	
3	—do—	Surge Monitor	Check that surge monitor is properly connected and is in working order & shows a leakage current.	
4.	Annual	Jumpers and clamps	Check jumpers and clamps for tightness	
5	—do—	Porcelain shells and insulators	Clean porcelain insulators and arrestor unit shells, Repair chipped spots on procelain with lacquel such as red glyptal	
6	—do—	Grading rings	Check and tighten grading rings on high voltage arrestors	
7.	—do—	Gaps	Check external gaps Smooth off arc burned spots and read just spacing	
8	Annual	Weather sheds and hooks	See that weather sheds and hooks of oxide film arresters are securely fastened in place, repaint if necessary	
9	—do—	Line and Ground connection	Check and tighten line and ground connections Check ground lead for corrosion or damage below ground line Check ground resistance See that all leads are as short and direct as possible	
10	—do—	Operation tests (Surge-generating equipment under procurement)	To check the general working of lightning arresters by M & P divisions	

NOTE i) S E (M & P), Ambala Cantt and Hissar should procu two sets each of field testing kit for lightning arreste for their circle

ii) These charts should be displayed in the Substation

ANNEXURE 'F'

INSPECTION & MAINTENANCE SCHEDULE OF STORATE BATTERES & BATTERY CHARGER

Sr No	Frequency of Inspection	Items to be inspected	Details of Inspection	Remarks
1	Daily	Battery Room & ventilation	See that battery room enterance doors are kept closed and that ventilation to out side air are open and air is circulating by running of the exhaust Fan	
2	—do—	Operation	Check charging rate hourly Check and record pilot cell specific gravity temperature and floating voltage	
3	—do—	Bulb for dry rectifier element	Check for burnt bulb and replace when necessary,	
4	Daily (Before and after charging (weekly when trickle charge exists)	Operation	Checking specific gravity and voltage of each cell of lead acid cells	
5	Daily (each shift)	Leakage test	Perform leakage test by lamp or voltmeter method	
6	Weakly (for lead acid batteries)	—	Cleaning of terminals applying vaseline and topping up with distilled water	
7	Monthly	Cell jars and covers	Check for cracked or leaking jars or covers and replace when necessary. Keep jars and covers clean	

1	2	3	4	5
8	Monthly	Plates	Inspect plates carefully for sign of deterioration due to improper charging Note quantity, colour and texture of sediment	
9	—do—	Seperaters	See that the seperators remain in place and are keeping the plates properly spaced	
10	—do—	Electrolyte	Check electrolyte level and ad- distilled water when required	
11	—do—	Acid and distilled water sterage	See that enough distilled water and acid are kept in storage to meet current needs Check containers for cleanliness	
12	—do—	Operation	Check and record specific gravity and voltage of each cell with help of tongs type voltmeter, provided with built in load suitable for battery.	
13	—do—	Transformer or reactor	Check genaral condition and operating temperature of transformer or reactor used in bulb or dry type rectifiers	
14	Quarterly	Connections	Checking all connections of charger and battery for tightness	
15	Half yearly	Discharging and charging cycle	This is required to be carried out as prescribed by the manufacturer in order to prolong the life of the battery.	

1	2	3	4	5
16	Half yearly	Bulb or dry rectifier element	See that copper oxide or selenium rectifier elements are not operating too hot, this will shorten their life	
17	—do—	Rheostat	Check that sliding mechanism of the rheostat is in order and clean the sliding contacts, if required Check contact heating and spring pressure	
18	Annual	Battery Room and ventilation	Check metalic structures/parts located in the room for corrosion and clean and paint as necessary, check ventilation system fan etc for proper operation, to make sure that no explosive gases are being accumulated in battery room due to excessive gassing or poor ventilation	
19	—do—	Base or rack	Inspect concrete base or wooden racks for deterioration Repair and repaint with acid resistant paint as necessary	
20	—do—	Case Pad	Check base pad of sheet rubber, sand or other material for deterioration from acid or other causes	
21.	—do—	Inter Cell connectors and terminals	Clean acid corrosion from connectors and terminals should be lead coated, Tighten terminals and apply petroleum jelly for exposed surface	

1	2	3	4	5
22	Annual	Hydrometer and thermometers	Check condition of hydrometer and thermometer Check hydrometers and thermometers used for daily and monthly readings against spare units held in reserve	
23	—do—	Sink, Funnel and fillers	See that the sink, funnels, fillers and othr distilled water and acid handling facilities kept clean and in good useable condition	
24	—do—	Water still	Check still for proper operation and adequacy and purity of distilled water delivered See that equipment is kept clean	
25	Yearly or as recommended by manufacturer	—	Complete overhaul of the battery	

Note : These charts should be displayed in the Substation,

ANNEXURE 'G'

INSPECTION & MAINTENANCE SCHEDULE OF OIL AND AIR CIRCUIT BREAKERS

Sr No	Frequency of Inspection	Items to be inspected	Details of Inspection	Remarks
1	Daily	General cleanliness	Examine the switchgear premises doors, circuit breaker etc for general cleanliness	
2	—do—	Oil	Check oil leakage, if so level be also ascertained	
3	—do—	Tank	Check for temperature by touch and for any unusual noise and smell	
4	—do—	Alarms and lamp indication circuit etc	Test the alarm circuit for continuity and lighting circuit and earthing system	
5	—do—		Draining and blowing down of main air receivers, checking all air & air conditioning flow meters	
6	—do—	Battery	Check for rated voltage and specific gravity of the electrolyte	
7	—do—	Safety aids	Check safety aids for proper operation/condition	
8	—do—	Load	Check for load conditions on 3 phases, adjust relay settings, if necessary.	
9	—do—	Indicating & Measuring Instruments.	Check indicating and measuring instruments for correct readings and being in proper working order	

1	2	3	4	5
10	Weekly	Auxiliary fuses	Check that auxiliary fuses are intact	
11	—do—	Oil level & guages	Check oil level in guages of the Tank/poles/oil filled bushing Replenish oil if below normal	
12	—do—	Bushings or insulators	Check for chipped or broken insulator, excessive dirt film	
13	—do—	Closing solenoid of air cylinder, motor or spring	Visual inspection to see that equipment is in operating condition Drain condensation from air cylinder	
14	—do—	Latch and trip mechanism	Visual (or otherwise) inspection to see that mechanism is in operating condition	
15	—do—	Tripping solenoid	Visual inspection to see that solenoid trip device is in operating condition	
16	—do—	Cabinet lights and heaters	Check cabinet heaters and see that they are in service during cold waether Replace burnt out lamps	
17	—do—	Power supplies and wiring	See that all power control circuit switches are closed.	
18	Weekly	Breathers and vents	Check for external obstructions to breathers and vents and condition of silica-gel	
19	Monthly	Nuts, Bolts, Jumpers etc	Check whether nuts and bolts are tight and jumpers are properly connected	
20	—do—	Drain Plug	Check that drain plug is tight	

1	2	3	4	5
21	Monthly	Operation counter	Observe and record reading of operation counter	
22	Quarterly	Local remote operation	Check that breaker can be operated locally and remote control operation	
23	—do—	Exhaust pipes	Check and clean the exhaust pipe	
24	—do —	Dash Pot	Check the working of dash pot	
25	—do—	Shutter Mechanism and trolly alignment for 11 KV breaker	To check for proper working of shutter mechanism and to verify the alignment of trolly	
26	—do—	Manual Operating Device	Check that manual operating lever or jack is kept on hand and is in visible condition See that Breaker is closable with it	
27	- do—	Latch and Trip mechanism	Observe mechanism during general tripping operations to see that every thing is in working order Check pins, bearings and latch for wear, binding and misalignment Clean and lubricate the moving parts Check latch carefully to see that it is not becoming worn so as to unlatch from vibration or stick or fail to trip Tighten bolts and screws	
28	-do—	Tripping solenoid	Observe operation during electrical tripping See that full	

1	2	3	4
	Quarterly		energy, snappy action of plunger is obtained Check plunger for sticking in guides Check oil and insulation resistance
29	—do—	—	Checking and adjusting oil levels in jumpers
30	—do—	Indicating and Measuring instruments	Check for satisfactory operation, adjust where necessary
31	Half yearly	I R Value	Check I R Value in ON & OFF between contacts in off position Check I R value of control cable with 400 V megger
32	— do—	Earth Resistance	Check earth resistance of body
33	—do —	Slow closing test	This test may be conducted and also check that all the three contacts are made simultaneously
34	—do—	Adjustment of gap (for MOCB) & other type to check the prescribed items by the manufacturer	The gap may be checked and adjusted to the required value
35	—do—	Wiring connection	Check and tighten wiring connection at terminal points Inpect wiring for open circuit, short circuit and damaged insulation.

1	2	3	4	5
36	Half yearly	Aux Switches	Check condition of contacts & refinish with fine file if burnt or corroded Check contact springs, operating rods and levers Check closing and operating position with respect to main contacts while breaker is slowly closed and opened manually	
37,	—do—	Control and protection Chamber of 11 KV switchgear	To check for alignment of front door opening/closing, for loose fitting, loose wiring of openings in 11 KV switchgear	
38	— de—	Insulated jumpers, CT and PT in 11KV switchgear	To check for tightness of connections, proper insulation and proper geometry	
39	— do —	11 KV cable connection	Check for overheating and proper connection and insulation	
	Note	While carrying out the above Mtc, the firms rocommendation are required to be followed for their equipment High voltage testing is recommended when checking insulation of high voltage circuits, particularly 11 KV cable & lines which may be done once in a year		
0	Annual	Foundation	Check foundation for cracks and setting, A shift of the breaker tank may break bushings or cause misalignment of contacts or bindings of operating mechanism	

1	2	3	4	5
41	Annual	Oil Valves and plugs	Check condition of paint Inspect oil valves and plugs Flush out oil and clean the oil tank/quenching chambers	
42	—do—	Oil levels and gauages	Clean dirty gauge glasses and connection into tank, Drain out and replace bushing oil if dirty or discoloured	
43	—do—	Breathers and Vents	Check to see that screens and baffles in vents or breathers are not obstructed or broken	
44	— do—	Panels & Cabinets	Check air circuit breaker or other panels of insulating material for cracks and cleanliness check condition of enclosing cabinets including hinges, latches, locks, door gaskets and paint	
45	—do—	Bushings or insulators	Clean porcelain with water, chloroethene or other suitable cleaner Repair chipped spots by painting with lacquer such as red glyptal Inspect gaskets for leaks, tighten bolts Check insulation resistance with contacts closed and (Tan delta for condenser type) check oil sample from bottom of bushing for dielectric strength and moisture Replace or replenish oil if necessary. Check and clean interior atleast once every five years	

1	2	3	4	5
46	Annually	Main terminals and ground connections	Tighten all nuts and ground connections Refinish joint mating surface, if they have been overheated Inspect ground cable to see that it is not loose or broken	
47	—do—	Main contacts	Remove the tanks or drain out oil, so that the contacts can be inspected dress contacts, if rough with a fine file Check contacts voltage drop with millivolt meter after inspecting reasonable current Frequency of contact maintenance should be based on number and severity of faults interrupted, rather than a definite period Check adjustment of gap when required	
48	—do—	Contact pressure springs	Check for loss of temper damage or other deterioration	
49	—do—	Flexible Shunt	Check flexible shunts at contact hinges for overheating or damages Tighten connections	
50	—do—	Magnetic, air or oil blow out devices	Check arc rupturing blow out coils magnetic circuit arc chutes, deion grids, oil blasts or other interruptors for proper operation	
51	—do—	Cross heads	Check contact cross head for misalignment breaks bends or looseness on lift rods	

1	2	3	4	5
52	Annually	Lift rods and Guides	Check contact for lift rods for brakes, weakening or wrapping, and pulling out at ends Check adequacy of guides	
53	—do	Operating rods, shafts and bell cranks	Check for loose locknuts, set screw, keys, bearings bent rods or twisted shafts etc Clean moving parts of rust, dirt and accumulated grease and oil Wash out bearings, pivots and gear with chloroethene or other suitable cleaner and operate breaker several times to work out dirt and old lubricant Lubricate with new grease or oil	
54	—do—	Closing solenoid air cylinder, Motor or Spring	Observe mechanism during several operations to see that everything is in proper working order Check solenoid plunger for sticking in guides Check Coil resistance and insulation resistance Dismentle air cylinder and clean & lubricate Check springs for proper tension and closing energy	
55	—do—	Solenoid Valves	Check for condition of valve, and refit as necessary See that moving parts are free to operate Check resistance & insulation resistance of solenoid coil	
56	—do—	Operation counter	Check that the operation counter is properly registering the breaker operations	

1	2	3	4	5
57	Annually	Position indicator	Check that position indicator is properly indicating the breaker position Check operating rods or levers for loose parts	
58	—do—	Dashpots	Check for proper setting and adjust as necessary Clean out and replenish liquid in liquid dashpots	
59	—do—	Mechanism cabinets	Check condition of metal and hardware Repaint as necessary See that doors gaskets are tight and properly exclude dust and dirt	
60	Annually	Power Supply & wiring	Inspect fuses of circuit breaker in all power and control supply circuits Check up insulation resistance of wiring, with devices connected	
61	—do—	Oil dielectric test & acidity test, dependent on actual tripping	Check dielectric strength of the insulating oil in the main tanks and oil filled bushings Oil should be filtered or replaced if dielectric strength is found to be below 25 KV, or if there is a noticeable amount of carbon in suspension on the bottom of the tanks Also check the acidity of the oil	
62	—do—	Operation	Some breakers particularly those carrying high values of current have a tendency to develop contact heating if left closed for long periods Opening and closing in breakers several	

1	2	3	4	5
	Annually	Operation	times at intervals, as system operation will permit and may alleviate the heating by wiping the oxide from the contact surfaces, as well as demonstrate that the breaker is in operating condition	
63	—do—	Bushing current transformers and potential devices	Check tap setting & adjustments at terminal board to see that they agree with diagrams Check insulation resistance of wiring with devices connected Check ratio & phase angle adjustments, of potential devices if changes have been made in secondary connection and burden Tighten connections, including potential device top in to bushing	
64	Once in two years	—	Testing of oil in oil filled bushings	
65	—do—	—	Cleaning blast tube internally & checking clamping down nuts,	
66	—do—	—	Overhaul and checking efficiency of main compresser	
67	Five yearly (The period canbe changed depending upon the load cycle of the equipment & manufacturer's recomendations)	—	Complete overhaul of the O C B	

NOTE These charts should be displayed in the substation.

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ANNEXURE 'H'

INSPECTION & MAINTENANCE SCHEDULE FOR 11 KV LINES (INCLUDING G O SWITCHES)

Sr No	Frequency of Inspection	Equipment/items to be inspected	Inspection Note	Action Required/ Remarks
1	Quarterly	Poles (1) Steel (2) Wood (3) Cement	Check for the following in case of all the 3 types of poles i) Damaged/broken poles or for ground level erosions and corrosions where the pole is not capable of safely supporting its load ii) Bowed or leaning poles due to improper guying or over loading iii) Unauthorised attachments such as fencing, aerial wires etc iv) Poles which are very much exposed to hitting/striking of animals and bumping & scrapping by vehicles	iv) Use of guy/ guards made of bright coloured PVC sleeves should be made where necessary so as to give indication of site of pole
			v) If the pole "Number Plate" is still distinct vi) Condition of foundation vii) Examine the condition of foundation block, i e, muffs in case of steel poles	

1	2	3	4	5
	Quarterly		viii) Examine if pole requires painting/creosoting or askew in case of steel/wood poles	
2	Quarterly	Stays	Check for the following , i) Correct direction and proper angle of the stay ii) Loose, broken or any other damage done to stays iii) Whether stay insulator is intact/ whether stay is properly earthed iv) If stay-rods are are corroded	
3	—do—	Cross-arms and pole top steel work	Check for the following i) If the cross arm/clamps/knee bracings has/have slipped ii) Bending of cross-arms due to uneven tension iii) Excessive rusting of the cross-arms bracing, etc iv] Cracked or splitting of the wooden cross arms v) Loose or damaged bracings	
4	—do—	Insulators and fittings	Check for the following i) Broken or chipped porcelain flashover marks ii) Tilted insulators	Set right the to hampers wher provided a n provide propo size wooden gutl washers below t insulator, wher necessary

2	3	4	5
Quarterly		iii) Excessive deposit of dust/salt/coal and other pollution	
		iv) Excessive rusting of fittings	
—do—	Conductors and earthwire	Check for the following	
		i) Examine, if securely tied to the insulator/pole/cross-arm	
		ii) Proper sag	
		iii) Proximity of trees and other objects including building, etc	Tree branches within 1.8 m from the line on its either side should be removed
		iv) Sufficient clearance between conductor and earthwires, and also from the ground	
		v) Sufficient clearancess from other electric/telephone lines passing along, below or above it	
		vi) Earthwire is properly supported	
		vii) All the lines guards are intact and installed, where necessary	
		viii) If joints in the jumpers & conductors appear all right	Use of "thermodetector" as devised by CPRI Bangalore or any other suitable infra-red

1	2	3	4	5
	Quarterly			fault joint locaters should be made to detect over-heated joints
			ix) Broken conductor strands	
			x) Nicking near insulator neck and/or near conductor clamps	
			xi) Binding wire has not become loose and open	
			xii) Midspan joints have not cracked	
			xiii) All joints and jumpers of aluminium conductors have proper clamps/jointing sleeves	
6	—do—	Jumpers & other line accessories	Check for the following	
			i) Proper supporting and jointing two ends of the jumpers with suitable clamps	PG clamps should be used Bi-metallic clamps should be used where aluminium/ACSR & copper conductors are jointed to avoid bimetallic action.
			ii) Sufficient clearance between jumpers on the 3 phases	
			iii) Sufficient clearances of jumpers from metal works/stays so as not	

1	2	3	4	5
	Quarterly		to swing close enough to strike an arc	
			iv) Provision of proper insulation of jumpers	1 Insulating beeds or PVC sleeves should be provided
			v) Signs of over heating and burnings on jumpers and other fittings	2 Use of tape should be avoided as far as possible
			vi) Loose / defective clamps, jointing sleeves, bolts and nuts, and other fittings	
7	—do—	G O Switch (with fuse unit)	Check for the following i) For smooth operation ii) Evidence of over-heating/ burning, corrosion/ pitting on the switch contacts iii) Broken or damaged insulators iv) Proper and tight earth connections v) Fuse links for continuity, tightness of connections and correct rating vi) Proper locking arrangement vii) Proper alignment of switch contacts	A method for field testing for switch contacts with live line consists in using an insulated rod (for 11 KV) adjustable height having at its upper end a tallow candle fixed in a clip Hold the candle against the hot contact for a few seconds & then examine If the grease slightly melts, mark the contact for attention

1	2	3	4	5
	Quarterly		viii) Proper and complete fitting of male contacts in to the female ones ix Arcing horns are intact	If the greas runs, the switc requires earl attention and it smokes, dangerous condit is assumed, th switch require immediate attentic
8	—do—	Lightning arrestors	Check for the following i) Broken/damaged porcelain ii) Intact and tight, line & earth connections iii) External indication of fused/spark-over arrestors	
9	—do—	11 KV cable and cable boxes	Check for the following i) Proper supporting of the cable and the cable boxes ii) Damaged insulators iii) Oil and compound leaks and that the cable box is properly topped up with the compound iv) Tight and intact connections v) Proper earthing vi) Overall condition of the cable and joint	

2	3	4	5
Quarterly	Earthing system	Check for tight and intact earth connections of all metal works of the line	
Half-yearly	Jumper and line accessories	i) Check for broken or burnt strands of the jumpers and replace, where necessary ii) Check for the proper material and size of the jumpers for the given conductors iii) Check for loose connections & signs of over-heating specially on copper to aluminium connections iv) Check for crowding or jumbling of wires and jumpers at the teeoff points & adjust where necessary v) Check for general condition of other line accessories such as different clamps, jointing sleeves & other fittings, etc re-adjust & replace, where necessary vi) Replace the binding wire joints of jumpers by proper clamps	It is quite common to find the two ends of

1	2	3	4	5
	Half-yearly		vii) Check for the condition of sleeves over the jumpers and replace, where necessary.	jumper joined by binding wire
12	Half-yearly (Its maintenance may be done even earlier as the functioning of G O switches is generally in disorder and is always a source of trouble)	G O Switch (with fuse unit)	i) Cleanliness : Clean all dust and other deposits with neat and dry cloth	
			ii) Switch contacts . 1) Check for alignment, adequate contact pressure and smooth operation & adjust where necessary.	i) These points should be particularly checked when contacts are replaced.
			2) Examine for burning/over-heating or other damages Recondition or replace, where necessary.	ii) Fixed and moving contacts may be dressed by using a fine file/fine sand paper. Use of rough sand paper be avoided
			3) Insulators 1) Check for cracks, chipping & other defects, replace, where	iii) Petroleum jelly/white vaseline or other suitable contact lubricant

1	2	3	4	5
	Half yearly		necessary 2) Remove dirt, coal and other pollutions by wiping with soft cloth Use weak acidic solution, if the deposit has set hard iv) Arching Horns Check if these are intact and replace if damaged/burnt v) Mechanism Clean, examine and renew worn out parts Relubricate & check for correct operation vi) Fuse Unit Replace old fuses with new ones of right type and capacity and proper length vii) Main connections and Earthing Proceed as described under seperate heading of 'Jumpers' and 'Earthing devices' viii) General · Check all hardware and tighten, if needed	should be applied on contacts Grease should be applied on all the moving parts
13.	Every six month (once before the monsoons & secondly	Tree trimming and bird's nests, etc	i) Cut off the tree branches where necessary to mantain a minimum clearance of 1 8m on each side of the line	Suitable repulsive chemicals may be sprayed to stop tree growth & formation of

1	2	3	4	5
	after monsoons or earlier, if necessary)		ii) Remove all dead wend iii) Remove all bird's nests	birds nest whe possible
14	Annually	Poles 1 Steel 2 Wood 3 Cement	The instructions given below are common to the 3 types of poles i) Replace the damaged/broken poles ii) Straighten/make vertical leaning poles by proper guying iii) Shift the position of poles exposed to accidents due to their being near or in common way iv) Reprint the pole No Plate, if defaced v) Pack and consolidate the foundation soil, where disturbed or eroded Steel Poles Examine for signs of rust, clean off with wire or brush and apply double coat of suitable paint where required over a primer base Wood Pole (i) Examine The decay	

1	2	3	4	5
	Annually		for decay of wood and creosetting/ascuer treatment may be done, where required	test should be performed by hammering the pole at some points on the upper portion and at 0 3m below the ground level with a one kg hammer A clear ring is indication of healthy wood, while a hollow ring is a sign of decay Provide butt joints where decayed wood is removed
			ii) Examine for burning of wood at hardware attachment points and recondition, where necessary.	
			Cement Pole No detailed maintenance required	
15	Annually	Stays	i) Tighten the loose stays ii) Replace the broken/ damaged stays and stay-bows	

1	2	3	4	5
	Annually		iii) Replace the broken stay insulator/recondition the earth iv) Provide sufficient barbed wire/cattle guards on the stay to avoid rubbing of cattles	
16	Annually	Cross arms	i) Replace the broken / splitted/ cracked/ bent / cross-arms by newones ii) Bring in position the slipped cross-arms / clamps/bracings iii) Paint the steel cross-arm and bracings, etc, if excessively rusted	
17	(The insulators be checked twice a year preferably before and after (monsoons)	Insulators and fittings	i) Clean and check for cracked/ chipped and punctured insulators Replace,where necessary	
			ii) Examine for the surface contamination and remove it by wiping with a soft cloth If the deposit has set hard, a weak acidic solution may be used.	Do not u cotton wasi
18	Annually	Conductors and earthwires	i) Tighten loose bindings and replace damaged ones	
			ii) Examine for corrosion at	To avoi

1	2	3	4	5
	Annually		the joints of conductors and insulators Clean & renew, where necessary	corrosion the conductors should always be secured with pin insulators by means of binding wire of the same metal as that forming the outer strand of the conductor
			iii) Examine closely for broken strands particularly, at the clamps and insulators due to vibration and repair, where necessary.	
			iv) Examine general condition of the conductor and earthwires, i e for kinks, crushed spots, over/under tensioning, etc, and recondition, where necessary.	
			v) Examine for any loose/ cracked joints of conductors in the midspan and recondition, where necessary	
			vi) Examine for slipping of conductors from the	

1	2	3	4	5
	Annually		clamps Tighten all clamps and fittings	
19	—do—	Lightning arrestor	i) Clean and examine insulators for cracks or flashover Replace, where necessary	
			ii) Perform impulse voltage sparkover test & leakage current test to know the condition of the arrestor, replace in case of unsatisfactory results	These tests can be performed by using lightning arrestor testing kit developed by C P R I, Bangalore or any other available instruments To know the condition of the arrestor the test results be compared with the standard/ manufacturer's specifications Alternatively meggar may be used for detecting faulty lightning arrestor
			iii) Keep records of test results	

1	2	3	4	5
	Annually		iv) Check and tighten all line connections and earth leads	
20	—do—	11 KV Cable and cable boxes	i) Clean and examine for damaged bushings ii) Check for compound level, if there is leakage iii) Perform insulation resistance test, recondition or replace, where necessary iv) Keep continuous records of insulation resistance	
21.	—do—	Earthing System	Replace all broken earth leads and tighten others Measure earth resistance of various earths with earth tester In case of low values, recondition them.	
22	—do—	Anti-climbing devices and danger plates etc	Recondition the anticlimbing devices such as barbed wire, locks, etc, paint and reprint the danger plates if defaced.	

NOTE : These charts should be displayed in the office rooms of the Xen and SSE/SDO concerned

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ANNEXURE 'I'

INSPECTION & MAINTENANCE SCHEDULE FOR L T LINE

Sr No 1	Frequency of Inspection 2	Equipment/items to be inspected 3	Inspection Note 4	Action Required/ Remarks 5
1	Four-monthly	a) Poles b) Stays c) Cross-arm d) Conductor e) Insulators f) Connectors g) Cable boxes etc	Same as recommended for these items under Schedule for H T Lines (Whether cobwebs, kite strings, etc, hanging on the conductor)	This becomes source of the heavy leakage when wet
2	Monthly	L T Switch	Check for the following i) If the switch with cover is intact ii) If the cable/switch running hot iii) Broken cut-outs iv) Signs of over-heating/ burning on contacts v) Proper size of fuse wire vi) If the switch is properly earthed vii) Safety from rain water etc	
3	Half yearly	L T Switch	i) Check lead on the L T circuit and	

1	2	3	4	5
	Half-yearly		replace the L T cable/ L T switch by higher capacity one, where necessary ii) Replace the damaged L T cable with new one of the right capacity iii) Examine the switch for smooth operation iv) Replace the burnt / cracked cut-outs v) Recondition the switch contacts vi) Replace the old fuses with new one of right capacity vii) Tighten all connections viii) Ensure that the inlet of the cable into the switch is plugged with plastic compound to avoid entry of rain water Refill, where necessary, ix) Clean of the cob-web and other nests, etc , from the inside of the switch	
4-	One to two yearly (Depending upon the volume of work)	a) Poles b) Stays c) Consuming d) Conductor e) Insulators f) Connector g) Cable boxes etc	Same as recommended for these item under Schedule for H T Line	

NOTE These charts should be displayed in the office rooms of the Xen and SDO concerned.