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Power Engineer Journal

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EDITOR'S NOTE



The Society of Power Engineers (India) is an apex body founded just before the Independence and has presently more than 2400 experts and eminent engineers on its strength who share their rich experience, express their views and give suggestions for sustainable growth of power sector with state of art technology. This objective is achieved by arranging seminars, workshops etc. The headquarter of SPE is in CBI&P, New Delhi.

The members of the society are from Civil, Mechanical, Electrical, Electronics, and Metallurgical disciplines from power utilities, power equipment manufacturing companies, Maintenance Engineers from Small, Medium & Large-scale industries, Academic institutions, and Consulting firms. The members are Diploma Holders or Degree Holders and Engineering Students. This constitutes a very co-hesive group of engineers related with Power Sector.

In order to ensure power development across the country, it has constituted its chapters at Vadodara, Jabalpur, Hyderabad, Delhi, Kolkata, Mumbai, Gwalior, Lucknow, Bangalore, Vallabh Vidhyanagar and Ahmedabad. The Vadodara Chapter of the society, is the most active chapter and completed silver jubilee in the year 2021 and have set various goal like Increase Membership, Complete digitization, Increase Industry and academic participation etc. Similarly the Ahmedabad Chapter of society, which is the new chapter, is taking excellent initiatives and has made massive plan for membership and organization of regular workshops on technical subjects.

We as Head Quarter are making efforts to expand the network of the Society of Power Engineers (India) to various places in the country. To enhance the activities and membership of Society, we have already increased the frequency of its yearly journal to half yearly, (January and July), with an aim to provide information of the latest development and advances in the field of Power Generation & Transmission and Distribution. The Journal is going to be made available both in print and online versions.

This issue of journal includes important articles, informative data and case studies connected with Power Sector besides Report of the recent activities by Head Quarter, Vadodara Chapter of Society.

We hope that the articles and other informations included in this issue of journal will be of interest to the readers

A handwritten signature in black ink, appearing to read 'A.K. Dinkar', with a long horizontal line extending from the end of the signature.

A.K. Dinkar
Secretary

Society of Power Engineers (India)

Failure Analysis of Current Transformer in Service Condition – A Case study

Abhishek Verma¹, Leena H. Roy² and Sarita Dongre²

ABSTRACT

This paper explores the analysis of current transformer failure. The parameters required to determine the healthy condition of current transformer are verified. The actual cause was detected from diagnostic test performed on the current transformer. It was concluded that the undervalued component of the current transformer may have contributed to the catastrophic collapse. The case study identifies the actual reason for failure.

Keywords : current transformer, electrical stress, failure analysis, diagnostic test, case study.

I. INTRODUCTION

A current transformer, often known as a CT, is typically built to generate an alternating current in its secondary winding that is proportional to the measured current in its primary [1].

The output required from a current transformer depends on the application and type of load connected to it [2]:

For metering purposes the core shall have high accuracy, low burden (output) and a low saturation voltage. This operates in a range of 1-120%.

The protection relays or other differential relays or other devices put in the system to keep track of any disturbances caused in the primary and transferred to the secondary side for protective purposes. Low accuracy but high capability to transform high current faults are needed for measurement at fault circumstances in the overcurrent range so that protection relays can measure and disconnect the fault. Although the protection core's accuracy class is not very good, it is designed in a way that prevents saturation over a wide range of current.

This paper presents a case study of a current transformer installed in a 33 kV substation that failed while in service.

The current transformer's physical damage, which happened while it was in use, signals serious interior damage.

The study carried out using the required diagnostic tests is discussed in the article, which comes to the conclusion that the catastrophic damage is not brought on by a malfunction or failure of the core and winding of the current transformer but the hidden cause which lead to the failure.

II. BACKGROUND INFORMATION

The Current transformer[3] was installed in the substation of the operation and maintenance section of the department. The current transformer was under the no-load condition as there was no load at the secondary side of the current transformer at the instant of failure. The transformer failed during the night time on a non-working day. The utility observed the fault in the system and disconnected the current transformer from the line by opening the feeder connections. Figure 1 depicts the current transformer's physical condition.

At first glance, it appears to be a short-circuit fault which generated dynamic forces acting on the tank of the current transformer, resulting in tank expansion and, ultimately, catastrophic failure of the current transformer.



Fig. 1 : Current transformer's physical condition after fault.

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III. ROOT CAUSE ANALYSIS

The current transformer was sent to the laboratory for diagnostic testing and analysis to determine the cause of the fault.

The rating of the current transformer installed was:

Rated Voltage : 33kV
Ratio : 200/5
Rated Burden : 15 VA
Accuracy Class : 5P
ALF : 10

The diagnostic tests carried out were :

- Inter-turn overvoltage test
- High voltage test between the primary and secondary winding
- Determination of error
- Secondary winding resistance
- Composite error test

The results of the test were as given below:

A. Inter turn overvoltage test:

The test was conducted as per IEC 61869-2 . The current transformer withstood the test for one minute.

B. High voltage test between primary and secondary winding:

The test was conducted by earthing the primary winding and applying the power frequency voltage of 3.0kVrms for one minute to the secondary winding. The current transformer withstood the test.

C. Determination of error:

The test was conducted for the accuracy class of 5P as per IEC 61869-2 and the results were:

Table 1 : Ratio and phase angle error on protection core

Ratio	Rated Burden	%RE	PAE in minute	Remark
200/5	15VA	-0.450	+5.20	Within the limits



Fig. 2 : Accuracy test of the CT

The results obtained were within the limits as specified in the standard.

D. Secondary winding resistance:

The value of resistance of secondary winding was measured and found as 0.119Ω at 27°C which is in line with the requirement for 5A secondary.

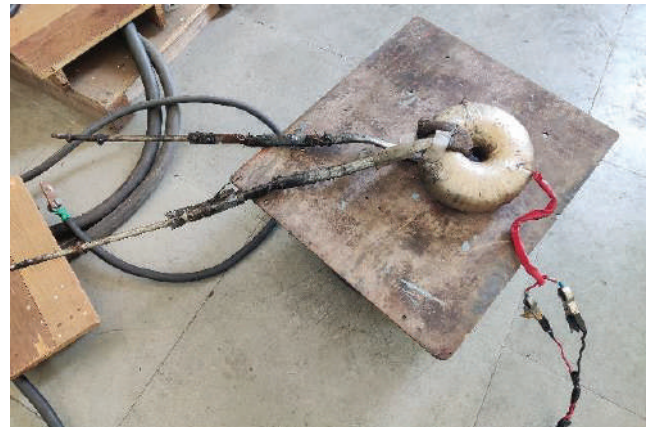


Fig. 3 : Secondary winding measurement of CT

E. Composite error test:

The composite error test was conducted at the secondary limiting voltage calculated from the secondary resistance and the declared value of ALF and the value found was as follows:

Table 2 : Measurement of exciting current on protection core

Ratio	Resistance at 75°C	Secondary limiting voltage	Exciting current	%CE
200/5	0.141Ω	37.05V	0.236A	0.472

The results of the diagnostic tests conducted conclude that the failure of the current transformer has not affected the core and the winding of the current transformer vis-a-vis it can be said that the winding or core was not the cause of the failure of the current transformer.

As mentioned in product standard IEC 61869-2 the diagnostics tests performed are the confirmatory test after short-circuit test. The satisfactory results of the diagnostic tests thus prove that the fault was not a short-circuit fault.

IV. ALTERNATE REASONS FOR THE CAUSE OF FAILURE

Over excitation, switching surges, turn-to-turn short circuit, layer-to-layer short circuit, partial discharges, insulation tracking, static electrification of oil, and flashovers are all possible causes of current transformer failure. Due to the inability to shut down, maintenance of equipment is

sometimes postponed, affecting the efficient operation of the equipment and causing further deterioration of the equipment condition.

The diagnostic tests performed on the current transformer eliminate many of the causes.

The test on the internal part of the current transformer can be used to determine the likelihood of failure. The core, winding (primary and secondary), and oil as a dielectric medium are the main components of the CT. The diagnostics tests performed eliminate the failure criteria of the core and winding. The oil was the only remanent factor that contributed to the failure. Most of the time, it is discovered that the cause is insulation degradation caused by moisture ingress and transient system voltages. The preventive maintenance schedule must take into account the likely areas of degradation and frequent occurrences of abnormal conditions, such as the DGA analysis and BDV of the oil.

In the case of current transformers, the presence of moisture in the paper-oil insulation of the CT and the presence of moisture in the internal insulation is the main contributing factors that cause the deterioration of the internal insulation. It has a knock-on effect in that the heat generated induces additional dielectric losses, causing the temperature to rise even further. The insulating oil then carbonises, producing acids that cause premature ageing and an increase in insulation power factor. Thermal runaway occurs, resulting in catastrophic CT failure.

Electrical ageing caused by partial discharges causes insulation deterioration and gas production, which eventually leads to insulating oil saturation. If the moisture content in the oil is not removed promptly and effectively, it causes the formation of gas bubbles in the form of a void in the insulation, which increases the losses within the dielectric, resulting in an increased insulation power factor. Because the properties of the solid and void dielectrics differ, a higher local electric stress is possible in a void. The presence of moisture in the oil causes the formation of partial discharges. Moisture content has a direct impact on the ageing of the insulation due to the production of gas bubbles. The presence of partial discharge indicates insulation deterioration and places excessive electrical stress on the CT's capability. With the onset of partial discharges and high electrical stress, the CT's life expectancy is jeopardized.

V. RECOMMENDATIONS

The authors recommend the following recommendations based on the case study for improving the life expectancy of a current transformer:

- Partial discharge detection as a routine diagnostic test.
- As sludge is usually deposited at the bottom of the tank, a drain plug should be provided. In installed conditions, the drain plug is required for sampling for BDV and DGA analysis.
- Existing installation conditions can be met by placing padded insulation beneath the CT tank and measuring the leakage current between the CT tank and the earth. This can be used as a diagnostic tool to detect electrical leakages in service and as a simple method to replace partial discharge measurements as a routine criterion.

VI. CONCLUSION

The current transformer's figures show that the catastrophic failure was caused by a heavy current fault seen by the CT. Further investigation reveals that the damage was not caused by a short circuit fault, but rather by an underappreciated component of the current transformer, namely the oil.

The suggested diagnostic tests can save and extend the life of the current transformer. Many utilities can reuse current transformers by performing diagnostic tests such as power frequency testing, insulation resistance testing, inter-turn overvoltage testing, secondary resistance measurement, and error determination. The majority of the tools required are available with the utilities. It can reduce procurement time and allow the CT to be reused by assembling it in a new tank. It can also prevent environmental hazards as one of the 3R's that is Reuse can be used in such a diagnosis.

VII. Acknowledgement

Authors would like to express their gratitude to Dr. A. K. Datta, Joint Director, CPRI Bhopal for extending his support and submitting the artefact for investigation.

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- [1] Thesis by Deepak Rampersad on "Investigation into current transformer failures within Eskom distribution" in December'2010
- [2] Instrument transformers application guide by ABB.
- [3] Artefact: The failed current transformer of the operation and maintenance department.

Impact of Winding Joint to the Failure of Distribution Transformers : A field study

Shashank Gupta¹, Manoj Tripathy¹ and D. K. Dwivedi²

ABSTRACT

Winding joints are the crucial part of a Distribution Transformer (DT) and improper joint affects the performance of DT by generating local hot-spot, which arise due to the increase in contact resistance. In this field study, two failed 25 kVA DTs and 22 HV coils of 25 kVA DTs were analyzed by measuring the contact resistances of winding joints. The correlation between the degradation of winding joints and the failure pattern of DTs has been investigated. The observations and measurements show a direct relationship between the failure of DTs and the degradation of winding joints. The higher and unstable contact resistance of the winding joint results in more damage in the corresponding coil due to increased temperature.

1. INTRODUCTION

Winding joints are the most vulnerable and unavoidable part of a DT, which connect different parts of the winding. A reliable winding joint should pass the current from one part of the winding to another and continue to do this in the long run without increasing the contact resistance. Any increase in contact resistance is manifested as an increase in the operating temperature, which raises the contact resistance further, thus worsening the operating condition while decreasing the expected life of the whole equipment [1][2]. Therefore, it is of utmost necessity to guarantee the winding joint performance and its impact on the DT since the failure of such components can lead to significant power outages with catastrophic and costly consequences.

In India during 2021-22, the failure rate of DTs was around 11%, due to which the distribution companies spent nearly 32 billion INR for the repair and replacement of DTs [3]. The statistical analysis shows that the DTs failure rate increases every year. DTs fail prematurely before completing their normal lives, resulting in poor reliability and monetary loss to the utility [4]. A number of researchers [3-5] analyzed various aspects of DTs to find the root causes of failure and remedies to lower the failure rate. J. Singh et al. [4] analyzed the 348 DTs for the failure modes, causes and effects and performed a criticality analysis based on risk priority number. The thermal image of six DTs were analyzed by Mariprasath and Kirubakaran, which observed that the hot-spot formed at the line joining points and was highly sensitive to other parts of DT [6]. In lower rating DTs (25/100/200/250 kVA), Aluminium (Al) is used as a

conductor material and mechanical joints like crimping and Western Union Splice (WUS) joints are commonly used for the winding connection. Thermo-mechanical stresses, differential strain recovery between ferrule and conductor, relaxation of interface pressure and

metal contact oxidation are the most critical factors for the degradation of mechanical joints [7]. All the stated degradation factors increase the contact resistance of the mechanical joints. The connection between Al conductors is a difficult process compared to copper conductors due to the formation of an insulation layer of Al₂O₃ and higher creep rate [8]. Creep deformation decreases the joint force in Al mechanical joints, reducing the area and number of contact points, which increases the resistance of joints [9].

The above literature revealed that the winding joints are the weak point in any DT. The contact resistance is the best indicator of the health condition of the winding joints. Due to various degradation mechanisms and prolonged equipment operation, joint contact resistance increases and negatively impacts thermal and electrical performances. Regardless of the key role that winding joints plays in a DT, to the best knowledge of authors, there are practically no studies focused on the analysis that shows the failure of DTs has a direct correlation with the degradation of winding joints. So, in this work, winding joints of failed 25 kVA DTs were analyzed. The physical condition of the DT coils along with the winding joints was also observed. The contact resistance of each winding joint was measured and an effort has been made to relate the failure of DTs with the degradation of winding joints.

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2. WINDING STRUCTURE AND JOINTS IN DTS

A DT generally consists of High Voltage (HV) and Low Voltage (LV) winding. HV winding failure is more prone to damage than LV winding in DTs [10]. The electromagnetic forces developed in a DT during energization are very high and produce tensile stress in the HV winding, which is the reason for creep in the HV winding [11]. HV winding of DTs is generally made of cross-over coils. Cross-over coils are wound over formers, each consisting of several layers with a number of turns per layer. The complete winding structure consists of a number of coils connected in series. Two ends of each coil are brought out, one from inside and one from outside. The inside end of a coil is connected to the outer end of the adjacent coil. So, the joints in the HV winding of DTs are required at the following places (as shown in Fig. 1):

- (i) Within the coil (internal winding joint)
- (ii) To connect the coils of a phase winding in series (S_a , S_b and S_c)
- (iii) The connection between winding end and lead wire (J_a , J_b and J_c)
- (iv) In the delta formation of the 3-phase winding (P_a , P_b and P_c)

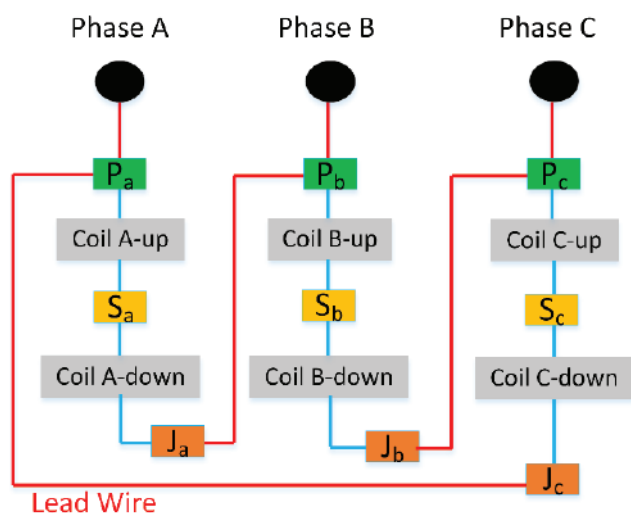


Fig. 1 : HV winding structure of DTs with joints

3. DT FAILURE ANALYSIS

A field survey was performed in different DT manufacturing companies (M/s United Electrical and Transformers, Roorkee, M/s Nuceon Switchgears, Ludhiana and M/s Sai Electricals, Meerut) and Uttarakhand Power Corporation Ltd. (UPCL) DT repairing workshop, Roorkee. In the survey, 15 DTs that failed within 2-3 years after the installation were closely observed for winding joints performance and its correlation with failure of DTs. Out of the 15 DTs, two worst failed 3-phase, 25 kVA (11/0.433 kV) DTs were discussed in this section. The 22 HV coils

were unwound to search for joints within the coil. Out of 22 HV coils, three coils were found with the Western Union Splice (WUS) joints and discussed in this section.

The contact resistance measurement of DT winding joints was done by the resistance meter Hioki RM-3545 with 0.006% accuracy, designed according to the 4-wire resistance measurement. The 4-wire resistance measurement eliminates the effect of lead wires to obtain a precise resistance value [12]. This section presents the observations, measurements and analysis of DT failure with respect to winding joints.

3.1 Case study 1

The failed DT-1 and respective HV coils of different phases are shown in Fig. 2 (a) and (b), respectively. The coils of phase A were severely damaged. The turns in the outer layer were fractured and paper insulation was also burned. The coils of phase B were in good condition with a resistance of 56 Ω . The coils of phase C were badly burned in many locations. The winding joints of failed DT-1 were categorized as per Fig. 1 and shown in Fig. 2 (c).

The contact resistance of DT winding joint was measured five times for each joint for statistically relevant values, as shown in Fig. 3. The 60 mm. length of winding joints was considered for contact resistance measurement. The copper lead wire was used for taking out the connections in DT-1. So, the connection between winding end and lead wire and the connection for delta formation of the 3-phase winding are of Al-Cu type. It was observed that for failed DT-1, the joints of phase B (S_b , P_b and J_b) were stable, while most of the joints of phases A (J_a and P_a) and C (S_c , J_c and P_c) showed a large variation in contact resistance. So, the higher and unstable contact resistance of winding joints in phases A and C caused excessive heat generation and corresponding phase coil damage.

3.2 Case study 2

The failed DT-2 and respective HV coils of different phases are shown in Fig. 4 (a) and (b), respectively. The upper coils of phases A and B were badly burned, while some outer turns were fractured in the lower coils. There was no physical damage in both the coils of phase C and showed a resistance of 56.2 Ω . The winding joints of failed DT-2 are shown in Fig. 4(c).

The contact resistance of winding joints of failed DT-2 was measured and shown in Fig. 5. In DT-2 also, the copper lead wire was used for taking connections out of DT. The joints of phase C (S_c and P_c) were stable and showed lower contact resistances. The joint used for the delta connection of phase B (P_b) offered a much higher and unstable contact resistance. An extra Western Union Splice (WUS) joint was found in the vicinity of the P_b joint, which was found broken, as highlighted in Fig. 4 (c). The P_a joint failed from the Al wire near to joint due

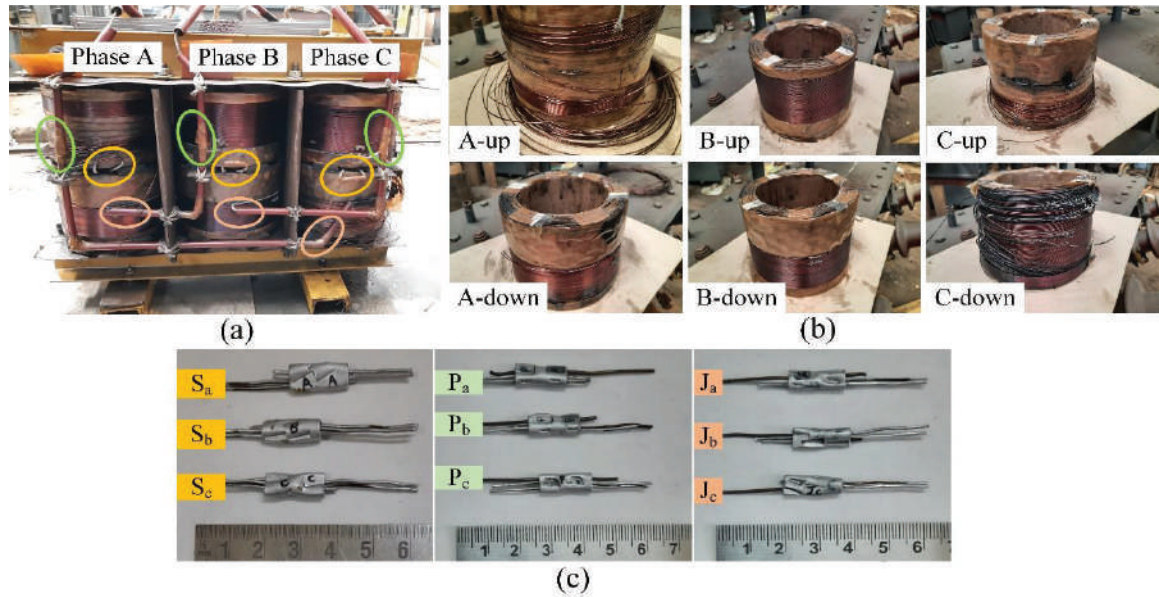


Fig. 2 : DT-1 photographs (a) Failed DT, (b) Coils of failed DT and (c) Winding joints

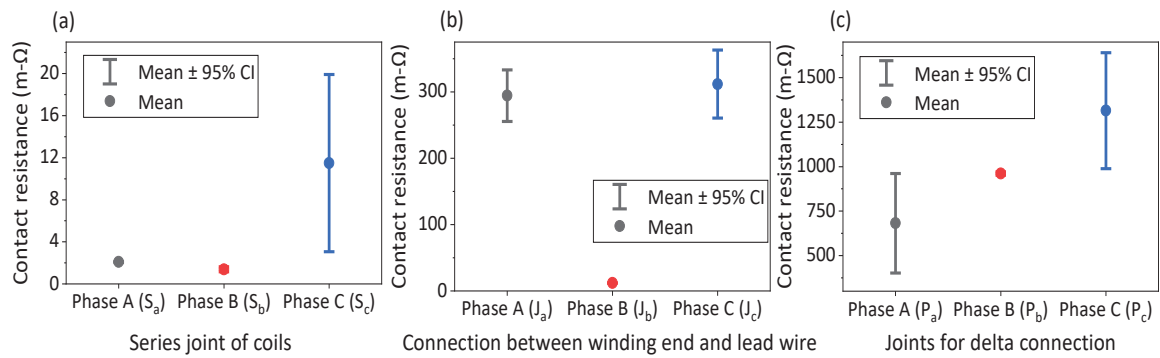


Fig. 3 : Contact resistances of failed DT-1 winding joints

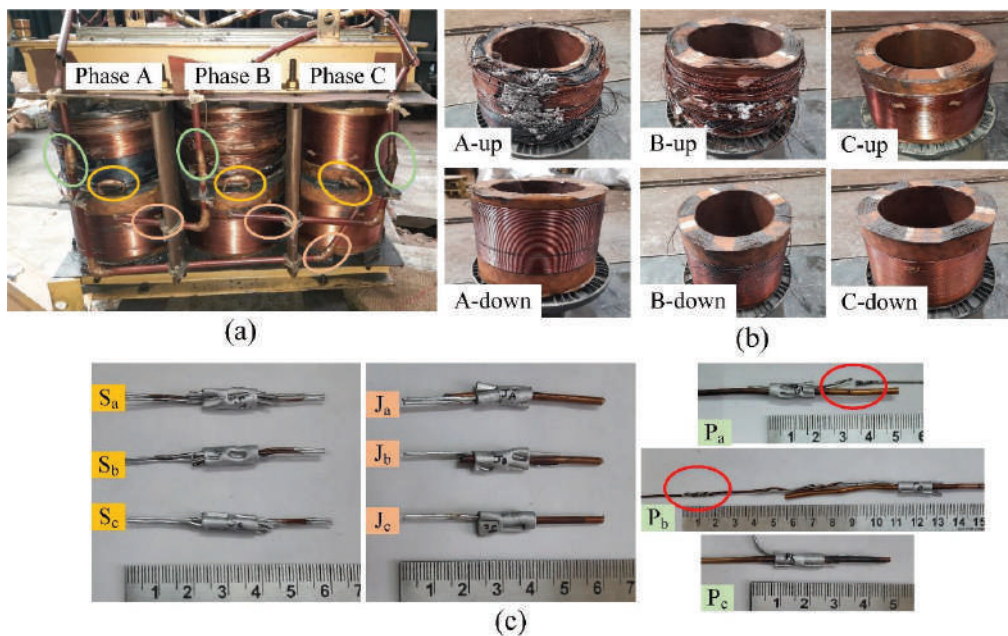


Fig. 4 : DT-2 photographs (a) Failed DT, (b) Coils of failed DT and (c) Winding joints

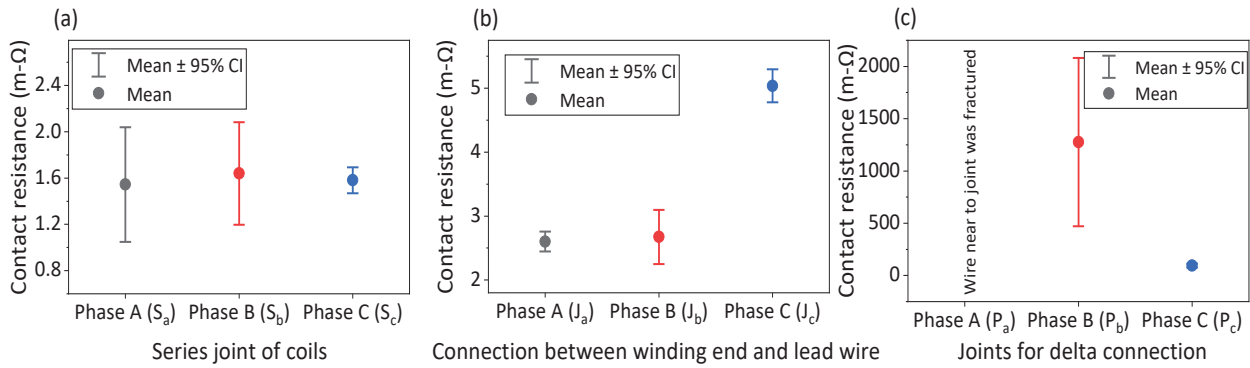


Fig. 5 : Contact resistances values of failed DT-2 winding joints

to hot-spot. The degradation of Al-Cu joints (P_a and P_b) is more in phase A and phase B, so that is the cause of damaged upper coils of phase A and phase B.

The external winding joints were inspected in the DTs and the contact resistance was measured. All the external winding joints are of crimp type. Most of the winding joints corresponding to damaged phases showed higher contact resistance and some of them were in the worst condition showing unstable contact resistance. This indicates a large degradation in the joint has taken place due to the service exposure and if any joint is in this condition, then that will cause the hot-spot formation, short-circuit and reduce the life of the DT.

3.3 Analysis of HV coils of failed DTs

The 22 HV coils of failed 25 kVA DT were collected from the DT manufacturing company and unwind for the search of inner winding joints. Three such coils were found in which the Western Union Splice (WUS) joint was used to fabricate these coils, as shown in Fig. 6. The joints were present in the 2nd, 5th and 12th layers from inside. The contact resistance of joints for 60 mm length was measured and compared with the resistance of wire

adjacent to the joint. The change in contact resistance was much greater for all the WUS joints, as shown in Fig. 7. In the WUS joint of coil-2, the insulation of Al conductor was not removed properly, which caused a much higher contact resistance compared to the WUS joint of coil-1 and coil-3. Higher contact resistance in the joints is the

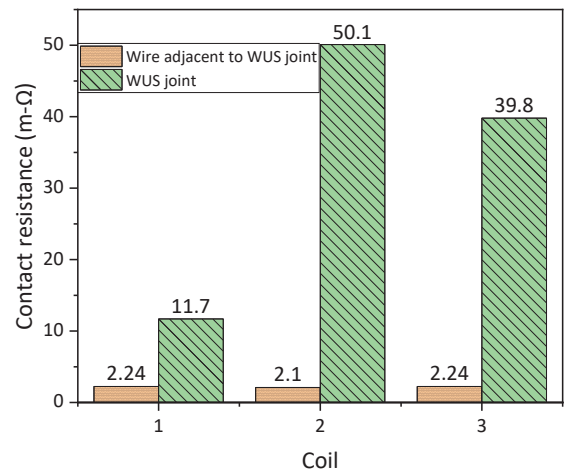


Fig. 7 : Contact resistance of WUS joints and wire adjacent to joints of failed DT coils

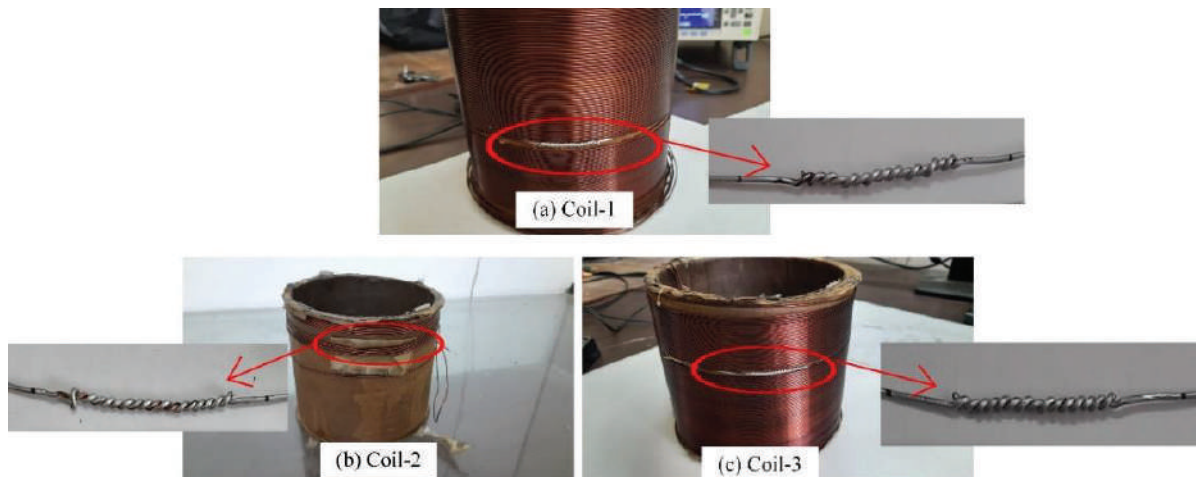


Fig. 6 : HV coils of failed DTs, (a) coil 1, (b) coil 2, (c) coil 3

combined effect of the poor creep behaviour of the Al joint and frequent switching of DTs. Poor connectivity between Al-Al conductors due to oxidation is also a significant factor for higher initial resistance and increasing the rate of rise of contact resistance.

4. DISCUSSION

Two Al wound 3-phase, 11/0.433 kV, 25 kVA DTs and 22 HV coils were analyzed for the correlation between the failure of DTs and degradation of winding joints. In DTs, the copper lead wire was used for better strength. So, the connection between the winding end and lead wire (J_a , J_b and J_c) and the connection used for delta formation of the 3-phase winding (P_a , P_b and P_c) are of Al-Cu type. However, the series connection between the coils (S_a , S_b and S_c) are always of Al-Al type, irrespective of the material of the lead wire. All the external winding joints are of crimp type. The higher resistance of crimp joints is due to oxidation of the contact interface and decreased joint force between the ferrule and conductors. The Al-Cu crimp joints show a much higher contact resistance. In Al-Cu joints, differential strain recovery between Al ferrule and copper conductor increased the stress relaxation in the crimp joint, which caused the increase in contact resistance and hot-spot (as in P_b joint of DT-2) and in the worst case winding fractured in the vicinity of the joint (as in the case of joint P_a of DT-2).

Out of 22 HV coils, three coils i.e., 13.6% coils used WUS joints for their formation. The joint within the coil is necessary only when the bobbin conductor is not sufficient to make the required turns. So, in manufacturing a DT coil, it is better to avoid joints within the coil by taking a fresh bobbin. For Al wound DTs, the WUS joint within the coil is of Al-Al material. In Al WUS joints, the insulation oxide layer creates problems in joining the conductors due to the discrete nature of the interface. A good electrical contact forms only at the points where the oxide layer ruptures. However, during the current loading, stress relaxation occurs in WUS joints due to creep, which reduces the contact interface points and increases the contact resistance of WUS joints. The increased resistance generates excessive heating and causes premature fracture of the DT.

5. CONCLUSIONS

The Al wound DTs consist of Al-Al and Al-Cu winding joints. The contact resistance of external winding joints corresponding to the damaged phases shows a higher and unstable contact resistance compared to healthy phases. The inner Al-Al WUS joints also showed a large change in contact resistance compared to adjacent wire resistance. The analysis indicated the poor performance of the Al-Al and Al-Cu winding joints is the reason for the premature failure of DTs.

Acknowledgment

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Importance of Transformer Neutral Earthing in a Substation – A Case Study

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ABSTRACT

The earthing system in a HV substation consisting of power transformer neutral, Lightning arresters, Current transformers, Potential transformers and metallic body parts of the equipment etc. The effectiveness of earthing system for reliable operation of power systems depends on proper maintenance of earthing system at regular intervals.

As part of regular operation & maintenance, measurement of earth resistance at regular intervals is very much essential to check the healthiness of the earthing system. In most of the substations, correct practice of measurement of earth resistance is not being followed. Because of the improper measurement of earth resistance of earthing system in a substation leads to most of the failures of the equipment and one such major failures is the failure of transformer. As the general practice, efficacy of earthing system is carried out in order to ensure that the earthing system is effectively bonded to all the equipments. This paper describes the importance of transformer neutral earthing and best practices to be followed in measurement of earth resistance during evaluation of earthing system in a substation which will be an insight to personnel for proper diagnosis of failure of system due to improper grounding.

Keywords : Earthing system, Transformer Neutral Earthing Earth resistance, Substation.

I. INTRODUCTION

In many types of electrical systems, it is necessary to have proper grounding installed i.e. an electrode or a system of electrodes which serves as a ground connection from earth to an electric circuit in the system. A grounding electrode or a grounding system is a metallic object embedded in the earth, used for maintaining ground potential on conductors connected to it and for dissipating fault current into the earth and to ensure safety for the personnel's and safe operation of the power system.

The essential requirement of effective grounding systems is low earth resistance, adequate current carrying capacity, uniform ground potential on all metal enclosures and structural metals in the substation & low contact resistance at the point of interconnection on metallic enclosures.

There are different types of grounding system viz., equipment grounding, system grounding, maintenance grounding, lightning grounding, electronic grounding and static grounding. All these grounding are broadly classified into two categories viz., equipment/protective grounding and system grounding.

The electrodes used for the such grounding system are rods, plates, strips, rings, counterpoise and ground mat. Generally, for substations of voltage class 33kV and above, it is necessary to have ground mats laid at the

substation in order to have uniform potential gradients all over the substation area.

A proper grounding system design shall consider suitable material to be used as a grounding conductor to ensure long life, cross sectional area to withstand fault current for longer duration, amenability of the material to brazing or welding to have low contact resistance, etc.

Any grounding system is subjected to ageing. Over the time period, corrosion will be developed, due to which the cross section of the grounding material gets reduced resulting in increased contact resistance between the grounding system and the equipment. This leads to equipment failures in most of the cases during faults. In addition to the above, if correct procedure is not adopted while measuring the earth resistance in a substation or if the continuity of the transformer earth pit with the earth mat is not ensured, then it will lead to equipment failures. This paper presents the study results of one of root cause analysis of transformer failure due to improper earthing system. The best practice of measurement of earth resistance in a substation is also discussed.

II. SYSTEM DESCRIPTION AND METHODOLOGY

A 400 kV substation comprising of 2x315 MVA transformers have been considered for evaluation of earthing system and the results are presented in this paper.

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The above station had a failure of transformer during fault. One of the reasons for this problem is attributed to improper grounding. In this case study, the methodology chosen to carryout different checks were as follows:

A. Ground Resistance Measurement

The main objective of ground resistance measurement is to determine the resistance of the grounding system, as a check on the design verification and to calculate the rise in ground potential during fault. This is also carried out periodically to check the healthiness of the grounding system. In general, these measurements are carried out as per the standard procedure mentioned in IS 3043:2018[3] and IEEE 81-2012 [6].

Various methods of measurement of ground resistance [1]- [7] is as follows:

- (i) Two-point method
- (ii) Fall of potential method
- (iii) E.B Curdts method or 61.8% method
- (iv) Slope method
- (v) Alternative method or 90°/180° method

Two-point method is used for measuring the earth resistance of an installations in a congested area where it is difficult to drive the remote test spike at a sufficiently large spacing. However, this method is subjected to large errors when the remote test spike is at a smaller spacing.

Fall of potential method is most widely adopted method for earth resistance measurement in substations. This method involves passing a current (I) between current terminals (C1-C2) and measuring the voltage (V) across potential terminals (P1-P2). This V/I ratio gives the resistance R in Ohms. The current is passed between the main earthing system and remote current test spike which is sufficiently placed at a larger distance from the main earthing system. This is done to overcome the effect of mutual interference between the remote current test spike and the main earthing system. The potential probe (P2) is then placed between main earthing system and remote current probe. This potential probe is moved in steps towards the remote current probe, resistance reading is obtained at each position and is plotted against distance from the main earthing system. The steady state value of the measured resistance represented by a flat portion of the graph which gives the value of resistance of grounding system. The typical setup for fall of potential method is as shown in Fig. 1.

E.B Curdts method is generally adopted for a smaller installation such as LV distribution substations. In this method, the potential probe (P2) is positioned at 61.8% of the remote current probe distance from the main

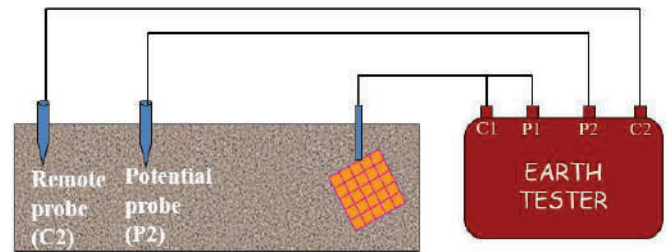


Fig. 1 : Fall of potential method.

earthing system. Reading corresponding to this is the true value of earth resistance.

Slope method is adopted when there are unsatisfactory results obtained from other methods. This is applicable for a larger earthing systems. Three resistance values corresponding to potential probe positions of 20%, 40% and 60% of the distance to the remote current spike is obtained. The actual positioning of potential probe (P2) is calculated from the slope coefficient and referring to the slope chart as indicated in standards. The resistance corresponding to the determined position of potential probe (P2) is true earth resistance of the earthing system.

Alternative method is used for measuring earth resistance of larger substations when the earth resistance is less than one ohm[3]. Generally, there is mutual interference between the current and potential leads when they are laid in the same directions. Hence to avoid such interferences, the potential probe (P2) is positioned at 90° or more to the direction of the remote current probe. The methodology is as illustrated in IS 3043:2018 is followed to obtain the true value of earth resistance.

The equipment and accessories used for the measurements are below and are shown in Fig. 2

- (i) Earth Tester
- (ii) Spikes
- (iii) Wires
- (iv) Connecting clips and other accessories



Fig. 2 : Equipments & accessories used for measurement

The digital earth tester is used for measurements which can inject a current of 50mA at 128Hz in order to avoid interference with power signals. If the electrode resistance is too high, then there is a chance of insufficient current injected by earth tester. Here, insufficient current means magnitude of stray currents presents inside the earth and lower than sensitivity of the earth tester.

B. Transformer Neutral Earthing.

The neutral of the transformer is generally earthed at two distinct earth pits and in turn connected to main earthing system [3]. The lead from the transformer neutral to earth pit shall be isolated from any other metallic objects.

C. Ground conductor size check.

The ground conductor cross sectional area is calculated based on system fault current occurring at that substation. Mild steel is most widely used grounding conductor in most of the substations. Generally, over a period of time and due to local soil resistivity, the mild steel would corrode. Hence sufficient corrosion allowance is considered since it is difficult to access and alter the ground mat once laid.

D. Equipment grounding continuity check

Grounding continuity check is to be done between ground connection and the main grounding system so as to ensure a permanent low resistance contact is established for all the structures and the equipment which is connected to the earth. All grounding connections shall be visible for inspection.

III. ADEQUACY CHECK OF GROUNDING SYSTEM

The total grounding system at this substation comprising of earth mat, vertical ground rods, distinct earth pits for transformer neutral & lightning arresters. Performance of individual grounding system pertaining to transformer neutral, lightning arresters, circuit breaker, CTs, etc., was evaluated.

A. Ground Resistance Measurement

In this case study as per the records of maintenance, it is observed that earth resistance measurement of the grounding system at HV substation is carried out by placing remote current probe at a distance of 30m from reference earth point and the potential probe (P2) placed at a distance of 15m from the reference earth point all inside the substation as shown in Fig. 3. This is an incorrect practice of measurement of earth resistance in a substation as the remote current probe is within the influence zone of the main earth mat and also the procedure for obtaining true value does not correspond to any methodology recommended in the standards.

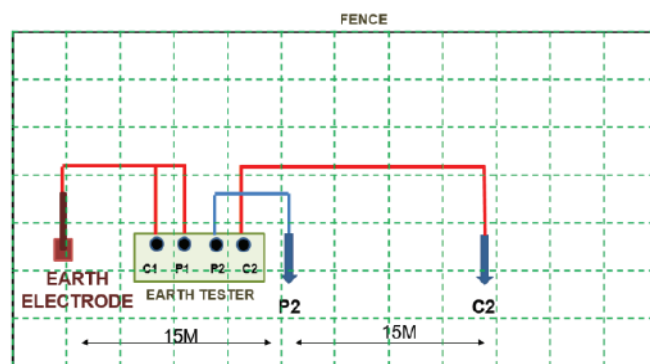


Fig. 3 : Incorrect practice of measurement of earth resistance in a substation

Since earth mat is normally laid at a depth of 0.3m to 1.0m below the surface of the soil, the remote current probe and potential probe is indirectly connected to the earth mat. This is indirectly measuring the loop resistance of the earthing conductor instead of measuring actual earth resistance of the earthing system. The value obtained by this method was very low. The personnel involved in the measurement got misled by this values and presumed that the earthing system was in healthy condition, which was not the actual condition of the earthing system. Hence, it is important to place the remote current probe at sufficiently large distance from the substation boundary during measurement which is as shown in Fig. 4.

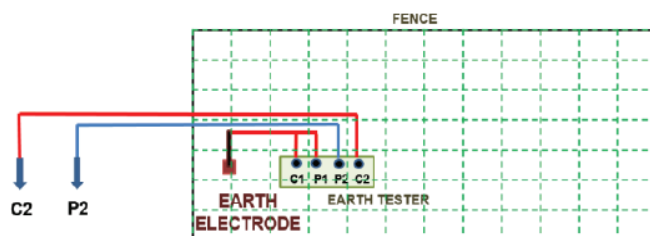


Fig. 4 : Correct practice of measurement of earth resistance in a substation.

In this substation, fall of potential method of measurement was adopted. The remote current probe was placed at a distance of about 380m from the substation fence which is considerably large when compared to the size of the earth mat. The reference point i.e., the earth mat riser at one of the structure inside the substation is connected to C1 and P1 of the earth tester. The potential probe (P2) was varied in steps of 20m. A calibrated earth tester was used for the measurement.

Referring to Fig. 5, the reading which corresponds to the flat portion of the resistance versus distance curve is 0.2 ohms which is combined interconnected earth resistance at this substation.

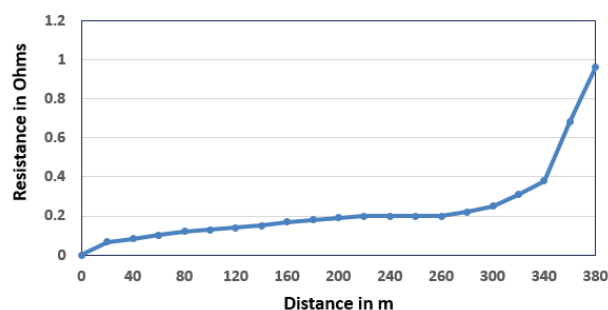


Fig. 5 : Earth resistance measurement in substation.

B. Transformer neutral earthing check

With same setup as in Fig. 4, the measurement was repeated by connecting C1 and P1 of the earth tester to the earth pit connected to transformer neutral. With this setup, the measured value of resistance of the earth pit is 32 ohms. This clearly indicates that the transformer neutral earth pit is not distinctly connected to the earth mat.

As part of routine maintenance, this check was carried out as per Fig. 3 which resulted in low value of resistance (loop resistance) due to incorrect practice.

C. Lightning arrester earthing check

This check was made to ensure that the ground connection is as short and straight as possible and is distinctly connected to earthing system [3], [4].

It was observed that the 220kV side R-Phase of transformer Lightning arrester is not firmly connected to the earthing system.

D. Ground conductor size check

This check was made to ensure that the ground connection is as short and straight as possible and is distinctly connected to earthing system.

E. Equipment grounding continuity check

It was ensured that all equipment located at substation, are having 2 separate distinct ground connection to the earthing system. It was also observed that the grounding conductor from the panel is not having firm contact with the earth as shown in Fig. 6.

IV. CONCLUSION

Systematic method of measurement of earth resistance in a substation is very important in maintaining the healthiness of the substation. Improper connection of the distinct earth pits of transformer neutral to the earthing system is one of the reasons of transformer failure in the substation. A detailed study of earth resistance measurement and adequacy check was carried out in a



Fig. 6 : Improper earthing connection to the panel.

400 kV substation. A systematic approach on appropriate measurement is adopted and discussed. Many of the incorrect practices of earthing system were identified and solutions were provided in this paper, which will be an insight to personnel involved in operation of maintenance substation.

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Advance Metering Infrastructure Solution Testing : A Case Study

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ABSTRACT

Reliable, affordable, and quality of power ensure the well functioning of electricity infrastructure. Number of schemes has been introduced to reduce Aggregate technical and commercial (AT&C) losses and the Average cost of supply-average revenue realized (ACS-ARR) gap. Revamped distribution sector scheme (RDSS) is one such scheme launched to help Distribution companies (DISCOMs) has introduced Advance metering infrastructure services providers (AMISP). More than 70 tests have been conducted in the selected testing laboratories with passing percentage of about 64% on both Cellular and RF technology. RF technology is found to be better in performance compared to Cellular technology. Meter malfunctioning, remote firmware upgrade and meter tampering detection is a big concern for the AMISPs during the testing. In this paper the procedure of AMISP demonstration testing, parameters of verification and analysis is discussed. Quantitative analysis model introduced in this paper may help the DISCOMs to have an idea of future reliability of AMISPs.

Keywords : AMISP, Service Level agreement, quantitative analysis, Cellular technology, RF technology

I. INTRODUCTION

Revamped distribution sector scheme (RDSS) is launched to help DISCOMs to improve their financial sustainability. An outlay of Rs 303758 Cr. for 5 years is sanctioned by Government of India [1]. In implementation of the scheme the Advance Metering Infrastructure Service Provider (AMISP) comes into the picture. AMISP testing has the number of components which includes Smart meters, test bench, Head and system (HES), meter data management system (MDM), Billing system, technology used. In near future it is desired to have consumer application which may help the consumer to have an idea of the consumption they made and it may also help to fulfill tariff based peak demand. Consumer application may also help to save electricity through the consumption graph available in application. There are different technologies they can opt for the testing purpose. Different technologies that are in fame are Power line Carrier Communication (PLCC), Radio Frequency Technology and Cellular Technology. In earlier systems PLC was used widely. PLC has a capability transmitting the data and power on single line only with different frequencies so as to avoid the interference. In current time PLC is used in telecommunication and tele-monitoring of the substations by means of EHV Lines. PLC has the drawback of slow data rate along

with signal distortion when power transformer or any inductive device comes into picture. For AMISP RF or Cellular technology is found to be competitive. By 2024-2025, through smart meter installation by AMISP's the scheme has an objective of reducing Aggregate technical and commercial (AT & C) losses to 12-15% [2]. The reduction in AT & C losses is a step forward to reduce the ACS-ARR gap to zero. Ideally it should be negative for DISCOM's to be profitable. This scheme also emphasis on affordability, reliability and quality of power through the AMISP's. Ministry of power floated a request for empanelment of interested bidders for providing Advance Metering Infrastructure (AMI) prepaid Solution under RDSS. All the AMISP's have to take certification from Rural electrification corporation (REC) which require a demonstration of their services and facility at national level government laboratories being nominated as demonstration Testing lab. Based on the results of the AMI solution testing at testing lab, REC will issue an implement certificate to AMISPs. Presently 35 Nos. of AMISPs have been registered for RF and cellular communication Technologies. There are number of challenges and issues for AMISP's which involved lack of finalization of the objectives and vision, lack of interoperability for the communication technologies, lack of consumer engagement plan and delay in integration. For installation of meters, HES, MDM and Billing

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systems, AMISP will be responsible. AMISPs have to tie up with the telecommunication service providers for data transmission along with the Network Interface Card (NIC) manufacturers. There are number of HES and MDM solution provider companies, so selection of the perfect one is a challenge that can be faced by AMISPs. The HES and MDM Solution providers must be approved Cloud service providers. Advance metering technology is not only meant for the energy meter but it can be extending to water meters, gas meters and other remote metering. Figure1 shows the simple architecture of the advance metering infrastructure.

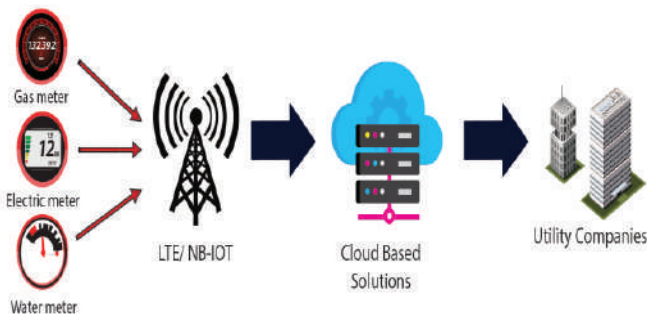


Fig. 1 : Test Setup during the Testing

Here in figure narrow band internet of thing (NB-IOT) communication is used to send the data to cloud. The HES and MDM has the access to the cloud data. In real scenario large number of meter will be going on installation and so the data on cloud will increase exponentially which in turn raise the issue of data security.

II. FUNCTIONALITY AND SERVICES OF AMISP

A. Functionalities

During the demonstration testing, all the AMISP's have to pass the functionality and service level agreement test. An action plan has been introduced for AMI solution testing. AMISPs have to bring DCU, HES, MDM, billing software, CIS/CRM and consumer interface software along with 20 Nos. of Smart prepaid meters. Testing will be carried out for 5 days as per the approved procedure which includes functionality demonstration and service levels demonstration. In order to check the interoperability the meters used during testing should be from at least two manufactures. Data concentrator unit (DCU) is applicable in RF technology. The functionality test corresponds to the verification of block load profile either on every 15 minutes or 30minutes interval, daily load profile once in a day, all kind of events, instantaneous profile, and name plate having basic information like meter serial number, Firmware version, manufacturer details etc. on daily basis. The events include the Current related, Voltage related, Power

related, non rollover and Transaction events. Along with this AMISP should be able to create the bill data from midnight day 1 to midnight day 4 as test happens for five days only it validate the monthly billing generation on time. Anytime when HES send the block data to billing system through MDM then Billing system calculate amount consumed by the meter in previous time interval the keep track of the balance in the meter, so whenever balance exhausted, MDM sends a command to HES to make meter disconnect so the meter relay should get disconnect itself. Now if the users make the payment through any application or consumer portal, then meter balance should update and the relay must get reconnect. Anytime if a user is Tampering the meter, the AMISP must get the intimation and it should create some tamper invoice that may helps the Utility to put some penalty on the user. Also in such cases AMISP should be able to disconnect the meter remotely. Sometime if AMISP wants then they should be able to upgrade the firmware version, Change of RTC, MD reset of the meter remotely. Figure.2 represents the testing set up in the laboratory during the testing which includes smart meters being installed on the test bench along with the HES and MDM solution providers. The bench has a capability of performing the test on 60 smart meters simultaneously. The routers and repeaters for good signal strengths are also available in the laboratory itself.



Fig. 2 : Test Setup during the Testing

B. Service Level Agreement

The services level agreement is the time constraints verification of these functionalities. There is a particular time by which HES or MDM must get the intimation about every function. Table1 represents the functions along with the allowed time

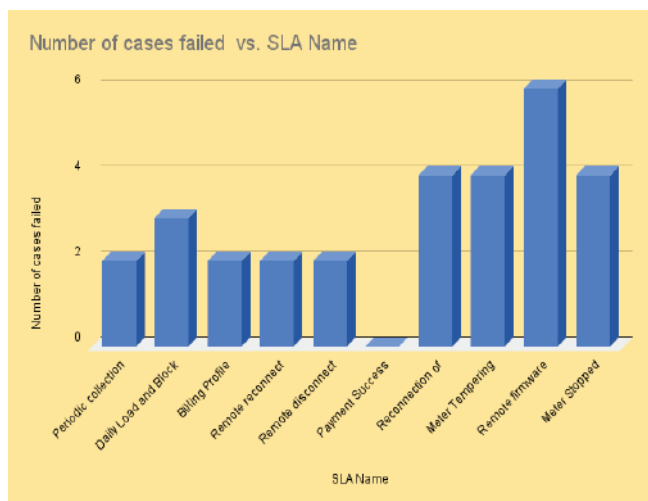
III. CASE STUDY

Testing agencies has conducted more than 75 tests till date, but for case study we have consider the first 70 test. It is observed that around 64% cases have been passed but the dark side for the AMISP's is 36% cases

Table 1 : Functionality With Time To Intimation

Sr. No	Function	Time to intimation	Number of meters
1	Periodic Collection of Block load for Last one hour	Within 5 minutes	20
2	Previous days' interval energy and total accumulated energy	Within 30 minutes after midnight	20
3	Collection of billing profile data for the bill period	Within 30 minutes after midnight	20
4	Remote reconnect/disconnect	Within 3 minutes	5
5	Payment success to consumer acknowledgement	Within 5 minutes	5
6	Reconnection of meter (90% / 99%) after Payment success	Within 30 minutes / 60 minutes	20
7	Meter Tamper Detection	Within 3 minutes	5
8	Remote firmware upgrade	Within 120 minutes	20

wherein they got failed. The percentage failure at two testing agency is 31.25% and 38.88% respectively based on both Cellular and RF technology. The percentage failure in Cellular only at two testing agency is 45.45% and 41.02% respectively which is almost same. There are different SLA's wherein test got failed. Figure3 shows the individual analysis of the SLA's. In fig.3 we can see that Six (Maximum) number of test got failed in remote firmware version upgrade. After Firmware upgrade, meter tampering, reconnection after recharge and meter stopped working are the causes where test got failed with four numbers of cases for each. Few cases failed in daily profile data collection, periodic collection and billing profile data collection. When a user makes a payment then he/she get an alert for payment success. Payment success alert is only the SLA where every test got passed for all AMISP's. The worst case scenario for the AMISP is meter's malfunctioning. If the meter starts malfunctioning or stop working then test can't be performed for other SLAs.

**Fig. 3** : Number of Tests failed in Different SLAs

A. Cellular V/s RF Technology

Selecting a better communication technology is always a challenge for the AMISPs. PLC, Cellular and RF technologies are available in current scenario. PLC technology is used in Tele-monitoring and Tele-protection by EHV power lines. Slower data rate is big disadvantage of PLC however this PLC is best reliable among all. RF technology is also known as wireless technology extended from 20 KHz to few 300GHz. Less bandwidth is available in RF because of high frequency carrier usage. The technology suffers the interference and fading of signals in wireless media. To avoid interference different spectrum can be used but it is a long process to allocate a new spectrum to DISCOMs for RF technology. Currently some bands are free to use which correspond 865-868MHz with bandwidth 200 KHz, 2.4 to 2.4835GHz and 5.825 to 5.875 GHz with bandwidth of Few MHz with carrier spread [4]. The power transmitted must not exceed the 1W [3]. In RF a canopy is designed which reduced the running cost but its installation cost is high. In AMISP testing smart meters communicate with a Data concentrator Unit (DCU) and then data is transferred to HES and vice versa. DCU is used in tests which uses RF technology. It is the backbone of the technology and used for data acquisition and is provided with some communication service provider. The meters under test send or receive the data from DCU. Data storage, data recopy, alarming, onsite coping function, time hack function are the other basic functionality of the DCU. cellular technology has evolved in last 2 decades from 1G to 4G. Now it can handle data and voice with good speed on same network. Functionality comparison of RF and Cellular Technology (GPRS based) is given in the Table 2. Out of 70 tests conducted in two testing agencies with passing percentage of about 64% on both Cellular and RF technology. The percentage failure in Cellular in two testing agencies located at different place is 45.45% and 41.02% respectively which shows that the

performance of AMISPs is almost same in at different locations. Hence AMISP testing or implementation is not area specific rather it is dependent on the technology being used by the AMISPs during the testing.

Table 2 : Functionality with Time to Intimation

Sr. No	Function	RF Based	GPRS Based
1	Service Quality	Better	Good
2	Latency	High	Medium
3	Service Level Agreement	Faster	fast
4	Initial Cost	High	Low
5	Communication Success rate	High	Medium
6	Role of Network Provider	Low	High
7	Power Consumption	Less	More
8	Maintenance Cost	Less	More

In AMISP solution testing our main focus is on service level agreement. On the basis of results obtained in the testing, RF technology is found to be better than Cellular technology. If we compare the Cellular and RF technology failure test cases, then it is found that failure percentage in Cellular technology is far high compared to RF technology. Maximum cases failed in remote firmware upgrade in cellular technology while for RF technology Daily profile collection SLA is found to be worst one. It is also observed that responses in RF technology are found to be faster. There are only 3 SLAs where RF test got failed. Figure 4 shows the failure of test in Cellular and RF.

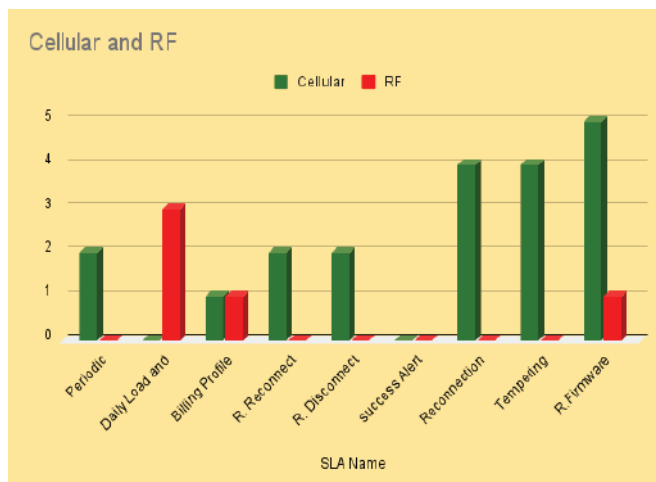


Fig. 4 : Test Failure in Cellular and RF Technology

IV. QUANTITATIVE ANALYSIS

Finally AMISPs will install and run the systems to help DISCOMs. Before installation DISCOMs may get the idea about the future performance of the system by means of quantitative analysis model for any number of energy meters planned to be installed.

A. Quantitative analysis Model

For any of the city with any number of energy meters installed an idea of reliability or expected number of meters failure can be made from analysis model

Considering the SLAs to be independent

If Total number of Test Conducted = N

Total number of meters failed = F

Total number of meters tested per test per SLA= M

Then Probability of meter failure = $F/N \times M$

Expected number of meter to be failed= $(F/M \times N) \times (\text{Number of meters installed in the city})$

Analysis for daily load profile can be inferred from periodic collection. In daily load and periodic collection number of blocks is the main concern. In periodic collection of data it is expected to report 80 or 40 blocks in last completed one hour, as block load collection is either 15 minutes or 30 minutes. One meter sends either 4 or 2 blocks, so for all 20 meters number goes to 80 or 40. For periodic collection the analysis model will be like as follows:

If Total number of Test Conducted = N

Total number of blocks left = F

Total number of meters tested per test per SLA = M
Number of blocks expected to arrive per meter = B

Then Probability of meter failure = $F/N \times M \times B$

Expected number of meter to be failed = $(F/M \times N \times B) \times (\text{Number of meters installed in the city})$

Study shows that probability of failure in periodic collection is 0.0058 as 33 blocks didn't come in allowed time interval. The number of samples failed in different SLAs are along with number of meters tested are given in Table 3. It can be a mislead for anyone from the table that, number of test failed in remote disconnect are less but on real analysis it can be realized that these two test covers a large part of failure probability.

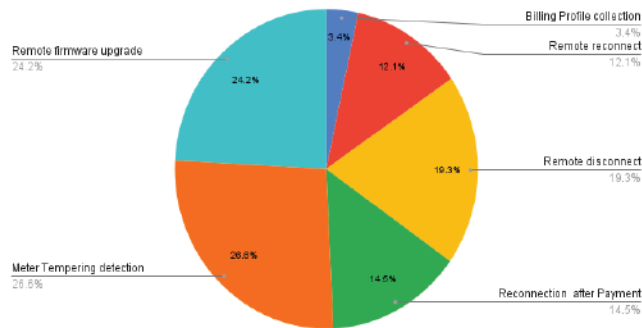
B. Graphical Analysis

Using the quantitative analysis model, probabilistic analysis is shown in Figure 5 it can be seen that 70% test failure probability is covered by remote firmware upgrade, meter tampering and remote disconnect. So the AMISPs have to be more concerned to avoid failure of these test cases. Also there must not be any

Table 3 : Functionality With Time To Intimation

Sr No.	Service Level Agreement	Total meter failed in all tests	Meters tested/test / SLA
1	Billing Profile data	2	20
2	Remote connect	2	5
3	Remote Disconnect	3	5
4	Reconnection after payment	9	20
5	Tamper detection	4	5
6	Remote Firmware upgrade	15	20

malfunctioning of the meters during their testing or in real scenario.

**Fig. 5** : Probability of failure in Individual SLA

V. CONCLUSION

AMISPs introduced by RDSS schemes have to take certification from REC and demonstrate their functionality and services by means of HES, MDM and Billing system using Cellular or RF technology in test agency selected by ministry of power. Number of parameters is there to select the technology. RF technology is found to be faster and effective but having high installation cost. Performance of AMISPs is not area specific as passing percentage at different location is almost same. Analysis model can be used to have an idea of future performance of AMISPs. Service providers have to work on Tampering of meter and Remote meter firmware upgrade along with proper

functioning of the meter. As all the data will be available at cloud so data security will be another issue for DISCOMs in the future. So skill development is also need to take care of.

Acknowledgement

The authors are thankful to the management of Central Power Research Institute for providing testing facilities to perform the testing work and to generate the results.

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**Save One Unit A Day
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Test Method and Analysis of Temperature Rise Test on Prefabricated Sub-station

Guguloth Ravi¹, Sumit Srivastava², Leena H. Roy³ and Sarita Dongre³

ABSTRACT

This paper describes the temperature rise test method on compact substation (prefabricated substation) and analyzed the transformer temperature rise test results using alternative method. It also discuss about shortcoming of alternative method and suggested to incorporate the test procedure discussed in this paper

Keywords : Enclosure, Prefabricated substation, Internal arc classification, Temperature rise

I. INTRODUCTION

The various stages involved in the distribution of power are; Generation, transmission and distribution. The power generated at the generating station is transmitted to the load areas. Energy generated is step up and transmitted and is gradually step down depending on load stages. This stepping down stage has a substation, and these substations are usually outdoor conventional substation. This paper discuss about distribution substation i.e compact substation also known as prefabricated substation or substation which is enclosed in metal enclosure.

The substation having a number of equipment's, large space for installation, safety for inhabitants and huge amount of money for its operation and maintenance placed many obstacles for the new upcoming projects. In such situation it has become mandatory to go for maintenance free, safe and compact installation which can save space, money and environment [4].

The challenge of constructing new compact substations with the same voltage ratings as existing outdoor substations is introduced by rising electricity demand and difficulties in obtaining land for new developments in metro areas. For several reasons, the compact substation contributes significantly to global cost reduction for utilities as well as industrial users. First, the reduced surface area required to install the substation saves money, which is especially important in urban areas where space is limited and costly. The compact substation requires less labour to install because it is pre-assembled. Buying the substation as a whole simplifies purchasing, management, storage, and handling operations. The compact substation can be customized based on the load.

The growing in design of compact substation based on problems faced in present systems has given an

option of replacement. With a constant development and research over a few years in all aspects has led to tremendous improvement in compact substation. As this substation have a lot of benefits over the existing conventional outdoor substation, they are likely to be in more and more demand by end users whether it be public or private sector. The reliability, safety, capability to transport, preassembled components are few of the reasons why they are being considered over conventional substations.

II. DESIGN OF COMPACT SUBSTATION

The compact substation consist of MV switchgear and controlgear, a transformer and a LV switchgear and controlgear located in three separate compartments which are segregated from each other by means of partitions in order to ensure personnel safety and the accessibility to operate or maintain the equipment through lockable doors provided for each compartment to maximize security. Assembly of the complete substation is factory ready to save the site installation time and cost. All equipment is of high quality and tested as a complete unit [1].

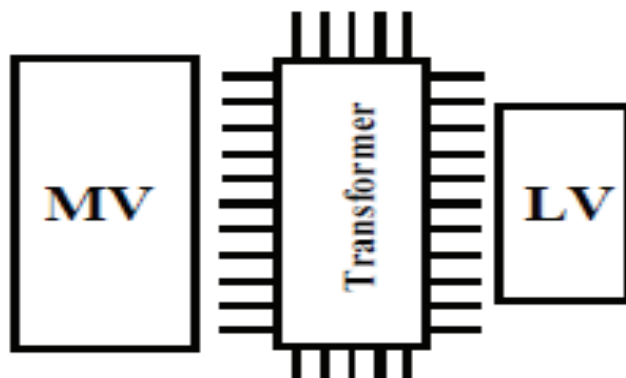


Fig. 1 : Internal layout of compact substation

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2. M.Tech, IET

3. Joint Director, CPRI

The prefabricated substation's maximum rated power is defined by the maximum rated power and total losses of the transformer installed in the enclosure. The main earthing conductor is provided to connect to the earth all metallic parts of the prefabricated substation. The components to be connected to the earth system include the metallic enclosure of Package substation, the enclosure of High voltage switchgear & control gear from the terminal provided for the purpose, the metal screen & the high voltage cable earth conductor, the transformer tank or metal frame of transformer and the frame & enclosure of low voltage switchgear. It is not necessary to connect covers, doors, and other accessible metallic parts of the prefabricated substation enclosure to the earthing circuit if the enclosure is not metallic, unless there is a risk of live parts coming into contact with them[1].



Fig. 2 : External layout of compact substation



Fig. 3 : High voltage switchgear and controlgear compartment



Fig. 4 : Low voltage switchgear and controlgear compartment

III. SELECTION GUIDE FOR COMPACT SUBSTATION [1]

Prefabricated substations, such as fixed type prefabricated substations or mobile prefabricated substations have been developed in a variety of forms to accommodate evolving technology and functional needs. Identification of the functional requirements at the site installation is essentially required for the selection of prefabricated substations. The prefabricated substation is chosen for a certain service demand by taking into account the individual rated values needed under normal load conditions and in the event of a fault condition for each of its components.

The prefabricated substation enclosure class is chosen based on the (average) ambient temperature at the site, as well as the load factor and temperature rises of the transformer. The enclosure class is determined by the transformer's load factor, temperature rises and ambient temperature at the installation site.

The manufacturer's information on the class of enclosure for a specific substation is based on the type test of the substation with given ventilation opening grids and its maximum power and transformer losses applied continuously. This continuous full-load condition may be more difficult and deviate significantly from the expected loading cycle in service. In such a case, the ventilation may be overly strong in comparison to what is required to prevent the transformer from overheating. To mitigate any unfavorable side effects of this over-specification (for example, cost, excessive hazard of equipment pollution), the user could specify a higher temperature class of enclosure with less ventilation with the same nominal rating after assessing the expected service condition.

When selecting a prefabricated substation, the risk of internal arc faults should be considered, and the manufacturer should declare the type of accessibility to protect from internal arc in specifications, with the goal of providing an acceptable level of protection for operators and the general public.

The following criteria can be used to select a suitable prefabricated substation in terms of internal arcs.

- (i) Where the risk is deemed negligible, an IAC-classified prefabricated substation is not required.
- (ii) Where the risk is deemed relevant, the IAC classification must be declared. In the second case, the IAC classification should be made by comparing the rated values of the tested equipment to the foreseeable maximum level of current and duration of the fault. In addition, the manufacturer's installation instructions must be followed. The location of personnel during an internal arc fault is critical. In the case of walk-in substations, the manufacturer should specify which areas of the prefabricated substation are accessible based on the testing arrangement and the user should carefully follow the instructions. Allowing personnel to enter an area that has not been designated as accessible may result in injury.

The protection of users from internal arcs is dependent not only on the design and IAC classification of the switchgear and controlgear, but also on the installation conditions. The arc energy produced by an arc in any insulating fluid within the high voltage switchgear or high voltage interconnection causes internal overpressure and local overheating, resulting Mechanical and thermal stressing of the substation enclosure. Furthermore, the materials involved may produce hot decomposition products that are either gaseous or vaporous and can be discharged both inside and outside the substation. In this case, immediate evacuation and further ventilation of the prefabricated substation enclosure are required before reentering the site, and appropriate measures for on-site installation should be considered.

IV. TEST METHOD

Type tests must be performed on a designed configuration of the components of an entire prefabricated substation. The components of a prefabricated substation must be tested in accordance with the applicable standards. Because of the various types, ratings, and possible component combinations. In this section, we will go over the temperature rise test method and its shortcomings.

The purpose of the temperature rise test is to ensure that the design of the prefabricated substation with enclosure works properly, does not reduce the life expectancy of the substation component, and that the deterioration of insulation due to thermal effects is not

exceeded. The temperature rise test is used to ensure that the temperature rises of the transformer inside the enclosure do not exceed those measured on the same transformer outside the enclosure by more than the manufacturer-specified class of enclosure. Figure 4 depicts the temperature rise test procedure performed on the transformer alone, as well as the temperature rise of the oil/winding determined in accordance with IEC 60076-2:2011.

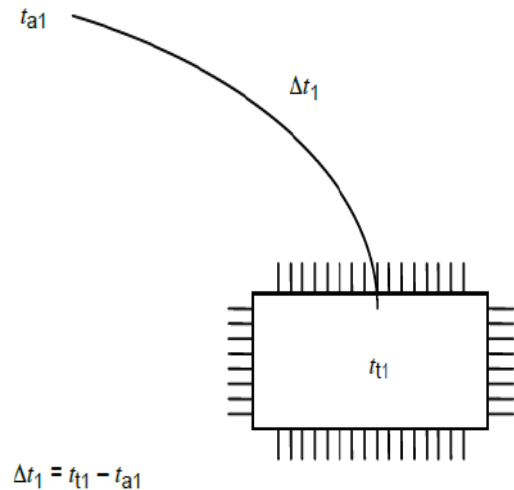


Fig. 5 : Calculation of temperature rise of transformer alone at ambient air [1]

Where

t_{a1} = Ambient air temperature surrounding transformer,

t_{t1} = Transformer temperature measured as per IEC 60076-2

Δt_1 = temperature rise of the transformer outside an enclosure

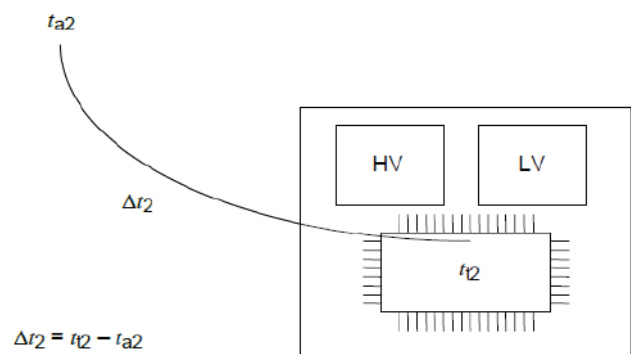


Fig. 6 : Calculation of transformer temperature rise in an enclosure [1]

Where

t_{a2} = Ambient air temperature surrounding enclosure

t_{12} = Transformer temperature measured as per IEC 60076-2

Δ_{12} = temperature rise of the transformer inside an enclosure

The enclosure, complete with all of its components positioned as intended for service. To represent service conditions, the doors were closed and cable access points were sealed. The transformer's power and losses must correspond to the rated maximum power of the prefabricated substation, and temperature-rise tests of the transformer, high voltage and low voltage interconnections, and low-voltage equipment must be performed parallelly.

The test should be conducted in a room whose dimensions, insulation, or air conditioning will keep the ambient air temperature of the room free of air velocity and not affected by external conditions. Further the detailed temperature rise test procedure for liquid filled transformer installed in enclosure will be discussed.

If the compact substation is equipped with liquid filled transformers two test methods can be used to carry out the temperature-rise tests.

Preferred Method

The preferred test method uses the independent sources to supply the high voltage and the low voltage sides of the compact substation simultaneously as follows.

The temperature rise test was performed on the transformer, high voltage switchgear, and controlgear interconnection with enough current to produce total transformer losses, i.e. measured no-load loss and load loss, and the transformer's secondary winding terminals were short-circuited. The supply must be connected to the incoming terminals of high voltage switchgear [1]. Refer to Fig.7.

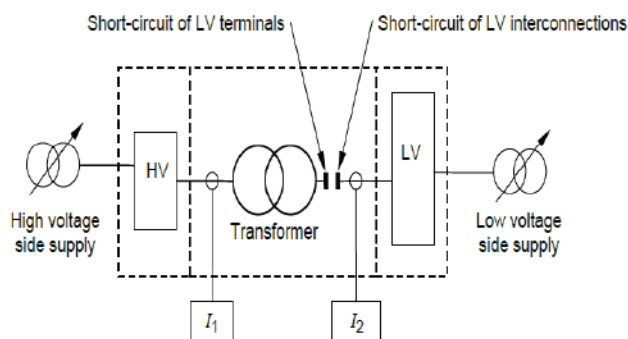


Fig. 7 : Connection for preferred temperature rise test method[1]

The temperature-rise test on the low-voltage side is carried by supplying low-voltage current from outgoing feeders and LV switchgear shall be isolated from the

transformer, at a convenient point as close as practicable to the transformer terminals. At this point adjacent to the transformer terminals, a short-circuit shall be applied to the connections between the transformer and the low-voltage switchgear.

V. ANALYSIS OF TEMPERATURE RISE TEST PREFABRICATED SUBSTATION BY SINGLE SOURCE METHOD

CPRI, STDS Bhopal is a pioneer testing organization in India for testing and certification of various power & distribution transformers as per national and international standards.

The temperature rise test was conducted on 630kVA, 11/0.433kV prefabricated substation in CPRI, Bhopal as per IEC 62271-202:2022.

CASE STUDY:

As per standard IEC 62271-202:2022 transformer alone temperature rise test measured according to IEC 60076-2:2011 as follows

- The transformer is subjected to a test current corresponding to the total losses of the transformer, i.e. no-load and load losses, in the first step. The test current will be greater than the rated current, resulting in an additional amount of loss equal to the no-load loss at rated voltage, and the winding temperature will rise proportionally. The temperature of the top-liquid and the temperature of the cooling medium are monitored, and the test is repeated until steady-state liquid temperature rises are achieved. When the rate of change of top-liquid temperature rise falls below 1 K/h and stays there for 3 hours, the first part of the test can be stopped [2].
- The second step is rated current injection, which means that once the top-liquid temperature rise has been established, the test must be run continuously with the test current reduced to the rated current for the winding combination connected. This condition is maintained for one hour before measuring the resistances of the windings following a quick disconnect of the supply. Table 1 shows the calculated temperature rise parameters.

Table 1 : Temperature rise of transformer outside an enclosure

Transformer alone	Oil	HV winding	LV winding
Temperature Rise measured	36.20 K	41.22K	44.68K

After completion of transformer temperature rise measurement, the same transformer is inserted in metal

enclosure and the temperature rise test was conducted as procedure given in alternative method as follows.

Alternative method:

This method requires one single supply of current.

Connection of supplies

The high voltage switchgear and controlgear, as well as the high voltage/low voltage power transformer and low voltage switchgear and controlgear, was interconnected, as shown in Fig. 8.

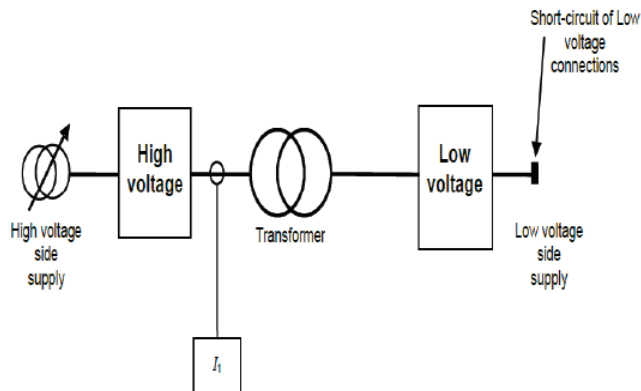


Fig. 8 : Connection for alternative temperature rise test method[1]

The substation is supplied with current to produce the total rated losses of liquid filled transformers, and it is observed that the current drawn by the transformer was reduced as LV switchgear is connected to secondary winding of transformer because of contribution of LV switchgear impedance. Temperature rise parameters calculated for Oil, HV/LV winding as shows in table 2 and values shows that temperature rise of transformer inside the enclosure was less than the transformer alone. But as per IEC 62271-202:2022 temperature rise of transformer inside the enclosure should be more than the temperature rise of transformer outside the enclosure .

Table 2 : Temperature rise of transformer inside an enclosure

Transformer inside an enclosure	Oil	HV winding	LV winding
Temperature Rise measured	31.80K	36.24K	36.95K

As the results obtained from the alternate method mentioned in the standard were not convincing. CPRI team repeated the test with recommended method and results are as follows:

Table 3 : Temperature rise of transformer inside an enclosure

Transformer inside an enclosure	Oil	HV winding	LV winding
Temperature Rise measured	39.70 K	43.97K	46.67K

The transformer temperature rises in table 3 exceeded the corresponding temperature rises measured on the same transformer without an enclosure in Table 1.

For compliance of alternate method, the method suggested by CPRI is with the change as recommended. The change in the recommended method by CPRI was the losses measured were taken with LV switchgear connected to the LV winding of the transformer and the shorting point was at the distribution end of the LV switchgear. In this way the losses contributed by the LV switchgear were considered, where as in the method suggested in standard do not consider the losses contributed by the LV switchgear, ultimately due to the impedance of LV switchgear the current required for actual losses of transformer becomes less. One more thing is to be taken into consideration and that is the shorting done at LV switchgear end. The shorting connections done during measurement losses shall remain same while conducting the temperature rise test.

VI. CONCLUSION

Based on the case studies mentioned above and with reference to the temperature rise test on prefabricated substation, it has been observed that alternative method of temperature rise has shortcoming as discussed in case studies and it is suggested that the while using alternative method for temperature rise on prefabricated substation the losses contributed by the LV switchgear shall be considered for actual results. If two sources are available then preferred method must be used.

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Concept of Effective Unscheduled Interchange Rate in Availability Base Tariff

N.D. Makwana¹

Availability based tariff was introduced in India first in western region in July 2002. Gujarat could gain due to auto power tread scope in ABT by strategic operation with this concept.

1. SALIENT FEATURES OF ABT SCHEME

Availability base tariff is based on three rates as under.

1.1 Capital Cost charges of generators claimed as Fix Charge is linked to assured (declared) capacity of generator rather than actual generation.

This provision is to control undue generation by generators just to achieve target for full recovery of fix charge even during high frequency operation.

1.2 Running Cost claimed as Variable Charges is linked to Energy Indented by utility.

This provision is to facilitate utility to manage required power as per merit order.

1.3 Deviation in power generation or drawal is Unscheduled Interchange (UI).

Rate of this power is linked to operating frequency at the time. The rate is lower at higher frequency and higher at lower frequency. The rate is zero when operating frequency is 50.5 Hz and above and increasing at 5.6 paisa per unit for each drop of 0.02 Hz of frequency up to rupee 4.20 at 49.00 Hz.

This provision is in the form of indirect penalty/incentive for frequency control by constituents of the grid.

2. GRID OPERATING SCENARIO

Utility may have schedule export or import depending upon location of Shared Generation (Inter State Generating Stations - Central Sector Generation) in the grid.

Utility importing more than schedule or exporting less than schedule is considered as UI import.

Same way, importing less than schedule or exporting more than schedule is considered as UI export.

Generator producing power more than schedule is UI export and producing power less than schedule is UI import.

Payment is receivable by exporters and is payable by

importers at UI rate corresponding to average frequency during concern block of fifteen minutes.

This provision provides auto action by all participants for frequency control. During high frequency all like to import cheaper power that results in frequency drop. During low frequency all like to export power at higher rate that results in frequency rise. Indirectly it is like open access platform to sell (export) or purchase (import) power at desired rates.

3. SYSTEM OPERATING APPROACH

All system managers are fervent for optimum economic operation. Therefore they monitor and manage for required power on merit order from sources. UI power can be imported or exported based on prevailing rate as per frequency for optimum economic operation. But sometime apparent beneficial action may result as detrimental act.

Continuous observation revealed that UI rate actually effective for change made in power transfer is different than rate linked to frequency while action was initiated. By study of such events learnt that the difference in rates is due to system characteristic.

4. SYSTEM CHARACTERISTIC

Increase/decrease of import/export from/to grid is done by picking/dropping of generation or load in the concern system. So along with change in export/import grid frequency also changes. Hence UI rate also changes corresponding to changed frequency. This new UI rate is applicable not only to change in import or export but to total import or export after the change.

5. EFFECT OF LOAD CHANGE

Consider one power system A of 4000 MW in grid system of 20000 MW. So rest of the grid system is of 16000 MW. System BIAS may be in the range of 3% to 5% depending upon the load mix. Here assumed 4% as System Bias.

	Total Grid	System A	Rest of Grid
System Size MW	20000	4000	16000
System Bias MW/Hz	800	160	640

1. Former Sr. Eng., State Load Dispatch Center

Assumed that System A is already importing 200 MW at grid frequency of 49.90 Hz with UI rate of Rs 1.68/unit. System manager decides to import more power at this rate for relief in load shedding. So 80 MW load is resumed in the system.

This has two way effects on grid operating condition.

5.1 Grid Frequency: Frequency drops by $80/800 = 0.1$ Hz. So new frequency will be $49.90 - 0.10 = 49.80$ Hz. UI rate corresponding to new frequency is Rs 1.96/Unit

5.2 Power Transfer: Power transfer between rest of the grid and system A.

5.2.1 System A

Area Control Error $ACE = \delta P_i + B\delta F$

80 MW load is increased in the system. So ACE is 80 MW

Therefore $80 = \delta P_i + 160 \times 0.1$

Therefore $\delta P_i = 64$ MW

This ACE is indicative that system A has shortage of 64 MW at this operating condition.

5.2.2 Similarly rest of the grid system.

ACE is zero as no change made in load or generation.

Therefore $0 = \delta P_i + B\delta F$

$0 = \delta P_i + 640 \times 0.1$

Therefore $\delta P_i = -64$ MW

This negative ACE is indicative that the rest of the grid system is surplus 64 MW at this operating condition.

Hence as obvious, 64 MW power flows from the rest of the grid to system A.

Now revised power import of system A is $200 + 64 = 264$ MW.

6. SCRUTINY OF CHANGE

Finding the end result comparing pre and post act condition.

6.1 Pre-act condition.

Frequency 49.9 Hz

UI rate 1.68 Rs/Unit

UI import by A = 200

UI payment rate = $200 \times 1000 \times 1.68 = 336000$ Rs/Hr

6.2 Post act condition

Frequency 49.8 Hz

UI rate 1.96 Rs/Unit

UI import by A = 264 MW

UI payment rate = $264 \times 1000 \times 1.96 = 517440$ Rs/Hr

6.3 End Result

Additional import is $264 - 200 = 64$ MW

Additional Payment rate is $517440 - 336000 = 181440$ Rs/Hr

Hence unit rate is $181440 / 64000 = 2.835$ Rs/Unit

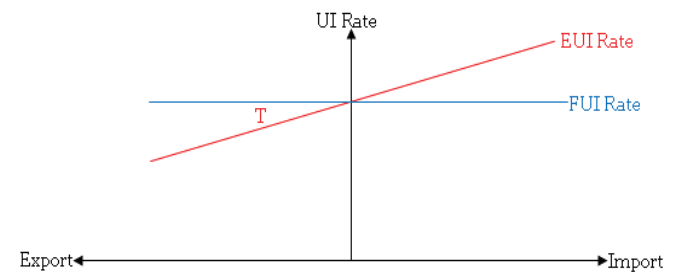
This is actual Effective UI rate for additional power import that initiated when Frequency linked UI rate was 1.68 Rs/Unit.

7. FACTORS AFFECTING THE UI RATE

Effective Unscheduled Interchange (EUI) rate is based on Frequency Linked Unscheduled Interchange (FUI) rate. But has no specific relation in term of difference, percentage or ratio etc. However effect of some operating condition is as under.

7.1 Pre UI Condition

Pre UI is Import or Export more or less than schedule exchange just when change initiated.



7.1.1 The difference of EUI rate and FUI rate is meager when NO Pre UI.

7.1.2 The EUI rate is higher than the FUI rate when Pre UI is import.

The rate difference is more at higher pre import.

7.1.3 The EUI rate is lower than the FUI rate when Pre UI is export.

The rate difference is more at higher pre export.

7.2 System Size in Grid

Larger the system size, wider is the change in EUI rate and FUI rate.

7.3 Operating Frequency

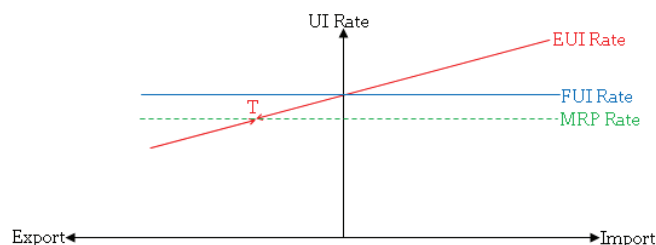
FUI rate and Frequency relationship is uniform over the full range from 49.00 to 50.50 Hz. Therefore difference in the rates is unaffected by operating frequency.

In case of non linear relation of FUI rate and Frequency, deviation is effected by operating frequency.

8. CONCLUSION

Generally frequency based unscheduled interchange (FUI) rate is equated with rate of Marginal Regulating

Power (MRP) in the system to decide import or export of power from/to grid. But in some case, it may be uneconomical operation in view of the above fact. Whereas decision based on EUI rate instead of FUI rate has no scope for loss.



Typical chart above is plot of FUI rate, EUI rate and MRP rate for one of power system in the grid operating at particular frequency. It represents EUI rate variations for different import or export condition. FUI rate line may be above or below the MRP rate line depending upon operating frequency and available MRP

The intersection point N of EUI rate line and MRP rate line can be the operational target for optimum economical system operation. Interaction point N may be anywhere in import or export zone. Efforts should be to move operating status towards target to the extent possible. This may require reduction or increase of import or export as per situation.

Judgment in the matter is rather complex for real time operation. Ready beckoner in the form of charts etc may be useful to system engineers for timely implementation.

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Measurement of Earth Resistance of Electrode Station of HVDC substation using DC Current Source

Prabhakar C¹, Jithin Pauly P¹, Bandi Venkata Nagachandra¹ and G Pandian¹

ABSTRACT

This paper is aimed at providing the substation design engineer, to accustom with methods of earth resistance measurement and soil resistivity measurement using DC Source of higher current magnitude. In most of the cases, the measurements were conducted using conventional methods by adopting earth testers. However, the knowledge gained by experience from time to time has resulted in the adoption of High Current DC source in measurements especially for an electrode station of HVDC substation. These measurements are of more realistic in nature. This paper discusses the methodology adopted for the earth resistance measurement using dc source of higher current magnitude at an electrode station of HVDC substation.

Keywords : HVDC electrode Station, high current DC Source, soil resistivity, earth resistance.

I. INTRODUCTION

The purpose of a grounding system is to limit the potential gradient within and immediately outside, say a substation area to a value safe for personnel. This requirement must be met under normal and abnormal operating conditions of the power system. A grounding system is used for providing a uniform electric potential in all non-current carrying parts at all structures, apparatus etc., as well as ensuring that the operators and attendants are always working at the same potential. For designing the grounding system, Soil Resistivity plays an vital role in determining the resistance of any grounding system.

Since early days, the earth was used as a conductor of electricity. In some cases the soil was deliberately used as a return path like in HVDC stations and in High Voltage distribution system. Due to infinite extent of soil, it was rightly thought that the resistance to current flow in soil would be negligible.

The electrical properties of soils are in themselves of great importance, particularly the specific resistance or resistivity of the soil. Soil or earth resistivity, expressed in ohm-m is the resistance of a cubic metre of earth measured between opposite surfaces.

Soil resistivity measurement, grounding system design and earth resistance measurement are the three steps involved during planning stage of any grounding system. Once the grounding system is designed and installed, the effectiveness of the same has to be verified by means of measurement of earth resistance. Earth resistance of any grounding system is the resistance offered due to resistivity of soil surrounding the earth electrode or grounding system.

Generally, the most widely used instruments for soil resistivity measurement and earth resistance measurement at site are conventional earth tester. It drives a current through the soil and measures the voltage. Thus, the meter computes the resistance and displays the same [2]. Since the conduction of electricity in the soil is electrolytic, the earth resistance measurement or soil resistivity measurement is subjected to the effects of chemical action and of polarization. It is therefore necessary that alternating current (or periodically reversed direct current) be used in such measurements [2].

DC source of higher current magnitude helps to adopt a more realistic approach for soil resistivity measurement and earth resistance measurement especially for electrode stations of HVDC substation. This paper deliberates the methodology and the outcome of earth resistance measurement performed at an electrode station of HVDC substations by adopting DC source of higher current magnitude.

II. METHODOLOGY

The procedures for conducting the Soil resistivity and earth resistance measurements are as per the IEEE 81-2012 [2] and IS 3043-2018 [3]. The instrumentation adopted was high current DC source instead of earth tester[1].

A. Methodology for Soil Resistivity Measurement

Among the various methods, Wenner's four electrode method[2][3][4] is the widely preferred. This method is used for determining the resistivity of soil for varying depth from smaller depth to a deeper depth without driving the spikes to a deeper layer to determine the resistivity.

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B. Methodology for Measurement of Earth Resistance.

The different methods that are normally followed to conduct measurement of earth resistance are:

- (i) Fall-of-Potential Method
 - (ii) E B Curdt's (61.8%) method
 - (iii) Alternate method (90°/180°)
 - (iv) Slope Method
- (i) Fall-of-Potential method**

The basic measurement normally used consists essentially of passing a current through the grounding system via a ground electrode or probe remote from the station and measuring the voltage produced between the grounding system and the surface of the ground at a remote area. The term "remote" implies very large probe spacing since the probes are considered to be placed in locations where the earth current density approaches zero. The procedure is as described in [2][3][4].

Generally, for all the above measurement, earth testers are adopted as a source of current injection. In this paper, the application of DC source of higher current magnitude is discussed.

(ii) DC source of higher current magnitude

Using this source, the magnitude of current is varied by adjusting the source voltage. This current magnitude depends on the earth resistance of main earthing system, remote electrode earth resistance and lead resistance in case of earth resistance measurement.

Portable DC source available at CPRI is having the capability to drive DC current of upto 100A, 200V is as shown in Fig. 1.



Fig. 1 : 100A, 200V DC source.

III. DETERMINATION OF SOIL RESISTIVITY

A. Soil Resistivity determination by adopting Earth Tester

Generally soil resistivity measurement with wenner's method is performed as per the methodology described in [2][3][4]. Fig. 2 shows the connection diagram for determining the soil resistivity with earth tester as a source of current injection. The inter-electrode spacing is varied from small distance upto the required spacings while performing the measurements.

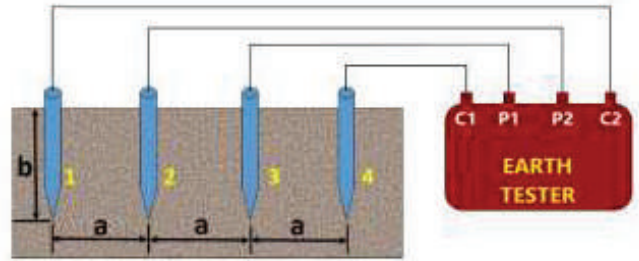


Fig. 2 : Measurement of Soil resistivity using Earth Tester

The soil resistivity ' ρ ' is calculated as per the formula given below [2][3] (for cases where $a \gg b$) :

$$\rho = 2 \pi a R \quad \dots(1)$$

where

ρ = soil resistivity in Ω -m.

a = inter electrode spacing (m).

R = Resistance in Ω .

B. Measurement of Soil Resistivity by adopting DC source

The earth tester used during the measurement as mentioned above is replaced by a DC source of higher current magnitude. The procedure is as defined in [1]. Fig. 3 shows the arrangement for soil resistivity determination using DC source

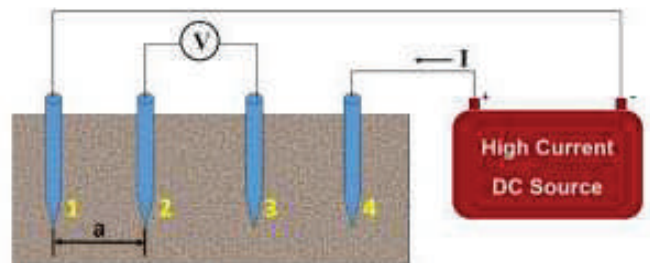


Fig. 3 : Measurement of soil resistivity using DC source

Due to injection of DC current in the soil, there will be galvanic effect, polarization and corrosion. This effect can be overcome by reversing the dc source polarities during each measurement. A case study on this measurement for the same site is published in our earlier paper [1].

IV. MEASUREMENT OF EARTH RESISTANCE

A. Measurement of Earth Resistance by adopting Earth Tester

Normally earth resistance measurement is made by adopting Fall-of-Potential method as per [2][3][4] with earth tester as source of injection which is as shown in Fig. 4. This tester injects current between the grounding grid and the remote electrode. It also measures the voltage between the grounding grid and the potential electrode/probe. The earth resistance is calculated with these two parameters for a particular distance between grounding grid and potential probe.

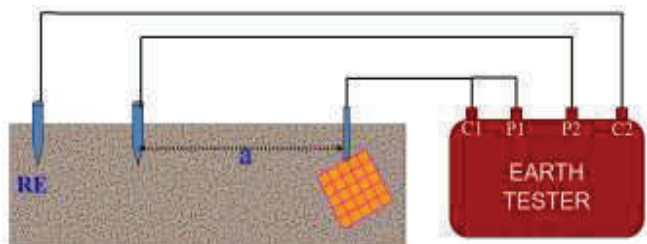


Fig. 4 : Earth Resistance measurement with Earth Tester as a source

B. Earth Resistance Measurement by adopting DC source

Fall-of-Potential method [2],[3],[4] was chosen for earth resistance measurement by adopting DC source of higher current magnitude. Fig. 5 shows the measurement of earth resistance using DC source. The DC source injects constant current between the grounding grid and the remote electrode. A high accuracy multimeter measures the voltage between the grounding grid and the potential electrode/probe. The earth resistance is calculated with these two parameters for a particular distance between grounding grid and potential probe.

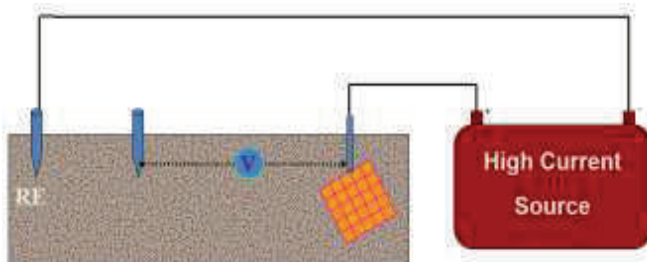


Fig. 5 : Measurement of Earth Resistance using DC source

Measurement of earth resistance was made at a riser connected to electrode station of HVDC substation. During the measurement, the remote electrode was placed at about 1170 meters away from the test earth strip. DC source of higher current magnitude was used for current injection and measurement. This Potential probe is moved towards the remote current probe in increments

of distance starting from the edge of the grounding system and voltage measurements are measured at various locations outside the grounding system. The readings are as tabulated in Table I.

Table I : Earth Resistance Measurement Results

Distance of potential point from ground electrode (m)	Injection current (20A)
	Measured Voltage (V)
224	1.40
226	1.395
270	2.168
360	3.55
450	4.30
540	4.75
630	5.09
720	5.37
765	5.75
810	5.97
855	5.98
900	6.00
945	6.03
990	6.10
1080	6.20
1170	6.50

In order to determine the resistance of the earthing system by Fall-of-Potential method, it is necessary to plot the apparent resistance versus the distance of potential probe from the test system. The steady state values of the readings given in Table I represent a value of earth resistance which is outside the influence of the remote current electrode employed in the measurement.

$$\text{Earth resistance} = V/I = 5.975/20 = 0.299 \Omega.$$

The resistance corresponding to the steady state value is the resistance of the earthing system. Referring to Table I, the earth resistance of the earthing system of the electrode station of HVDC substation is 0.299Ω .

V. CONCLUSION

Measurement of Earth resistance is essential in order to ascertain the design value and the healthiness of existing grounding system. A detailed measurement of earth resistance at electrode station of HVDC substation was carried out using DC source of higher current magnitude. An appropriate instrumentation to be used for the measurement for earth resistance in an electrode

station of HVDC substation is discussed. Generally, these measurements are done using conventional earth testers. But for the locations like in electrode station of HVDC substation, the usage of DC source will give more realistic results. Thus this paper helps the professionals involved in earthing system designing to familiarize with the concepts of measurements using DC source. Apart from HVDC stations, this technique shall also be applied for measurement of earthing resistance of large grounding system.

Acknowledgment

We thank the management of Central Power Research Institute for their support in publishing this paper. We also thank Mr. Jayakumar and M. M. Babu Narayanan for their support in this study.

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Failure of Distribution Transformers due to Lightning

Anandu Gopan¹

ABSTRACT

This paper explains the inefficiency of Surge Arresters in protecting distribution transformers during lightning, due to the wrong installation of surge arrestors. Transformers with a primary voltage up to 33kV are considered in this paper. CEA Regulations (Measures relating to Safety and Electric Supply) on protection against lightning is explained, then the typical installation practices are studied and correct installation as per IS 15086: Part 5: 2020 and IEEE 142 are explained. The conclusion is drawn from the effectiveness of the regulation and recommendations are given.

1. INTRODUCTION

Surge Arresters play a vital role in protecting transformers from deterioration and insulation breakdowns. To protect distribution transformers from Lightning and Switching transient voltage surges, protection against these are made mandatory in Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023. Various standards including the IS 15086: Part 5: 2020: Surge Arresters Part 5 Selection and Application Recommendations (First Revision), IEEE 142 are analysed and evaluated with the practical installation carried out in different sites. This paper explains different methods of installing Surge Arresters in distribution (up to 33 kV) and analyses the effectiveness of this protection.

2. NATIONAL REGULATION FOR SAFETY: CEA REGULATION

Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations are the mandatory requirement to be followed in every electrical installation. The erstwhile 2010 regulations were replaced by a new regulation in June 2023. Regulation 74 of 2010 and 77 of 2023 explains about the subject as below.

(2010) 74. Protection against lightning.

- (1) The owner of every overhead line, sub-station or generating station which is exposed to lightning shall adopt efficient means for diverting to earth any electrical surges due to lightning which may result in injuries.
- (2) The earthing lead for any lightning arrester shall not pass through any iron or steel pipe but shall be taken as directly as possible from the lightning arrester without touching any metal part to a separate vertical ground electrode or junction of the earth mat already provided for the sub-station of voltage exceeding

650 V subject to the avoidance of bends wherever practicable

(2023) 77. Protection against lightning.

- (1) The owner of every overhead line, substation or generating station which is exposed to lightning shall adopt means as per relevant standards for diverting electrical surges to the earth due to lightning which may result in injuries.
- (2) The earthing lead for any lightning arrester shall be as short as possible and shall not pass through any iron or steel pipe, but shall be taken as directly as possible from the lightning arrester without touching any metal part to a separate vertical earth electrode or junction of the earth mat already provided for the substation of voltage exceeding 650 V subject to the avoidance of bends wherever practicable: Provided that a vertical earth electrode shall be connected to the junction of the earth mat.

3. INSTALLATIONS

Case 1:

A typical installation of a surge arrester from an outdoor substation is taken as a reference from Nagpur, Maharashtra. Figure 1 shows the connections of separate earth pits and surge arrestors, and Figure 2 shows the earth pits for the surge arrestors.

Case 2:

A typical installation of a surge arrester from an indoor substation is taken as a reference from Chennai, Tamil Nadu. Figure 3 shows surge arrestors earthing conductors running without touching the frame of the structure or any other conductive surfaces (insulated). Figure 4 and Figure 5 show its separate vertical pipe earth electrode.

1. Chennai



Fig. 1 : Surge Arrestors connected to separate earth pits.



Fig. 2 : Separate earth pits



Fig. 3 : Surge arrestors connected through insulated busing.



Fig. 4 : Vertical pipe earth electrode .

4. RECOMMENDATIONS FROM IS AND IEEE STANDARDS ON SURGE ARRESTORS

In IEEE 142 Chapter 2, it has been stated that locating the surge arrester at any substantial distance, such as at the pole-top cross arm, with an independent grounding conductor can seriously increase the surge voltage stress on a transformer or switchgear. Thus, surge arrestors must be installed as close as possible to the equipment to be protected and to the ground.

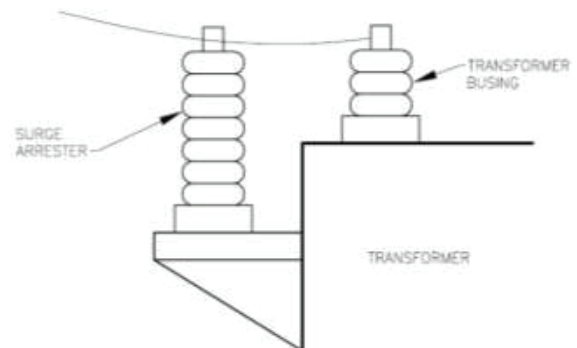


Fig. 5 : Good installation of a surge arrester, explained in IEEE142.

IS 15086: Part 5: 2020 clause 5.2.5.5.2 states that for distribution voltage levels ($U_s < 52 \text{ kV}$), the surge arresters should be located very close to the equipment to be protected, and wherever possible the earth terminal of the surge arrester and equipment should be bonded with a very short straight conductor. Clause 5.2.5.5.4 also states that the location of the distribution arrester relative to the protected equipment can be very important when considering the fast-rising lightning surge. When protecting from fast-rising surges the lead length in series with the arrester and in parallel with the protected equipment can generate a significant voltage due to its inherent inductance. This lead voltage is in addition to the fast front characteristics of the surge arrester. The connections shall be installed as short and straight as possible.

5. RELATION BETWEEN INDUCED VOLTAGES AND LENGTH OF THE WIRE

The inductive voltage in the connecting conductors of the surge arrester in fast-raising surges can be calculated as:

$$U_i = L \times di / dt \quad \dots(1)$$

From equation (1) it can be inferred that the length of the connecting wire is directly proportional to the induced voltage, meaning if the length is increased from 1 meter to 2 meters, the induced voltage will increase by a factor of two. And since the rate of change di/dt will be high in lightning strikes, it is important to have a low wire length so that an effective voltage protection level can be achieved.

6. INSTALLATION PRACTICES ACCORDING TO STANDARDS

Three types of surge arrester installations are explained in IS 15086: Part 5:

Bad installation practice 1 : The connection type 1 shows a bad connection. The connection length is too long, resulting in a huge voltage drop which affects the effective protection of the surge arrester. It is commonly noted in this case the surge arrester does not work and the surges damage the transformer.

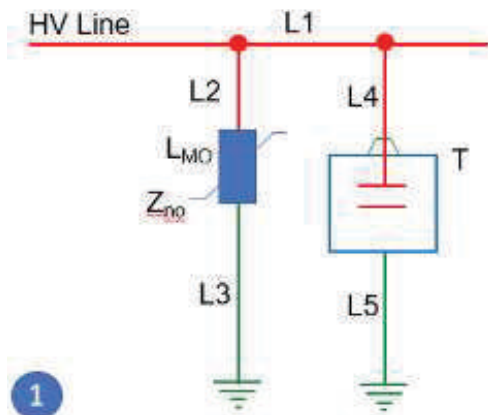


Fig. 6 : Installation type 1.

The connection leads are too long and, in the transformer, and arrester do not have the same earthing point. The loop $L1 + L2 + L3 + L4 + L5 + LMO$ is too long.

Good installation practice 2 : The connection type 2 shows a good connection. The connection length from the arrester to the transformer is short and good since it is directly connected to the body of the transformer. But it is preferable to keep the connection length as short as possible.

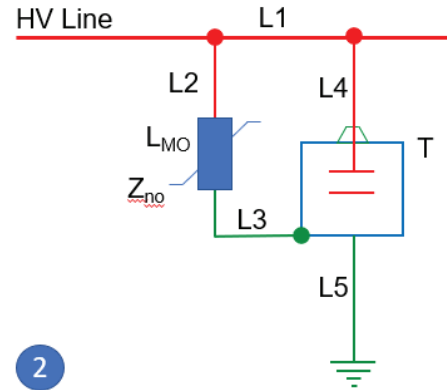


Fig. 7 : Installation type 2.

Best installation practice 3: The connection type 3 shows the best connection. The voltage drop in the lead length will be as small as possible; hence, the effective protection level will not exceed the protection level needed by the transformer, resulting in the best operation of the surge arrester.

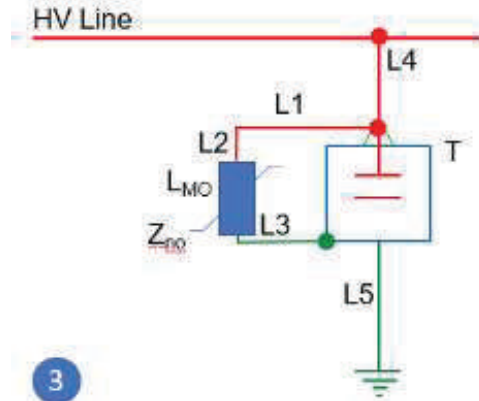


Fig. 8 : Installtions type 3.

Key:

L1 to L-5 length of connection leads

LMO Length of arrester

OH overhead line. Is assumed to be of infinite length before and after the transformer and arrester connection point.

C internal capacitance of the transformer

T transformer

7. ANALYSIS

Case 1 (Figure 1 and 2): The surge arrester is installed as shown in Figure 5. Wire length L3 is approximately 8 meters. The transformer is 11kV, having an impulse voltage withstanding of approximately 75kV. Any overvoltage above 75kV may lead to insulation deterioration or failure.

Considering a di/dt of $10\text{kA}/\mu\text{s}$, the voltage drop in L3 will be 80kV. Considering the protection level of an MOV based gapless surge arrester as 30kV, (for a surge arrester of rated voltage 9kV used in an earthed 11 kV supply line), and the potential drop in the loop L1 + L2 + L3 + L4 + L5 + LMO will be much higher than the impulse voltage withstanding of the transformer. Hence the surge arrester will not provide any protection.

Case 2 (Figure 3 and 4): The surge arrester is installed as shown in Figure 5. Wire length L3 is approximately 5 meters. The transformer is 11kV, having an impulse voltage withstanding of approximately 75kV. Any overvoltage above 75kV may lead to insulation deterioration.

Considering a di/dt of $10\text{kA}/\mu\text{s}$, the voltage drop in L3 will be 50kV. Considering the protection level of a MOV-based gapless surge arrester as 30kV, (for a surge arrester of rated voltage 9kV used in an earthed 11 kV supply line), and the potential drop in the loop L1 + L2 + L3 + L4 + L5 + LMO will be much higher than the impulse voltage withstanding of the transformer. Hence the surge arrester will not provide any protection.

The above analysis is made considering that the “vertical earth electrode is connected to the junction of the earth mat” as specified in regulation 77 with a short wire. However, in practice, the earth electrode of the surge arrester is separate from other earthing of the substation. In such a case, L3 should be considered infinite, and the surge arrester fails to provide any protection.

8. CONCLUSIONS

It can be concluded that most of the installations follow bad installation practices (Figure 5) due to wrong wording in the regulation.

9. RECOMMENDATIONS

The mistake in the CEA regulation is leading to the wrong earthing practice of Surge Arrester. The current practices do not follow the IS and IEC standards.

CEA regulations are to be modified as below.

1. Regulation 77, Sub regulation (1) needs to be changed appropriately as recommended below.
2. Regulation 77, Sub regulation (2) complete sub regulation (2) to be removed.

After the above recommendation, the regulation looks like:

77. Protection against lightning.

- (1) The owner of every overhead line, substation or generating station which is exposed to lightning shall adopt means as per relevant standards for diverting electrical surges due to lightning.

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Technocommercial Aspects and Safety Checks for Electrical Installations

Pravinchandra Mehta¹

SYNOPSIS

Safety being the prime concern for each and every installation, earthing and Lightning Protection (LP) which plays major role in maintaining safety of human, livestock and system should be given top priority. To keep pace with the progress made worldwide one has to focus on maintaining continuous operation of power system/installations with reliability and safety. That's why the role of earthing cannot be neglected, and everyone concerned is more cautious about the design of earthing system and LP at the design stage. Designing the Earthing system for any installation is a kind of art and science both.

This paper describes some tips on the design of earthing system with selection of particular inputs so as to make the entire project economical one without compromising the safety. It throws a light on how to save the cost of installation with a few examples. The paper also mentions considering safety as priority and few of points to take care of it.

1. INTRODUCTION

1.1 Personal safety at any and every electrical installation is undoubtedly an issue of prime concern. The Earthing System plays the role of safeguarding the above aspects. This paper given for proceedings of "14th National Conference on Safety Earthing and Lightning Protection System" at CBIP New Delhi is a humble effort in support of CBIP's gigantic work of bringing the awareness on this issue by publishing lot many documents (manuals, papers etc.) This paper is sharing the experience on reviewing the earthing system design for commercial aspects of total CAPEX involved in the project implementation without compromising the safety.

2. INPUTS REQUIRED FOR DESIGN OF EARTHING SYSTEM.

2.1 For large substation of grid following data is needed.

Area (boundary of station) L x B – mxm

Average Soil resistivity - Rho ohm m

Depth of burial of mesh - 0.6 m

Ht of surface layer- 150 mm (or other as the case may be)

Resistivity of surface layer-3000-ohm m (or other as the case may be)

Conductor material -MS/Copper

Diameter of conductor d- m

Length of the electrodes used- L -3 m (or other as the case may be)

Distance between two conductors in mesh D-m

Ground fault current- If kA

Clearing Time of fault -0.5 s

2.2 Design of earthing grid

Split factor is obtained from appropriate graph of Ann C given in IEEE 80.

Grid current $I_g = S_f \times I_f = \text{kA}$

Design with conventional method

Tolerable potential for 50kg body weight E_t – touch potential E_s - Step potential.

E_t - as per equation 32 of IEEE 80-2003

$E_t = (1000 + 1.5C_s \times p_s) \times 0.116 / \sqrt{3}$ Volts

E_s - as per equation 29 of IEEE 80 2003

$E_s = (1000 + 6C_s \times p_s) \times 0.116 / \sqrt{3}$ Volts

Grid resistance- R_g (as per equation 57 of IEEE 80-2003)

$R_g = \rho \{ 1/L_t + 1/\sqrt{20A(1 + 1/(1+h\sqrt{20A}))} \}$ ohm

Attainable values can be calculated as per equation 85 & 97 of IEEE 80-2013

3. ECONOMIC ASPECTS AND SAFETY WITH EXAMPLE

3.1 Example-1 Earthing system for the large EHV (220/132kV) substation

The inputs considered for design are as under.

- Area of switchyard 200x210 mtr $A = 42000$ Sq mtr
- Average Soil Resistivity – $\rho = 60 \Omega$ mtr.
- Fault current $I_{sc} = 40$ kA 1 sec

1. CEO, Persotech Solutions, Vadodara

- Duration of fault current for calculation of Estep and Etouch $t = 0.5$ sec
- Depth of burial -- $h = 0.6$ mtr
- Resistivity of Surface layer - $\rho_s = 3000 \Omega \text{ mtr}$
- Height of surface layer $h_s = 0.1$ mtr.
- Dist between two conductor $D = 12$ mtr

For the mesh E_{mesh} and E_{step} are calculated and compared with permissible values.

Attained E_{mesh} = 510.0 V which is less than permissible value of Etouch -650 V

Attained E_{step} = 360 V which is less than permissible value of Estep -2110 V

Attained $R_g = 0.12 \Omega$

The separation between two conductors originally calculated as 12 mtr showing safe design it is then reviewed and studied that if kept as 10 mtr, it will reduce the length of below and above ground risers for all the equipment, auxiliaries, cable trenches etc. Due to this, the requirement of main mesh conductor increases but it is adding the safety. The length of risers is noticeably reduced. This is more beneficial particularly where the quantity of equipment is huge.

For this case 10 nos. of 220kV line bays and 10 nos. of 66kV line bay station were considered for study.

Safety check with revised separation of conductors

Attained E_{mesh} = 446.0 V which is less than permissible value of Etouch- 650 V

Attained E_{step} = 364 V which is less than permissible value of Estep -2110 V

Attained $R_g = 0.114 \Omega$

3.2 Other aspects where cost can be saved, and safety is increased/maintained .

- Use of software for the design of earthing system- it ensures safety by calculating proper dangerous potentials and use of material (horizontal conductor/ vertical rod) may be optimized at the needy locations.
- Length of below ground risers (partial length) may be added to the length of main mesh to consider the total length of conductor for design.
- Erection of below ground riser shall be such that maximum horizontal length laid at the depth as same as main mesh. This will maintain safety.
- Design should be reviewed in case of very high soil resistivity, option of using concrete case electrodes may be more economical compared to enhancement of entire soil.
- Earthing for LP (for shield wire or LM) shall be done with due care.
- From the physical properties viewpoint copper is the best material as a conductor for earthing and bonding as it has the least resistivity and other few benefits. For the purpose of grounding used for lightning protection(LP), copper is preferable. For other application, other materials can be used for economic reasons.
- For earthing to Surge Arrester, riser length should be as less as possible and without twists ,it will increase the safety of the system.
- Pipeline passing through substation to the residential or other area should be earthed at some interval so maintain safety of human and animals at remote end.
- Pipelines containing Chemicals shall be protected from galvanic effect of ground fault current, earthing

Qunatity Analysis

Sr No	Name of item	Qty in mtr (as per optimized design d=10 m)	Qty in mtr (before optimization)	Difference	Total Unit Rate* (supply and erection) Rs per mtr	Cost Diff (+ for saving - for increase) in Rupees.
		D=10 mtr	D=12 mtr			
1	40 dia MS rod	8500	7600	-900	700	-6,30,000
2	75x10 GI Flat	6500	9000	2500	400	10,00,00
3	50x6 GI Flat	3800	5500	1700	250	4,25,000
	Net saving		7,95,000/-			

* Rates taken are tentative

The designer can try even with smaller D to check with the cost benefit .

shall be provided to these lines and accessories as per specific galvanic study.

- Many times, the designer takes the vertical ground rods at each junction of the periphery of mesh. In many cases, increasing no. of rods may not be beneficial for safety. Hence use of vertical ground rod should be reviewed properly to get the economical solution.
- For surge protection of transformers, Surge Arresters should be provided on each winding and each phase with the location as near to the winding as possible. Riser for connection to the ground for SA should be as short as possible.

4. SNAP SHOT OF SIMULATION ON SOFTWARES

Figure 4.1

5. CONCLUSION

- An adequate earthing system should be designed and executed for each particular electrical installation.
- Guidelines of IEEE -80 for AC switchyard, IEEE- 142 for industrial and commercial power system and IEEEstd-1110 for grounding electronic equipments shall be followed.
- Careful simulation for related cases should be carried out in order to estimate all the dangerous potentials

and optimize the design with the taking care of safety.

- To achieve the estimated output of the earthing system, correct selection of specifications for each equipment and cables should be made.
- When large motors are connected as load, during fault condition, motor behaves as generator and can feed to the fault. While deriving grid current this should be taken into considerations. Use of software to calculate ground fault current for the power system under study will take care of above aspect.
- Study of single phase to ground fault current and three phase short ckt current should be made carefully so that proper earthing factor of the system may be derived and accordingly voltage rise in the healthy phase during phase to grd fault may be estimated. This is most important for the safety of equipment.

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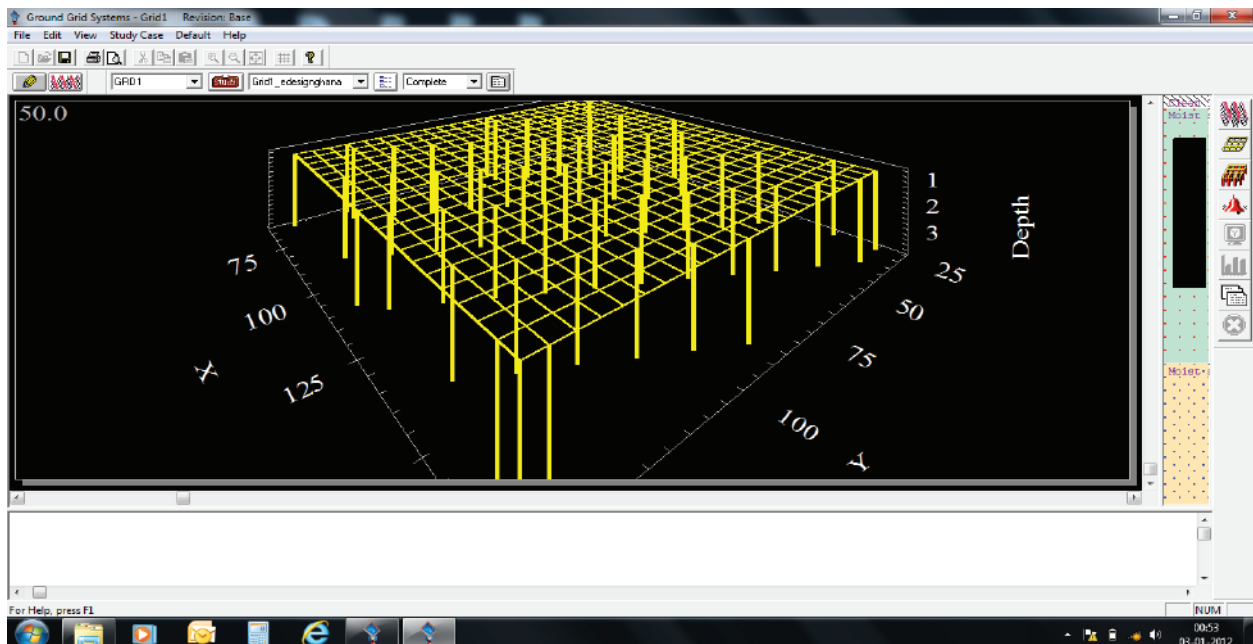


Fig. 4.1 : Snapshot of ETAP design of mexh for switchyard

**National Tutorial on
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15th - 16th February 2023, New Delhi



View of the dais during opening session (L-R), Shri K.K. Singh, Director (WR), CBIP, Shri N. Murugesan, Former DG, CPRI, Shri Gopa Kumar, President, National Federation of Engineers of Electrical Safety & MD, CAPE Electric Pvt. Ltd., Shri U.K. Bhattacharya, Director – Projects, NTPC Limited, Shri Upendra Kumar, CE - Chief Electrical Inspectorate Division, CEA, Shri A.K. Dinkar, Secretary, CBIP and Shri Sanjeev Singh, Director (Energy), CBIP

Brief Report

Life without electricity in the present times is unimaginable and beyond acceptance. On the other hand, the National Crime Record Bureau highlights the increasing trend in fatal accidents to the humans due to electrocution. Electricity is unseen, and intentionally or unintentionally, misconduct results in a fatal or non-fatal accident to the defaulter and/or damage or irreparable loss of equipment or property. Any accident is undesirable, unplanned, unwanted & may cause loss of human life, loss of property or both. It is the need of today to reduce accidents and to developed a safety culture, and to provide key insights, which help in reducing electrical accidents and in improving the workplace safety; and in building confidence in the common man in his using electricity. The effective implementation of a set of appropriate training programs would help reduce the accidents to a large extent. There are a number of standards on the topic of safety, which have been specifically developed by the various standards organizations around the world. It is, therefore, considered necessary to inform and update the professionals about the various standards in force, so that they may understand and select and apply the correct standard



Shri U.K. Bhattacharya, Director – Projects, NTPC addressing the participants

according to the situational requirement, without having to go into the depth of all the available standards.

Keeping in view the above, and the importance of the subject, Central Board of Irrigation & Power organised a National Tutorial on this important subject "Electric Safety and Accident Prevention – Practice and Standards", on 15th and 16th February 2023, at the CBIP Conference Hall, New Delhi.

Apart from providing the requisite information on the subject, the aim of the tutorial was also to provide a forum for open discussion and for the exchange of information, and to acquaint and update the concerned professionals/ engineers about the various Electrical safety practices and also the standards, their specifications and the applicability, and the need thereof.

The tutorial commenced with the opening session on the 15th February 2023.

The following dignitaries graced the dais during the inaugural session:

- Shri U.K. Bhattacharya, Director – Projects, NTPC Limited.
- Shri Upendra Kumar, Chief Engineer- Chief Electrical Inspectorate Division, Central Electricity Authority
- Shri Gopa Kumar, President, Safety and MD, CAPE Electric Private Limited
- Shri N. Murugesan, Former DG, CPRI
- Shri A.K. Dinkar, Secretary, CBIP
- Shri Sanjeev Singh, Director- Energy, CBIP
- Shri K.K. Singh, Director- Water Resources, CBIP

The opening session started with a welcome address by **Sh. A.K. Dinkar**, Secretary, CBIP. He welcomed the Chief Guest, Shri U.K. Bhattacharya, Director – Projects, NTPC Limited, Shri Upendra Kumar, Chief Engineer-Chief Electrical Inspectorate Division, Central Electricity Authority and Shri Gopa Kumar, President of National Federation of Engineers for Electrical Safety and MD, CAPE Electric Pvt. Limited, and commended them for their contribution over the years in the Power Sector. He also welcomed Shri N. Murugesan, Former DG, CPRI, the main faculty for the two days program, and the invitees and all the participants of this Tutorial. He further emphasised that in the present competitive and challenging era, updating the knowledge in one's respective field, is an essential need, which helps in improving the skills of the individual, the organization and the country as a whole. He added that CBIP organises such knowledge sharing sessions on many important topics on a regular basis, and is contributing to a great extent, in helping the professionals in accentuating their knowledge. Further, he requested the participants to



Shri A.K. Dinkar, Secretary, CBIP delivering the welcome Address



Shri Upendra Kumar, CE- Chief Electrical Inspectorate Division, CEA, addressing the participants



Shri N. Murugesan, Former DG, CPRI, addressing the participants

make maximum use of the opportunities provided, and take part in the various CBIP programs being organised from time to time.

Shri Murugesan in his brief address informed the importance of Electrical safety. He added more than 60 to 70% of the electrical accidents occurred due to the electrical faults caused on account of ignoring the safety instructions, the lack of training to the staff, etc., at times resulting in death of the humans and the animals. He brought out that a systemic approach is needed to reduce the accidents due to electrical negligence. He emphasized that people should be trained, and he advocated that a certificate level training should be started. He was hopeful that he would be able to achieve the objective of the tutorial.

Shri Gopa Kumar, in his address, appreciated the efforts and contribution of CBIP & AARO in for organizing a tutorial on this important topic. He informed that many standards are available on the subject, like, IS 4043, IS 732 IEC 64 etc.; and there are committees like ETD 20, working group TC-81 working on this subject. However, important is the implementation of these standards, which has been neglected. He shared that he is presently associated with the various working groups and committees of BIS, IEC, National Building Code etc., which are working on the updation and the formulation of the various standards on the subject. He added that in Mumbai, 80% of the accidents have occurred due to electrical fire, which is the highest across all the states in India. Even during the corona pandemic period, 125 people died due to electrical accidents. He was of the opinion that training can play an important role in reducing such accidents, and in this context, he has organized over 402 training programs on the subject. His lectures are available on YouTube, and requested the gathering to take advantage of the same.



Shri Gopa Kumar, President, Safety and MD, CAPE Electric Private Limited, addressing the participants



Shri Sanjeev Singh, Director (Energy), CBIP proposing vote of thanks



Releasing of a poster on Electrical Fire and Safety Tips for Public awareness

He once again complemented CBIP and advised all the participants that this is a major opportunity to interact with the experts and to understand in detail the need and the importance of the subject.

Shri Upendra Kumar emphasised the importance of subject to the Power System. He informed that electrical accidents is a field, where due attention has not been given in the country. The number of electrical accidents that have taken place during the past few years in India is quite alarming; 15,000 fatal accidents are reported per annum; and non-reported accidents may be even more! He further stated that there are various safety regulations and standards on the subject, which gives insight on the safety provisions, which need to be adopted for the construction, operation & maintenance of electrical installations, whether it is a part of generation, transmission or distribution. CEA is an apex body and is involved in the formulation of various guidelines. He informed that IE rules, 1956 which were made under section 37 of the Indian electricity act, 1910 had ensured that every rule was related, either directly or indirectly, to safety. Further, after enactment of Electricity Act, 2003, IE rules were repealed and superseded by the rules defined by CEA, in 2010 (measures relating to safety and electric supply regulations), which were notified on 24 September 2010. Subsequently three amendments were carried out and notified in 2015, 2018 & 2019 respectively.

Owing to the emerging requirements and technical updation, the comprehensive review of the CEA safety regulations is being done by CEA, and it will be notified very soon.

The basic intent of these regulations is to eliminate or reduce the risk of personal injury to any person or the damage to any property, due to the use of or the supply of electricity. He further emphasised that it's legally binding to implement these provisions, however, he requested everybody present to introduce the same in their daily practices, whether at the workplace or at home. He further informed that CEA inspectorate is very active in sensitization on the issue of electrical safety, and organises regularly workshops at the utility level, and has already organised more than 50 such workshops in the last few years.

He acknowledged the presence of numerous subject experts in the hall, including Shri Murugesan, former DG CPRI, Dr. Rajesh Arora from DTL, Ms. Shivani Sharma from Hitachi and Shri Dinesh Sharma from CTR. He hoped for extensive knowledge sharing during the training. Lastly, he acknowledged the efforts of the CBIP in organising this tutorial.

Shri A.K. Bhattacharya, in his inaugural address, highlighting the importance of the subject, and mentioned



Dr. Rajesh Arora, Sr. Manager, DTL making presentation



Ms. Shivani Sharma from Hitachi Energy making presentation



Shri Dinesh Sharma, Sr. Regional Manager CTR making presentation

his huge interest therein. He shared his own experience as a part of his address. He emphasised that accidents are accidents, and are unavoidable, and may occur any time. Since these could occur any time, we need to be ready with the requisite resources, in terms of equipment and knowledge, to be able to handle the situation speedily and effectively. He added that in our country a majority of the accidents happen at the workplace, and requested the participants to adhere to the safety practices, by adopting the various standards/ regulations. He requested all the professionals present in the hall that they can bring improvement in the electrical safety ecosystem at their work place, and that they would be helping in building an electrical accident-free society and the country as a whole. He also made a mention of the various innovations adopted by NTPC on safety, for the strengthening their system. Electricity is a good servant but a bad master, he added. He expressed happiness on seeing so many young engineers in the audience. At the end, he told of a very important slogan, that **'some body is waiting at home'**, and complimented CBIP for organising this training, and wished it all success.

The address was very informative, and was appreciated by one and all. Not only did he emphasise the importance this tutorial, but he also hoped that this tutorial would provide valuable food for thought for the participants, and encourage them to apply it in their own workspace.

Release of poster on 'Electrical Fire & safety tips for public awareness'

One of the objectives of CBIP is to prepare guidelines and other publications for benefits of the professionals in the power and water resources sectors, to achieve the aim and the objective, a poster on 'Electrical Fire & safety tips for public awareness' created by CBIP with the expert guidance of Dr. Rajesh Arora, Sr. Manager, Delhi TRANSCO Ltd., was also released during inaugural session.

At the end of opening session, **Shri Sanjeev Singh**, Director, CBIP expressed gratefulness to all for their participation in the event. He individually thanked each one of the participating dignitaries by name, both on and off the dais, as also, the speakers of the coming sessions. Further, he thanked all those who supported and helped in the organising of the Tutorial. He thanked the participants for showing a keen interest in the topic, and for coming out in such large numbers, to add to the success of the Tutorial. Towards the end, he thanked the CBIP team for making the event possible. This was the end of the Inaugural Session.

Lively discussions during Technical Sessions

There were seven Technical Sessions conducted over two days.

Following topics were deliberated in two days deliberations by Shri N. Murugesan, Main faculty of the tutorial:

- Why is Electricity safety so important & Hazards and risks from electricity
- Statistics for electrical accidents, types of accidents and injuries, common causes of accidents and injuries, employer duties
- Fundamentals of Electrical safety
- Introduction of Earth and Grounding system
- Effect of current passing through the human body and safety requirements
- Fundamentals of Ground Grid Design
- Ground Grid Design Procedures
- Example Design from IEEE Standard 80
- Safety Aspects of Ground Grid Operation and Maintenance
- Effects of High Fault Currents, Damage or Failure of Grounding

Equipment, Recommendations

- Grounding of Distribution Systems
- Grounding and Over voltages in Distribution Systems
- High-Resistance Grounding of Distribution Systems
- Electrical accidents and dangerous occurrences
- Basic safety precautions & Safety procedures and methods
- Earth electrode, protective conductors, grounding and bonding of electrical

Systems and Equipment

- Electrical maintenance and relationship to safety, Testing Electrical safety
- Accident prevention, accident investigation, rescue and first aid
- Human factors in electric safety, Safety management and organizational structure, Safety training methods systems
- High voltage safety, Arc Flash Analysis, Hazardous Area Classification
- Statutory Legislative frame work- Electricity Act 1910, Electricity Rules 1956
- Environment Protection Act 1985, Electricity Act 2003, Energy Conservation

Act 2001, Applicable part of National Building Code, 2016

- Electrical safety codes and standards – National Electrical Code 2011, IEC 60364

- CEA Regulations for measures relating to safety and electric supply -2010 and amendments
- Designating persons to operate & carry out the work on Electrical apparatus,

Inspection & Safety Measures

- General Safety requirements, General Conditions relating to supply and use Electricity
- Safety Provisions for Electrical installations & Apparatus of voltage not exceeding 650 volts and Safety Provisions for Electrical installations & Apparatus of voltage exceeding 650 volts.
- Safety Requirements for overhead lines, underground cables & Generating stations.
- Measurement & Monitoring
 - Thermography
 - Periodic testing & maintenance
 - Electrical Safety Self-Assessment (audit)
- National Electrical Code- 2011
 - Part 1 General and common aspects
 - Part 2 Electrical installations in stand-by generating stations and captive substations
 - Part 3 Electrical installations in non-industrial buildings
 - Part 4 Electrical installations in industrial buildings
 - Part 5 Outdoor installations
 - Part 6 Electrical installations in agricultural premises
 - Part 7 Electrical installations in hazardous areas
 - Part 8 Solar photovoltaic (PV) power supply systems

Following additional presentations were made by some of the eminent experts during the tutorial:

1. Electrical Fire in Residential and Commercial Buildings - **Dr. Rajesh Arora**, Sr. Manager, Delhi Transco Limited

2. Modern trends of electrical arc flash analysis & its mitigation - **Dr. Shivani Sharma**, Principal Technical Consultant, Power Consulting, Hitachi Energy
3. Passive Fire Safety - **Shri Dinesh Sharma**, Sr. Regional Manager, CTR
4. Transformer/Rectifier Fire Protection – **Shri Arvind Yadav**, Sr. Marketing Manager, CTR

All the presentations were focused, technical and to the point. Almost all the aspects of the 'Electric Safety and Accident Prevention' and the allied topics were deliberated during the Tutorial. The presenters made every effort to make it easy for the participants to grasp the subject. Further clarity was enabled by the Q&A opportunity in each session.

The program was attended by about 50 participants from various PSUs, the State, and the Central Power & RE sector organizations, and also included some participants from the manufacturers, as also from IIT Roorkee.

A certificate of participation was given to each participant, at the end of the tutorial. The feedback received from the participants was very encouraging.

The program concluded with a Vote of thanks, proposed by Shri Batra, Consultant, CBIP, expressing thanks to Shri Murugusan, the main faculty of the tutorial, Dr. Rajesh Arora, Dr. Shivani Sharma, Shri Dinesh Sharma and Shri Arvind Yadav for conducting very effectively the two days tutorial; and also to the participants for making the sessions participative, interactive & lively.



A view of the participants

**Two Days Training Program on
Disaster Management
(Hybrid Mode)
(Jointly Organised by CBIP & SPE)
26-27 June, 2023**

Central Board of Irrigation and Power (CBIP) jointly with Society of Power Engineers India (SPE) organized two days Training Program on "Disaster Management" on 26-27 June, 2024 on Hybrid Management.

The key focuses of the training program were:

- Disaster and its Classification
- History of Disasters in India and its Impact
- HRVA
- Institutional Arrangements within the Power Utilities
- DM Act and Policies – NDMA & CEA recent guidelines
- Prevention and mitigation strategies
- DRR and building Resilience
- Preparedness and response
- Capacity building
- Recovery and steps for restorations
- Financial Arrangements and Budgets
- Plan management- SOPs
- Developing DM Manual

Participants from Adani, CESC Ltd., WBSETCL, AP Transco, MAHAGENCO, BNC Power etc.. attended this training program.

Experienced and reputed faculty having in-depth knowledge on the subject were drawn for delivering the lectures. Case studies were also discussed during the program.,

All the important aspects of Disaster Management were covered by the experts in a very interactive manner and clarifications were clarified and explained by the presenters as per the satisfaction of the participants. Feedback of the program was quite encouraging.

HIGHLIGHTS OF POWER SECTOR

GROWTH OF INSTALLED CAPACITY

(Figures in MW)

	At the end of 12th Plan (August 2017)	As on 30.6.2023
THERMAL	218330	237928.911
HYDRO	44478	46850.17
NUCLEAR	6780	7480
RENEWABLE ENERGY SOURCES	57244	129642.545
TOTAL	326832	421901.626

Source : CEA

ALL INDIA REGION WISE INSTALLED CAPACITY

As on 30.6.2023

(Figures in MW)

Region	Thermal	Nuclear	Hydro	RES*(MNRE)	Total
Northern	62797.927	1620	20751.76	33965.54	119135.227
Western	86808.406	2540	7562.5	41730.43	138641.336
Southern	57562.531	3320	11827.48	51500.66	124210.671
Eastern	28308.519	0	4764.42	1856.79	34929.729
N. Eastern	2331.985	0	1944.01	550.695	4826.69
Islands	119.543	0	0	38.43	157.973
All India	237928.911	7480	46850.17	129642.545	421901.626
Percentage	56.39440484	1.772925142	11.10452464	30.72814538	100

Source : CEA

SECTOR WISE INSTALLED CAPACITY AND GENERATION

As on 30.6.2023

Sector	Installed Capacity (MW)					Percentage Share	Net Capacity added
	Thermal	Nuclear	Hydro	RES* (MNRE)	Total		During June 2023
STATE	75979.868	0	27254.45	2492.112	105726.43	25.05949811	4233.51 MW
PRIVATE	85311.135	0	3931	125518.133	214760.268	50.90292494	
CENTRAL	76637.908	7480	15664.72	1632.3	101414.928	24.03757695	
TOTAL	237928.911	7480	46850.17	129642.545	421901.626	100	

Source : CEA

GROWTH OF TRANSMISSION SECTOR

	Unit	At the end of 12 th Plan (August 2017)	As on June 2023	Addition after 12 th plan (2017-23) (up to June 2023)
TRANSMISSION LINES				
HVDC	ckm	15556	19375	106286
765 kV	ckm	31240	52678	
400 kV	ckm	157787	199246	
220 kV	ckm	163268	202838	
Total Transmission Lines	ckm	367851	474137	106286
SUBSTATIONS				
	Unit	At the end of 12 th Plan (August 2017)	As on June 2023	Addition after 12 th plan (2017-23) (up to June 2023)
HVDC	MW	19500	33500	451003
765 kV	MVA	167500	278200	
400 kV	MVA	240807	431258	
220 kV	MVA	312958	448810	
TOTAL	MW/MVA	740765	1191768	451003

RURAL ELECTRIFICATION / PER CAPITA CONSUMPTION

Total No. of Villages	597464
% of Villages Electrified	100.00
No. of Pump-sets Energized (2020-21)	22089217
Per Capita Consumption during 2021-22*	1255 kWh

*Provisional

RENEWABLE ENERGY SECTOR IN INDIA: POTENTIAL AND ACHIEVEMENTS

Sector	FY 2022-23	
	Achievements (June 2023)	Cumulative Achievements (as on 30.6.2023)
I. Installed RE Capacity (CAPACITIES IN MW)		
Wind Power	1139.95	43773.08
Solar Power	3316.47	70096.83
Small Hydro Power	14.75	4959.05
Biomass (Bagasse) Cogeneration	0.00	9433.56
Biomass (non-bagasse) Cogeneration	0.00	814.45
Waste to Power	1.60	249.74
Waste to Energy (off-grid)	9.94	315.84
Total	4482.71	129642.55

Source: MNRE

GOVERNMENT ACCEPTS EXPERT PANEL REPORT ON SMART ELECTRICITY TRANSMISSION SYSTEM IN INDIA

The power ministry on Tuesday said that the government has accepted a report of a task force or expert panel, which paves the way for modern and smart electricity transmission system in India. The country will soon have a modern and smart power transmission system with features such as real-time monitoring and automated operation of grid, better situational assessment, capability to have increased share of renewable capacity in the power-mix, enhanced utilisation of transmission capacity, greater resilience against cyber attacks as well as natural disasters, centralised and data-driven decision-making, reduction in forced outages through self-correcting systems etc., a power ministry statement said.

These and other recommendations are part of a report of a task force set up by the power ministry in September 2021 under the chairmanship of POWERGRID chairman and managing director to suggest ways for modernisation of transmission sector and making it smart and future-ready, it stated.

The other members of the task force included representatives from state transmission utilities, Central Electricity Authority (CEA), central transmission utilities, MeitY (Ministry of Electronics and Information Technology), IIT Kanpur, NSGPMU and EPTA.

The report of the committee was accepted by the government after deliberations with Union power minister R K Singh last week, it stated.

During the meeting, the minister emphasised that a modern transmission grid is vital to achieve the government's vision to provide 24x7 reliable and affordable power to the people and also meet the sustainability goals.

Singh said that a fully automated, digitally controlled, fast responsive grid which is resilient to cyber attacks and natural disasters is the need of the hour.

The minister said that such a system should ensure isolation of specific areas in case of any contingency, so as to protect the grid and prevent larger outages.

Appreciating the efforts of the task force, Singh directed the CEA to formulate necessary standards and regulations for adoption of identified technological solutions and set benchmark performance levels so as to build a robust and modern transmission network in the country.

The task force in its report has recommended a bouquet of technological and digital solutions, which can be adopted to make the state transmission grids future ready.



These recommendations have been clubbed under categories of modernisation of existing transmission system; use of advanced technology in construction and supervision, operations and management; smart and future-ready transmission system; and up-skilling of workforce.

The task force has recommended centralised remote monitoring, operation of substations including SCADA, flexible AC transmission devices (FACTS), Dynamic Line Loading system (DLL), Wide Area Measurement System (WAMS) using PMUs and data analytics, Hybrid AC/HVDC system, predictive maintenance technique using AI/ML algorithms, HTLS conductors, process bus based protection automation and control GIS/Hybrid substation, cyber security, energy storage system, and drones & robots in construction/inspection of transmission assets.

The use of robots is expected to not only minimise human intervention and life risks/hazards but also save time while ensuring accuracy during construction and maintenance.

The task force also recommended benchmarks for transmission network availability and voltage control based on performance of global transmission utilities.

While the short-term to medium term recommendations will be implemented over 1-3 years, the long-term interventions are proposed to be implemented over a period of 3-5 years, it stated.

Source : PTI, Mar 07, 2023

TATA POWER JOINS HANDS WITH ENEL GROUP TO POWER DIGITALISATION, AUTOMATION IN ELECTRICITY DISTRIBUTION

Tata Power on Thursday said that it has collaborated with Enel Group to power digitalisation and automation of India's distribution network. "Tata Power joined hands with

Enel Group -- one of the largest integrated players in the global power and renewable markets -- for implementing two key pilot projects through former's Delhi based distribution business," a company statement said.

The agreement towards the same was signed by Robert Ronald Denda - CEO Gridspertise Srl, and Praveer Sinha, CEO & MD, Tata Power, in New Delhi.

The agreement was signed on the sidelines of the official visit of the President of the Council of Ministers of Italy Giorgia Meloni.

Under the agreement, Tata Power's distribution arm Tata Power Delhi Distribution Ltd (TPDDL), serving 1.9 million customers in north Delhi, will work closely with Enel Group affiliated company Gridspertise, jointly controlled by Enel Grids and CVC Capital Partners, on project implementation.

The first pilot project will focus on to accelerating digitalisation and automation of secondary substations and see Tata Power joining the international co-creation programme of Gridspertise's proprietary QEd - Quantum Edge Device. This collaborative programme will virtualise grid functionalities and enable protection and control, automation, real-time fault detection and service restoration of the network.

The other project is aimed at deploying Gridspertise's metering technology on a pilot basis in the Delhi power distribution network. It focuses on testing and evaluating the new hybrid smart metering technology featuring dual communication channel, via hybrid Power Line Communication (PLC) and Radio Frequency (RF).

It offers a robust, efficient and secure communication channel by auto-switching between PLC and RF channels depending on real time field conditions. Both the projects are in line with Tata Power's and Enel Group's commitment to strengthen the mutual goal of driving energy transformation.

Sinha said in the statement, "Our association with Enel Group will help us accelerate digitalisation and automation of distribution grid, including implementation of the hybrid meter technology. We believe that these tech advancements will pave the way for sustainable and future-ready discoms in the country."

Tata Power is spearheading major transformation in the Indian power distribution landscape via focussed tech interventions and manages a distribution network of more than 0.4 million circuit kilometres with 12 million customers across India via its discoms. It has also reached a milestone of installing 0.5 million smart meters. Antonio Cammisecra, Head of Enel Grids, commented, "The agreements announced during the India Italy Business Roundtable result from years of close collaboration

between the Enel Group and leading Indian power sector organisations."

INDIGRID COMPLETES ACQUISITION OF KHARGONE TRANSMISSION LTD

India Grid Trust (IndiGrid) on Thursday announced completing acquisition of 100 per cent "shareholding and economic interest" in Khargone Transmission Ltd from Sterlite Power Transmission Ltd (SPTL). IndiGrid is India's first listed power sector infrastructure investment trust (InvIT) and STL is one of the sponsors of IndiGrid.

"IndiGrid announces the completion of acquisition of 100 per cent shareholding and economic interest in Khargone Transmission Ltd (KTL) from SPTL," it said in a statement.

"Acquired at an enterprise value of Rs 15 billion, the addition of KTL to the portfolio will take IndiGrid's assets under management to Rs 227 billion and its overall asset base to 8,416 ckms of transmission lines and 17,550 MVA of transformation capacity," the company said.

The acquisition was funded through a combination of equity, internal accruals, and debt. On January 21, IndiGrid and SPTL signed a binding share purchase agreement for the acquisition. The IndiGrid received its unitholders' approval on February 23.

KTL is an Inter-state Transmission System TBCB (Tariff Based Competitive Bidding) project and has been operating commercially since December 2021. It is a Build-Own-Operate-Maintain (BOOM) based project and has a remaining transmission service agreement life of 32 years with a levelised tariff of Rs 159.1 crore.

The asset spans across Madhya Pradesh and Maharashtra and terminates in one end at the Dhule substation of Bhopal Dhule Transmission Company Ltd (BDTCL). Harsh Shah, Chief Executive Officer of IndiGrid, said that due to KTL's geographical proximity to its existing BDTCL project, the acquisition provides an operational leverage and will help drive operational efficiency.

Source : PTI, Mar 02, 2023

GOVERNMENT APPROVES RS 687 CR FOR UPGRADATION OF POWER DISTRIBUTION INFRASTRUCTURE IN LADAKH

The central government has given its approval for the implementation of Revamped Distribution Sector Scheme (RDSS) in the Union Territory of Ladakh with a sanctioned cost of Rs 687.05 crore, officials said. The ministry of power conveyed its approval to RDSS for implementation in Ladakh, they said.

In this regard, an agreement was signed between chief engineer, Distribution, Ladakh Power Development Department (LPDD), Tsewang Paljor and executive

director WAPCOS Limited A K Gahlot in the presence of administrative Secretary Power, Ladakh, Ravinder Kumar, they added.

The scheme includes the grid connectivity of the Changthang region, downline infrastructure in the Zaskar region along with other loss reduction works in the Leh and Kargil districts of Ladakh, they said.

The ministry of power also approved the appointment of WAPCOS, a Government of India undertaking as the project management agency (PMA) for the implementation of RDSS in Ladakh.

The Revamped Distribution Sector Scheme aims to improve operational efficiencies and financial sustainability, by providing result-linked financial assistance to DISCOMs for strengthening of supply infrastructure based on meeting pre-qualifying criteria and achieving basic minimum benchmarks.

Source : PTI, May 03, 2023

TRIPURA FORMS SEPARATE ENTITY FOR INTRA-STATE ELECTRICITY TRANSMISSION

To bring down the power sector's aggregate technical and commercial (AT&C) losses, the Tripura government has formed a separate entity for electricity transmission in the state, a senior government official said. Tripura State Power Transmission Ltd (TPTL) has been formed this month as a wholly-owned subsidiary of Tripura State Electricity Corporation Limited (TSECL) for power transmission, State Power Secretary Brijesh Pandey told PTI here.

The official was part of a delegation which visited New Delhi recently to sign an agreement with NTPC for the development of renewable energy projects in the northeastern state.

"Carving out a separate transmission segment from TSECL was a big challenge. However, it was possible with the support of the government and various stakeholders," the official said. Until now TSECL was responsible for the generation, distribution and transmission of power in Tripura. A dedicated entity for intra-state transportation of power will help reduce AT&C losses which were at 31.7 per cent in FY2021-22, he said.

The target is to bring down the same to 28 per cent in FY23, he said.

The new entity will receive power produced by OTPC, NEEPCO, and Agartala-based TSECL from the National Grid for transmission of power across Tripura.

TPTL has come into operation with effect from January 14, 2023. The New entity TPTL will manage 83 operational power sub-stations and 1,861 km of transmission lines

(including 59 sub-stations and 875 km of lines in 33kv systems) within the state.

A committee constituted by the Union Ministry Power had recommended bringing the 33 KV system under state transmission utility for improvement in performance.

The committee under the Chairman and Managing Director, Power Grid Corporation of India Limited with representatives from Central Electricity Authority, State Transmission Utilities and Central Transmission suggested measures for the reduction of losses in the sub-transmission system and for ensuring reliability and efficient performance.

Source : PTI, Jan 22, 2023

MAHANADI COALFIELDS TO SET UP 1,600 MW POWER PLANT IN ODISHA

Mahanadi Coalfields Limited (MCL), a subsidiary of Coal India Limited, is looking to diversify into power generation, and plans to set up a Rs 12,000 crore power plant in Odisha.

It also aims to enter into aluminium business and may soon set up a greenfield aluminium project.

Sources informed that the 1,600 megawatt capacity coal-fired power project would come up in Odisha's Sundargarh district as a wholly owned subsidiary of MCL.

MCL also plans to enter into the aluminium business, they further said.

The mini ratna company is currently looking to secure a bauxite mine for the purpose. Coal India's board in October 2021 had approved a pre-feasibility report for setting up an integrated aluminium project in Odisha.

Earlier, the coal behemoth in December 2020 had got in-principle approval for venturing into aluminium and solar sectors and creation of special purpose vehicles.

Coal India in a regulatory filing in October 2021 had said that the proposed aluminium project would include bauxite mining, alumina refinery, aluminium smelter and an associated captive power plant by its wholly owned subsidiary MCL.

Source : IANS, Jan 23, 2023

ADANI MEETS BANGLADESH PM AFTER THE GROUP STARTS INDIA'S FIRST TRANSNATIONAL POWER PROJECT

Adani Group Chairman, Gautam Adani paid a visit to Bangladesh's Prime Minister Sheikh Hasina in Dhaka on Saturday after the full load commencement of power supply to Bangladesh from the group's thermal power plant in Godda, India.

The new project of the conglomerate will mark the group's entry into transnational power projects. This project will also commence India's first commissioned transnational power project where 100 per cent of the generated power is supplied to another nation.

Adani Power Jharkhand Ltd (APJL), a wholly owned subsidiary of Adani Power Ltd, will supply 1,496 MW from the Godda USCTPP under the PPA with the Bangladesh Power Development Board, executed in November 2017 for a period of 25 years, via a 400 kV dedicated transmission system connected to the Bangladesh grid. The subsidiary completed the dependable capacity test for the Godda plant on 12 July.

The particular test is a mandatory requirement under the Power Purchase Agreement (PPA) with Bangladesh. The test was conducted over a period of six hours to assess the functioning of the plant with two units with a total capacity of 1600 MW.

On 6 April, the first unit of 800 MW capacity of the Godda plant, in Jharkhand, began commercial operations. The second unit, also of 800 MW capacity, followed on 26 June.

"Electricity supplied from Godda will have a positive impact on Bangladesh's power situation by replacing costly power generated by using liquid fuel," Adani Group said in its statement

Adani Group has listed issues such as the establishing 105 km-long 400 kV Double Circuit Transmission Line, constructing a private railway line and water pipeline from the Ganga to be some of the hindrances they came across in this project.

The Godda power plant will also be first in India to have started operations with 100% flue gas desulphurization (FGD), selective catalytic reconverter (SCR) and zero water discharge for minimizing emissions and for environment friendly operations in alignment with the norms set by the Ministry of Environment, Forests, and Climate Change of the Government of India.

Source : ET Online, Jul 15, 2023

SJVN'S TWO PLANTS IN HIMACHAL PRADESH PRODUCE 50.498 MILLION UNITS OF POWER IN SINGLE DAY

Power producer SJVN has achieved record single-day generation of 50.498 million units from two hydro power

stations in Himachal Pradesh, the company's CMD Nand Lal Sharma said on Tuesday. The 1500 MW Nathpa Jhakri Hydro Power Station (NJHPS) achieved a new milestone of 39.527 MU of power generation, surpassing its previous record of 39.526 MU on August 29, 2022.

The Rampur Hydro Power Station (Rampur HPS) achieved 10.971 MU of power generation, breaking its previous record of 10.954 MU on July 16, 2023, Sharma said in a statement. Both plants recorded their respective highest power generation levels on July 17.

"SJVN has established a new all time high record of 50.498 MU in single day power generation from its two flagship hydro power stations in Himachal Pradesh," Sharma said.

The milestone is the result of efficient management, optimum operation and maintenance practices as well as proper repair and maintenance of the project components which has contributed in achieving maximum efficiency and productivity, he said.

Total generation from all the operational solar and wind power stations of SJVN in the June quarter stood at 101.051 MU, which is 73.04 per cent higher what was generated in the year-ago period.

Source : PTI, Jul 18, 2023

STERLITE POWER COMMISSIONS RS 1,600 CR PROJECT IN BRAZIL

Sterlite Power on Thursday announced commissioning of its sixth transmission project in Brazil built with an investment of Rs 1,600 crore. The project, Marituba involved developing a 344-km 500kV transmission corridor connecting Brazil's largest hydropower plant at Tucuruí to the metropolitan region of Belem to deliver up to 1000 MW of green energy, a company statement said.

Since its foray in Brazil in 2017, Sterlite Power has built a significant footprint in the country, acquiring 13 projects through greenfield global auction process.

Currently, the company has a strong portfolio of 8 power transmission projects, of which it has developed six, spanning approximately 2000 kilometre of transmission lines and 22 substations.

Located in the Amazon region, it is the largest power transmission project executed by Sterlite Power Brazil.

Source : PTI, Jul 20, 2023

Society of Power Engineers (India)

AIMS AND OBJECTIVES

The aims and objects for which the Society is constituted to promote the advancement of power engineering and allied subjects, and their applications, and to provide facilities for the exchange of information and ideas on those subjects amongst the members of the Society. This objective is achieved by arranging seminars, workshops, study tours etc and by publishing Journals. In order to ensure power development across the country, it has constituted its chapters at Vadodara, Jabalpur, Hyderabad, Delhi, Kolkata, Mumbai, Gwalior, Lucknow, Bangalore and recently opened chapter at *Vallabh Vidhyanagar*.

Establishment of Indian Chapters

The Society of Power Engineers (India) is an apex body constituted in the year 1947 and registered as society on 15th Dec. 1969.

Benefits to Members

The following benefits are available to all members:

- A copy of half yearly journal of the society containing articles from experts.
- Preference to Publication of articles in Journal.
- Regular intimation about the activities and events being organized by Society and its chapters from time to time.
- 10% discount maximum up to Rs. 500/- in the participation fee for the events being organized from time to time by the Society.
- 10% concession for publishing advertisement in the periodical/Journal of the Society.
- Inclusion of one page write-up about the Organisation in Journal for Institutional Members.
- A copy of Membership directory when published.

SOCIETY OF POWER ENGINEERS (INDIA)

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भारत को उसकी अपार जलविद्युत क्षमता से लाभान्वित कर रहा एनएचपीसी

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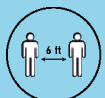
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