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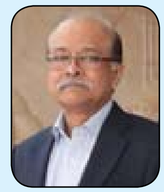

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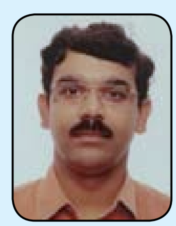

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All communications to be addressed to:

The Secretary & Treasurer
CIGRE India
CBIP Building, Malcha Marg
Chanakyapuri, New Delhi - 110021

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EDITOR'S NOTE

CIGRE the International Council on Large Electric Systems founded in 1921, is leading worldwide Organization on Electric Power Systems, covering technical, economic, environmental, organisational and regulatory aspects. It deals with all the main themes of electricity. CIGRE is the unique worldwide organization of its kind - 14,000 equivalent members in around 90 countries. CIGRE is focused on practical technical applications. The main aim of CIGRE is to facilitate and develop the exchange of engineering knowledge and information, between engineering personnel and technical specialists in all countries as regards generation and high voltage transmission of electricity. CIGRE achieves its objective through the 16 Study Committees, each consisting of about 30 members from different countries. India is representing in all the 16 Study Committee of CIGRE.

Besides National Committees in about 60 Countries CIGRE has also constituted its regional chapters in the world. The chapter created for Asia is named as CIGRE-AORC (Asia Oceans Regional Council). CIGRE-AORC is a forum for sharing experience and knowledge regarding pertinent technical issues particularly those affecting power systems in the Asia-Oceana Region. The countries from Asia Oceana Region, who are associated with the forum are Australia, China, Cambodia, Gulf Cooperative Council, Hong Kong, India, Indonesia, Iran, Jordan, Japan, Korea, Malaysia, New Zealand, Taiwan and Thailand.

It is a matter of great honour for India that CIGRE AORC has been chaired by India during 2016-2018. Dr. Subir Sen, ED, POWERGRID was Chairman and Shri P.P. Wahi, Secretary of CIGRE AORC for two year during 2016-18.

It is a matter of pride that CIGRE (India) has been in the administrative Council of CIGRE since 1970 and got seat in Steering Committee in 2018. CIGRE India functions as the National Committee, for CIGRE HQ (Paris). The CIGRE (India) coordinates interest of Indian members; organises National Study Committee (NSC) meetings. It recommends appropriate persons for CIGRE Study Committees. The National representatives are instrumental in providing feed back to CIGRE Study Committees at Paris.

The aims and objectives for which the committee, i.e., CIGRE (India), is constituted, is to implement and promote objectives of the International Council on Large Electric Systems (CIGRE) and accelerate its activities, which include the interchange of technical knowledge and information between all countries in the general fields of electricity generation transmission at high voltage and distribution etc.

All-out efforts are being made to increase the CIGRE membership and activities in India. CIGRE India has regularly been making efforts to invite various CIGRE study committees and their working groups to hold their meeting in India. We in the recent past have already hosted SC D2 on Information and telecommunication in 2013; SC B4 on HVDC - in 2015 and SC B1 on HV Insulated cables in 2017 in India. In the Year 2019 we have hosted four Study Committees SC A1 on Rotating Electrical Machines in Sept. 2019 & SC A2; SC B2 & SC D1 on Transformers, Overhead Lines and Materials & test techniques respectively in Nov. 2019. This is done with the aim to provide opportunities to professional to exchange & share views / knowledge with international experts. We have already got approval from CIGRE to host Study Committee SC A3 on high voltage equipment's and B5 on Power System Protection in 2021 and 2023 respectively. There was excellent participation from India in CIGRE session 2018 at Paris. Total 22 papers were presented and more than 150 officers from India including CEOs & Sr. Officers from various PSUs, State Electricity Corporation and various Regulatory Commissions participated in CIGRE session 2018 besides six exhibitors.

For CIGRE Session 2020, CIGRE India received 240 Abstract for consideration. Out of the 45 Abstracts were recommended to CIGRE HQ for their consideration, 37 abstracts were accepted.

The Covid 2019 affected organisation of CIGRE session 2020, virtual session was organised by CIGRE, where these were 107 participants from India.

In this present COVID-19 situation where skill enhancement and training of professional is emerged as an important aspect and a challenge, CIGRE- India held series of virtual Tutorials/ Workshops/ Webinars on the subject relevant to 16 CIGRE Study Committees, to further promote CIGRE in India and involve additional professional including New Generation / Young professionals with CIGRE. The reports of the virtual tutorials is included in this issue of journal.

The Membership of CIGRE from India is also on the rise and in the year 2018 we achieved membership count to 827 Nos. and the same was maintained for 2019. For 2020 total 800 members were registered as CIGRE Member from India.

We are bringing out this Journal on half yearly basis. The last issue was published in the month of July 2020.

This issue covers the informative and useful technical articles and statistical data on the subject.

I am thankful to the Governing Council and the Technical Committee of CIGRE-India for their valuable time and guidance, but for which, it would not have been possible to achieve the above significant progress, appreciated by CIGRE HQ Paris.

I am also thankful to all the senior experts from India and abroad and also to one and all who have supported in the past to realize the goal set forth for CIGRE India and expect the similar support in future too.

A.K. Dinkar

Secretary & Treasurer CIGRE India

Open Line Test Application in UHVDC for Condition Monitoring of Insulation Health of Ultra High Voltage Equipments

Tuhin Suvra Das **Vinita Kumari**

Powergrid Corporation of India Ltd.

ABSTRACT

Open Line Test is used in Ultra High Voltage DC Transmissionsystem to test the voltage insulation capability of a line or a converter after an extended period of de-energization or after recovering from insulation faults. It is done in order to avoid converter startup towards a solid ground fault. OLT can be done on the internal dc pole bus in each station/converter or in the dc line. To perform OLT, converteris deblockedin open circuit condition and the dc voltage is increased to the desired reference level at a predefined ramp rate. DC voltage reference level and the voltage ramp rate are operator selectable. For any kind of persisting insulation fault, the converter fails to build up the dc voltage across the pole to neutral.

To understand the behavior of HVDC system during OLT, modeling and simulation for following converter configurations have been done

(a) Converter is connected to DC bus without DC filter and without DC line.

(b) Converter is connected to DC line with DC filter.

The simulation results thus obtained have been compared with the actual OLT operation results.This paper analyses the application of the results of the Open Line Test as an effective tool for condition monitoring of the insulation health of HVDC equipments.

***Keywords**: Open Line Test, HVDC, Insulation Health monitoring of UHVDC equipments*

1. INTRODUCTION

Open Line Test is used in Ultra High Voltage DC Transmission system to test the voltage insulation capability of a line or a converter after an extended period of de-energization or after recovering frominsulation faults. To perform OLT, converter is deblocked in open circuit condition and the dc voltage is increased to the desired reference level at a predefined ramp rate. The phenomenon can be described as the charging of the capacitance of the various dc voltage equipments through the reactance and resistance of the line. The charging capacitances are the snubber circuit, valve support insulators, pole bushing,arrester insulators, bus post insulators, pole smoothing reactor post insulator, dc voltage divider and line insulators. The charging currents of the capacitances are limited by the pole smoothing reactor, valve reactors, transformer leakage reactance and dc line reactance. The low value of series resistance provides damping of LC oscillations. The high value of parallel resistance across each non ideal capacitancesincurspower losses.

There is very few information available in literatureregarding Open Line Test. As mathematical expression for DC voltage across the opened dc line in Open Line Test is complex and is not only the function of thyristor firing angle (alpha) but also of the equivalent circuit parameters i.e., equivalent resistance, inductance and capacitance. With the variation of line capacitance and inductancethe peak to peak DC voltage ripple also varies.The dielectric loss accounts for the power losses in Open Line Test mode. The loss varies with the line length, weather, pollution and other factors.

HVDC converter characteristics in Open Line Test mode is different from that of normal power flow operation mode.For power flow operation mode,the dc current must be in continuous conduction mode and the DC voltage across the pole to neutral can be inverted by varying the thyristor firing angle.The thyristor firing angle control between 0 to 90 degree and 90 to 180 degree operates the converter as rectifier and inverter respectively. This inversion of dc voltage is valid for continuous current conduction mode. But in case of Open Line Test the dc voltage across the pole to neutral cannot be inverted by varying the thyristor firing angle, as the dc current remains in discontinuous conduction mode. The polarity of the dc voltage is decided by the grounding of the valve anode or cathode. DC voltage is positive for anode grounding of lower most valve and negative for cathode grounding of upper most valve. So in Open Line Test mode, the converter operates as a rectifier for any firing angle between 0 to180 degree.

2. EQUIVALENT CIRCUIT MODEL OF OPEN LINE TEST

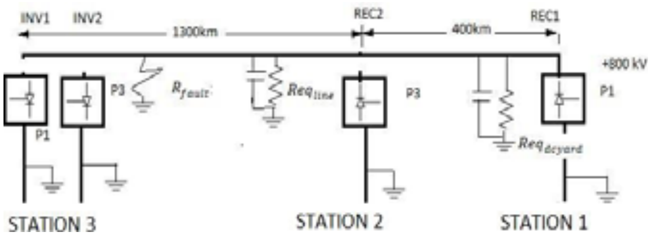

Fig. 1 : Equivalent Impedance model of Open Line Test (Rectifier Converter of Station 1 is connected to DC line with DC filter)

Equivalent circuit model has been taken from the configuration of ±800kV NEA-Agra multi-terminal HVDC system.

In the configuration shown above OLT is being performed at rectifier converterof Station 1 (converter is connected to DC line with DC filter).The equivalent circuit parameters can be modelledas :

$$Req = Req_{dcyard} \,\|Req_{line}\, \|R_{fault} \;(1) \qquad ...(1)$$

$$Req \approx R_{fault} \text{ (very low value in case of fault) (2)} \qquad ...(2)$$

$$Vdc_{pole} = \frac{4\pi}{3\sqrt{3}} * Vdio * Cos(alpha - 60°) \qquad ...(3)$$

$$Vdio = V_{LL} * \sqrt{2} * (Transformer\ ratio * tap\ changer\ ratio) \qquad ...(4)$$

The capacitances shown in the Fig. 1 are the equivalent capacitances of the insulators in dc yard as well as in dc line. Similarly the resistances shown in Fig. 1 are the equivalent shunt resistance across each non-ideal capacitance. The resistance can be calculated from the dielectric loss or tan delta value.The theoretical equation (3) used to calculate the dc voltage in controller is a function of the thyristor firing angle *alpha* and no load dc voltage *Vdio* V_{LL} in equation (4) is the line to line voltage of the ac bus. In Open Line Test mode the controller keeps the no load dc voltage *Vdio* constant to a set value by controlling the tap changer position. In case of persisting insulation fault, the *Reg* across the capacitance reduces to a very low value which forces the controller to reduce the thyristor firing angle to a very low value tobuild the dc voltage. Voltage difference between the theoretically calculated voltage and the actual voltage enforces the controller to operate Open Line Test protection. The plot of dc voltage with respect to *Cos*(*alpha* – 60°) helps to understand the behavior of Open Line Test.

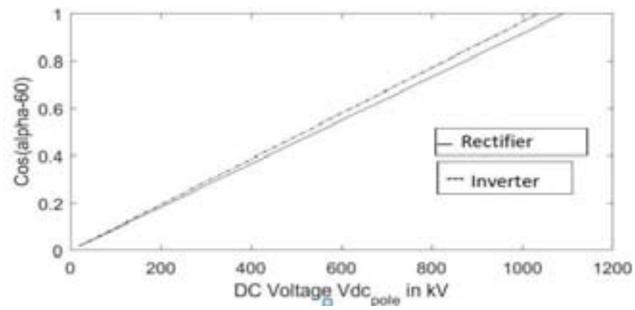

Fig. 2 : Theoretical relation between *Cos* (*alpha* – 60°) and Vdc_{pole} during normal power flow operation

The rectifier station valves are designed to take more voltage than inverter station. Hence, the no load voltage of inverter station is less than the rectifier station. The theoretically calculated dc pole voltage follows a cosine relation with alpha.The dc pole voltage doesn't depend on any other circuit parameter as per the Fig 3. In Fig 4 & Fig. 5, the theoretically calculated dc pole voltage can be plotted with the actual one from the operational experience of Open Line Test operation.

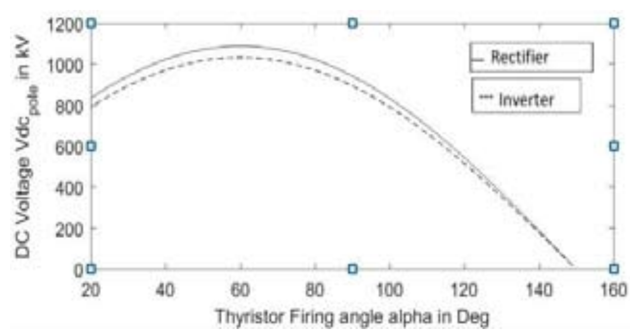

Fig. 3 : Theoretical relation between Vdc_{pole} and *alpha* during normal power flow operation

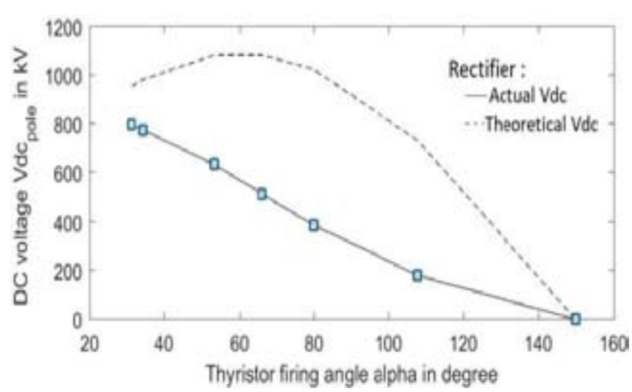

Fig. 4 : Theoretical and actualrelation between Vdc_{pole} and *alpha* for rectifier during OLT

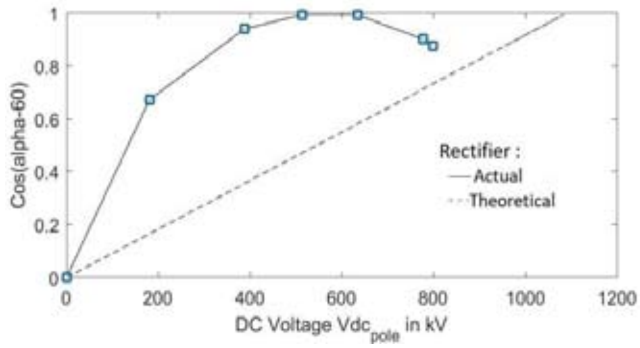

Fig. 5 : Theoretical and actual relation between *Cos* (*alpha* – 60°) and Vdc_{pole} for rectifier during OLT

Fig. 4 and Fig. 5 have been plotted with the actual data sets taken from an OLT operation performed on converter of station1(+ve pole) of ±800kV NEA-Agra multi-terminal HVDC project as per the configuration shown in Fig. 1.

Fig 4. shows the deviation of actual dc pole voltage from the theoretically calculated one. The dc pole voltage varies linearly with alpha. The linear relationship of dc voltage with alpha can be better interpreted by plotting *Cos*(*alpha* – 60°) with respect to Vdc_{pole}. The *Cos*(*alpha* – 60°) follows a cosine curve for different dc voltages.

The deviation of actual curve from the theoretical one in Fig. 5 shows the nonlinearity between *Cos*(*alpha* – 60°) and Vdc_{pole}. To understand the behavior of the Open Line Test the practical data is required for different configurations which is not feasible from commercial point of view. So electrical modelling is necessary for better understanding of the basic Open Line Test circuit configurations.

3. MODELLING OF OPEN LINE TEST CONFIGURATION OF HVDC SYSTEM

OLT can be performed for the following circuit configurations:

(a) Converter is connected to DC bus without DC filter and without DC line.

(b) Converter is connected to DC bus with DC filter and without DC line.

(c) Converter is connected to DC line with DC filter.

(d) Converter is connected to DC line without DC filter

An equivalent electrical model can be designed in any of the simulationplatforms like EMTDC/PSCAD, RSCAD, HYPERSIM, MATLAB SIMULINK etc. All the simulation platformshave their own advantages. Most of them use their patent solving technique or solver for simulation results. The basic control and electrical blocks are the IEEE/IEC standard blocks. The parameter of the blocks can be changed to customize the model.

To run the electrical model a closed loop control system is required, which can be done with the help of control system replica with RTDS simulation.But to design in MATLAB Simulink platform or in any kind of offline simulation platform it is required to design the controller in the respective platform. The controller has to be same as the main controller used in real HVDC system. The controller shown in Fig. 6 used for Open Line Test has been replicated from the controller used by ABB for the ±800kV NEA-Agra multi-terminal HVDC project.

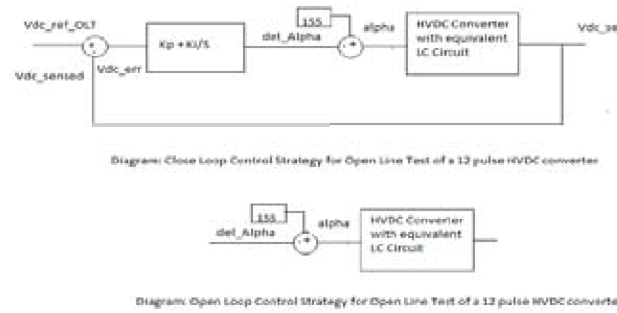

Fig. 6 : Closed and Open Loop control strategy for Open Line Test of a rectifier

3.2 Closed Loop Control Model in MATLAB Simulink

The basic controller shown in fig 7 is a negative feedback loop using a comparator, PI controller and the HVDC equivalent electrical model. The PI controller is designed to have a faster response so that the simulation time to reach steady state is less. The open loop electrical model with an alpha regulator can be used to check the behavior of the system for different values of alpha.

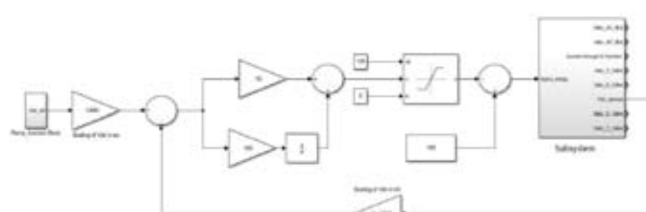

Fig. 7 : Closed loop control model in MATLAB Simulink

The Vdc_ref input is given by using a ramp function and a ramp rate is used to build up the dc voltage. An alpha limiter is used in the controller to maintain the alpha between a given maximum and minimum value.The positive phase voltage across anode to cathode of a valve is required for forward biasing. The forward biased voltage is increased slowly by regulating alpha to get the required dc pole voltage. The subsystem consists of the electrical modelling of the AC source,Converter transformer and Converter subsystem with the DC filter and line equivalent parameter shown in Fig 8.

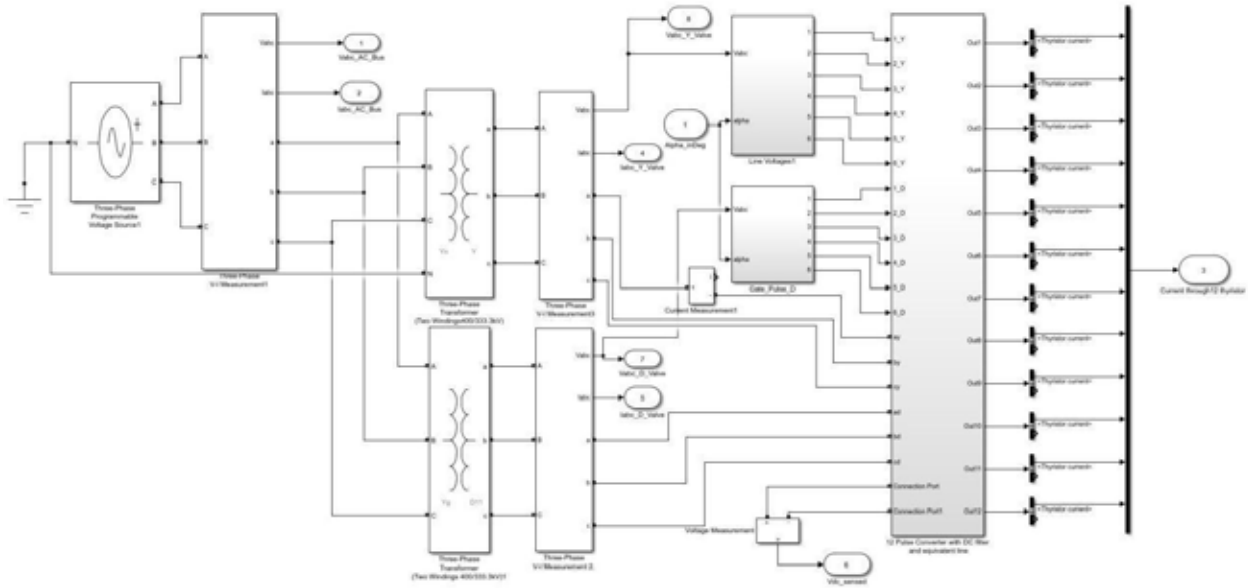

Fig. 8 : HVDC Subsystem Module model in MATLAB Simulink

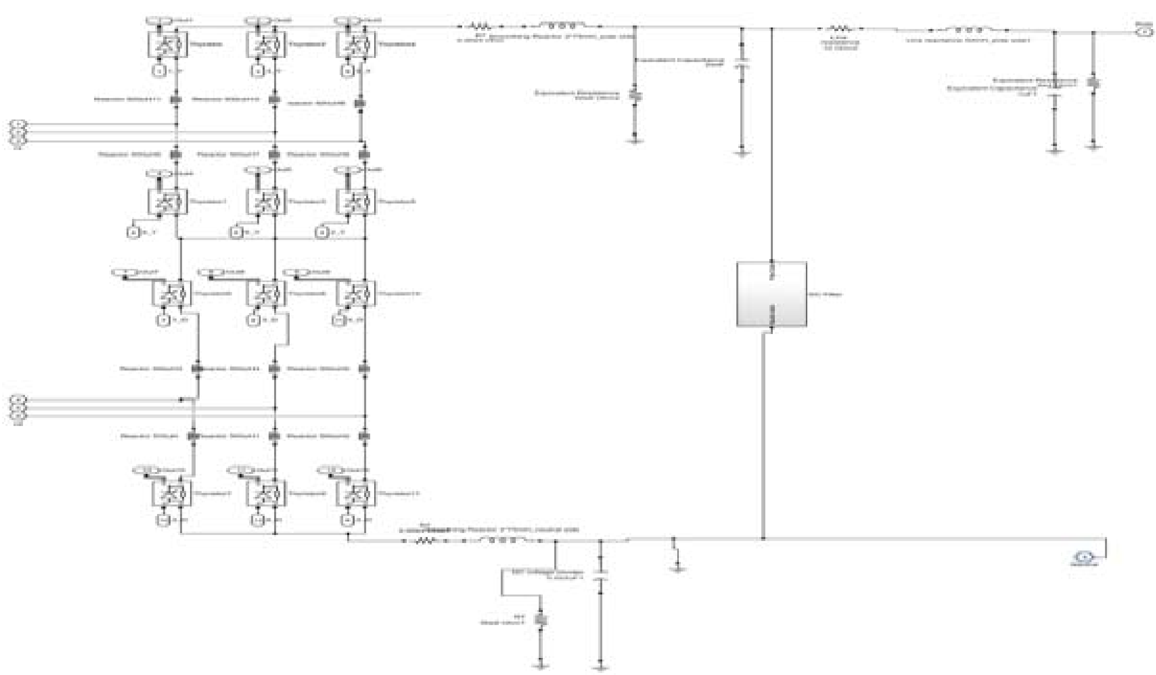

Fig. 9 : Converter Subsystem model in MATLAB Simulink with DC filter, DC yard and DC line equivalent model

The control pulse generation scheme is the Equidistance Phase Control (EPC) by using the phase voltages. In practical scenario there is a Phase Locked Loop (PLL) to change the pulse generation depending upon the frequency of AC bus voltages. In the simulation, ac bus voltages and frequencies have been kept constant which is a valid approximation for the steady state condition.

Each converter valve consists of an equivalent thyristor, a valve reactor, connected in series with another valve and an equivalent snubber capacitance and resistance across the valve.

The DC yard components consists of smoothing and blocking reactor, bus post insulator, dc voltage divider and other supporting insulator. The insulators can be modelled as an equivalent capacitance of parallel connected insulators with an equivalent resistance across the capacitance.

Similarly the dc line can be modelled like the dc yard component. The dielectric loss coefficient tan delta is the measuring index for insulation resistance. The loss coefficient varies with ageing, weather, pollution and other factors. The string insulators connected between conductor and tower provides the insulation. The equivalent capacitance is the series and parallel combination of the insulation capacitance. The equivalent resistance is calculated from dielectric loss in actual circuit.

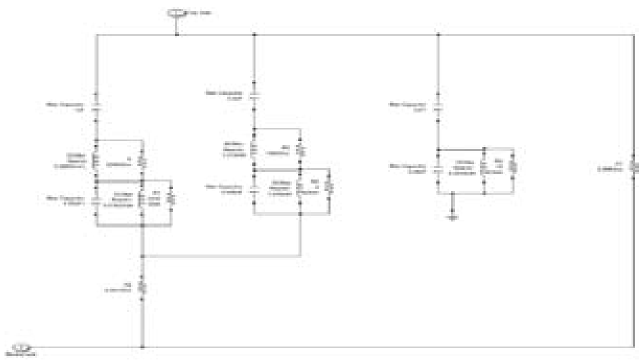

Fig.10 : DC filter equivalent model in MATLAB SIMULINKwith equivalent electrical parameters

The DC filter is modelled on the basis of parameters used in the electrical model of ±800kV NEA-Agra multi-terminal HVDC system replica.This DC filter model used in the simulation decreases the simulation speed and increases the computational burden.To achieve the simulation response nearly equal to the actual response, an equivalent model can be used to represent the DC filter with an equivalent RLC circuit.

3.2 Mathematical Modelling of Converter in Open Circuit Condition

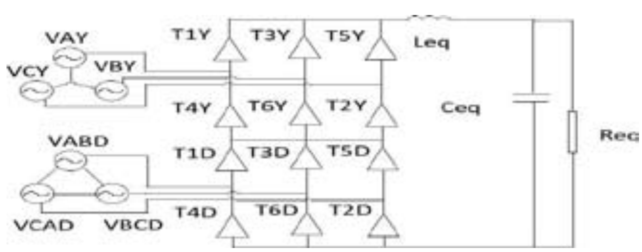

Fig. 11 : Schematic diagram of 12 pulse bridge ac to dc converter in open loop condition

In this circuit, while the first valve is fired at ωt = *alpha*, the KVL equation can be written as

$$Vm * \sin\left(\omega t + alpha + \frac{\pi}{6}\right) - Leq * \frac{di}{dt} - Vceq(t) = 0 \quad ...(5)$$

Where i = current through inductor Leq

Vceq(t) = voltage across capacitance Ceq

Vm = maximum phase voltage

ω = fundamental frequency of the AC voltage

The operation of rectifier under open circuit condition can be described as simultaneous charging and discharging of the equivalent circuit capacitances. The charging capacitances(Ceq) consists of the snubber circuit, valve support insulators, pole bushing, arrester insulators, bus post insulators, pole smoothing reactor post insulator, dc voltage divider and line insulators. The charging currents of the capacitances are limited by the pole smoothing reactor, valve reactors, transformer leakage reactance and dc line reactance which has been shown as Leq.

During charging and discharging operation the 2nd order Capacitor Voltage equation can be written as

$$\frac{d2}{dt2}\text{Vceq(t)} + \tau * \omega n^2 * \frac{dVceq(t)}{dt} + \omega n^2 * Vceq(t) = \omega n^2 * Vm * \omega * \cos(\omega t + alpha + \pi/6) \quad ...(6)$$

Where time constant, $\tau = \frac{Leq}{Req}$ and natural frequency of oscillation, $\omega n = \sqrt[2]{\frac{1}{Leq * Ceq}}$

Equation (6) can be solved analytically.

The current through the capacitor can be expressed as

$$ic(t) = \frac{Vm * \sin\left(alpha + \frac{\pi}{6}\right) - Vceq\,(0)}{\omega n * Leq} * e^{-\xi * \omega n * t} * \cos(\omega n * t) \quad ...(7)$$

damping ratio $\xi = \frac{1}{2*R}\sqrt[2]{\frac{Leq}{Ceq}}$ ...(8)

where R = resistance of line

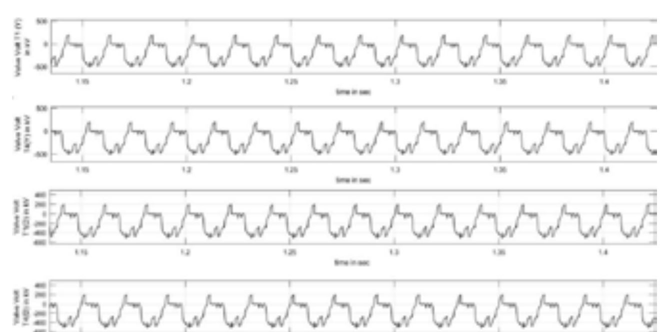

Fig. 12 : Voltage across the valves in first leg

From Fig. 13 and Fig. 14, it can be observed that during OLT there is a high amount of current ripple which is caused due to fast charging and discharging of circuit capacitances. Hence it is not recommended to per form OLT for a long time duration.Typically the time for staying in OLT may be less than 30 minutes. Also the successive OLT should be performed after a gap of atleast 2 hours.

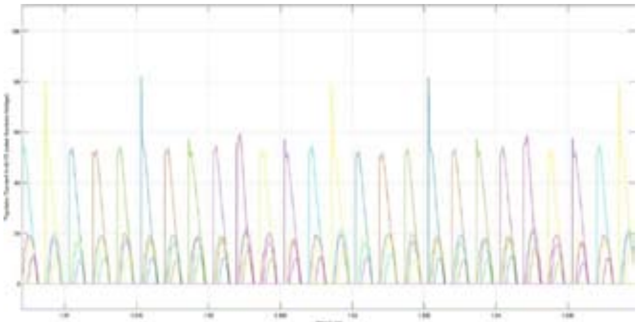

Fig. 13 : Current through 12 valves

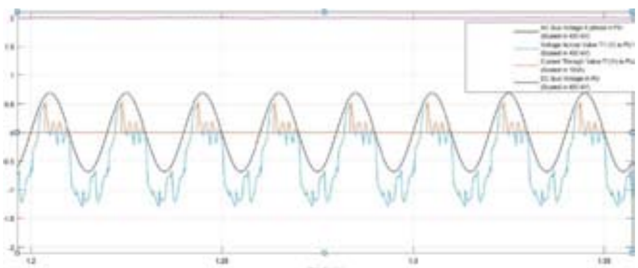

Fig. 14 : Current through valve T1 and voltage across valve T1

4. SIMULATION OF OLT CONFIGURATIONS

Closed loop simulation has been done for following configurations of OLT operation :

Case 1 : Converter is connected to DC line with DC filter Vdc_ref of 400kV, 600kV and 800kV is given.

The simulation results thus obtained for three reference voltages has been shown in fig 15, fig 16 and fig17 respectively. The TFR data from an actual OLT operation is shown in Fig 18.

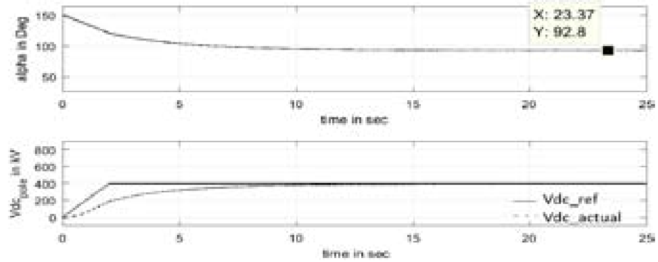

Fig. 15 : Closed loop simulation of rectifier(+ve pole) with circuit configuration 3 (c). DC Voltagecommand = 400 kV

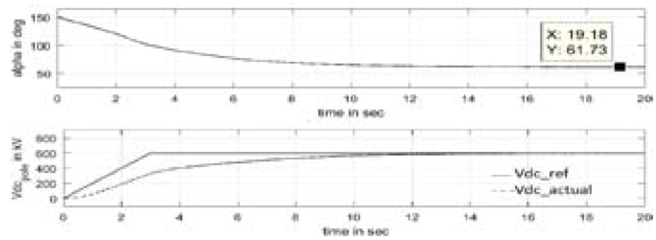

Fig. 16 : Closed loop simulation of rectifier(+ve pole) with circuit configuration 3 (c). DC Voltage command = 600 kV

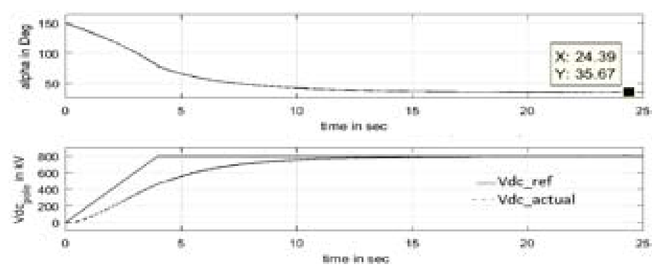

Fig. 17 : Closed loop simulation of rectifier(+ve pole) with circuit configuration 3 (c). DC Voltage command=800kV

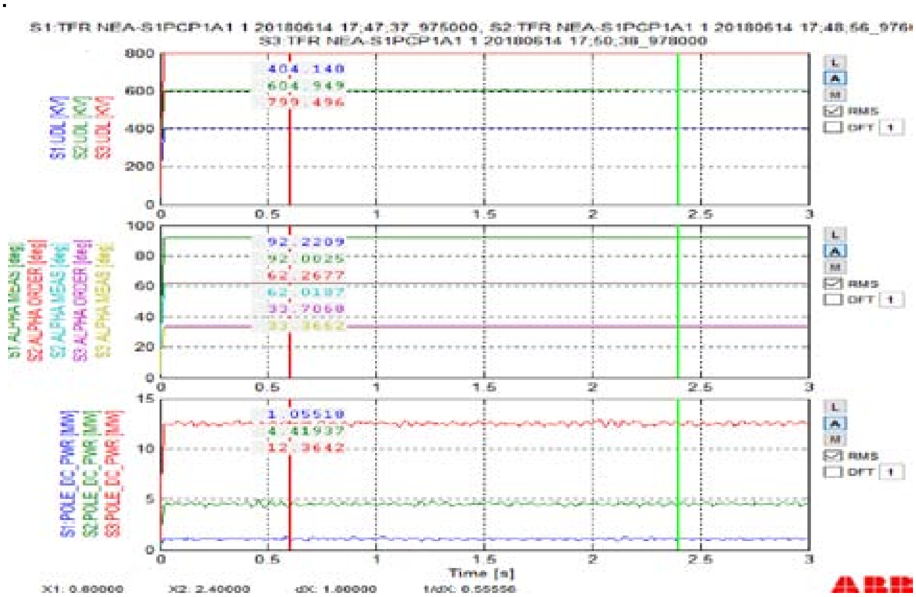

Fig 18 : Three sets of data (S1, S2, S3) for different reference voltages of 400 kV, 600 kV, 800 kV during Open Line Test operation of +ve pole at rectifier station 1.

Case 2: Converter is connected to DC bus without DC filter and without DC line.

Vdc_ref=-800kV is given

Simulation result is shown in Fig. 19 and actual TFR data for OLT performed at –ve pole of rectifier station 2is shown in Fig. 20.

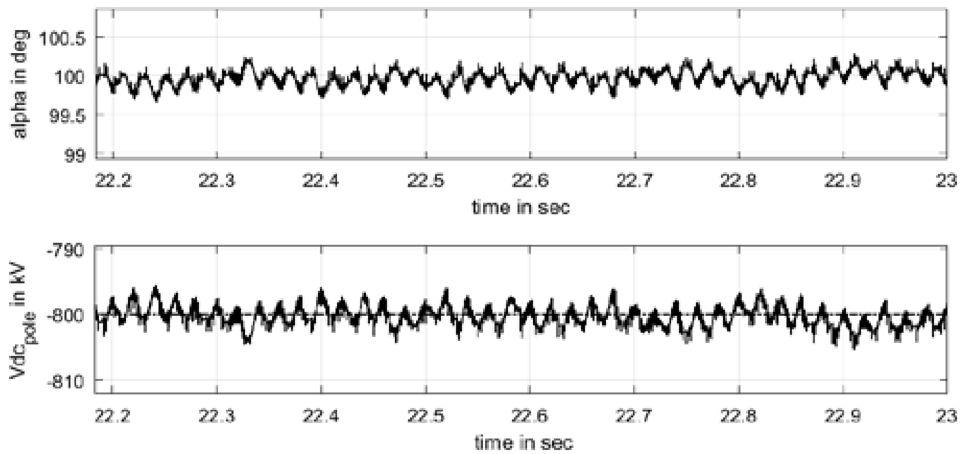

Fig. 19 : Closed loop simulation of (–vepole) of Station 2 with circuit configuration 3(a). DC Voltage command = -800 kV

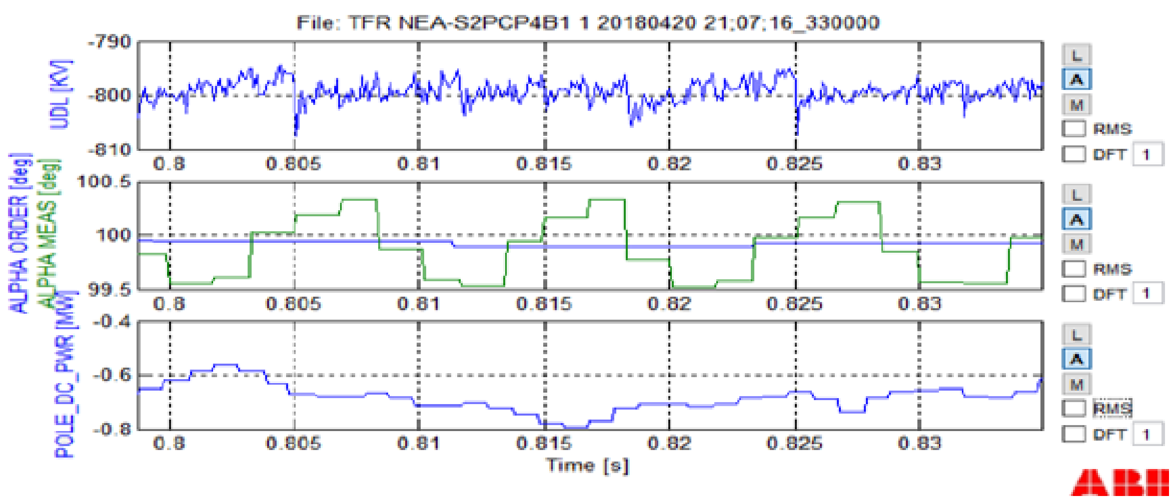

Fig. 20 : Negative pole of Station 2 with circuit configuration 3(a). DC Voltage command = 800 kV without considering the sign.

5. RESULTS AND DISCUSSIONS

In both the cases, it can be seen that alpha required to build up the reference dc voltages is almost same in the simulation result as well as in the actual OLT operationresult.This validates the accuracy of the simulation model.

In addition to Vdc and alpha values, the TFR data obtained from actual OLT operation (Fig. 18 & Fig. 20) shows the DC power during OLT. This small DC power is a measure of the dielectric losses incurred in the insulation of the HVDC circuit equipments during OLT operation.

The dielectric loss is inversely proportional to the IR value. As the line length increases the number of parallel connected insulators between conductor and tower increases.So the equivalent IR value decreases. As the equivalent IR decreases for a long line, the loss increases during open line test. It is evident from fig16 that the dielectric loss is very less in case of a circuit configuration where the converter is only connected to dc bus.The equivalent IR value is typically between 10MΩ to 100MΩ for a circuit configuration where converter is connected to dc bus without line and dc filter. The different equivalent IR values have been used in the simulation for different configurations.

As seen from the results of actual OLT operation in Fig. 18, for constant IR the losses vary significantly for different dc pole voltages. The theoretically calculated losses with respect to different dc pole voltages for different equivalent insulation resistance (IR) is shown in Fig. 21.

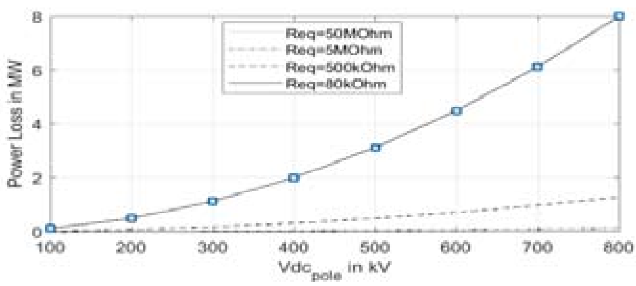

Fig. 21 : Theoretical dielectric loss with respect to dc pole voltage during Open Line Test for different equivalent resistance *Reg* (1)

The losses during Open Line Test indicates the insulation health of the line. Any degradation in IR increases the losses. The lowest IR value is more significant in case of equivalent resistance across the capacitor. The equivalent IR is less than the IR value of the weakest insulator. There must be a parameter to show the variation of IR value. In this case thyristorfiring angle alpha can be used as an important factor to detect the variation of IR. The *Cos*(*alpha* – 60°) is further plotted for different equivalent IR with respect to Vdc_{pole} in Fig. 22. The *Cos*(*alpha* – 60°) increases due to reduction in equivalent IR for a specific dc pole voltage. Similarly the *alpha* can be plotted with respect to dc voltage for different IR values shown in Fig. 23. During annual maintenance of the HVDC substation, OLT can be performed for different configurations and the characteristic graphs can be plotted to track down the rate of change of equivalent IR value.The signature curve obtained for a circuit configuration where converter is isolated from dc line is very important.

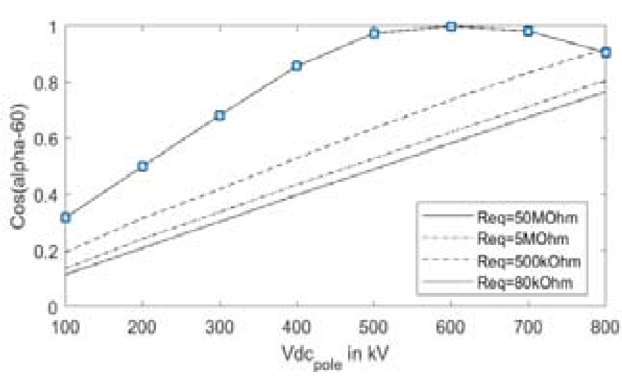

Fig 22 : *Cos*(*alpha* – 60°) with respect to dc pole voltage, Vdc_{pole} during OLT for different *Reg*.

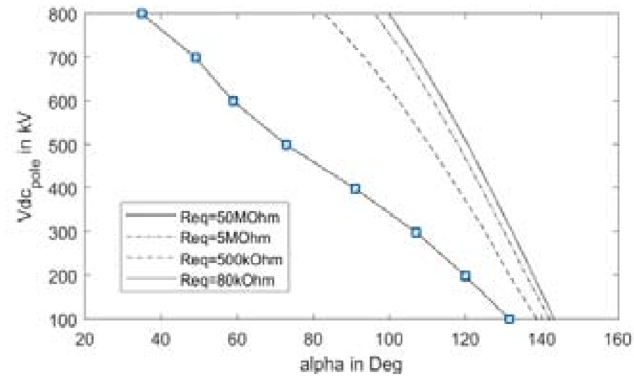

Fig. 23 : Vdc_{pole} with respect to alpha in degree during OLT for different *Reg*

CONCLUSION

The losses during Open Line Test indicates the insulation health of the line. Any degradation in IR increases the losses. The condition monitoring of insulation health is of utmost importance to the Ultra High Voltage system where the failure of even one insulator can cause a prolonged outage of the concerned pole. During the maintenance shutdown when the system is healthy i.e., free from any insulation fault, OLT can be performed for different configurations.The plot between *alpha* and Vdc_{pole} obtained from the TFR can be treated as a signature curve for the insulation health of the HVDC circuit components.Signature curve of OLT performed during subsequent maintenance shutdowns can be compared with the previous one. If to build up the same dc voltagereduction of alpha value is observed, it clearly indicates the degradation of insulation. The results from different configurations can be used to identify the degraded insulation zone. If the reduction in the IR value obtained from the Open Line Test is less than the threshold value, a preventive action can be taken by replacing the faulty insulator. The faulty insulators can be detected by IR test. Thus, using the results of Open Line Test,insulation failure can be anticipated well in advance and hence preventive action can be taken.Thus,OLTproves to be an effective tool for the condition monitoring of insulation health of the HVDC equipments.

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Significance of Quality & Quantity of Gravel for Safe Designing of Grounding (Earthing) System of Substations

Dr. Rajesh Kumar Arora
Delhi Transco Ltd (DTL), Delhi, India

ABSTRACT

An electrical sub-station is an assemblage of electrical components including busbars, switchgear, power transformers, auxiliaries etc. These components are connected in a definite sequence such that a circuit can be switched off during normal operation by manual command and also automatically during abnormal conditions such as short-circuit.

Sub-station are integral parts of a power system and form important links between the generating station, transmission systems, distribution systems and the load points.

The main objective of grounding electrical systems is to provide a suitably low resistance path for the discharge of fault current which ultimately provide safety to working personnel and costly installed equipments in the substation. The flow of heavy fault current results in rise of potential in the vicinity of point /area of fault (ground fault) with respect to remote ground. There is need to ensure that the ground potential rise, and touch and step voltages are within permissible limits.

This paper provides an overview of significance of quality and quantity of gravel in the substation in accurate designing of grounding system.

Keywords *: Electrical Shock, Grounding (Earthing), Step and Touch Potential, Gravel (Surface Material)*

1. INTRODUCTION

The grounding system in a substation is very crucial for a few reasons, all of which are related to either the protection of people and equipment and/or the optimal operation of the electrical system. These include:

1. The grounding system provides a low resistance return path for earth faults within the substation, which protects both personnel and equipment
2. For earth faults occurred in far away generation sources, a low resistance grounding grid relative to remote earth prevents dangerous ground potential rises (GPR)
3. The grounding system provides a low resistance path for voltage transients such as lightning and surges / over voltages in the system
4. Equipotential bonding of conductive objects (e.g. metallic equipments, buildings, piping etc) to the grounding system prevents the presence of dangerous voltages between objects (and earth).
5. Equipotential bonding helps prevent building up of electrostatic charge and discharge within the substation, which can cause sparks with enough energy to ignite flammable atmospheres
6. The grounding system provides a reference potential for electronic circuits and helps reduce electrical noise for electronic, instrumentation and communication systems

Fig. 1 : Air Insulated Substation with Gravel Surface

2. ACCIDENTAL CIRCUIT EQUIVALENTS

The following notations are used for the accidental circuit equivalent shown in Figure 2:

I_b is the body current (body is part of the accidental circuit) in A

R_A is the total effective resistance of the accidental circuit in Ω

V_A is the total effective voltage of the accidental circuit (touch or step voltage) in V

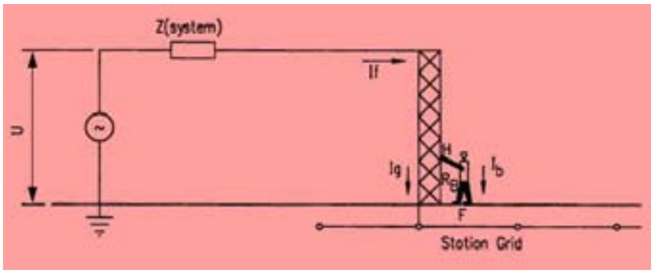

Fig. 2 : Flow of Current through the Working Staff during Fault

The tolerable body current, Ib, above, is used to define the tolerable total effective voltage of the accidental circuit (touch or step voltage) i.e. the tolerable total effective voltage of the accidental circuit is that voltage that will cause the flow of a body current, I_b,, equal to the tolerable body current, I_b.

Figure 2 shows the fault current If being discharged to the ground by the grounding system of the substation and a person touching a grounded metallic structure at H. Various impedances in the circuit are shown in Figure 3 . Terminal H is a point in the system at the same potential as the grid into which the fault current flows and terminal F is the small area on the surface of the earth that is in contact with the person's two feet. The current, I_b, flows from H through the body of the person to the ground at F the Thevenin theorem allows us to represent this tow terminal (H,F) network of Figure 3 by the circuit shown in Figure 4.

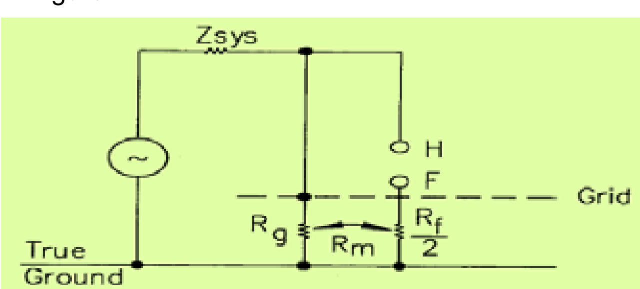

Fig. 3 : Different Resistances of Circuit for Touch Voltage

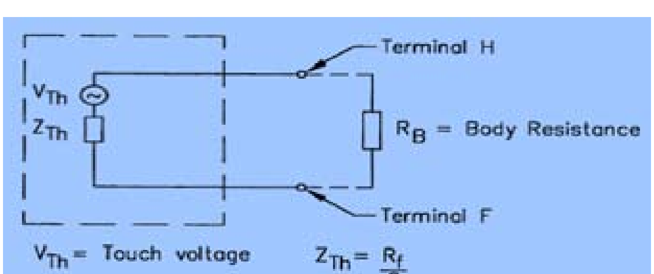

Fig. 4 : Thevenin Equivalent of Circuit of figure 3

The Thevenin voltage V_{Th} is the voltage between terminals H and F when the person is not present. The Thevenin impedance Z_{Th} is the impedance of the system as seen from points H and F with voltage sources of the system short circuited. The current Ib, through the body of a person coming in contact with H and F is given by

$$I_b = \frac{V_{Th}}{Z_{Th+R_B}} \quad \text{...Equation (1)}$$

Figure 5 shows the fault current If being discharged to the ground by the grounding system of the substation. The current, Ib, flows from one foot F1 through the body of the person to the other foot, F2. Terminals F1 and F2 are the areas on the surface of the earth that are in contact with the two feet, respectively. The Thevenin theorem allows us to represent this two-terminal (F1, F2) network in Figure 6. The Thevenin voltage VTh is the voltage between terminals F1 and F2 when the person is not present . The Thevenin impedance ZTh is the impedance of the system as ween from the terminals F1 and F2 with the voltage sources of the system short circuited.

For touch voltage accidental circuit

$$z_{Th} = R_{f/2}) \quad \text{...Equation (2)}$$

And for the step voltage accidental circuit

$$z_{Th} = 2R_f \quad \text{...Equation (3)}$$

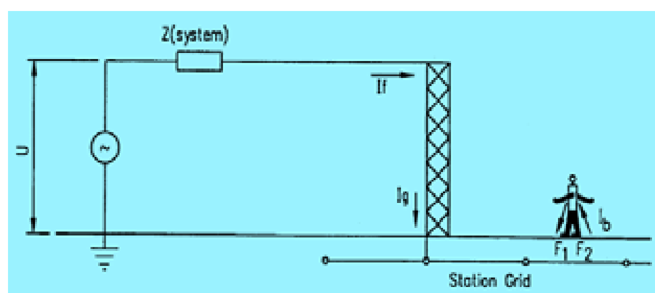

Fig. 5 : Different Resistances of Circuit for Step Voltage

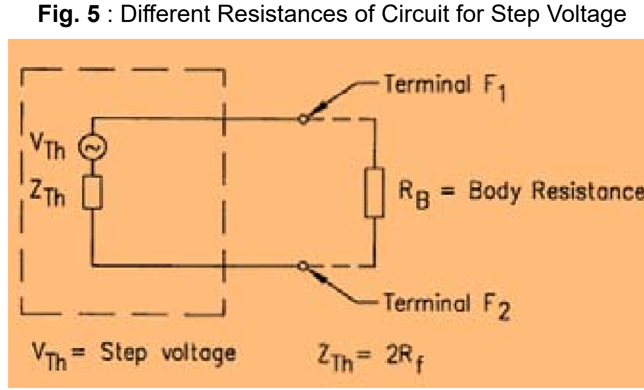

Fig. 6 : Thevenin Equivalent of Circuit of figure 5

For the purpose of circuit analysis, the human foot is usually represented as a conducting metallic disc and the contact resistance of shoes, socks, etc., is neglected. Traditionally, the metallic disc representing the foot is taken as a circular plate with a radius of 0.08m. With only slight approximation, equations for Z_{Th} can be obtained in numerical from and expressed in terms of as follows:

$$R_f = \frac{\rho}{4b}$$ ...Equation (4)

Where ρ = Resistivity of the soil

For touch voltage accidental circuit

$Z_{Th} = 1.5\ \rho$ ...Equation (5)

For step voltage accidental circuit

$Z_{Th} = 6.0\ \rho$ ...Equation (6)

The permissible total equivalent voltage (i.e., tolerable touch and step voltage), using above Equations are

$E_{touch} = IB\ (R_B+1.5\ \rho)$ ...Equation (7)

$E_{step} = IB\ (R_B+6.0\ \rho)$ ...Equation (8)

The equations 7 and 8 shall be changed into equation 9 &10 and 11&12 respectively if we are using surface material with resistivity ρ_s.

The maximum tolerable voltages for step and touch scenarios can be calculated empirically from IEEE Std Section 8.3 for body weights of 50 kg and 70 kg:

$$E_{touch,50} = (1000 + 1.5C_s\rho_s)\frac{0.116}{\sqrt{t_s}}$$ ...Equation (9)

$$E_{touch,70} = (1000 + 1.5C_s\rho_s)\frac{0.157}{\sqrt{t_s}}$$ ...Equation (10)

$$E_{step,50} = (1000 + 6C_s\rho_s)\frac{0.116}{\sqrt{t_s}}$$ ...Equation (11)

$$E_{step,70} = (1000 + 6C_s\rho_s)\frac{0.157}{\sqrt{t_s}}$$ ...Equation (12)

Where E_{touch} is the touch voltage limit (V)

E_{step} is the step voltage limit (V)

is the surface layer derating factor

ρ_s is the soil resistivity (Ω.m)

t_s is the maximum fault clearing time (s)

The choice of body weight (50kg or 70kg) depends on the expected weight of the personnel at the site. Typically, where women are expected to be on site, the conservative option is to choose 50kg.

This derating factor can be approximated by an empirical formula as per IEEE Std 80 Equation 13:

$$C_s = 1 - \frac{0.09\left(1 - \frac{\rho}{\rho_s}\right)}{2h_s + 0.09}$$ ...Equation (13)

Where C_s is the surface layer derating factor

ρ is the soil resistivity (Ω.m)

P_s is the resistivity of the surface layer material (Ω.m)

h_s is the thickness of the surface layer (m)

3. PURPOSE OF GRAVEL (SURFACE MATERIAL) IN SWITCHYARD

There are various benefits of using Stones/Gravel over the PCC (Plain Cement Concrete) in Switchyard.

1. Gravel Increases Resistance between Our Foot & Ground.

Substation Switchyard is already grounded by earth mats to provide a very low resistance path to the fault current to flow to the ground. But, the Stones or Gravels are used in the Switchyard to **decrease the Foot Surface Area**. When the touch surface area decreases the resistance increases.

So, the main purpose of filling Switchyard with Stones/ Gravels is to provide an **extra layer of high resistance and act as an insulator between our foot and the ground.**

Thus, gravels in Switchyard increases the resistance between our foot and ground.

2. Gravels Prevent the Accumulation of Rain Water in Switchyard

Stones/Gravels prevent the accumulation of water over the PCC surface in Switchyard and even if some water accumulates over some part of PCC due to the non-uniform (not fully plain) surface then Gravel provides some breaks over the surface of the water. It makes the current non-continuous through our body and finally, it increases the resistance.

Finally, the **rainwater can drop faster** and it **doesn't make any mud** inside the Substation. It protects the moisture content evaporation and keeps the ground wet.

3. Gravel Increases Tolerable Step Potential & Touch Potential

Step and Touch potentials increase during Short circuit current. Gravel/Stones in Switchyard is provided to increase the tower footing resistance & helps in improving tolerable step potential and touch potential when operators work on Switchyard in the Substation.

4. Stone Prevents Vegetation & Growth of Small Weeds, Plants inside the Switchyard:

Vegetation is already prevented by PCC in the switchyard.

But, if we don't fill with gravels then after some days/ months/years, some soils & water will accumulate in many parts on the Switchyard and grass will also grow.

Thus, Gravels prevents the growth of grass & other small plants inside the Switchyard and Substation remains nice & clean.

5. Prevents the Entry of Animals & Wildlife:

The entry of animals likes Rats, Snakes, Lizards, etc. are also prevented to some extent by spreading Gravels over the Switchyard surface.

6. Improves Yard Working Condition

Gravels also improve the working condition in the Switchyard of a Substation.

7. Protect from Fire when Oil Spillage Takes Place

In Substation, Power Transformers & Shut Reactors are filled with oil as a cooling and insulating medium. Oil leakage may takes place during operation or when changing the oil in the transformer. The spillage oil which can catch fire is dangerous to the switchyard operation. So, Stones/Gravel is provided to protect from fire when oil spillage takes place.

4. IMPACT OF QUALITY AND QUANTITY OF GRAVEL (SURFACE MATERIAL) ON GROUNDING (EARTHING) DESIGN

It is very interesting to understand the impact of resistivity (quality) of gravel (surface layer material) & height of gravel (quantity) on different parameters of design of earthing (grounding) system.

First of all , to analyze the impact of gravel resistivity on safe step and touch potential for 70 kg body weight refer Table 1 along with Figure 7 below.

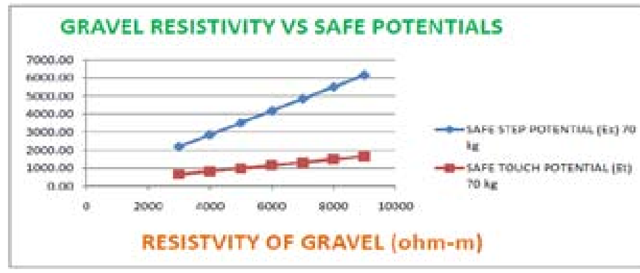

Fig. 7 : Impact of Resistivity of Gravel on Safe Potentials (70 kg)

Further to analyze the impact of gravel resistivity on safe step and touch potential for 50 kg body weight refer Table 2 along with Figure 8.

Table 1 : Impact of Gravel Resistivity on Safe Potentials (70 kg)

RESITIVITY OF GRAVEL (ohm-m)	HEIGHT OF GRAVEL (cm)	RESISTIVITY OF SOIL (ohm-m)	DERATING FACTOR (Cs)	DURTAION OF FAULT (ts)- sec	SAFE STEP POTENTIAL (Es) 70 kg	SAFE TOUCH POTENTIAL (Et) 70 kg
3000	15.00	200.00	0.7208	1.00	2194.09	666.27
4000	15.00	200.00	0.7159	1.00	2854.33	831.33
5000	15.00	200.00	0.7129	1.00	3514.58	996.39
6000	15.00	200.00	0.7109	1.00	4174.82	1161.46
7000	15.00	200.00	0.7094	1.00	4835.07	1326.52
8000	15.00	200.00	0.7084	1.00	5495.31	1491.58
9000	15.00	200.00	0.7075	1.00	6155.56	1656.64

Table 2 : Impact of Gravel Resistivity on Safe Potentials (50 kg)

RESITIVITY OF GRAVEL (ohm-m)	HEIGHT OF GRAVEL (cm)	RESISTIVITY OF SOIL (ohm-m)	DERATING FACTOR (Cs)	DURTAION OF FAULT (ts)- sec	SAFE STEP POTENTIAL (Es) 50 kg	SAFE TOUCH POTENTIAL (Et) 50 kg
3000	15.00	200.00	0.7208	1.00	1621.11	492.28
4000	15.00	200.00	0.7159	1.00	2108.93	614.23
5000	15.00	200.00	0.7129	1.00	2596.76	736.19
6000	15.00	200.00	0.7109	1.00	3084.58	858.15
7000	15.00	200.00	0.7094	1.00	3572.41	980.10
8000	15.00	200.00	0.7084	1.00	4060.23	1102.06
9000	15.00	200.00	0.7075	1.00	4548.06	1224.01

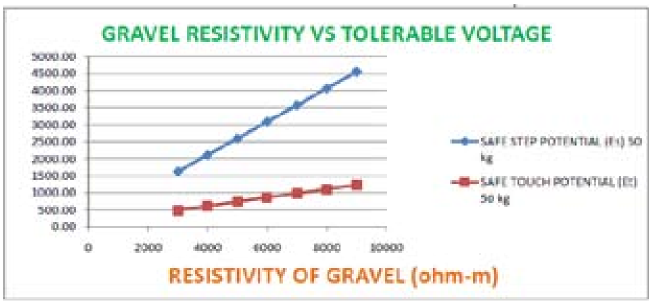

Fig. 8 : Impact of Resistivity of Gravel on Safe Potentials (50 kg)

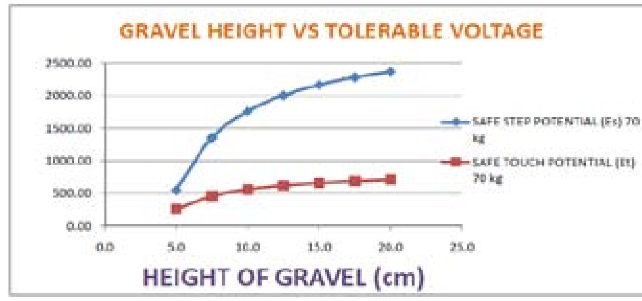

Fig. 9 : Impact of Height of Gravel on Safe Potentials (70 kg)

From above it can be seen that with the increase in the resistivity of the gravel the safe potentials (step and touch potential) also increase.

Next, to analyze the impact of height of gravel on safe step and touch potential for 70 kg body weight refer Table 3 along with Figure 9.

Now to analyze the impact of height of gravel on safe step and touch potential for 50 kg body weight refer Table 4 along with Figure 10.

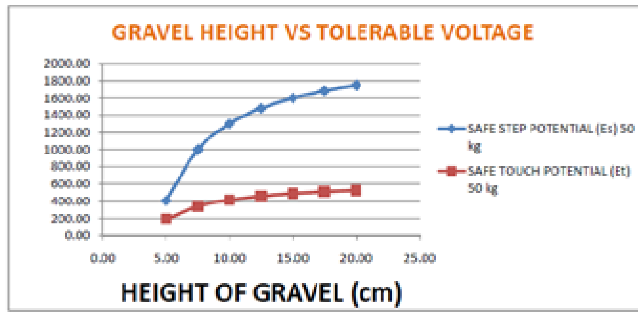

Fig. 10 : Impact of Height of Gravel on Safe Potentials (50 kg)

Table 3 : Impact of Gravel Height on Safe Potentials (70 kg)

RESITIVITY OF GRAVEL (ohm-m)	HEIGHT OF GRAVEL (cm)	RESISTIVITY OF SOIL (ohm-m)	DERATING FACTOR (Cs)	DURTAION OF FAULT (ts)- sec	SAFE STEP POTENTIAL (Es) 70 kg	SAFE TOUCH POTENTIAL (Et) 70 kg
3000	5.0	100.0	0.1378	1.00	546.31	254.33
3000	7.5	100.0	0.4235	1.00	1353.70	456.17
3000	10.0	100.0	0.5669	1.00	1759.20	557.55
3000	12.5	100.0	0.6532	1.00	2003.08	618.52
3000	15.0	100.0	0.7109	1.00	2165.91	659.23
3000	17.5	100.0	0.7521	1.00	2282.34	688.33
3000	20.0	100.0	0.7830	1.00	2369.72	710.18

Table 4 : Impact of Gravel Height on Safe Potentials (50 kg)

RESITIVITY OF GRAVEL (ohm-m)	HEIGHT OF GRAVEL (cm)	RESISTIVITY OF SOIL (ohm-m)	DERATING FACTOR (Cs)	DURTAION OF FAULT (ts)- sec	SAFE STEP POTENTIAL (Es) 50 kg	SAFE TOUCH POTENTIAL (Et) 50 kg
3000	5.00	100.00	0.1378	1.00	403.64	187.91
3000	7.50	100.00	0.4235	1.00	1000.18	337.05
3000	10.00	100.00	0.5669	1.00	1299.79	411.95
3000	12.50	100.00	0.6532	1.00	1479.98	457.00
3000	15.00	100.00	0.7109	1.00	1600.29	487.07
3000	17.50	100.00	0.7521	1.00	1686.31	508.58
3000	20.00	100.00	0.7830	1.00	1750.88	524.72

From above it can be seen that with the increase in the height of the gravel the safe potentials (step and touch potential) also increase.

It is very interesting to analyze the impact resistivity of gravel on derating factor refer Table 5 along with Figure 11 below.

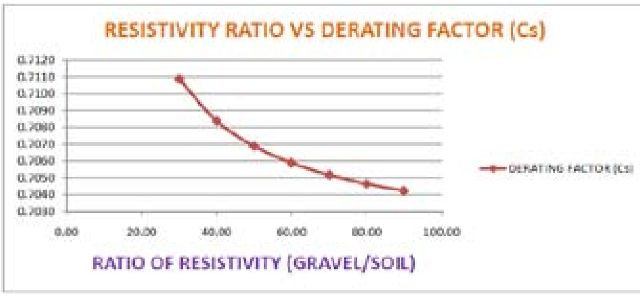

Fig. 11 : Impact of Resistivity of Gravel on Derating Factor

From above it can be seen that with the increase in the resistivity of the gravel (ratio of gravel to soil resistivity) the derating factor decreases.

Further to analyze the impact height of gravel on derating factor refer Table 6 along with Figure 12 below.

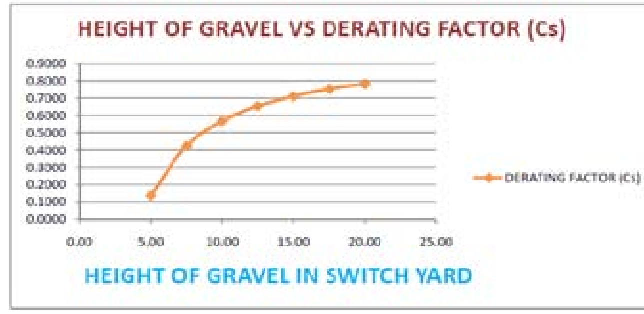

Fig.12 : Impact of Resistivity of Gravel on Safe Potentials

From above it can be seen that with the increase in the height of the gravel the derating factor also increases which further increase the safe potentials.

5. CONCLUSION

The voltage drop in the soil surrounding the grounding system can present hazards i.e. Step and touch voltage for personnel standing in the vicinity of the grounding system. Adequate designing of grounding system will help in mitigating or eliminating electric shocks, fire and damage to equipments.

Table 5 : Impact of Resistivity of Gravel on Derating Factor

RESITIVITY OF GRAVEL (ohm-m)	HEIGHT OF GRAVEL (cm)	RESISTIVITY OF SOIL (ohm-m)	RATIO OF RESISTIVITY (GRAVEL/ SOIL)	DERATING FACTOR (Cs)
3000	15.00	100.00	30.00	0.7109
4000	15.00	100.00	40.00	0.7084
5000	15.00	100.00	50.00	0.7069
6000	15.00	100.00	60.00	0.7059
7000	15.00	100.00	70.00	0.7052
8000	15.00	100.00	80.00	0.7046
9000	15.00	100.00	90.00	0.7042

Table 6 : Impact of Gravel Height on Derating Factor

HEIGHT OF GRAVEL (cm)	RESITIVITY OF GRAVEL (ohm-m)	RESISTIVITY OF SOIL (ohm-m)	RATIO OF RESISTIVITY (GRAVEL/ SOIL)	DERATING FACTOR (Cs)
5.00	3000	100.00	30.00	0.1378
7.50	3000	100.00	30.00	0.4235
10.00	3000	100.00	30.00	0.5669
12.50	3000	100.00	30.00	0.6532
15.00	3000	100.00	30.00	0.7109
17.50	3000	100.00	30.00	0.7521
20.00	3000	100.00	30.00	0.7830

Role of quality (resistivity) and quantity (height) of gravel in the switchyard play important role in deciding the safe potential (tolerable potentials i.e. touch and step potentials).

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AUTHORS BIOGRAPHICAL DETAIL

Dr. RAJESH KUMAR ARORA obtained the B. Tech. & Master of Engineering (ME) degrees in Electrical Engineering from Delhi College of Engineering, University of Delhi, India in 1999 and 2003 respectively. He completed his PhD in grounding system design from UPES, Dehradun. He is also certified Energy Manager and Auditor. He has worked in 400 kV and 220 kV Substation for more than 14 years in Delhi Transco Limited (DTL). He has also worked as Deputy Director (Transmission and Distribution) in Delhi Electricity Regulatory Commission (DERC) for 03 years and 06 months. He has also given his contribution in the OS department of DTL for more than 2 years and rendered his services in the SLDC of Delhi Transco Limited (DTL) also. Presently he is working in D&E (Design and Engineering) department of DTL. His research interests include high voltage technology, grounding system, protection system, computer application and power distribution automation.

Condition Monitoring of GIS Surge Arresters



M. Mohana Rao **Archana L** **Mritunjay Kumar**

BHEL Corp. R&D, Hyderabad, India

ABSTRACT

Leakage current measurement plays an important role in determining the healthiness of high voltage insulation of a power apparatus. The accurate and real time measurement of leakage current enables the utilities to access the healthiness of the gas insulated surge arrester. This paper describes about the design, development, calibration and testing of a novel non-contact type passive leakage current sensor, which can be used for monitoring of gas insulated surge arresters. Metal enclosed gas insulated surge arrester is one of the important components of Gas Insulated Substation (GIS). These arresters are installed to protect various electrical equipment in the GIS against over voltages. While in service high-energy stresses may lead to degradation and damage of surge arresters. To establish capabilities of the developed sensor with optimized design parameters, laboratory measurements of leakage current on 420 kV and 145 kV GIS surge arrester prototypes have been carried out and reported in the paper. Third harmonic content of surge arrester leakage current has been estimated in-line with IEC requirement to assess the healthiness of the surge arrester. Finally, resistive component has been extracted from leakage current of a 145kV GIS surge arrester under laboratory conditions.

Keywords – *Diagnostics, gas insulated surge arrester, GIS, leakage current, resistive component.*

I. INTRODUCTION

Gas-insulated metal oxide arresters provide protection for gas insulated substation modules against operational over voltages, lightning and switching surges. The gas insulated surge arrester with excellent protection characteristics would decrease the overvoltage level applied on the power apparatus, hence helps to reduce their insulation levels and improve reliability. Surge arrester is a vital component of substation and in case of its failure, offer limited protection to the substation equipment against over voltages. Under these conditions, over voltages lead disruptive discharges may result to failures in substation equipment. Hence, to avoid surge arrester failures, it is necessary to monitor healthiness of the surge arrester regularly. Measurement of resistive leakage current and third harmonic leakage current of gas insulated metal oxide surge arresters under operating voltage are widely used techniques to evaluate degradation level of the surge arrester [1]-[3].

The total leakage current of surge arrester (SA) is the sum of capacitive and resistive current components. Under normal working conditions, the leakage current is mainly contributed by capacitive current component and resistive current component is only a small part of it. Due to aging of non-linear SA blocks, the resistive current increases substantially. However, the leakage current has only little change. The increase of the resistive component would lead to heating up of the arrester, which may finally cause damage to the arrester. Therefore, the resistive component of leakage current is of great importance in GIS arresters and should be monitored continuously. Sometimes, absorption of moisture by ZnO blocks result to increase in resistive component significantly [4]-[5]. It is also important to note that the resistive component of leakage current reflects the third harmonic current and hence it is of great importance in GIS arresters. In view of above, measurement of third harmonic leakage current of gas insulated metal oxide surge arrester under operating voltage is one of widely used techniques to evaluate degradation level of the surge arrester [6]-[8].

In the recent years, various leakage current measurement systems for high voltage power equipment, have been developed and are available in the market. In the available systems, the ground connection of the electrical device is disconnected and suitable impedance in the form of a resistor or a capacitance is introduced. The voltage that appears across this impedance is taken as a measure of the leakage current [1]. A typical conventional setup for measurement of leakage current is given in Fig. 1. In this system, there is a provision for leakage current measurement (LCM) as required during service to analyze healthiness of equipment [1]-[3]. However, this method has its own limitations and drawbacks. In case the connection with the impedance is disconnected or else there is an over voltage which appear across the impedance, the measurement circuit experiences high voltage that can damage the circuit and is also unsafe to the operating personnel. In such cases, a protection circuit and also an isolation circuit are employed to minimize the effect of the over voltage. However, such protection/isolation circuit is always not reliable, and further increases the cost. It is also important that most of the equipment manufactures usually may not recommend the disconnection of the equipment ground connection.

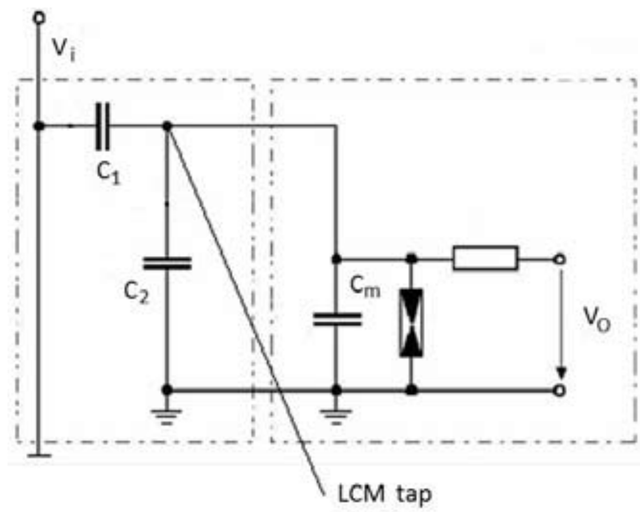


Fig. 1 : Conventional Leakage Current Measurement Set-up

In the present paper, a non-contact type leakage current sensor has been developed, which can be directly integrated with the HV device, using suitable adapters. Using the developed leakage current sensor, the ground connection of the HV device is maintained through the sensor, thereby eliminating the drawbacks of the conventional system as mentioned above. The output of the sensor can be integrated with an online monitoring system to assess the healthiness of the insulation on continuous basis. In this paper detailed analysis of the developed sensor to monitor surge arresters has been presented.

In this paper, an experimental investigation of GIS surge arrester monitoring as per IEC 60099-5 standard is discussed. For leakage current measurements, a non-contact type current sensor designed in the study, is installed at the insulated ground terminal of GIS surge arrester. Optimization of sensor design and its suitability for measurement of leakage current for present application are discussed in detail in the paper. The leakage current has been measured for 145 kV and 420 kV gas insulated surge arrester modules developed in the study. The resistive current component was extracted from leakage current data measured from the 145 kV gas insulated surge arrester.

II. LEAKAGE CURRENT SENSOR DESIGN

The leakage current from the high voltage insulation depends mainly on the capacitance of the insulation and the applied voltage. Mathematically, if the capacitance of the insulation is C and the applied voltage to the insulation is V, then the capacitive impedance Z of the insulating material would be $1/\omega C$. Thus, the leakage current I, shall be $V\omega C$. This condition is valid assuming that the resistive impedance of the insulation is much more than the capacitive impedance and thus the total leakage current is primarily the capacitive leakage current.

Thus, based on the capacitance value of the insulation, the corresponding leakage current can range from few micro amps to few milli amps. Hence a sensitive sensor must be designed to work in this range. Further, to maintain a non-contact type approach, the sensor should be designed to form a closed loop around current carrying conductor and produce an output voltage proportional to the current flowing in the conductor. The typical sensor construction is as shown in Fig. 2. Theoretically, measurement of magnetic flux produced by the leakage current carrying conductor gives a direct measurement of the leakage current. The produced magnetic flux is linked to the sensor coil and can be measured in terms of the sensor coil output voltage. In practice, it is desirable that this voltage shall be large enough to be measured easily and accurately. The sensors output signal amplitude is increased optimally by designing suitable number of turns, cross section of the sensor core and choosing core material with required magnetic properties. The B-H characteristic of the core material used is such that, even for very low current (leakage current) the output from the sensor is at substantial level with linear characteristics. Since the current to be measured with the sensor is of micro ampere range, special magnetic core material was used. Further, it is necessary to observe the operation limits in the hysteresis and saturation curves with the purpose to avoid non-linearity problems. More clearly, the operation region has been selected optimally to obtain a linear ratio between the voltage V and the leakage current, I in the current sensor operation. To further enhance the output voltage from the sensor, a power frequency filter with RC combination can be integrated with the sensor. The filter rejects any high frequency (HF) noises associated with the leakage current and thereby increasing the output signal strength of the sensor. The sensor design as explained above ensures that the sensor is fully passive and does not require any input voltage for its operation. This enables a low cost solution for sensor manufacturing and its subsequent utilization for various online monitoring applications. The typical design parameters of a leakage current sensor for power equipment monitoring applications are:

- Core : Special magnetic core material with high permeability
- Core Inner Diameter (ID) : 40 mm

- Core Outer Diameter (OD) : 65 mm
- Core Height : 30 mm
- Gauge of winding wire : 30 SWG
- No. of turns : 400
- No. of layers : 2

These parameters are the optimized values after evaluating sensor designs with different ID, OD, number of turns and number of layers. The above design parameters not only give us the best electrical output which can drive the data acquisition module of the associated monitoring system, but also ensures that the sensors are small in size. Small sensor is more portable and also requires less core material which results in reduction of cost of the sensor. A typical sensor development made in the study is shown in Fig 2. Equivalent electrical circuit is also shown in Fig. 2.

Fig. 2 : Typical Leakage Current Sensor developed in study

III. VOLTAGE-CURRENT CHARACTERISTICS OF GAS INSULATED SURGE ARRESTER

The surge arrester is one of the critical components of the gas insulated substation, as it is extensively used in both transmission and distribution networks to limit over voltages. In view of above, IEC 60099-5 covers the various diagnostic methods and indicators for revealing the possible deterioration or failure of the insulating properties of surge arresters. According to the standards, most common and reliable diagnostic method is measurement of the arrester's total leakage current and isolating its resistive component [9]. This component is an indicator of the arrester's condition, as deterioration or damage of arrester blocks lead to an increase of the resistive leakage current. From the various research works published it is known that the change in third harmonic component of leakage current of the surge arrester faithfully represents the change in resistive component of the leakage current. Some of the important methods are leakage current measurements, infrared imaging, acoustic partial discharge measurements etc. The surge arrester shows an excellent non linearity for current ranging from few tens of micro-amperes to tens of kilo-amperes. The characteristic of the surge arrester can be divided into three regions, low current region, operating region and high current region. The high current region relates to protective characteristic of the arrester when the current due to over voltage has flown through the arrester. In the continuous operating voltage region (up to rated voltage of the arrester), the ZnO surge arrester can be modeled as a non-linear resistor with a linear capacitive element in parallel. Increase in the resistive leakage current, in general, increases the power losses and hence, increases the temperature of the arrester. The resistive leakage current, at certain instants, exceed a critical limit, where the accumulated energy in the ZnO-blocks exceeds the energy capability of the arrester. This may lead to abrupt failure of the arrester. The total leakage current (It) of the arrester is the vector sum of a capacitive component (Ic), and the resistive leakage current component (Ir).

The leakage current of the surge arrester is in the range of tens of microamperes to few milliamps based on the applied voltage of the arrester. The sensor employed for the measurement was a non-contact type, Rogowski coil based sensor which forms a closed loop around leakage current carrying conductor and gives an output voltage proportional to the current flowing in the conductor. The laboratory setup for measurement of leakage current of 145 kV GIS surge arrester is shown in Figure 3(a). The experimental set-up consists of a gas insulated transformer that energizes a gas insulated surge arrester through a gas insulated bus duct comprises of grounded enclosure with a central conductor. 145 kV GIS surge arrester is excited with voltage up to continuous operating voltage to establish V-I characteristics. Gas insulated test transformer is rated for 325 kV(rms), 1 A and filled at a gas pressure of 3.5 bar(g). The system is partial discharge (PD) free for its rated voltage. For measuring leakage current, the designed leakage current sensor was clamped on to the insulated ground terminal of the arrester. The test results are shown in Table 1. Accuracy of this measurement of leakage current is confirmed by comparing current levels with the data measured using digital earth leakage clamp-on meter Model No. DCM 300E of resolution in the order of 1 μA (refer Table 1). From the results, it is evident that current levels are within 5% difference and signifies accuracy of the developed portable CT sensor. The laboratory setup for measurement of leakage current from 420 kV GIS surge arrester is further shown in Fig. 3(b). The experimental set-up consists of a gas filled test transformer that energizes a gas insulated surge arrester through a gas insulated bus duct comprises of grounded enclosure with a central conductor and two epoxy insulators that support the conductor. A test transformer is rated for 1000 kV (rms) and is partial discharge (PD) free for rated voltage.

(a) 145 kV

(b) 420 kV

Fig. 3 : Experimental Set-up for Measurement of Leakage Current

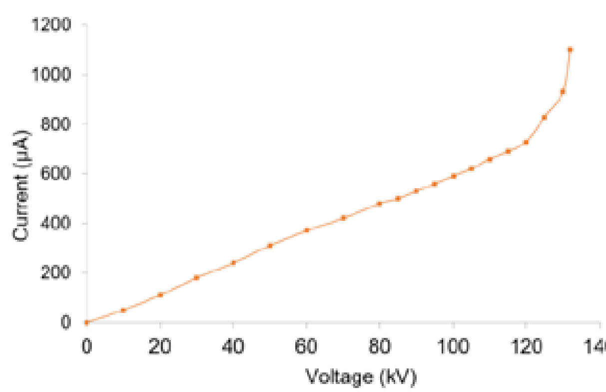
Table 1 : Measurement of Leakage current of Surge arrester

Applied voltage, kV	Measurement through non-contact type CT sensor, milli Amp	% deviation of current measurement through Clamp-on Meter
5.0	0.0249	+5.0
30.0	0.1624	+4.5
40.0	0.2553	+2.55
50.0	0.2872	+0.97
60.0	0.3399	+3.46
70.0	0.3911	+2.70
80.0	0.4492	-0.48
90.0	0.5115	-1.69
100.0	0.5624	-1.32

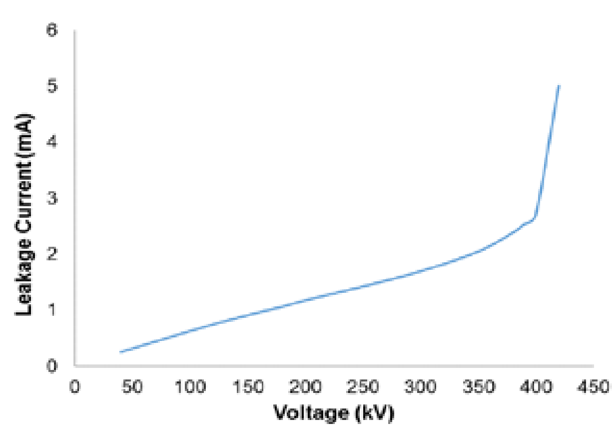
Table 2 : Leakage current sensor data for 420kV GIS Surge Arrester

Applied Voltage (kV)	Leakage current meter reading (mA)	Leakage current sensor output voltage, mV
20	0.136	0.42
40	0.260	0.84
60	0.390	1.24
80	0.550	1.63
100	0.607	1.90
120	0.716	2.20
140	0.847	2.66
160	1.000	2.90
180	1.075	3.10
200	1.181	3.38
220	1.274	3.65
240	1.390	4.00
250	1.432	4.20

* where x= leakage current in mA and y = sensor output in mV; y= 2.5824*x + 0.4213



(a) 145 kV



(b) 420 kV

Fig. 4 : Leakage current calibration curve for gas insulated surge arrester

The leakage current of the surge arrester is in the range of tens of microamperes to few milliamps depending on the applied voltage of the arrester. The sensor forms a closed loop around the insulated ground terminal and gives an output voltage proportional to the current flowing to the ground which is primarily the leakage current. Voltage (in steps of 10 to 20 kV) has been applied to the 420 kV surge arrester and the test results obtained are as shown in Table 2. Accuracy of this measurement of leakage current is confirmed by comparing current levels with the data measured using digital earth leakage clamp-on meter Model No. DCM 300E of resolution in the order of 1 μA. From the results, it was evident that current levels are within 2.0% difference in the operating region and signifies accuracy of the developed sensor. Fig. 4 shows the V-I characteristics of the 145 kV and 420 kV gas insulated surge arresters. For 420 kV surge arrester, beyond 390 kV, characteristics become non-linear and reference voltage is found to be close to 438 kV. Similarly, for 145 kV surge arrester, beyond 130 kV, characteristics become non-linear and reference voltage is found to be close to 145kV (rms).

IV. EXPERIMENTAL REALIZATION OF GIS SURGE ARRESTER DIAGNOSTIC METHODS

The GIS arrester was developed with ZnO elements stack and the number of elements is based on its rated voltage. For calculating the resistive leakage current and to assess the condition of the arrester an in-direct determination of the resistive component has been carried out by means of leakage current measurement.

A. Determination of the resistive component from leakage current measurement

A power frequency filter (50Hz filter) was designed and integrated with the sensor, as described earlier. Similarly, a third harmonic filter (150Hz) was also designed for measurement of third harmonic component of the leakage current. These filters reject the high frequency noises and only allow the leakage current of 50Hz and 150 Hz frequencies respectively to pass through them, as required for monitoring of the surge arrester. 145 kV GIS surge arrester is energized with various voltage levels and the leakage current sensor output was measured and analyzed. The corresponding plot of the third harmonic content of the leakage current is shown in Fig 5. By using fundamental component and third harmonic component of current, total leakage current has been calculated. From the figure, it is seen that third harmonic component increases continuously and the rate of increase is predominant at higher voltages. At lower applied voltages (from 5kV to 20kV) the resistive component of the arrester leakage current would be negligible as compared to the capacitive leakage current. Thus the total leakage current at these voltages can be taken as purely capacitive current. So the average value of the capacitance of the ZnO block of the arrester was calculated to be close to 480pF. The capacitance of the ZnO block is also got verified through experimentation on limited number of blocks. Assuming that the capacitance of the arrester ZnO block would remain more or less the same at all the voltages (5kV to 120kV) and any abrupt change in the total leakage current at higher applied voltages can be attributed mostly to the resistive component of the leakage current.

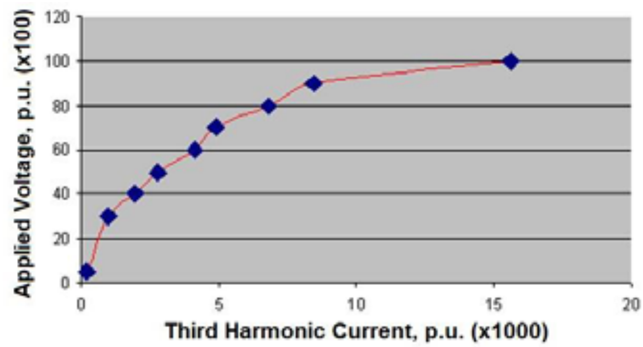


Fig. 5 : Variation of third harmonic component of leakage current with respect to applied voltage

Using this concept, the capacitive current component (I_c) from 30 kV to 120 kV is estimated. Knowing the total leakage current (refer Table 2) the resistive component of the leakage current was calculated by assuming that the capacitive and resistive current components differ in phase by 90°. The results are shown in Table 3. Here, the resistive leakage current is calculated by considering non-uniform voltage factors as 0% and -8% (highest value obtained through voltage distribution studies across blocks). The variation of the resistive leakage current with respect to the applied voltage is shown in Fig. 6. From the above figures, variation of third harmonic component and the resistive component of leakage current with applied voltage are mostly alike and similar. In other words, we can safely conclude that the third harmonic component of leakage current of the GIS surge arrester faithfully represents the healthiness of the surge arrester.

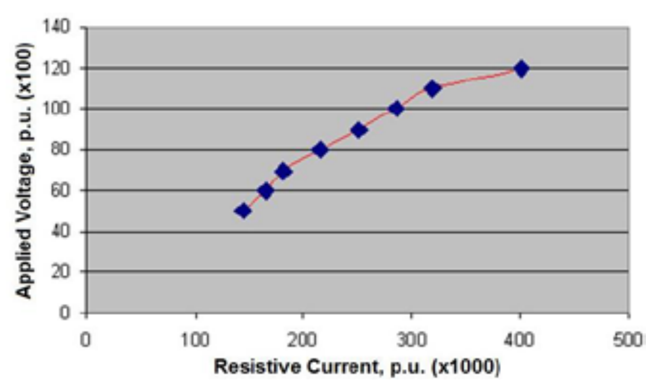


Fig. 6 : Variation of resistive component of leakage current with respect to applied voltage

Table 3 : Calculation of Leakage Current components using indirect method.

Voltage, kV	Ic, p.u. (0% non-linearity voltage factor)	Ir, p.u. (0% non -linearity voltage factor)	Ic, p.u. (-8% non-linearity voltage factor)	Ir, p.u. (-8% non-linearity voltage factor)
30.0	0.1508	0.0603	0.1387	0.0844
40.0	0.2011	0.1573	0.1850	0.1760
50.0	0.2513	0.1390	0.2312	0.1704
60.0	0.3016	0.1568	0.2774	0.1963
70.0	0.3518	0.1708	0.3237	0.2195
80.0	0.4021	0.2002	0.3699	0.2548
.90.0	0.4524	0.2387	0.4162	0.2974
100.0	0.5026	0.2523	0.4624	0.3201
110.0	0.5529	0.3024	0.5087	0.3720
120.0	0.6032	0.3937	0.5549	0.4592

One of the most widely used techniques for extracting the resistive leakage current for the purpose of condition monitoring of surge arrester is the compensation technique. In the compensation technique, for measurement of the resistive leakage current, the applied voltage is not required to be monitored. This technique is most suitable for on-site conditions. The method is based on the conditioning of the total leakage current waveform to get its resistive component. Authors developed a system with necessary software module to calculate the resistive component of the leakage current of the GIS surge arrester using above compensation technique [9]. Results obtained in the present study are compared with resistive leakage currents extracted from leakage current data using compensation technique. From the available data, it is evident that the proposed estimation of resistive leakage current from leakage current measurement is accurate enough to monitor healthiness of GIS surge arrester.

CONCLUSION

The leakage current measurement can be used for monitoring healthiness of surge arresters, insulators and various other electrical power apparatus. The insulation failure of an electrical device is always unintentional and causes a flow of either leakage current or short circuit current. The leakage current, however, flows continuously unlike short circuit current, with its magnitude being related to the condition of the insulation. The leakage current sensor as described in this paper is based on novel, compact and low cost design. The sensor design is optimized based on the type of power equipment and the leakage current levels to be monitored. The sensors output signal amplitude is increased optimally by designing suitable number of turns, cross section of the sensor core and choosing core material with required properties. More clearly, the sensitivity of the developed sensor as per its design is in the order of few micro-amperes for surge arrester monitoring.

The leakage current measurements have been carried out on 145 kV and 420 kV GIS surge arrester prototypes and results are validated with the conventionally available current sensors. From the measurements, the variation of third harmonic component and the resistive component of leakage current with applied voltage are found to be mostly similar and alike. The extraction of resistive component from the total leakage current is found to be accurate enough with the method proposed in the study.

Acknowledgment

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Project GPTL

Sandip Maity **Abshan Farooq**

Sterlite Power Transmission Ld.

ABSTRACT

The Project Gurgaon Palwal Transmission Limited (GPTL), is designed and created to cater to the power requirements of the flourishing metropolis of Gurugram, Haryana, India. Gurugram, as we know, houses leading industrial and financial institutions, along with a thriving population, it often witnesses power-cuts, especially during summers. Since it is one of the growing and leading industrial and financial establishment in the North, GPTL Project has been designed to deliver over MW of power through three GIS establishments built across three different locations in Haryana, viz, Prithala, Kadarpur& Sohna Road.

I. INTRODUCTION

GPTL is a very crucial transmission project awarded, in terms that the new (GIS) substations being built under this project are a part of Inter-State Transmission System (ISTS).

The project includes three new 400/220 kV GIS Substations in Palwal & Gurgaon districts. It also includes an extension project in an existing 400/220 kV AIS Substation at Dhanonda (Haryana), which comes under HVPNL (Haryana Vidyut Prasaran Nigam Limited). In addition to this extension work at Dhanonda, HVPNL Substation, a double circuit 400kV transmission line too is under scope which connects the aforementioned substation and PGCIL Neemrana Substation (Rajasthan).

The project scope also includes, a 400kV double circuit transmission line, which runs from PGCIL Aligarh (U.P.) to (new) 400/220kV GIS Substation in Prithala (Palwal). From Prithala Substation, a 400kV double circuit line connects the second (new) 400/220kV GIS Substation at Kadarpur (Gurgaon). Further, from Kadarpur Substation, a 400kV double circuit line connects the third (new) 400/220kV GIS Substation at Sohna Road (Gurgaon). Furthermore, a double circuit 400kV line which connects PGCIL Manesar and PGCIL Gurgaon, is being LILOed at Sohna Road Substation.

The paper describes a Gas Insulated sub-station (GIS) installation executed by Sterlite Power, India, which employs an unconventional approach towards a 400/220kV GIS installation. The project is situated near the large metropolis of Gurgaon in India, with availability of land being a major challenge as three 400/220kV GIS sub-stations had to be built relatively near to one another. Being so close to a major city, availability of land, along with the high cost of land was a major issue which required that the stations be built with the smallest footprint for economic reasons without compromising any technical standards.

II. GIS SUBSTATION

As explained in the introductory section that Gurgaon being a metropolis has major land availability issues. This constraint, with respect to land, led to a solution which was an innovative layout, giving a remarkable reduction in footprint meeting all the functionalities required.

The 400/220 kV GIS layout has the location of the 400kV & 220 kV GIS installations at multiple levels of the same building, with 220kV line side equipment placed in the same building, thereby increasing the power handled per unit area. The layout has the 400 kV GIS with its Control & Protection system installed on the ground floor, which is further connected to 500 MVA 400/220/33kV ICTs and 420 kV 125 MVAr Reactor placed just adjacent to the building. This connection is

Fig. 1 : 400 kV Gas Insulated Switchgear

through Gas Insulated Bus (GIB) ducts, thus eliminating SF6 to Oil Bushings for the Transformers and Reactor. The GIB ducts from 220kV side of transformer is routed from inside the building. This forms the bus ducts being routed from ground floor to the first floor of the building, where 220kV GIS is placed, alongside its Control &

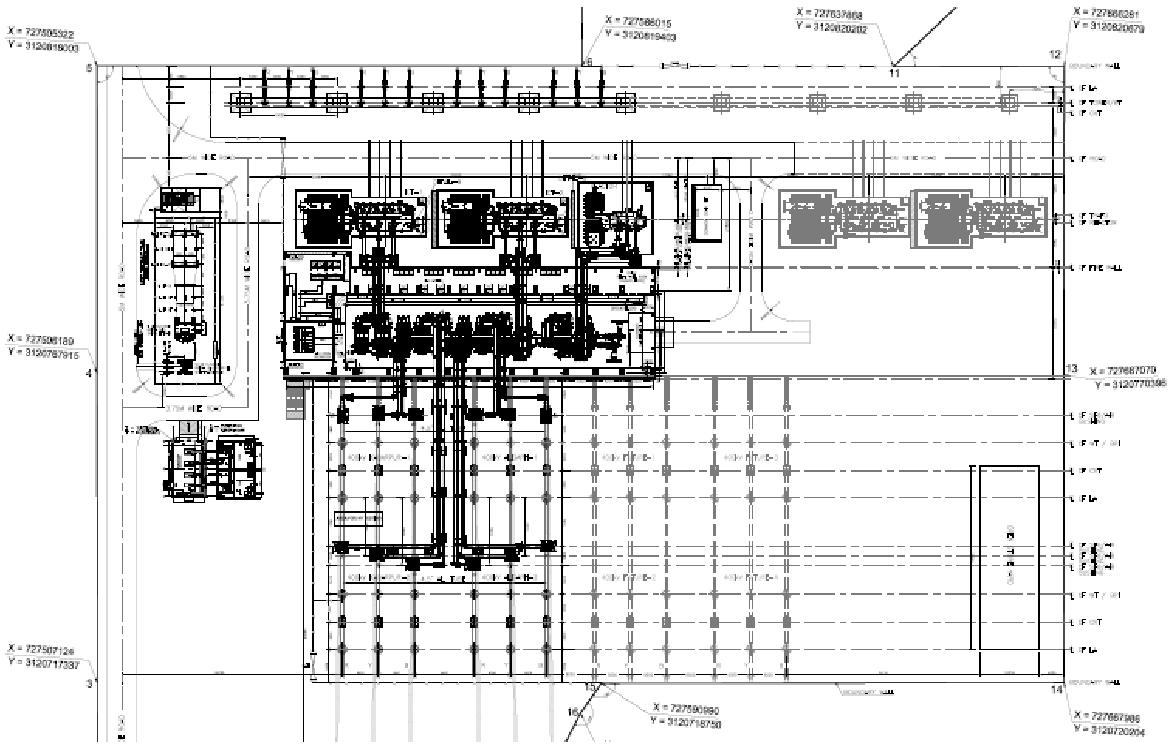


Fig. 2 : 400 kV GIS Building (Ground Floor) Layout

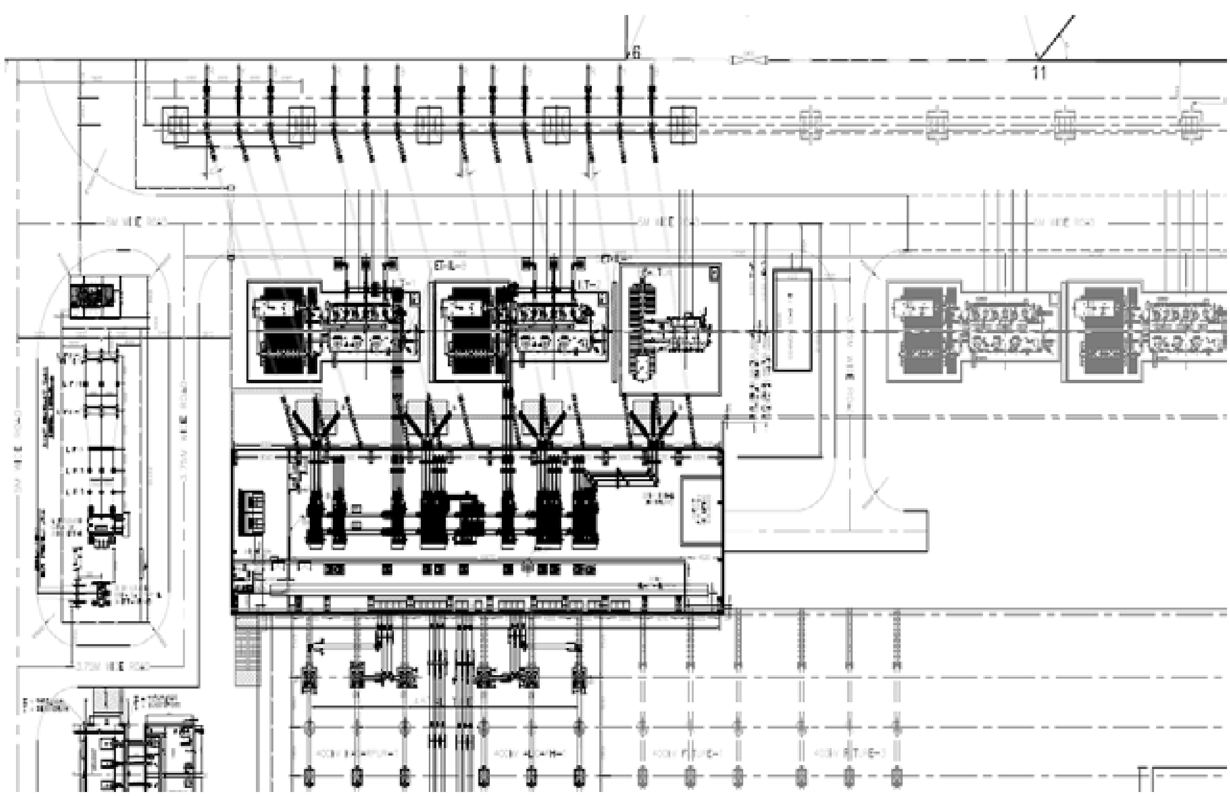


Fig. 3 : 220kV GIS Building (First Floor) Layout

Protection system.

Fig. 4 : 220kV Gas Insulated Switchgear

This innovative layout also corresponds to elimination of 400kV gantry which is entirely made up of steel structure; hence benefitting in reducing the overall carbon footprint for the project. Stringing for the 220kV & 400kV circuits is done by erecting suitable steel structures along the length of the building. For both the voltage levels, viz. 400kV & 220kV, the jack bus is strung in two levels, one above the other, on either side of the building. Since the jack buses are placed just one above the other, phase segregation double tension string insulators are installed to insulate and establish necessary clearances between

Fig. 5 : 400kV Switchyard (View from Rooftop)

two circuits. The innovative layout of the building ensures that a control room with other facilities like, battery room, AHU room and LT switchgear room are accommodated in the same building.

Conventionally, GIS layout for a 400/220kV sub-station of 2000MVA capacity would require about 15 acres of land whereas the innovative layout described above accommodates the whole station in approximately 3.8 acres of land. This huge reduction in land by almost 75% has not only resulted in making the scheme economical to execute but will also set a benchmark for the future installations and thus ensuring economic delivery of

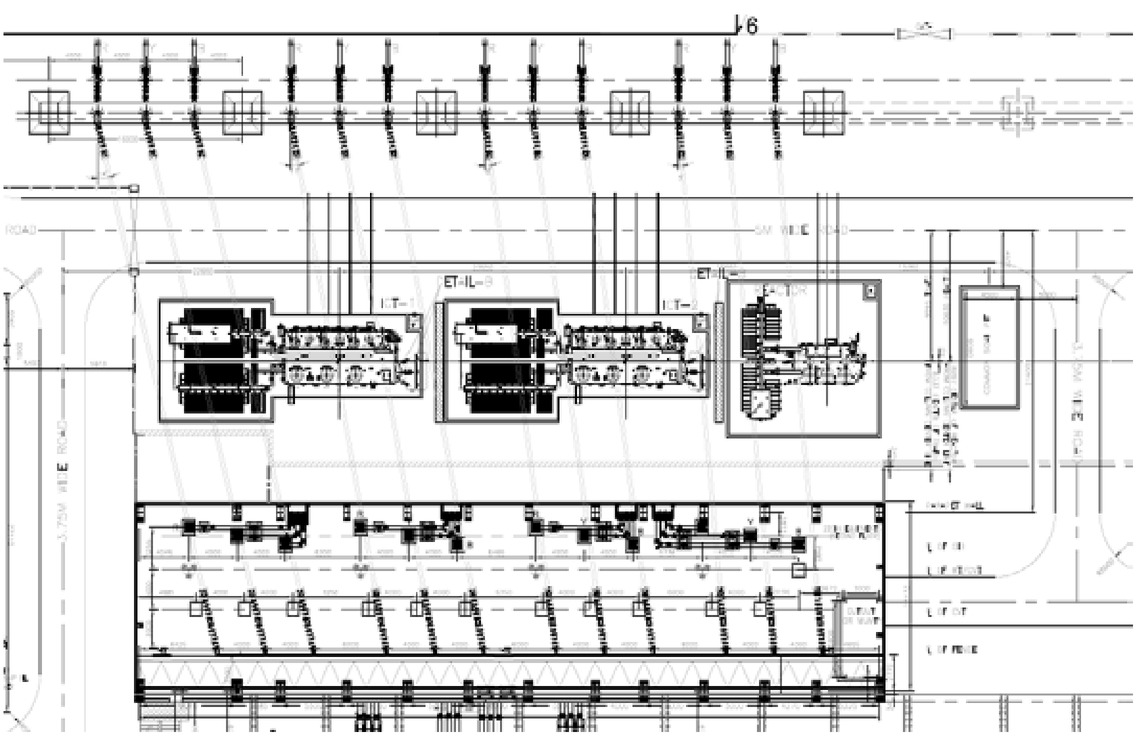


Fig. 6 : Line Side Equipment (Rooftop) Layout

power.

III. TRANSMISSION TOWERS AND LINES

Facing some ROW (Right of Way) issues, the transmission towers are designed, manufactured, and erected for a span of 500 meters.

Tower footing has been reduced drastically keeping in view the agricultural land.

In purview of the innovative layout which is adopted in case of the newly constructed GIS substations, dead end towers have been designed as a double layered

Fig. 7 : Monopole

Fig. 8 : Monopole

Utility Roadmap for System Strength Aspects for Reliability, Stability and Flexibility of RE Rich Modern Power Grid– Indian Grid Context

B.P. SONI
(I/C Superintending Engineer)

N. M. SHETH
(Executive Engineer)

Gujarat Energy Transmission Corporation Limited

INTRODUCTION

Renewal energy's rise and increased role in meeting energy demand has brought with it serious concerns about its impact on grid performance. In the initial stage of RE penetration grid was at comfortable level and very stable because of inherent supportive capabilities of conventional synchronous generation. But, due to different characteristics and behaviour of RE, it greatly impacts the power system steady as well as dynamic performance and thereby may jeopardize the reliability & stability by imposing lot of challenges if not dealt properly.

Renewable energy is the area of focus across the globe as well as in India. The wind and solar generation is poised to grow significantly due to aggressive planning by Government of India i.e.175GW renewables by 2022 that includes 100 GW Solar and 60GW wind from current 31 GW and 37 GW level respectively. Share of RE in Indian power system is @24% (Fig.1) and shortly it will be @30% with this planning. It is also planned to have 40% share of clean energy sources by 2030 due to tremendous growth potential (Fig.1).

At national front, many activities regarding steady state aspects are going on. Recently, a pilot project regarding Fast Response Ancillary Services (FRAS) for improving frequency profile and analysing operational aspects of ancillary services without RE curtailment for 175 GW RE scenario with the use of hydro power plant capability features is implemented i.e. basically secondary & tertiary frequency response aspects (Fig 2). As an outcome 6% improvement in Nos of time frequency remain in IEGC band and 7% decrement in frequency above IEGC band is achieved.

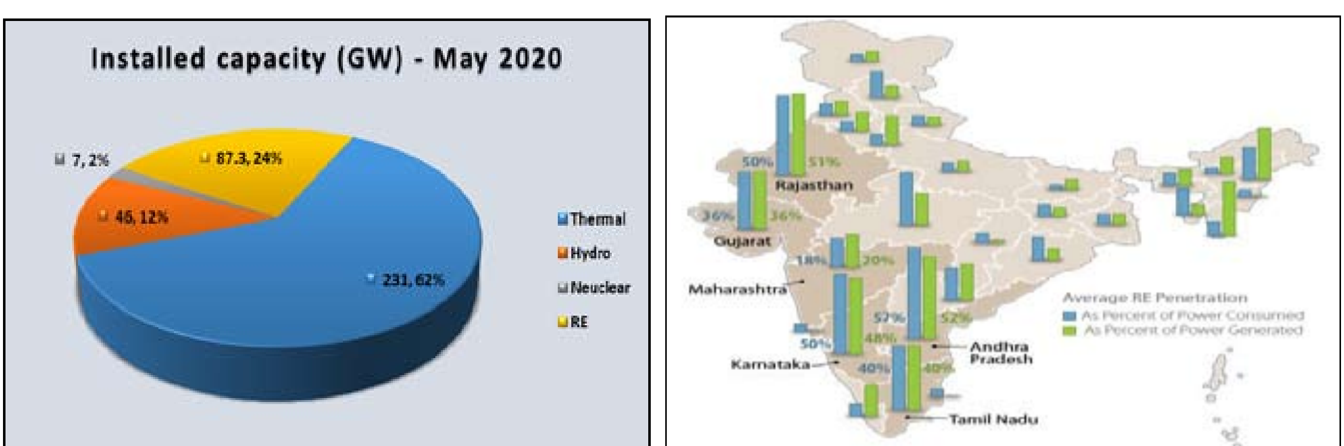


Fig.1 : Power generation scenario & growth potential

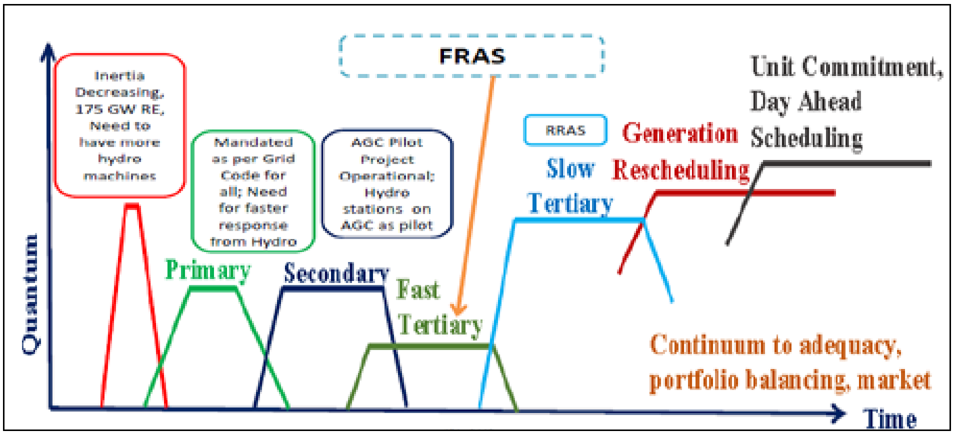


Fig. 2 : Role of Hydro in system balancing

But, with planned development there will be impact on dynamic aspects also. Hence, now there is need to look into study of dynamic aspects of inertial, primary frequency response and also reactive power support. Paper focuses on these aspects.

1. Synchronous generation (SG) Vs Inverter based generation (IBG) - Characteristics difference

There is a fundamental difference between synchronous generation and inverter based generation (IBG) (Fig.3). IBGs inherently do not have following characteristics.

1. Inertia
2. Frequency response capability
3. Frequency sensitive mode
4. Constant voltage source
5. Fault ride through capability
6. Short circuit capability
7. Grid voltage support
8. Reactive power support
9. Synchronization capability (Torque)
10. Damping torque
11. Harmonic voltage reduction etc.

Recently many new capabilities are covered in Grid code for technical requirements. Annexure-A depicts the potential difference between SG and IBG along with the feasibility of advanced capability.

Some of the characteristics and behavioural differences are elaborated in brief hereunder.

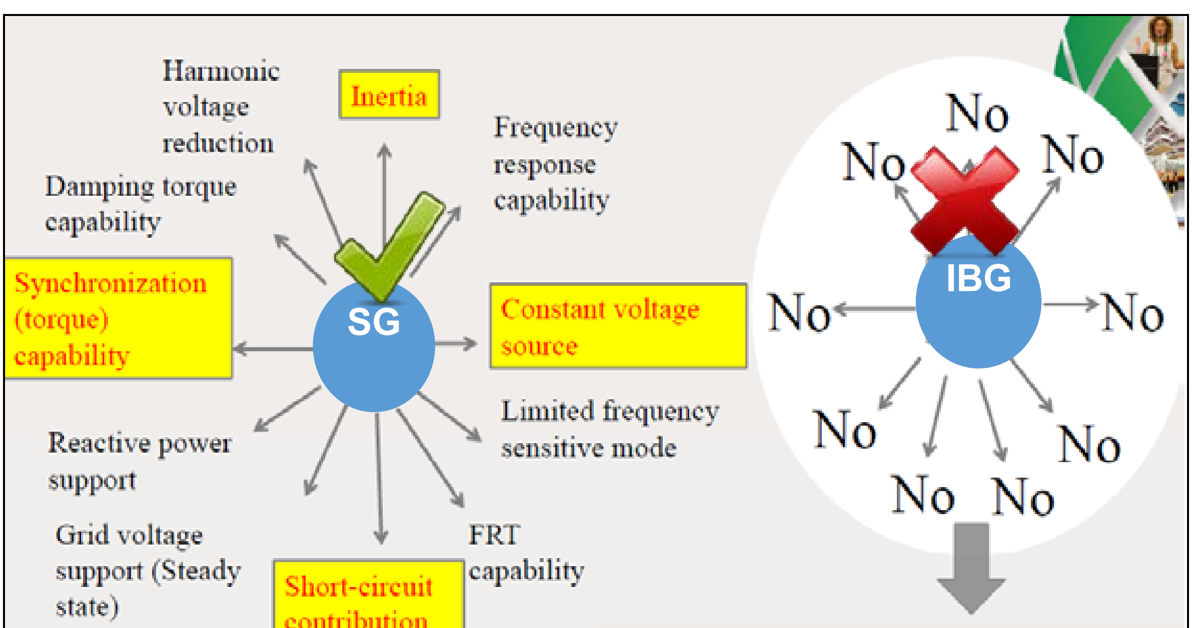


Fig. 3 : Characteristics Difference between SG and IBG

(a) Rotating mass

- IBGs do not have
- Available reserve energy in IBG is limited and inertial response is not of significance inherently
- Rating of electronic devices also limits for additional energy
- To really use inertial response, a significant oversized IBG inverters are required

(b) Fault current contribution

- Inverter predominantly lack inductive characteristics associated with rotating mass
- Short circuit contribution by Synchronous generator is due to law of constant flux in rotating machine.
- IBGs can contribute fault current slightly above 1 p.u. unless specifically designed for over size.

(c) Constant voltage source

- In case of Synchronous generator
  - (i) Internal induced voltage is independently regulated from grid voltage.
  - (ii) Also it is higher than grid voltage.
  - (iii) This will cause increased current when grid voltage sags.
- In case of IBGs this is limited to 1 p.u. due to control system behaviour unless designed oversized.

(d) Transmission level voltage support

- Synchronous generators operate in AVR mode where as IBGs operate in unity Power factor mode means AQR mode.
- Thus voltage support cannot be expected unless designed for oversized.

(e) Fault ride through capabilities

- Synchronous generators are required to withstand short circuit of any kind without failure as it follows law of electrodynamics.
- In case of IBGs, voltage phase angle cannot be detected when line voltage is very low as magnetic contactor loses excitation. However, new IBGs are available with this characteristic.

(f) Reactive power support

- During steady state
  - (i) Rate P.F. of synchronous machine is 0.8 to 0.95, in case of IBG it is unity.
  - (ii) Most of the IBGs are not desired to provide reactive support at full output voltage unless larger sized IBGs are designed.
- During transient condition
  - (i) Synchronous generator instantaneously/immediately provides reactive power output as an electrodynamic phenomenon.
  - (ii) In case of IBGs, due to detection time of controllers, it cannot be physically instantaneous.
  - (iii) Additional reactive power can be supported by decreasing active power output within rated current range.

This reveals that, steady state as well as dynamic behaviour of inverter based generation is quiet different. Even, different type of machines behaves differently when exposed to transient condition. This has given rise to stability and reliability aspects. Apart from above, renewable generation is intermittent and highly variable which challenges existing operational aspects also.

Looking to above challenges, a multidimensional conceptual approach to enhance the stability and reliability of RE rich modern power system should be adopted at state, region as well as national level (Fig. 4).

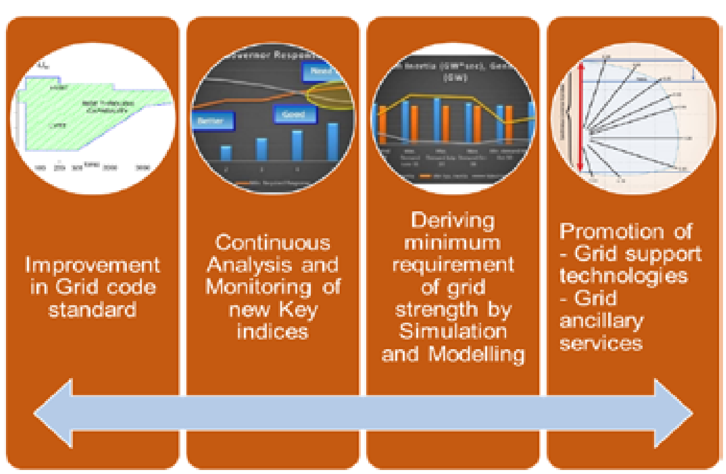


Fig. 4 : Multidimensional Approach

2. Improvement in technical requirement for grid connectivity as per new grid code standard

For RE integration, Indian grid code standard 2013 is specifying some basic requirements like;

(i) Harmonic current injections limit: As per IEEE- 519 (2014)

(ii) DC current injection not greater than 0.5 % of the full rated output

(iii) Flicker limit: As per IEC 61000 Class A

(iv) Measurement of Harmonic, DC injection and flicker - Once in a year

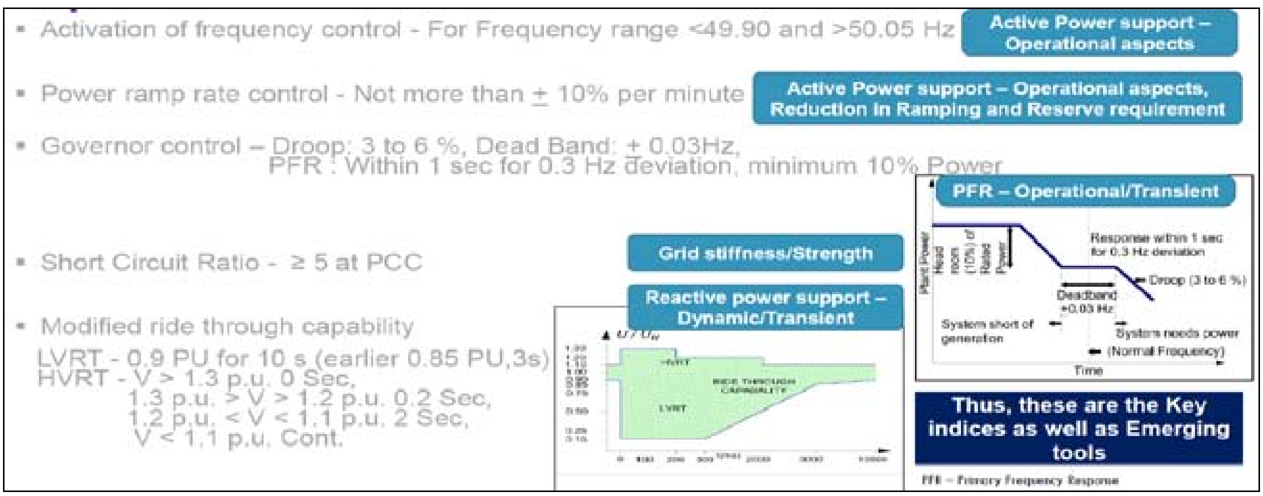
(v) Dynamically varying Reactive power support - Power factor within the limits of +0.95

(vi) Frequency: Operating range - 47.5 Hz to 52 Hz & Rated output range - 49.5 Hz to 50.5 Hz

(vii) LVRT Capability: V/Vn - 0.15 p.u. for 300ms & 0.85 p.u. for 3 sec

But, with present planning and future scenario, these requirements are not sufficient as they do not address the aspects necessary to articulate IBG characteristics nearer to conventional generation for steady as well as dynamic operations and leading towards need for improvement in technical requirements.

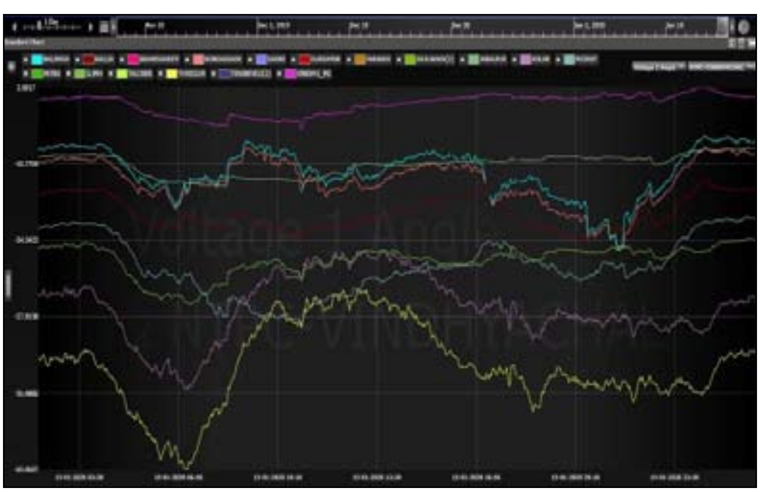
In Feb 2019, the grid code requirements are amended by hon'ble CEA including many of these technical aspects along with quantification of parameters as under.



These parameters are now the "Key reliability indices" as well as "Emerging tools" for further analysis, monitoring & considerations of system strength as well as operational aspects to enhance the grid strength by improving steady as well as dynamic performance of the grid.

3. Continuous analysis and monitoring of new technical parameters – Concept thereof

Today, as grid reliability indices parameters like Angular diff., Voltage Deviation Index, Violation of Available Transfer Capacity etc. are being continuously monitored at national level (Fig. 5).



Voltage Profile (Voltage Deviation Index) Monitoring

Sr. No.	Station	% of time voltage below 728/380kV	% of time voltage between range 728/380kV to 800/420kV	% of time voltage above 800/420kV	Voltage Deviation Index (% of time Voltage is outside IEGC band)
1	Agra	0%	99.93%	0.07%	0.07%
2	Batia	0%	100%	0%	0%
3	Bara	0%	100%	0%	0%
4	Meerut	0%	94.72%	5.28%	5.28%
5	Lucknow	0%	84.65%	15.35%	15.35%

% of times ATC violated

Sr. No.	Corridor	Nos of Block violated	Nos of Hours violated	% Violation
1	WR-NR	0%	0.00%	0.00%
2	ER-NR	0%	0%	0%
3	Import to NR	0%	0.00%	0.00%
4	NEW-SR	0%	0%	0%
5	NER Import	0%	0.00%	0.00%

Fig. 5 : Angular Difference, Voltage Deviation Index, Violation of ATC monitoring & analysis

Now, it is proposed to monitor new grid code parameters also. This will definitely improve the increased concern to these aspects as well as their compliances. On the other end there will be clear idea regarding grid support and ultimately the available system strength at any given time.

For quantifying the grid performance at any given time, a system of metrics providing the details of percentage generation providing above technical support should be adopted at State, Region as well as National level. Also, minimum requirement of percentage generation providing above support for grid strength under various operating scenarios should be derived (based on simulation studies) and accordingly, it should be considered for system operational aspects e.g. for Parameter: Governor Response

% Generation providing support at 20% RE is x machines and

Minimum requirement for grid strength at 20% RE is a machines. Now,

If x=a : Good operating condition,

If x < a: More machines (having governor response) should be considered for operation

If x>a: better operating condition (Similarly for other parameters, Fig. 6).

Today machines are running based on merit order dispatch and IBGs are must run. But, for RE rich future grid, if required, machines having better grid code compliance may also be required to be considered for operation irrespective of merit order dispatch to maintain minimum strength of the grid (highlighted part). With this vision, system operational aspects should also be replanned if necessary.

Thus, these are the useful tools in planning of many power system aspects like;

(i) Frequency control reserve requirement

(ii) Ancillary services requirement

(iii) Optimization of ramping requirement of conventional generation

(iv) Additional reactive support requirement etc.

and help to add to efficient and reliable system operation in new generation mix scenario.

4. System strength aspects and related concerns

System strength can be defined as an ability of power system to produce and maintain control of sinusoidal 3 phase voltage waveforms which are the basis of AC network.

It provides indication of network sensitivity to any sudden changes in operating conditions such as variations in active and reactive power flows, status of the network elements and occurrence of fault induced disturbances. It is a fundamental characteristics specific to each connection point and will vary over a time as power flow and generation dispatch condition change.

Thus, strength of the grid is an intrinsic characteristic of the local power system and reflects the sensitivity of power system variables to disturbances. It indicates inherent local system robustness.

It is a measure of the stability of power electronic interfaced control systems, synchronous generators, network dynamics and protection systems to assist the power system rapidly returning to steady-state conditions following a disturbance.

Before going to further details, we need to understand why there is a concern for grid strength. In this regard, types of generators and its behavioural impact is highlighted.

Type of generation and its characteristics:

(a) Synchronous generation

(i) It has its own source

(ii) Synchronous generation is balanced sinusoidal waveform.

Governor Response							
Sr. No.	Attribute	Typical Values					
1	RE Penetration	5%	10%	15%	20%	25%	30%
2	Min. Required Response	35%	40%	40%	45%	48%	50%
3	Actual Respnse	55%	53%	50%	45%	40%	38%

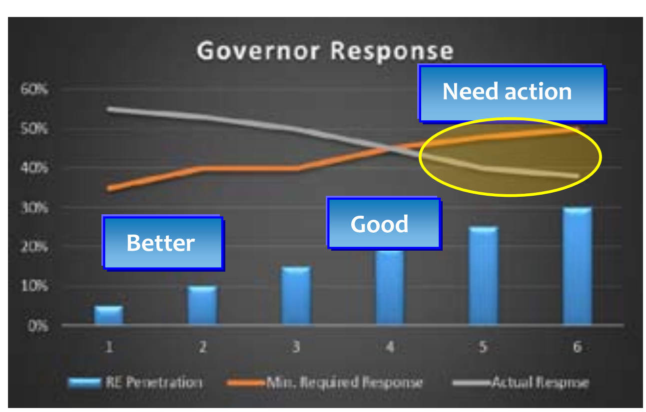


Fig. 6 : Grid code parameter monitoring

(iii) Active and Reactive power transfer influenced by angular position and MMF.

(iv) Response of machine is by electrodynamics and hence inherently act in right direction to support/stabilize the grid.

(v) The instantaneous response is without relying on any measurement.

(vi) No requirement of minimum strength

(vii) Predictive and linear response

(viii) Large fault current contribution during disturbance

(ix) They act as a source of fault current having positive contribution.

(b) Inverter based generation (Traditional)

(i) IBGs are constant current source rather than an "Independent Voltage Source".

(ii) IBGs act by measuring magnitude and phase angle of grid and thus they are "Grid following" generation technology.

(iii) It is called grid following inverter

(iv) Need sufficient synchronous generation nearby for stable operation

(v) Two important factors determining system stability

- Strength of interconnected network
- Design and tuning of controller

(vi) Highly controlled, sophisticated and non-linear response

(vii) Limited fault current contribution generally 1 p.u. and sometimes 2 p.u. if designed due to rating of semiconductor components

(viii) They act as a sink of fault current having negative contribution

(c) Inverter based generation (Grid forming)

(i) Aiming to emulate synchronous machine characteristics as close as possible (virtual synchronous generation)

(ii) Synthesises voltage sine wave with constant frequency without need of external reference.

(iii) Do not cause any adverse interaction with other generators and grid devices.

(iv) Can provide black start capability where needed

(v) Key concern is; how similar/dissimilar they are compared to Synchronous generation

What are the factors weakening the grid?

Following are the fundamental building blocks for "Weak network operating condition".

(i) Large scale solar and wind generally connected to grid at larger distance from load centres

(ii) It is also remote from Synchronous generation

(iii) Energy input from RE takes priority in dispatch even other alternate exists

(iv) Renewable energy targets are being achieved earlier than planned.

(v) Reduced synchronous generation online

(vi) High power transfer over a long distance

Impact of System strength:

A. During normal network operation:

(i) Poor voltage regulation, potentially exceeding the acceptable steady state limits as power flow conditions vary over a time.

(ii) Large changes in voltage during and following switching events including operation of shunt connected reactive plant.

(iii) High sensitivity of voltage magnitude to changes in active/reactive power flow can give rise to unstable behaviour of fast control systems unless they are appropriately tuned and coordinated. This is particularly when multiple IBGs are operating in close proximity to one another.

(iv) Increased risk of voltage instability, including occurrence of localised voltage collapse.

B. During and following contingency event:

(i) Much wider propagation of fault induced voltage depression which can cause converter connected equipment to "see the fault" and foster FRT (Fault Ride Through) mode which in turn has potential negativity on system frequency.

(ii) High sensitivity of voltage magnitude to changes in active/reactive power flow making stable recovery from FRT difficult unless active and reactive power controls are properly coordinated. Particularly area where multiple IBGs operate in close proximity and attempts to recover at same time (means repeated FRT behaviour which is credible risk).

(iii) High sensitivity of voltage phase angle to changes in active power flow and voltage magnitude impending the performance of Phase locked loops (PLL) which are required for stable operation of power converters which are grid following.

(iv) Voltage angle transient being mis interpreted as changes in local network frequency which creates risk of mal-operation of frequency based protection including ROCOF.

(v) Increased risk of over voltage if dynamic control of reactive power is slow, poorly designed or not available.

(vi) Reduced fault currents which can reduce effectiveness and/or impedance based or over current based protection schemes.

The most significant impact of most of these aspects is instability results in disconnection of generating equipments.

System Strength Parameters :

Thus system strength is a multidimensional problem. Following are the key indicators for system strength aspects but not limited to (Fig. 7);

(i) Ratio of the Non-synchronous generation to Synchronous generation. (System Non synchronous penetration – SNSP)

(ii) System Inertia

(iii) Proximity of the synchronous generation (SCR, CSCR, WSCR, ESCR)

Further set of question will be:

(a) How many synchronous machines are needed to look after increased number of IBGs?

(b) How much close synchronous machines to load centres?

(c) Can IBGs look after themselves in future?

Until a precise matric of system strength can be defined, the most reliable method to determine how to operate power system in secure manner is to perform detailed power system simulation studies. These studies will provide insight into how system performs for varying despatch scenarios, fault conditions and thereby evaluation of the strength of the grid. (Fig. 8)

It is emphasized to identify pre-determined sets of synchronous machines needed to remain online to maintain sufficient system strength, with high proportions of non-synchronous generation/IBGs and identify “Key efficiency breakpoint”, which is the “largest overall amount of non-synchronous generation/IBGs that can be online for the least number of synchronous generators” necessary to alleviate system strength concerns and should be included in monitoring aspects

5. SYSTEM STRENGTH PARAMETERS

5.1 Inertia

***Concept* :**

Inertia is the first and fastest line of defence after transient period followed by disturbance or contingency event

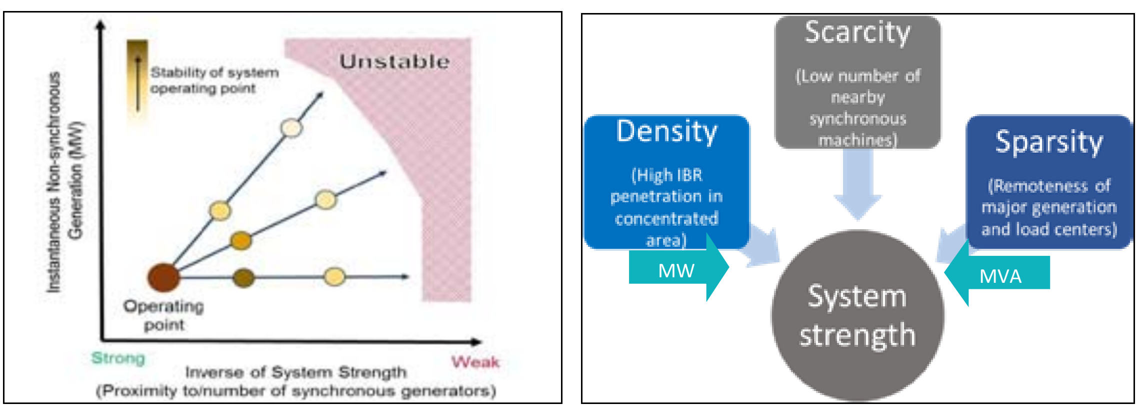


Fig. 7 : System strength variables

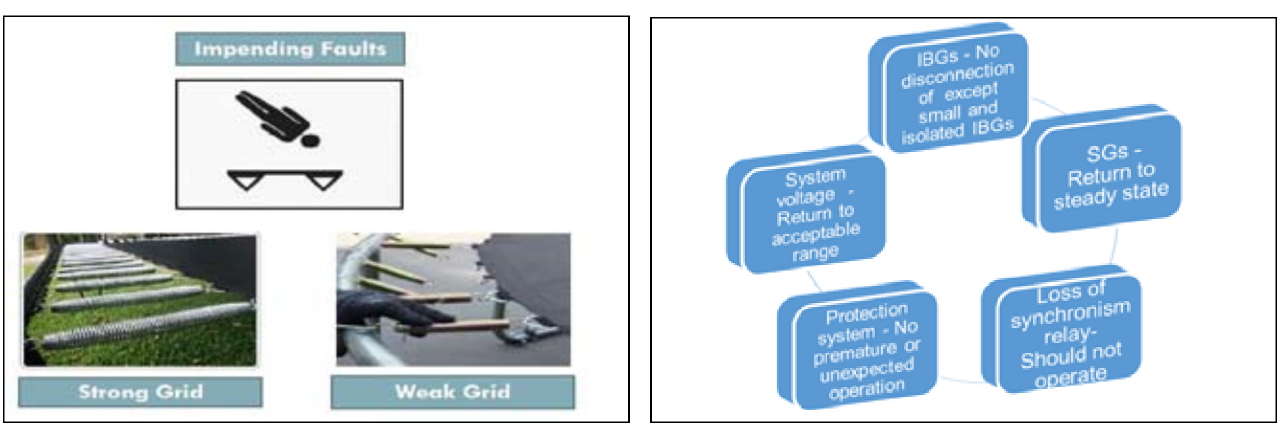


Fig. 8 : Grid strength analysis criteria

in arresting frequency drops before primary frequency response becomes available to supply lost energy. When sufficient rotational inertia is available, severe frequency drops can be avoided. (Fig. 9)

As penetration levels of IBGs (that do not naturally contribute inertia to the system) continue to increase and displace synchronous generators in a power system's generation mix, synchronous inertia will inevitably decline. World vide TSO survey shows that, 'decreasing inertia as the most important issue of the modern power system'.

In recent years, world vide number of dynamic studies are being carried out and found that;

(i) The amount of frequency containment reserve (called Responsive Reserve Service or RRS) needed to arrest the frequency above the AUFLS trigger after the largest generation loss depends on system inertia conditions.

(ii) There is a critical inertia level below which existing frequency response mechanisms are not fast enough to arrest the frequency before it reaches AUFLS after the largest generation loss.

(iii) If system inertia is expected to fall below this value, system operators have to follow procedures to start more synchronous generators or to consider ancillary services in order to increase synchronous inertia online.

5.1.1 *Determination of critical inertia level*

From the basic swing equation of rotating machine any power system has its minimum rotational ineria requirement which is called critical inertia level below which system cannot withstand the given contingency. It depends on given contingency (loss of power) and allowed rate of change of frequency.

$$E\,kin(min) = \Delta P \frac{fn}{2*ROCOF} + E\,kin(Cont.) \qquad ...(1)$$

Where, E kin(min) is minimum system inertia required (MW*sec), ΔP is the worst case multiple contingency (MW), fn is system frequency (Hz), RoCoF is predefined rate of change of frequency(Hz/s) and E kin(Cont.) is the amount of system inertia lost (MW*sec) .

For typical example; critical inertia level for GETCO grid is calculated based on AUFLS setting parameters and largest inertial loss. Worst case contingency for df/dt operation is 1800 MW at 49.9 Hz base frequency and 0.4 Hz/s as RoCoF (setting guide lines provided by WRPC). Largest ineria loss is CGPL Mundra's 5 Nos 830 MW generators. Thus critical inertia arrived is 128.4 GW*sec. Now, this is another very important monitoring parameter in context to system strength.

For further analysis, system inertia of various extreme scenarios like maximum wind, maximum demand, minimum demand etc. is derived and analysed with respect to minimum system ineria. (Fig.10).

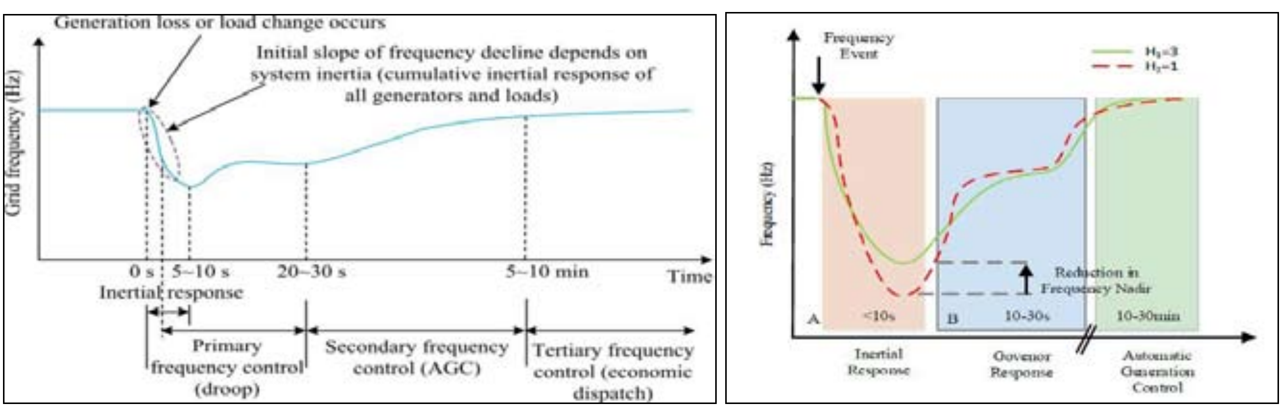


Fig. 9 : Frequency response spectrum & impact of Inertia on ROCOF

Sr. No.	Attributes	Max Wind Aug-09	Max. Demand June-11	Max. Demand July-20	Max. Demand Oct-08	Min. demand Oct-30	Min. demand Sep-15
1	Actual Sys.Inertia (GW*Sec)	136	146	155	137	130	141
2	Min. Sys. Inertia (GW*Sec)	128	128	128	128	128	128
3	Wind Gen. (GW)	4.157	1.127	0.79	0.1	1.7	1.3
4	Total Gen. (GW)	11.015	18.27	17.8	17.3	7.9	10

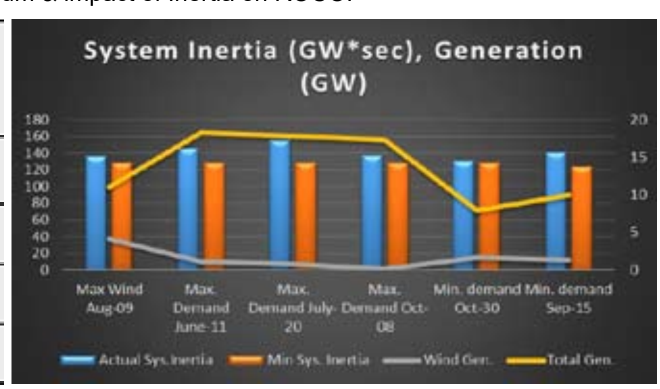


Figure 10 : System inertia analysis

ΔIn almost all the cases system inertia is comfortably above the minimum requirement except October 30 th (where it was just above the critical inertia) which was minimum demand scenario and all hydro, gas and many thermal plants were not in operation.

Such practices should be adopted at state, region as well as national level as reliability aspects and counter measures if any.

5.1.2 *Real time tracking of Inertia*

Details of machines which are connected to grid is available on unit commitment and despatch plan. Based on these details, current as well as future total inertia contribution of all online synchronous generators can be calculated based on the inertia parameters of individual units in the network with aggregation. Thus, system inertia can be continuously monitored as situational awareness tools (Fig. 11). If at any time period where the expected system inertia is less than the critical level can be identified and appropriate actions should be planned to maintain it above critical level.

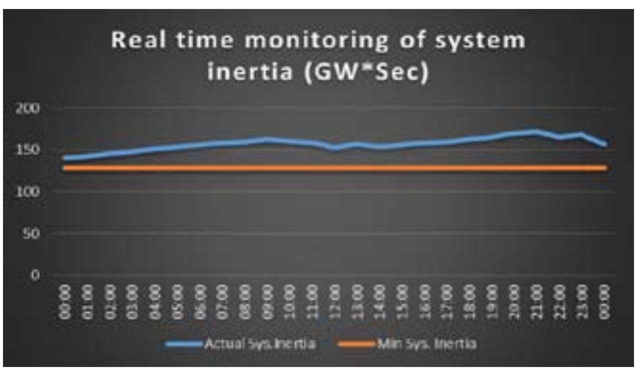


Fig. 11 : Real time monitoring of system inertia

Looking to above aspects, it is preferable to include inertial aspects in grid code requirements for IBGs also. Though, they inherently do not exhibit inertia but, it is possible to program the controls to provide a form of inertial response called synthetic inertia which will add to grid strength and also reduce the reserve requirement and ancillary services.

5.2 Short Circuit Ratio (Grid stiffness)

The most basic and easily applied metric to determine the relative strength of a power system is short circuit ratio (SCR). SCR is defined as the ratio between short circuit apparent power (SC_{MVA}) from a 3LG fault at a given location in the power system to the rating of the inverter-based resource connected to that location (i.e. it is location specific unlike frequency).

$$SCR_{POI} = \frac{SCMVA_{POI}}{MW_{VER}} \quad ...(2)$$

where SCMVA is the short circuit capacity at PCC without current contribution from IBG, MWVER is the nominal power rating of IBG.

Significance:

(i) SCR is a measure of thevenin impedance of AC system.

(ii) A low SCR system ("weak system") indicates high sensitivity of voltage (magnitude and phase angle) to changes in active and reactive power injections or consumptions.

(iii) High SCR ("stiff") systems have a low sensitivity and are predominantly unaffected by changes in active and reactive power injection.

(iv) Low SCR is of significance concern because internal plant controls will not function in a stable manner and may not represent the true behaviour of plant which increases the chance of sub synchronous behaviour and control interactions.

(v) The SCR metric is most appropriate when considering a single inverter-based resource operating at PCC (i.e. does not account for the presence of other inverter-based resources or power electronic-based equipment electrically close to the PCC).

5.2.1 *SCR in case of multiple inverter based sources at or near PCC*

IBGs connected close to other IBGs may interact with each other and oscillate which can lead to overly optimistic results with SCR. In this regard, several methods are there.

(i) Composite Short Circuit Ratio (CSCR)

Composite short circuit ratio (CSCR) estimates the equivalent system impedance seen by multiple inverter-based resources by creating a common medium voltage bus and tying all inverter-based resources of interest together at that common bus. CSCR can then be calculated as;

$$CSCR = \frac{CSC_{MVA}}{MW_{VER}} \quad ...(3)$$

where, MWVER is the nominal power rating of all IBGs considered and CSCMVA is the composite short circuit MVA at common bus without current contribution from IBG.

(ii) Weighted Short Circuit Ratio (WSCR)

The weighted short circuit ratio (WSCR) has been recently started for more accurate metrics applied in defining system strength aspects. In his method it is assumed that, all IBGs are electrically close to each other and provides SCR at a "Virtual" point of connection. WSCR is defined as;

$$\text{WSCR} = \frac{\sum_i^N \text{SCMVAi} * \text{PRMWi}}{\sum_i^N (\text{PRMW}i)^2} \quad \ldots(4)$$

where, SC_{MVAi} is the short circuit capacity at bus i without current contribution from non-synchronous generation and PR_{MWi} is the MW output of non-synchronous generation to be connected at bus i. N is the number of wind plants fully interacting with each other and i is the wind plant index.

For typical example SCR, CSCR and WSCR parameters are calculated for some of the highest IBG penetrated area of GETCO grid (Table-II) which are at the western coast and at extreme end of the network (Fig. 12). Analysis shows that, CSCR and WSCR are at comfortable level though SCR at one bus is low.

Table-II : SCR calculation aspects

Sr. No.	Wind farm	GETCO grid subsation	SC MVA	Connected IBGs (MW)	SCR
1	Lamba	132kV Bhatia	998	22.5	3.69
	Navdra			21.6	
	Bhogat			204.06	
	Ganthvi			22.10	
2	Patelka	66kV Kalyanpur	311	17.37	17.89
3	Vasai	66kV Varvala	475	30.78	15.44
4	Mota Gunda	132kV Bhomiyavadar	738	119.7	6.16
5	Kobavadar	66kV Goinj	173	70	2.47
6	Bhatel	132kV Kahmbhaliya	933	50.6	18.43
	CSCR = 6.04		WSCR = 4.53		

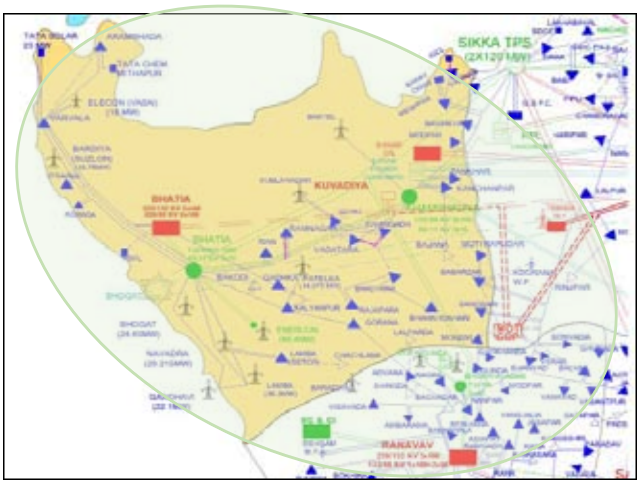


Fig. 12 : Western cost high IBG penetration network

This is another good monitoring aspect and it is proposed for adoption at state, region as well as national level and should be considered for;

(i) System planning criteria

(ii) Mitigation measures to counter the lower SCR aspects.

5.2.2 *Short Circuit Interaction Factor (SCRIF)*

When multiple inverter based resources are located very close to each other, they share the grid strength and short circuit level. Hence grid strength is much lower than overall short circuit level calculated at buses.

SCRIF captures the changes in bus voltage at one bus corresponding to resulting from changes in bus voltage at other bus. Metric considering SCRIF is ESCR (Effective SCR) which can be derived as formula mentioned hereunder.

$$ESCR_i = \frac{S_i}{P_{WFi} + \sum_j (WPIF_{ji} \times P_{WFj})}$$

where, Si is the short circuit capacity at bus i without current contribution from non-synchronous generation and P_{MFi} is the MW output of non-synchronous generation to be connected at bus i. P_{MFj} is the MW output of non-synchronous generation to be connected at bus j. W_{PIFji} is the ratio of change in bus voltage at Bus i due to change in bus voltage at Bus j.

5.2.3 *Monitoring*

Based on available generation data, SCR parameters can be derived for various extreme scenarios and utilized for analysis, monitoring and planning. Here again typical example of GETCO grid is presented for maximum demand, minimum demand and maximum wind scenarios. Results shows that, Nos of IBG connected buses where SCR is <5 and just above 5 are not changing in any of the scenario (Fig. 13).

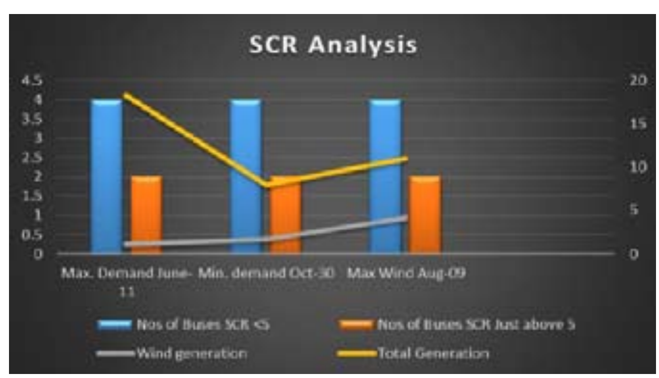


Fig. 13 : SCR analysis of IBG connected Buses under various scenarios

From the unit commitment and despatch plan real time system scenario will be available. It is also possible to track SCR in real time by integrating real time status of network elements in short circuit studies to derive short circuit levels. Then, these details can be utilized to calculate SCR, CSCR and WSCR.

Comparison of different SCR methods are summarised hereunder. Accordingly, it should be implemented for system strength aspects.

Table III : SCR calculation methods and its applicability

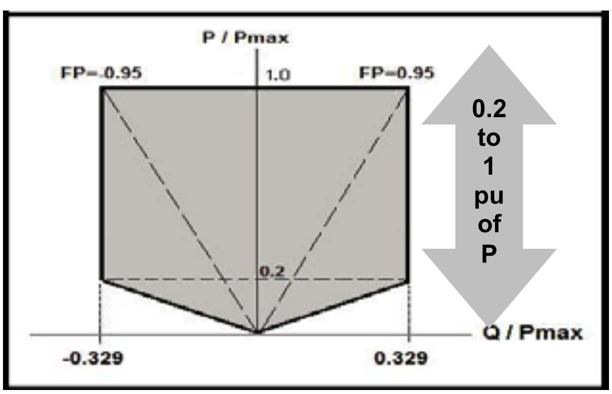
Metric		Simple calculation using short circuit program	Accounts for nearby inverter based equipment	Provides common metric across a larger group of VER	Accounts for weak electrical coupling between plants within larger group	Considers non-active power inverter capacity*	Able to consider individual sub-plants within larger group
SCR	Short Circuit Ratio	★★	X	X	X	X	X
CSCR	Composite SCR	★	★★	★★	X	X	X
WSCR-MW	Weighted SCR using MW	★	★★	★★	★	X	X
WSCR-MVA	Weighted SCR using MVA	★	★★	★★	★	★★	X
SCRIF	Multi-Infeed SCR	X	★★	X	★★	★★	★★

* e.g., STATCOMs or partial power inverter-based resources

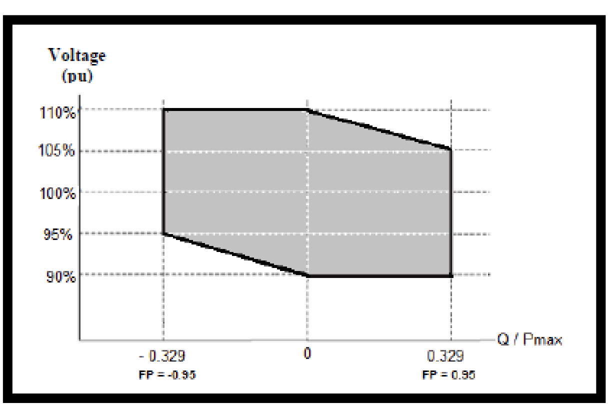
As a way forward and to add to grid strength aspects, technical parameters like;

(i) Synthetic Inertia

(ii) Voltage Control through Reactive Power Control or Power Factor Control

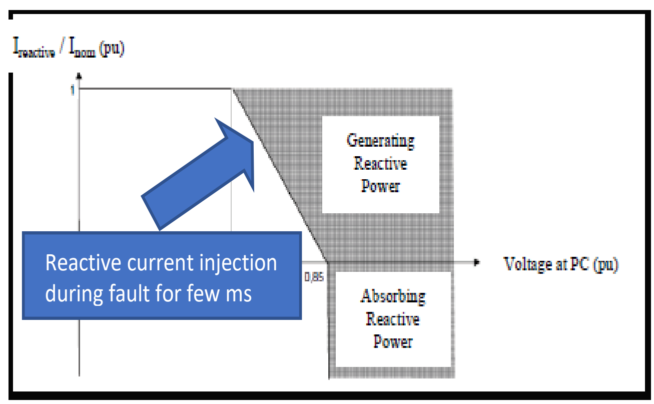


Reactive Power Compensation at POC



Power Factor at POC

(iii) Special requirement of voltage control are proposed to review for including in Indian grid code standard including continuous power quality monitoring



6. GRID SUPPORT TECHNOLOGIES:

Various aspects discussed in the paper reveals that, the developing scenario has cumulative impact on inertia, reactive power support and short circuit capability aspects (Fig. 14). Even if we build synthetic inertia in IBGs by modifying controls, it depends on measured RoCoF and hence cannot be considered completely equivalent to inertia provided by synchronous generators. With this pace grid will face deficit of Inertia, Reactive power support, Short circuit capabilities, Ride through capabilities etc.

Here, synchronous condenser can play key role due to multifaceted characteristics (Fig.14) which supports all above aspects like;

(i) Provide inertia due to rotating heavy mass

(ii) Meets reactive power requirement arising out of retiring generators

(iii) Dynamic reactive power compensation

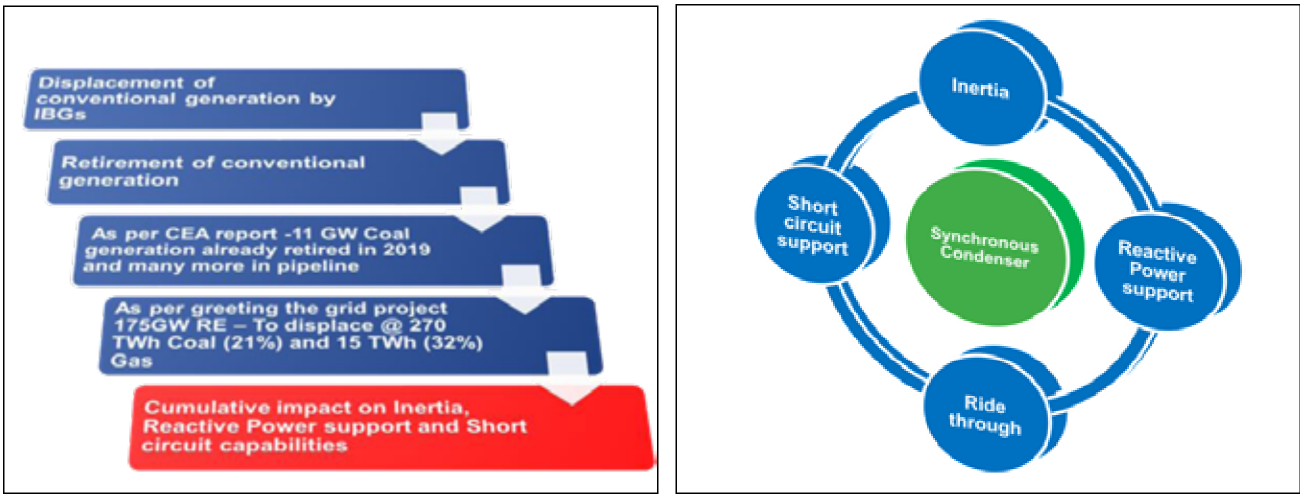


Fig. 14 : Developing scenario and solution

(iv) Ride through capabilities

(v) Excellent short circuit support means; a) increased SCR and b) Reduced risk of converter control interactions

(vi) Inherent stabilizing response

(vii) Short project cycle

(viii) Lower losses than legacy system

Accordingly, following options should be reviewed for optimum utilization.

(i) Conversion of Old /Obsolete thermal generating plants into Synchronous condensers

(ii) New installations in weaker part of the grid

(iii) New installations at IBG end as a system strength aspect

There are other technologies also to support the grid as mentioned in the roadmap.

7. GLOBAL SCENARIO

Looking to large scale RE shaping in India, many actions are being taken and many more steps are required in near future. Before taking leap forward, system dynamics are required to be studied thoroughly with advanced modelling and simulation practices (RMS as well as EMT) in deriving the system strength aspects and need thereof.

World vide RE rich TSOs has adopted many new solutions and practices in order to maintain system strength in any of the dispatch scenarios to avoid the catastrophic impact on the grid even in case of high IBG in real time dispatch.

Some of the important points are;

(i) Contracting synchronous condenser capabilities offered by existing plants

(ii) Installation of new synchronous condenser by network service providers

(iii) Retuning of inverter controller to overcome small signal instabilities

(iv) Installation of FACT devices to counter dynamic over voltage and voltage collapse

(v) Defining fault level nodes in each region

(vi) Defining minimum synchronous fault level at each node

(vii) Loss of synchronous generation support to be compensated by

- (a) Installing synchronous condensers
- (b) Contracting with generation for synchronous condenser mode operation or low load operation

viii) New IBGs must be able for successful operation at defined minimum levels or install own equipments to achieve this (i.e. “Do not harm principle”)

(ix) As a last resort to maintain power system security;

- (a) Limit Nos of online inverters at specific IBG sites
- (b) Dispatch of particular synchronous generators out of merit order

8. ROADMAP

It is clear that we are building a system where system dynamics are going to change considerably and it seems prudent to address these challenges in right manner and look forward for new opportunities emerging from this.

In this regard industry domain stakeholders have to come together on a common ground for moving ahead. Following are some of the aspects which could be a pathway for Indian power industry.

A. Grid code aspects

Following parameters should be reviewed for including in the grid code requirement.

(i) Synthetic Inertia
(ii) Weighted SCR, Effective SCR
(iii) Special requirement of Voltage Control
(iv) Voltage Control through PF & Q

B. Power system monitoring and analysis

Power system monitoring and analysis practices should be enhanced and system metrics should be developed and considered for real time system operation, outage planning, merit order dispatch as well as system planning.

(i) Deriving system Inertia and monitoring including Real time monitoring
(ii) Deriving SCR, WSCR, ESCR metric of IBG prone area including Real time monitoring
(iii) Grid code compliance metric
(iv) Scheduling considering system strength aspects
(v) Frequency reserve requirement under various dispatch scenarios
(vi) Ramping reserve requirement under various dispatch scenarios
(vii) Reactive power support requirement

C. Additional technical analysis through modelling and simulation

Present simulation and modelling practices should be enhanced and following parameters should be derived under various operating and dispatch scenarios including extreme conditions and should be considered for real time system operation, outage planning, merit order dispatch as well as system planning.

(i) ROCOF limits
(ii) Minimum fault level of synchronous generation
(iii) Key efficiency break point
(iv) SNSP (System Non synchronous Penetration) ratio
(v) Critical Inertia level
(vi) Utilization of hydro plants as synchronous condenser
(vii) Identifying weaker part of the grid and counter measures

D. New equipments or technology

Following technology (not limited to) should be promoted based on power system requirements in maintaining sufficient system strength aspects.

(i) Synchronous condenser (New installation as well as conversion of old power plants)
(ii) Grid forming inverter technologies
(iii) Grid ancillary services
(iv) FACT devices

E. Regulatory aspects

Market mechanism for following ancillary services should be developed and considered for maintaining minimum system strength aspects in RE rich future grid.

(i) Synchronous inertial services
(ii) Fast frequency response
(iii) Primary frequency response
(iv) Secondary frequency response
(v) Tertiary frequency response
(vi) Fast Ramping response
(vii) Slow Ramping response

9. CONCLUSION

Changing power system development scenario and new generation mix aspects are offering challenges at present for seamless transition to RE rich future grid with prevailing practices of system planning, operation, monitoring and simulation.

Hence, there is a need to have paradigm shift in these aspects. In this regard, roadmap proposes comprehensive multi-dimensional approach to harmonise seamless integration of planned Renewable generation in Indian grid.

Significance of new grid code parameters as reliability indices as well as utilization of them as emerging tools, system strength aspects, Inertia and SCR monitoring with typical examples of GETCO grid and roadmap are discussed in an attempt of deriving appropriate counter measures as well as system planning to operate future grid in efficient and reliable manner with sufficient system strength at any given time.

There is no any simple solution to the system strength aspects. Continuous analysis and monitoring of power system is necessary for studying and analysing the emerging needs and it is a continuous process. Here, an effort is made to support the journey of Indian power system towards greener world.

Annexure A **– Potential Difference SG & IBG**

	Relevant phenomena	Conventional synchronous generator with standard AVR and turbine governor	IBG with minimum functionalities (before interconnection requirements are evolved)	Advanced capability / Advanced feasibility of IBG (after interconnection requirements are evolved)
Rotating mass/inertia	Frequency Stability	Yes	No	Yes (prime mover dependent), but enough headroom (or unloaded synchronized capacity) is required (The use of battery energy storage could be needed depending on the type of devices). The capability might also depend on the direction of frequency deviation (over- or under-frequency). In addition, exact emulation cannot be performed[16]. See (1) above.
Frequency response capability (primary, secondary and tertiary)	Frequency Stability	Yes*	No	Yes (prime mover dependent), but enough headroom and/or upper margin need to be ensured. See (9) above.
Limited frequency sensitive mode	Frequency Stability (over-frequency)	Yes**	No	Yes (prime mover dependent). See (10) above.
Constant voltage source[17]	Voltage stability	Yes, internal induced voltage	No, if connected to the grid (inverter is synchronized to external grid frequency/phase)	Yes, but isolated system is required. Stiff voltage and stiff frequency (U-F mode) are required for inverter). Oversized IBG may be required. See (4) above.
Transmission-level voltage support (steady state)	Voltage Stability	Yes, but large capacity machines with AVR only	No	Yes (large-scale IBGs only) often with large capacity reactive power compensators such as shunt capacitor/reactor, SVC. See (5) above.
Reactive power support (V-Q control during steady state)	Voltage Stability /support	Yes, according to PQ-capability	No	Yes, but larger IBG is required or active power needs to be reduced according to PQ capability characteristics. See (13) above.

	Relevant phenomena	Conventional synchronous generator with standard AVR and turbine governor	IBG with minimum functionalities (before interconnection requirements are evolved)	Advanced capability / Advanced feasibility of IBG (after interconnection requirements are evolved)
Reactive power support (reactive current control during network incidents)	Rotor angle stability Voltage Stability	Yes	No	Yes, usually during faults IBGs may be able to provide a reactive current injection with some delay which helps keeping them grid connected, as per TSO/DSO requirements. See (13) above.
Synchronization (torque) capability[18]	Rotor angle stability	Yes	No	Yes (but almost infeasible), angle difference needs to be observed without time delay. See (6) above.
Damping torque capability (power oscillation damping capability)	Rotor angle stability	Yes, damper windings and addition of PSS	No	Yes, POD functionality. See (8) above.
Loss of synchronism	Rotor angle (transient) stability Protection	Yes	Not applicable to IBGs	See (7) above.
FRT capability	Rotor angle (transient) stability Frequency stability	Yes***	No	Yes (prime mover dependent). See (12) above.
Harmonic emission	Power quality	Low	Yes, including the frequency band dedicated to utilities for PLC based communications	See (14) above.
Harmonic voltage reduction	Power quality	Yes, for low order harmonics	Yes	Yes. See (15) above.
Short-circuit contribution in case of symmetrical and unsymmetrical faults	Protection, limit voltage decline	Yes	No	Yes, but contribution is limited to around 1 p.u., unless inverter has short-term rating to exceed 1 p.u.). See (2) above.

	Relevant phenomena	Conventional synchronous generator with standard AVR and turbine governor	IBG with minimum functionalities (before interconnection requirements are evolved)	Advanced capability / Advanced feasibility of IBG (after interconnection requirements are evolved)
Control response capability	Voltage and frequency stability	Fast, depending on the time constants involved or other external dependencies****	Inverter itself very fast (faster than generator controllers of synchronous generators), limitations possible due to measurement delay, prime mover or other external dependencies****	See (3) above.
Overload capability (up to few seconds)	misc.	Yes	Limited (nearly negligible), depending on semiconductor devices*****	Yes, but significant oversized IBGs are required. See (2) above.
Maintenance	misc.	regularly	Low for inverter itself, prime mover depending on the type	See (11) above.

* Generator with enough headroom and/or upper margin.

** Depending on rotating prime mover characteristics.

*** Generators with damper windings are for local modes of oscillations, while generators with the PSS are for inter-area modes of oscillations.

**** E.g. industrial process supplying primary energy to be converted in electricity

***** Air-cooled IGBT converters have pretty good short-term overload capability (E.g. up to 1s), while water cooled MV-connected converters have almost no short-term overload capability.

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[14] Cigre 2020 Tutorial on "System strength Aspects – A story of not enough Shepherds and too many Ships" covering following

(a) Description of system strength and its relation with inertia

(b) How lack of system strength can create issues

(c) Tools and techniques for analysing low system strength operating condition

(d) Design planning and Operational requirements under low system strength condition

(e) Current and prospective system strength solutions

BIOGRAPHICAL DETAILS OF THE AUTHORS

B. P. Soni – I/C Superintending Engineer Corporate Engineering, Obtained Graduation in Electronics Engineering from Birla Vishwakarma Mahavidyalaya, Vallabh Vidyanagar (Gujarat) in 1989. He joined erstwhile Gujarat Electricity Board (GEB) in 1990. Having total 30 years of experience in Power Generation & Transmission, he has worked in various fields e.g. Hydro and Thermal Power Plants, Operation & Maintenance of EHV Substations, Telecommunication, Protection and Automation, Substation Design and Equipment Engineering.

Presently, he is working as an In-Charge Superintending Engineer at Engineering Department, GETCO, Corporate office, Vadodara looking after all the engineering activities. A BVQI – TUV certified ISO auditor, he is a member of CIGRE and various Technical Committees of Electrotechnical Department of Bureau of Indian Standards (BIS). He was also a Technical Committee Member of CBIP for Substation Manual 2019. He has presented Technical Papers in various National & International conferences like GRIDTECH, SWITCHCON, CBIP & PowerLine events

N. M. Sheth – Executive Engineer, Corporate Engineering, Obtained Graduation in Electrical Engineering from Saurashtra University Rajkot; and Qualification of Certified Project Management Associate (Project Management Level-D, National Ranker) from International Project Management Association (IPMA). Working in GETCO since 1994. Experience in the field of Substation Operation & Maintenance as well as Commissioning.

Presently working in Engineering department and responsible for Design & Engineering of Control, Protection, Automation, schemes & Philosophies, Digital substation, Secondary engineering as well as RE integration related domains. Presented several technical papers at various national and international conferences CIGRE, GRIDTECH, CBIP, POWERLINE etc. on Relay protection, Substation Automation, Digital Substation and RE Integration challenges related matter. One of the contributor from GETCO to review Draft Grid code standards and suggesting some of the additional Technical requirement in context to RE integration challenges.

Member of distinguished organization committees like; (i) BIS Relay committee ETD 35, (ii) 35 th RAC Committee ERDA, (ii) Substation Automation Expert Group of CBIP and Cigre India (iv) R&D consortium of National Institute of Wind Energy (NIWE)

Activities of CIGRE-India - 2020-21

About CIGRE-India

CIGRE-India functions as the National Committee for CIGRE and coordinates CIGRE activities in India. It Organizes National Study Committee (NSC) meetings and Events at National Level. Affairs of CIGRE-India are administered by the General Body / Governing Council

Governing Body of CIGRE India

President – CIGRE-India

I.S. Jha
Member, CERC

Vice-Presidents

U.K. Bhattacharya
Director, NTPC

Renuka Gera
Director, BHEL

Seema Gupta
Director, Powergrid

Anil Saboo
President, IEEMA

Praveer Sinha
MD, Tata Power

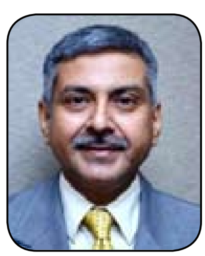
Manish Agrawal
CEO, Sterlite Power Transmission

Technical Council

Chair
R.P. Sasmal
Ex Director, POWERGRID

Joint Chair
N.N. Misra
Ex Director, NTPC

Member

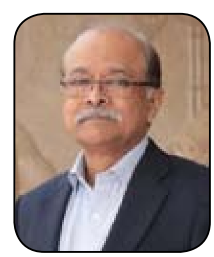


Sunil Misra
Director General, IEEMA

Secretary, CIGRE-India

A.K. Dinkar
Secretary, CBIP

Director, CIGRE-India



A.K. Bhatnagar
Director, CBIP

1. **Membership in CIGRE**
   (i) **Steering Committee Members:**
   - Mr. I S Jha Hon'ble Member, CERC in 2018-2020 & 2020-2022
   - Mr. R P Singh the then President CIGRE-India and Former CMD, POWERGRID in 2006-2008

   (ii) **Administrative Council Member:**
   Mr. I.S.Jha Member, Steering Committee, CIGRE (Paris) & Hon'ble Member, CERC

iii. Honorary Member :

- Mr. C.V.J.Verma, Former -MS, CBIP

iv. Growth of Membership :

- In the year 2016 - 593 nos. equivalent members
  (Individual: 131; Young: 24; Collective-I: 69; Collective-II: 12)
- In the year 2017 - 768 nos. equivalent members
  (Individual: 151; Young: 28; Collective-I: 91; Collective-II: 19)
- In the year 2018 - 826 nos. equivalent members
  (Individual: 169; Young: 35; Collective-I: 98; Collective-II: 17)
- In the year 2019 – 820 nos. equivalent members
  (Individual: 165; Young: 25; Collective-I: 96; Collective-II: 22; Student Member: 96)
- In the year 2020 - 800 nos. equivalent members
  (Individual: 159; Young: 22; Collective-I: 95; Collective-II: 20; Student Member: 142)

- Almost Maintained the 2018 figure of 826 members for 2019 also.
- At present India is at fifth position in the world on the basis of membership. Four countries ahead than India are: China (1061), US (958), Brazil (939) and Japan (903).
- Membership count for few more countries: German (810); Russia (790); Australia (640); U.K. (610); France (590).
- The country wise rank for nine top countries where members are maximum accessing CIGRE documents are; US; India; Germany; UK; China; Australia; brazil; Canada and Japan.

2. Participation in CIGRE Study Committee meeting at various places in the world:

- All the study committees in the year 2019 were attended by its members / representatives except SC B1on HV Insulated cables.
- List of participants in CIGRE Study Committee at various placed from India since 2016 is attached as Annexure 1.

3. CIGRE Study Committee Meetings held in the recent past, proposed in India and status of approval by CIGRE

Year	Event
2013	SC D2: Information Systems & Telecommunication
2015	SC B4: DC Systems & Power Electronics
2017	SC B1: Insulated Cables
2019	SC A1: Rotating Electrical Machines
	SC A2 : Power Transformers & Reactors SC B2 : Overhead Lines SC D1 : Materials and Emerging Test Techniques
2021 - Approved	SC B5 – Protection & Automation (Proposed Oct. 2021), Due to Shifting of Session to 2021 Likely to be shifted to Oct 2023
	SC A3 : Transmission & Distribution Equipment (planned on 15-20 Nov. 2021)
2023 - Proposed	SC B3 : Substations & Electrical Installations SC C2 : Power System Operation & Control SC C4 : Power System Technical Performance SC C5 : Electricity Markets & Regulation
2025 - Proposed	C1: Power System Development & Economics C6: Active Distribution System and Distributed Energy Resources

4. Participation in CIGRE Paris session (e session 2020 from 24th August-3rd September 2020 & Session 2021 from 20-25 August 2021)

(i) Total 240 abstracts were reviewed. Synopsis accepted – 35 Nos. out of 45 recommended Full papers submitted to Paris.

(ii) Two additional papers under Chairman Quota have also been approved one from Sterlite and another from CEA in Study Committee B2: Overhead Lines & C6: Active Distribution Systems and Distribution Energy Resources respectively.

(iii) 2020 shall be e-session because of Covid -2019. (from 24th August – 3rd Sept. 2020).

(iv) Authors have been invited to make presentations (10 Minutes time; 10 Slides), information circulated to all concerned about registration for e-session 2020.

(v) Those who will register for 2021 Paris session for them e-session for 2020 shall is free.

(vi) Only Cigre 2020 e-session, 100 Euro for members and 200 Euro for non-member is the Registration. E-session 2020 registration shall be done by HQ Paris. Last date for registration is 15 August 2020.

(vii) Information sent to exhibitors that who are already registered for Cigre 2020 shall continue to be an exhibitor for session 2021 without any additional cost

(viii) For e-session 50 Participants have already registered, so far, including Authors of papers from India.

(ix) NGN – Papers for CIGRE session 2020 :

- Out of four papers recommended from CIGRE India ,two papers from GETCO have been accepted. The authors have been recommended for consideration for free registration for 2021 Session

(x) Participation in CEO Meet at Paris during CIGRE Session 2021

The following Sr. Executives have been invited for participation from India :

Gurdeep Singh
CMD, NTPC

K. Sreekant
CMD, POWERGRID

K.V.S. Baba
CMD, POSOCO

Praveer Sinha
MD, Tata Power

Prateek Agarwal
Group CEO, Sterlite

(x) Participation in Workshop in Grid Disturbance during session 2021

The presentation received from Shri K.V.S Baba, CMD, POSOCO has been sent to Paris.

(xi) Reaction to Key note speech by India during Opening Panel during session 2021

Madam Seema Gupta, Director Power Grid has been invited from India on the "Long-Term Technical Challenges and Opportunities of the Electrification for Decarbonisation".

(xii) India Pavilion in 2021 Session: Following are participating and make payment.

Scope (12 sqm),	Paid
KEI (18 sqm);	Paid
Modern Insul. (9 Sqm)	Paid- Full
IEEMA (45 sqm)	Paid
NTPC- 18 sqm	Paid
PowerGrid – 12 sqm	Soon
Total Space 114 sqm	

- Space allotted at third floor for India Pavilion. The layout has also been received.
- CIGRE has informed about postponement of session to 2021.
- They have requested 50% payment to ensure the booth.
- All the organizations listed have made the payment except the payment from POWERGRID is under process
- We have approached POSOCO to replace BHEL for 9 sqm Space as BHEL has withdrawn their participation.

5. CIGRE-India - Women in Engineering Forum

Forum has been created under chairmanship of Madam Seem Gupta Director (Operation) Powergrid

- 1st meeting of WIE forum held on 18/10/2019 at Power Grid.
- 2nd Meeting held on 19/11/2019 at Hotel Royal Plaza. The report covered in Electra
- We plan try to ensure :

  – Participation of at least five women engineers from India in CIGRE session 2021.

  – To induct at least one women engineer as member in each of the 16 NSC.

6. NGN Forum of CIGRE India

- The forum dedicated to the young professionals.
- The aim is to provide a good opportunity for development through networking with global Young Members
- The name of Mr. Rajesh Kumar, Sr. DGM, and distinguished member CIGRE (2020) has been nominated to lead this forum of young engineers.
- We plan to induct at least one young engineer as member in each of the 16 NSC.

7. CIGRE Steering Committee Meeting at Goa in India

- The meeting planned for 17-19 Nov. 2020 was cancelled due to current pandemic.
- The steering committee proposed to visit India and have their meeting in April 2021, which was confirmed by Shri R.P. Sasmal technical Chair, CIGRE-India during above steering committee meeting.
- As already decided, a two days Colloquium on "Grid stability with enhanced penetration of Renewables" will also be planned.

8. Distinguished Membership Award of CIGRE for 2020:

The following Names as proposal have been approved by CIGRE

B.B. Chauhan
MD, GETCO

S.R. Narasimhan,
Director, POSOCO

Y.V. Joshi
SE, GETCO

Vivek Pandey
DGM, POSOCO

Dipal Shah
Ex chair, NSC B1

V.K. Agrawal
Ex. ED, POSOCO

Rajesh Kumar,
DGM, POWERGRID

9. National Representative on Study Committee for 2020-22 from India.

The proposal from India:

- The approval on the proposal from India from CIGRE, has been received. We are representing in all the 16 Committees additional seat one each in two study committees i.e. C1 & C6

Seema Gupta
Director, Powergrid
Chairperson CIGRE NSC A2

B.B. Chauhan
Former MD, GETCO
Chairman CIGRE NSC C4

K.V.S. Baba
CMD, POSOCO
Chairman CIGRE NSC C2

Subir Sen
ED, Powergrid
Chairman CIGRE NSC C1

B.N. De Bhomick
Former ED, Powergrid
Chairman CIGRE NSC C3

Anish Anand
ED, Powergrid
Chairman CIGRE NSC B2

R.K. Tyagi
ED, Powergrid
Chairman CIGRE NSC A3

Subhas Thakur
AGM, NTPC
Chairman CIGRE NSC B5

D.K. Chaturvedi
Former GM, NTPC
Chairman CIGRE NSC A1

Dr. B.P. Muni
GM, BHEL
Chairman CIGRE NSC D1

Nihar Raj
VP, Adani
Chairman CIGRE NSC B3

S.S. Misra
GM, NTPC
Chairman CIGRE NSC C6

Santanu Sen
DGM, CESC Ltd.
Co-Chairman CIGRE NSC C1

Y. B. K. Reddy
AGM, SECI
Co-Chairman
CIGRE NSC C6

S.C. Saxena
SGM, POSOCO
Chairman CIGRE
NSC C5

Anil Kumar Arora,
ED, Powergrid
Chairman CIGRE
NSC B4

Debasis De,
ED, NLDC, POSOCO
Chairman CIGRE
NSC D2

Lalit Sharma
COO, KEI
Chairman CIGRE
NSC B1

10. CIGRE fellow Award from India:

The name of Shri D.K. Chaturvedi, Chairman, NSC A1 who fulfilled the entire requirement has been approved by CIGRE

11. CIGRE Events held in India in 2020-21

- International Tutorial (Online) HVAC and HVDC Cable Systems –Advances in testing and standardization areas with relevant experiences in 23rd July 2020.
- International Tutorial (Online) Accessories for HV Cables with Extruded Insulation-24th September 2020
- International Tutorial (Online) High-Voltage On-Site Testing of Power Apparatus with Partial Discharge Measurement - 23rd October 2020
- International Tutorial (Online) Insulated Cables -Construction, Laying and Installation Techniques - 26th October 2020
- International Tutorial (Online) Global Trends & Innovation in Voltage Source Converter (VSC) Technology - 30th October 2020
- International Tutorial (Online) Guidelines for Altitude Correction of Pollution Performance of Insulators - 3rd November 2020
- International Tutorial (Online) Cable accessories workmanship of extruded HV Cable-24th November 2020
- International Tutorial (Online) Requirements for grid forming and grid following inverters in weak or isolated grids and AC side harmonics and appropriate harmonic limits for VSC HVDC- 26th -27th November 2020
- International Tutorial (Online) Application Guide for Partial Discharge (PD) Detection in GIS using UHF or Acoustic Methods-2nd December 2020
- International Tutorial (Online) Methods for Dielectric Characterization of Polymeric Insulation Materials for Outdoor Applications-12th December 2020
- International Tutorial (Online) Technology Selection and Specification of HVDC and Protection and local control of HVDC grids-17-18th December 2020

12. CIGRE-India - Events Planned

(i) CIGRE Session at Paris – 20-25 August 2021.

(ii) International Conference on Renewable integration including energy storage – 16-20 April. 2021.

(iii) CIGRE SC B5 Colloquium in India - October 2023

(iv) CIGRE SC A3 Colloquium in India - Nov. 2021

(v) CIGRE-India plan to hold minimum one event by each National Committee (tutorials /workshop/conferences) in a year at National Level.

13. CIGRE AORC

- CIGRE-India had a privilege to Chair CIGRE-AORC During 2016-18.
- Dr. Subir Sen, Executive Director of Powergrid was, Chairman of CIGRE-AORC and Mr. P.P. Wahi, Ex-Director of CIGRE-India was the Secretary and Mr. Vishan Dutt, Chief Manager of CIGRE-India was Assistant Secretary.
- CIGRE-India Conducted CIGRE-AORC Administrative Meeting at New Zealand in Sept 2017 and at Paris in August 2018. We also organized CIGRE-AORC Technical meeting at Gangtok, Sikkim, India in May 2018.

14. CIGRE India Awards

To encourage & recognize the contribution of Members, CIGRE-India has recently instituted AWARDS for excellent contribution in the activities of CIGRE at National and International Level. The following were Awarded in 2019:

Special Appreciation Awards were presented during opening session to the following for their excellent contribution in CIGRE activities at National & Intl. Level:

- Mr. I.S. Jha, Member, Steering Committee, CIGRE (Paris) & Hon'ble Member, CERC
- Ms. Seema Gupta, Chairperson, NSC A2 and Director, POWERGRID
- Mr. R.P. Sasmal Technical Chair, Former Director, POWERGRID
- Mr. N.N. Misra, Joint Chair- Technical, Former Director, NTPC
- Mr. Anish Anand, Chairman, NSC B2 and CGM, POWERGRID
- Mr. A.K. Gupta, Director, NTPC, Vice-President, CIGRE-India
- Mr. D.K. Chaturvedi, Chairman, NSC A1 and Former General Manager, NTPC

15. List of CIGRE Executives already visited India in recent past :

- Mr. Rob Stephen, President - CIGRE
- Mr. Philippe Adam, Secretary General, CIGRE
- Mr. Michel Augonnet, Vice-President Finance
- Mr. Nico Smit, Chairman CIGRE SC A1
- Mr. Peter Wiehe, Secretary CIGRE SC A1
- Mr. Simon Ryder, Chairman CIGRE SC A2
- Mr. Hiroki Ito, Chairman CIGRE SC A3
- Mr. Marco Marelli, Chairman CIGRE SC B1
- Mr. Pierre Argaut, Former Chairman SC B1
- Dr. Konstantin Papailiou, Former Chairman CIGRE SC B2
- Mr. Herbert Lugschitz, Chairman CIGRE SC B2
- Mr. Terry Krieg, Chairman CIGRE SC B3
- Dr. Mohamed Rashwan, Chairman CIGRE SC B4
- Ms. Chirstine Schwaegerl, Chairperson CIGRE SC C6
- Mr. Nikos Hatziargyriou, Former Chairman CIGRE SC C6
- Dr. Ralf Pietsch, Chairman CIGRE SC D1
- Mr. Carlos Samitier, Chairman CIGRE SC D2
- Ms. Khayakazi Dioka, Chairperson of CIGRE WiE International

16. Publication of half yearly CIGRE India Journal

To increase the activities and membership CIGRE India has taken the initiative to publish its Journal initially with the frequency of six months. The issues of the Journal up to Dec. 2012 have already been published and the next Issue July 2013 is under print.

The CIGRE India journal contains details about the activities of the association, technical articles, and data and is circulated to its members within the country. The journal serves an excellent purpose of disseminating the technological, innovative developments etc. amongst the concerned organizations of the energy sector, which are taking place at the national and international level. The journal is available both in print and online versions.

17. New Initiatives

Online programme to overcome the effect of COVID 2019

CIGRE India launched series of online International Tutorials throughout the year @ each of the Studty Committee of CIGRE.

Online Programme Held in:

- SC B1 : on Insulated cables;
- SC B4 : DC Links and Power electronics;
- SC C1 : Power system development and economics
- SC D1 – Materials & Emerging test Techniques.

Online Programme planned :

- SC B2: Overhead lines
- SC C2: Power system operation and control
- SC C1: Power system development and economics
- SC C4: Power system technical performance
- SC D2: Information systems and telecommunication

Acknowledgement of support of CIGRE

CIGRE India acknowledges the support and guidance extended by CIGRE, which has helped CIGRE-India in increasing the activities of CIGRE in India.

Participation in CIGRE Study Committee Meetings Since 2016

Study Committee (SC)		2016 - at Paris in August 2026	2017		2018 - at Paris in August 2018	2019	
			Date & Venue	Participants		Date & Venue	Participants
1	**A1: Rotating Machine**	Mr. D.K. Chaturvedi, NTPC	18-23 Sept.17 Vienna, Austria	Mr. D.K. Chaturvedi, NTPC	Mr. D.K. Chaturvedi, NTPC Mr. N.N. Misra, CIGRE India	24 Sept. 2019 New Delhi	Mr. D.K. Chaturvedi NTPC
2	**A2 : Transformers**	Ms. Tanavi Srivastava, Alstom	29 Sept. to 6th Oct. 2017 Poland	Mr. B.N. De Bhowmick	Mr. Selvakumar P. Victor, PG	19th Nov. 2019 New Delhi	Ms. Seema Gupta, POWERGRID
3	**A3 : High Voltage Equipment**	Mr. N.N. Misra, CIGRE-India	30 Sept. – 6th Oct. 2017 Canada	R.K. Tyagi, PG	Mr. N.N. Misra and Mr. R.P. Sasmal CIGRE -India	7-13 Sept. 2019 Bucharest Romania	Mr. R.K. Tyagi, PG and Mr. Rakesh Kumar, PG
4.	**B1 : HV Insulated Cables**	Mr. Dipal Shah, Pfistrer	9-13 Oct. 2017 India	Mr. Dipal Shah	Mr. Lalit Sharma, KEI and Mr. Dipal Shah	9th Sept. 2019 (Denmark)	**NIL**
5	**B2 : Overhead Lines**	Mr. Gopal Ji, POWERGRID	29-30 May 2017 Dublin, Ireland	Prof. C. Johnson Excel Engg. college	Mr. A..K. Vyas, PG	19 Nov. 2019 New Delhi	Mr. Anish Anand, PG
6	**B3 : Substations**	Mr. Abhay Choudhary, POWERGRID	Sept. 2017 Brazil	Mr. Rajil Srivastava, PG	Mr. R.P. Sasmal, CIGRE-India and Mr. Rakesh Kumar,	20-25 Sept. 2019 China	Mr. Raji Srivastava, PG & Mr. Abhay Kumar, PG
7	**B4 : HVDC Link and AC Power Electronic Equipment**	Shri R.K. Chauhan, PowerGrid	30 Sept. – 6th Oct. 2017 Canada	Shri R.K. Chauhan PG	**Nil** ~~Mr. Rakesh Kumar~~	28-30th Sept 19, 1-5th Oct 2019- South Africa	Mr. R.K. Chauhan, Dir, PG and Mr. B.B. Mukharjee, PG
8	**B5 : Power System Protection and Local Control**	Mr. Subhash Thakur NTPC	Sept. 2017 New Zealand --	Mr. Subhash Thakur NTPC	Mr. Subhash Thakur	24-28th June 19 Norway	Mr. Abhishek Khanna, Mr. Debashish Dutta, Mr. Anand Pandey, NTPC
9	**C1 : Power System Planning and Development**	Ms. Seema Gupta, PowerGrid	May 2017 Dublin, Ireland	Mr. K.V.S. Baba, POSOCO	Mr. R.K. Verma and Mr. R.P. Sasmal, CIGRE -India	20-26th Sept. 2019 Chengdu, China	Ms. Seema Gupta, POWERGRID and Mr. Ashok Pal, PG
10	**C2 : Power System Operation and Control**	K.V.S. Baba POSOCO	May 2017 Dublin, Ireland	Mr. K.V.S. Baba, POSOCO	Mr. P.K. Agarwal	4-7th June 2019 Aalborg, Denmark	Mr. KVS Baba, POSOCO
11	**C3 : System Environmental Performance**	**Nil**	Sept. 2017 Seoul, Korea	Mr. K.V.S. Baba, POSOCO	**Nil** ~~Mr. Anil Jain, PG~~	4-7th June 2019 Aalborg, Denmark	Mr. B.N. De Bhowmick, PG
12	**C4 : System Technical Performance**	Mr. N.M. Seth, GETCO	May 2017 Dublin, Ireland	Mr. K.V.S. Baba, POSOCO	Mr. Selvakumar P. Victor,	4-7th June 2019 Aalborg, Denmark	Mr. B.B. Chauhan, GETCO
13	**C5 : Electricity Markets and Regulation**	K.V.S. Baba, POSOCO	May 2017 Dublin, Ireland	Mr. S.C. Saxena, POSOCO	Mr. P.K. Agarwal	16-19th Sept19 Canada	Mr. P.K. Agarwal, POSOCO
14	**C6 : Distribution Systems and Dispersed Generation**	Dr. Subir Sen, POWERGRID	May 2017 Dublin, Ireland	Mr. S.C. Saxena POSOCO	**Nil** ~~Dr. Subir Sen, PG~~	(3-6 June 2019) Aalborg, Denmark	Dr, Subir Sen, PG and Mr. Rajesh Kumar, PG
15	**D1 : Material for Electro technology**	Mr. Jithinsunder, BHEL	30 Sept. – 6th Oct. 2017 Canada	**Nil**	Mr. Jithinsunder, BHEL	18-23 Nov. 2019 New Delhi	Mr. B.P.Muni, BHEL
16	**D2 : Information Systems & Telecommunications for System**	N.S. Sodha, PowerGrid	20-22/09/2017 Moscow	Mr. N.S. Sodha	Mr. N.S. Sodha	11-14th June 2019 Helsinki, Finland	Mr. N.S. Sodha

CIGRE India - Women in Engineering (WiE)

A. 18TH OCTOBER 2019: BRAINSTORMING SESSION ON WIE-CIGRE INDIA

CIGRE India has launched its first "Women in engineering Forum" on 18th October 2019 at national level. The event was hosted in association with POWERGRID at its corporate office, Gurgaon. The objective of the event was to introduce CIGRE Women in Engineering forum, highlighting the contribution of women in CIGRE structure and to enable its members with knowledge transfer and networking. Participants from various organisations across INDIA such as NTPC, NHPC, POWERGRID, Sterlite, SJVN, POSOCO, KEC, L&T, NEEPCO, Siemens, TPDDL, WAPCOS, BYPL, KEI etc. has made the event remarkable.

Ms. Seema Gupta, Vice President, CIGRE-India and Director (Operation) POWERGRID has led the brain storming session of WIE forum as its Chairperson. Besides Mr. I.S. Jha, President CIGRE-India & Hon'ble Member, CERC, Mr. R.P. Sasmal, Technical Chair, CIGRE-India, Mr. K. Srikant, CMD, POWERGRID, Mr. R.K. Chauhan, Director (Projects), POWERGRID, Mr. V.K. Kanjlia, Secretary, CIGRE India and Mr. P.P. Wahi, Director, CIGRE-India addressed the participants.

The theme of the event was "To inspire and empower women as leaders in engineering and technology." Ms Seema Gupta introduced the participants about CIGRE WIE forum who is taking initiatives to grow women engineers and providing a platform to submit technical papers, attending workshops, technical discussions and getting mentored by experienced professionals. She presented about various study committees & working group of CIGRE- INDIA and activities to participate and get benefitted from them. She talked about women empowerment and challenges women's usually face in a technical field and provide solutions to deal with these problems.

An open house session was organised and women from various organisations shared challenges faced during their respective works and their experiences in dealing with them. The event was concluded by proposing recommendation to take full advantage of CIGRE forum and professional network of Women in Engineering was formed to connect, to interact, to share experiences in future.

B. 19TH NOVEMBER 2019: MEETING OF CIGRE INDIA WOMEN IN ENGINEERING FORUM

CIGRE – INDIA organised a meeting of Women in Engineering Forum on 19th November 2019 at New-Delhi. The agenda of the meeting was to inspire women engineers to come forward, interact, develop skills and improve their participation in the engineering domain. Ms. Seema Gupta, Chairperson, CIGRE- India WiE Forum had addressed the participants and spoke about women empowerment. Ms. Khayakazi Doika, Global Chairperson for CIGRE Women in Engineering has presented a session on the initiatives CIGRE WiE is taking for encouraging women professionals to break the conventional barriers.

Ms. Tara Lee (Australia) was the moderator of the Session. Ms. Rachana Garg - IEEE India WiE Vice Chair had raised the concern about the challenges women's face in technical field. Several Ex-CIGRE members share their experience and views that by being a member of CIGRE committee and part of its Working Group, it's an honour and opportunity to learn about technological advancement by connecting to global knowledge partners in Power System. The meeting was concluded with remarks of creating awareness across INDIA to inspire and empower more women to become part of this professional network.

Series of International Tutorial (Virtual) Organize by CIGRE-India in the Recent Past

CIGRE-India is one amongst the most active national committee. It is our honor that Mr. I.S. Jha, President CIGRE-India & Hon'ble Member of Central Electricity Regulatory Commission is representing India in CIGRE Steering Committee (the decision making body of top executives) as well as in CIGRE Administrative Council.

It is a matter of pride for all of us that India is represented in all the 16 CIGRE Study Committees and the members are actively involved in the activities of CIGRE study Committees.

It has always been our endeavor to promote CIGRE in India through its activities like organization of regular Training programmers/ Conferences/ Workshops/ Tutorials etc., which has greatly helped involvement of maximum professionals with CIGRE – India including young professionals.

In this unusual situation in the past where skill enhancement and training of professionals emerged as an important aspect and a challenge, CIGRE- India launched series of virtual Tutorials/ Workshops/ Webinars on the subject relevant to 16 CIGRE Study Committees

The tutorial organized in the past are listed below:

International Tutorial (Online)

HVAC and HVDC Cable Systems - Advances in Testing Procedures and Standardization Areas with Relevant Experiences

(Under the aegis of CIGRE National Study Committee B1 on Insulated Cables)

23rd July 2020

Number of Total Participants : 145

International Speaker from CIGRE

Dr. Vercellotti Uberto
Italy

National Study Committee Chairman-B1

Mr. Lalit Sharma
COO, KEI

International Tutorial (Online)

Accessories for HV Cables with Extruded Insulation

(Under the aegis of CIGRE National Study Committee B1 on Insulated Cables)

24th September 2020

Number of Total Participants : 136

International Speaker from CIGRE

Mr. Geir Clasen
Norway, Convener, CIGRE SC B1, TAG

National Study Committee Chairman-B1

Mr. Lalit Sharma
COO, KEI

TAKEAWAY

- Compatibility of materials.
- Metallic screen bonding requirement & earth currents.
- Environmental protection/mechanical forces / climatic condition.
- Type, routine and after lying testing /Quality Assurance Schemes.
- Maintenance of accessories.
- Cost considerations.

International Tutorial (Online)

High-Voltage On-Site Testing with Partial Discharge Measurement

(Under the aegis of CIGRE National Study Committee D1 on)

23rd October 2020

Number of Total Participants : 118

International Speaker from CIGRE

Mr. Ralf Pietsch
Germany, Chairman, SCD1

National Study Committee Chairman-D1

Dr. B P Muni
General Manager, BHEL

TAKEAWAYS

HV sources and accessories for on-site applications:

- AC, DAC (Damped AC voltage), VLF (Very-low frequency)
- HV filter, coupling capacitors, connections and grounding

On-site PD measurement:

- Conventional PD measurement
- Non-conventional electromagnetic PD detection
- Noise reduction
- Acoustic PD detection

- Important aspects for PD evaluation

Preconditions for on-site testing including PD measurement

Examples of test and measuring techniques for apparatus and systems :

- GIS /GIL (2 examples)
- Cable systems (5 examples)
- Rotating machines (3 examples)
- Power Transformers (4 examples)

International Tutorial (Online)

Insulated Cables - Construction, Laying and Installation Techniques

(Under the aegis of CIGRE National Study Committee B1 on Insulated Cables)

26th October 2020

Number of Total Participants : 40

International Speaker from CIGRE

Mr. Sergio Chinosi
Italy

National Study Committee Chairman-B1

Mr. Lalit Sharma
COO, KEI

TAKEAWAYS

- Description of the cable System
- Innovation, Construction & Installation Techniques
- Cable laying and Installation techniques

International Tutorial (Online)

Global Trends & Innovation in Voltage Source Converter (VSC) Technology

(Under the aegis of CIGRE National Study Committee B4 on DC Links and Power Electronics)

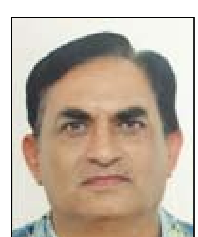
30th October 2020

Number of Total Participants : 80

International Speaker from CIGRE

Mr. Les Brand
Australia

National Study Committee Chairman-B4



Mr. Anil Kumar Arora
ED, POWER GRID

TAKEAWAYS

- Introduce both VSC and LCC technologies, explain how they work, summarise their history and development, and provide a comparison of the two, including which applications are suited to each and why.
- Focus on VSC – describing the key components, the formula that govern their operation, overall control philosophy and available control modes in operation. The various VSC technologies and topologies will be described, compared and contrasted and the key and defining characteristics of VSC technology summarised.
- Discuss the challenges in using VSC technology with overhead DC lines will be presented and explored.
- Include a couple of case studies of VSC applications – why VSC was chosen, key elements of design and operation and how they have performed since commissioning.
- Conclude with a summary of recent developments in VSC technology and what innovations are currently being explored globally.

International Tutorial (Online)

Guidelines for Altitude Correction of Pollution Performance of Insulators

(Under the aegis of CIGRE National Study Committee D1 on Material and Emerging Test Techniques)

Number of Total Participants : 50

03rd November 2020

International Speaker from CIGRE

Mr. Igor Gutman
Russia

National Study Committee Chairman-D1

Dr. B P Muni
General Manager, BHEL

TAKEAWAYS

Physical principles related to the influence of air density on the discharge process:

- Clean conditions
- Polluted conditions

Status of correction on altitude in IEC/CIGRE:

- AC
- DC

Collection and analysis of all available data on flashover voltages of polluted insulators:

- Different altitude from sea level to 6000m
- Covering the period of publications 1987-2010

Practical proposals for harmonization of the correction of the required creepage distance for altitude:

- AC
- DC

International Tutorial (Online)
Cable Accessories Workmanship of Extruded HV Cable
(Under the aegis of CIGRE National Study Committee B1 on Insulated Cables)

24th November 2020

Number of Total Participants : 60

International Speaker from CIGRE

Mr. Kieron Leeburn,
South Africa, CIGRE Convener, TB 476

National Study Committee Chairman-B1

Mr. Lalit Sharma
COO, KEI

TAKEAWAYS

- Technical risks for components.
- Set up of jointing / installation activities.
- Assessment of skills for jointers.

International Tutorial (Online)
Requirements for Grid Forming and Grid following Inverters in weak or isolated Grids and AC side Harmonics and Appropriate Harmonic Limits for VSC HVDC
(Under the aegis of CIGRE National Study Committee B4 on DC Links and Power Electronics)

26-27 November 2020

Number of Total Participants : 30

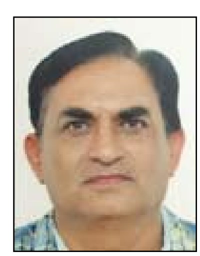
International Speaker from CIGRE

Dr. Chandana Karawita
Canada, Sectetary, WG-B4 87

Dr. Hiranya Suriyaarachchi
Canada, Converner

Dr. Nigel Shore
Sweden

National Study Committee Chairman-B4



Mr. Anil Kumar Arora
ED, POWER GRID

TAKEAWAYS

Day-1

The capabilities of the inverters currently used in renewable energy sources and HVDC systems may not be adequate for the grids with a small percentage or no synchronous generators. For more than a century, synchronous generators have been successfully operated in power systems. This tutorial will first evaluate the contributions from the synchronous generators in terms of voltage, inertia and frequency support and define the requirements for the grid-forming and grid-following inverters. The current capabilities and future expectations will be evaluated using example simulation cases.

Day-2

This tutorial presents the work of Working Group B4.68, which produced TB 754. This Technical Brochure examines the harmonic aspects of voltage source converters used for HVDC transmission. The harmonic profile of such converters differs greatly from that of the more established line commutated converters. The low magnitude of harmonic generation may imply that AC filters are not needed, or may be very small. The control system factors affecting both harmonic generation and the active internal impedance are examined. Possible deleterious effects of higher frequencies, inter-harmonics and even order harmonics are discussed, and recommendations given regarding statutory limitations. Mitigation of harmonics by means of either passive filtering or active filtering by converter control action is described. The Brochure explains various techniques for modelling the harmonic behaviour of VSC HVDC, and concludes with a review of harmonic stability issues and various techniques used to identify the risk of its occurrence and to indicate means of mitigation.

International Tutorial (Online)

Application Guide for Partial Discharge (PD) Detection in GIS using UHF or Acoustic Methods

(Under the aegis of CIGRE National Study Committee D1 on Material and Emerging Test Techniques)

2nd December 2020

Number of Total Participants : 80

International Speaker from CIGRE

Dr. Uwe Schichler
Germany, Convener, AGD1-03

National Study Committee Chairman-D1

Dr. B P Muni
General Manager, BHEL

TAKEAWAYS

Gas-insulated switchgear (GIS) have been in operation for more than 45 years and it shows a high level of reliability. However, the return of experience from GIS indicates that some of the in-service failures are related to defects in the insulation system. Many of these defects can be detected by partial discharge (PD) diagnostics. An Electra Report published in 1999 describes the two-step procedure for the sensitivity verification of the UHF and acoustic system. The CIGRE Technical Brochure No. 654 collects the available experience on sensitivity verification from the last 15 years and describes its practical applications for GIS. It summarizes the established guidelines and recommendations which will help manufacturers and users in the effective application of the UHF method for PD detection on GIS. In addition general guidelines on the acoustic method for PD detection will be presented.

International Tutorial (Online)

Methods for Dielectric Characterization of Polymeric Insulation Materials for Outdoor Applications

(Under the aegis of CIGRE National Study Committee D1 on Material and Emerging Test Techniques)

12th December 2020

Number of Total Participants : 25

International Speaker from CIGRE

Dr. Jens Seifert
Germany, Convener WG

National Study Committee Chairman-D1

Dr. B P Muni
General Manager, BHEL

TAKEAWAYS

- General Insight on Dielectric Diagnostic Methods (DDM)
- Understanding the Physical Background and Polarization Mechanisms
- Applications of DDM to Composite Insulating Materials
- Development of the Recommended Test Techniques
- Round Robin Testing
- The Importance of Standardization of Method and Equipment
- Lessons Learned
- Outlook to Applications for Insulation Systems in HV Equipment

  Secretary WG D1-56

International Tutorial (Online)

Technology Selection and Specification of HVDC & Protection and Local Control of HVDC Grids

(Under the aegis of CIGRE National Study Committee B4 on DC Systems & Power Electronics)

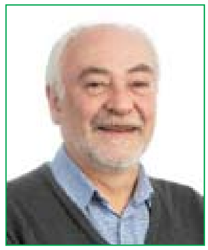
17-18th December 2020

Number of Total Participants : 25

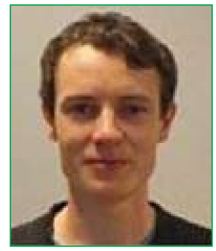
International Speaker from CIGRE

NSC - Chairman - B4

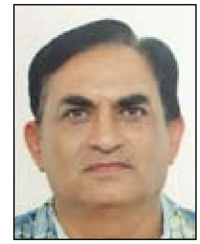
Mr. Bruno Bisewski
Canada



Mr. Kees Koreman
Netherlands, Chairman
JWG B4/B5-59



Mr. Willem Leterme
Belgium



Mr. A K Arora
ED, Powergrid

TAKEAWAYS

Day - 1

The key factors that the participant will take away from the tutorial is an understanding of the many considerations encountered when planning and specifying an HVDC system that will meet the requirements of the project. The material presented is based on long time experience on many projects in many countries will cover practical questions encountered while planning a new HVDC project including technology selection, cost, footprint, losses, maximum rating, and fault recovery performance that may be decisive in the selection of one technology as well as other factors which may not be decisive but could still influence the decision in favour of one technology over the other. The tutorial will also cover selected topics related to specification of both LCC and VSC technology including ratings, performance requirements and testing.

Day - 2

The webinar will inform the participants about protection and local control systems in HVDC grids. First, the fault response of converters with and without fault blocking capability is compared. Then, various strategies for clearing DC-side faults are discussed. Examples of short circuit calculations examples are given for both monopole and bipole HVDC grids. Thereafter, various principles in fault detection and localisation are explained and compared. Finally, the basic operation of DC Circuit Breakers is described.

Participants will get:

- Information about the different HVDC converter technologies.
- Short circuit phenomena in DC grids.
- Basic requirements on protection and local control.
- Fault clearance strategies.
- Protection system components such as measurement and detection systems.
- DC Circuit Breakers and fault localisation techniques.

The obtained knowledge can be used in the future development, engineering, design and operation of meshed DC networks, both offshore and onshore. It will allow for the design of protection systems including the selection of fault clearance strategies that will be applied.

CIGRE Members from India in 2020
(As on December 2020)

Summary of Membership

	Collective-1 (Organisation)	Collective-2 (Regulatory & Institution)	Individual-1	Young (below 35 years of age)	Student Members
	95	20	159	22	142
Total equivalent	x 06	x03	x01	x0.5	
	570	60	159	11	
Grand Total	**800**				**142**

INSTITUTIONAL MEMBERS

S. No.	Organisation
1	Andhra Pradesh Electricity Regulatory Commission
2	Bihar Electricity Regulatory Commission
3	Central Electricity Regulatory Commission
4	CIGRE INDIA- COE,Centre of Excellence
5	Delhi Electricity Regulatory Commission
6	Electrical Research and Development Association
7	Engineering College Banswara-Rajasthan
8	Gujarat Electricity Regulatory Commission
9	H P Electricity Regulatory Commission
10	IEEMA
11	Indian Inst. of Technology Kanpur
12	Indian Institute of Technology Bombay
13	Jharkhand State Electricity Reg. Comm.
14	Joint Electricity Reg. Com.-for Goa &Uts
15	Malaviya National Inst. of Tech.- Jaipur
16	Maharashtra Electricity Regulatory Comm.
17	Punjab State Electricity Regulatory Commission
18	Ramelex Testing & Research Institute
19	Uttarakhand Elec. Regul. Commission
20	U.P. Electricity Regulatory Commission

INDIVIDUAL MEMBERS

S. No.	Name	Organisation
1	ABB	Urmil Parikh
2	ABB Global Industries & Services Ltd.	Sachin Srivastava
3	ABB India Ltd.	Nihar Raj
4	Adani Electricity Mumbai Limited - Trans	Arvind Kumar Sharma
5	Adani Power Maharashtra Ltd.	Niraj Agrawal
6	Adishaktyai- India	Neeraj Khare
7	Aditya Birla Insulators	Harleen Singh
8	Aditya Birla Insulators	Sanjeev Sachdev
9	Alfa Consultants	Ramesh Dattaraya Suryavanshi
10	Anna University	Usa Savadamuthu
11	Apar Industries Ltd.	Srimanta Kumar Jana
12	AVAADA Power	Deepak Kumar Saxena
13	Bechtel (I) Pvt. Ltd.	Sanjeev Bhatia
14	BHEL Corporate R & D	Mohana Rao Mandava
15	CBIP	V K Kanjlia
16	Consultant	Narendra Nath Misra
17	Consultant	Virendra Kumar Lakhiani
18	Consultant	N S Sodha
19	Consultant	R P Sasmal
20	Consultant	Dhananjay Kumar Chaturvedi
21	Consultant	Sanjay Patki
22	Consultant	Pramod Rao

23	Consultant	Subhash Sethi
24	Consultant	Gopal Ji
25	Consultant	Krishnan S. Balasubramanian
26	Consultant	Lokesh Thakur
27	CTR Manufacturing Industries Ltd.	T P Govindan
28	CTR Manufacturing Industries Ltd.	Vijaykumar Wakchaure
29	CTR Manufacturing Industries Ltd.	Ravindra Vishnu Talegaonkar
30	Central Power Research Institute	Dr. Burjupati Nageshwar Rao
31	Central Electricity Regulatory Commission	Indu Shekhar Jha
32	Damodar Valley Corporation	Abhijit Chakraborty
33	Deccan	Vikas Jalan
34	DNV-KEMA	Ravi Kumar Puzhankara
35	DTL	Rajesh Kumar Arora
36	DVC	Sudipta Maiti
37	DVC	Arindam Das
38	Erode Sengunthar Engineering College	K. Singaram Christian Johnson
39	FEEM	Deepak Kumar Singh
40	Free Lance	Hosalli Bhashyam Mukund
41	GE Grid Solution (GE T&D India Ltd.)	Purshottam Kalky
42	GE T&D India Ltd.	Madhu Sudan
43	GE T&D India Ltd.	Vikrant Joshi
44	General Electric	Nitin Kumar Srivastava
45	General Electric T&D India	Narendra Sharma
46	Govt. of Tamil Nadu	K.C. Yoganandham Y. Kumaresan
47	GETCO	Pankajbhai Suthar
48	GETCO	Ashokkumar J. Chavda
49	GETCO	Jalpesh Trivedi
50	GETCO	Zulfikarali M Vijapura
51	GETCO	Vinay Rathod
52	GETCO	Bhasmang N. Trivedi

53	GETCO	Bhadreshkumar B. Mehta
54	GETCO	Nilesh Sheth
55	GETCO	Rameshchandra P. Satani
56	GETCO	Bankim Pravinchandra Soni
57	GETCO	Dipak kumar Patel
58	GETCO	Chetan G Thakkar
59	GETCO	Bhadresh B. Chauhan
60	GETCO	Yogesh Vishnu Joshi
61	GETCO	Asha M Agravatt
62	GETCO	Bhavesh Bachubhai Ahir
63	GETCO	Arjunbhai B. Rathod
64	GETCO	Kantilal M Chhaiya
65	Hindalco	Kaushik Tarafdar
66	IIT-Bombay	Himanshu Bahirat
67	India Infrastructure Publishing Limited	Anchal Pahwa
68	Indian Institute of Science	Joy Thomas Meledath
69	Indian Institute of Science	Udaya Kumar
70	Indolite Devices Pvt. Ltd.	Maninderjit Singh Sethi
71	IRADE	Vinod Kumar Agarwal
72	ITER-India, Institute for Plasma Res.	Bhavin Raval
73	J&K Power Development Department	Habib Chowdhary
74	Jacobs	Sanjib Mishra
75	Kalpataru Power Trans. Ltd	Pervinder Singh Chowdhry
76	Kalpataru Power Trans. Ltd	Milind Nene
77	KEI Industries Ltd	Lalit Sharma
78	KEC International Limited	Sunil Bhanot
79	M.P. Power Transmission Co. Ltd	K. Kamlesh Murty
80	Laxmi Associates	Aradhana Ray
81	Mahati Industries Pvt. Ltd.	Udaybabu Ratanchand Shah

82	Megawin Switchgear (P.) Ltd.	Muthuraj Ramaswamy
83	Modern Insulators Limited	Ram Kumar Vaithilingam
84	National Inst. of Technology Karnataka	I R Rao
85	NEEPCO	Angelica Pohshna
86	NHPC	Ravindra Sharma
87	North East Transmission Company Ltd.	Satyajit Ganguly
88	NTPC Ltd.	Nagesh Kondra
89	ONGC Tripura	Sanil Namboodiripad
90	Oman Transformers India Limited	Oommen P Joshua
91	Persotech Solutions	Pravinchandra Mehta
92	Polycab Wires Pvt. Ltd.	Tony Martens
93	POSOCO	Chitrankshi Ghangrekar
94	POSOCO	SUBHENDU MUKHERJEE
95	POSOCO	Santosh Kumar Jain
96	POSOCO	K V S Baba
97	POSOCO	Vivek Pandey
98	POSOCO	Aditya Prasad Das
99	POSOCO	Rajiv Kumar Porwal
100	POSOCO	S.R. Narasimhan
101	POSOCO	Samir Chandra Saxena
102	POSOCO	Praveen Kumar Agarwal
103	POSOCO	M. Venkateshan
104	POSOCO	Sajan George
105	Power Grid	Subhash C Taneja
106	Power Grid	Gyaneshwar Payasi
107	Power Grid	Rajeev Kumar Chauhan
108	Power Grid	Subir Sen
109	Power Grid	Seema Gupta
110	Power Grid	Arun Kumar Mishra
111	Power Grid	B N De Bhowmick
112	Power Grid	Biswajit Bandhu Mukherjee
113	Power Grid	Rajesh Kumar
114	Power Grid	Anish Anand
115	Power Grid	Nitesh Kumar
116	Power Grid	Dr. Sunita Chohan
117	Power Grid	Anil Kumar Arora
118	Power Grid	Ashok Pal
119	Power Grid	Shouvik Bhattacharya
120	Power Grid	Soni Tunisha
121	Power Grid	Deepa S Kumar
122	Power Grid	Sangita Sarkar
123	Power Grid	Vineeta Agarwal
124	Power Grid	Ram Naresh Singh
125	Power Grid	Chandra Kant
126	Power Grid	Rashmi Pant Joshi
127	Power Grid	Sukdev Bal
128	Power Trans.Corp. of Uttarakhand Ltd.	Lalit Kumar
129	Power Transmission RNT Consultants	Renu Singhal
130	Primemeiden Limited	Vijayakumaran Moorkath
131	Protection Engg. & Researh Laboratories	Pradeep Kumar Gangadharan
132	Prysmian Cable SYS.	Alwin Selva Paul Yesudass
133	Rajasthan Test & Research Centre	Jaspaul Kalra
134	Raj Petro Specialities Pvt Ltd	Sushil Chaudhari
135	Raj Petro Specialities Pvt Ltd	Dr. Daya Shankar Shukla
136	Raj Petro Specialities Pvt Ltd	Baburao Keshawatkar
137	REVEN-TEC	Niraj Kulkarni
138	SIEMENS Ltd	Jayasenan Chinnathambi
139	SJVN Ltd.	Rashi Tyagi
140	Sleepwalkers	Sivaji Burada
141	Sterlite Power Transmission Ltd.	Parantap Krishna Raha
142	Sterlite Power	Deepak Lakhapati
143	Sterlite Power Grid Ventures Ltd	Rajesh Suri
144	Syselec Technologie Private Limited	Hrushaabh Prashaant Mishra
145	Torrent	Bipin B. Shah

146	TAG Corporation	Vivek Thiruvenkatachari
147	Takalkar Powerr Engin&Consult. Pvt Ltd	Subhash Chandra Takalkar
148	Tata Power Skill Development	Umesh Maharaja
149	Taurus Powertronics Pvt. Ltd.	Narasimhan Ravinarayan MAKARAM
150	Technical Associates	Vishnu Agarwal
151	Telawne Cromptek Electricals Pvt. Ltd.	Yogesh Telawne
152	The Tata Power Co. Ltd.	Rajendra Vinayak Saraf
153	TS Transco	Arogya Raju Pudhota
154	UPPTCL	Suman Guchh
155	WAPCOS Ltd.	Hillol Biswas
156	Ziv Automation India Pvt Ltd	R C Anand
157	ZTT cable	Deepal Shah

ORGANISATIONAL MEMBERS

Sl. No.	Organisation
1	Adani Electricity Mumbai Limited - Tran.
2	APAR Industries Limited
3	Atlanta Electricals Pvt.Ltd.
4	ABB Power Products and Systems (I) Ltd.
5	Bhakra Beas Management Board (BBMB)
6	BAJAJ ELECTRICALS LTD.
7	Bharat Heavy Electricals Ltd, Hyderabad
8	Bharat Heavy Electricals Ltd., Noida
9	Bharat Heavy Electricals Ltd., Haridwar
10	Bharat Heavy Electricals Ltd., Bhopal
11	Bharat Heavy Electricals Ltd., Bangalore
12	Central Electricity Authority (CEA)
13	Central Power Research Institute
14	CESC Limited
15	CTR Manufacturing Industries Ltd.
16	CTC Global India Pvt. Ltd.
17	Delhi Metro Rail Corporation Ltd.
18	Easun-Mr Tap Changers (P) Limited
19	Gupta Power Infrastructure Limited
20	KEI Industries Ltd.
21	KSE Electricals Pvt Ltd.
22	Larsen & Toubro Limited- Construction
23	LS Cable India Pvt. Ltd.
24	Larsen & Toubro Limited- Construction
25	National High Power Test Lab. Pvt. Ltd.
26	NHDC Ltd.
27	NLC India Limited
28	NHPC Limited
29	North Eastern Electric Power Corp. Ltd
30	NTPC Limited, H.Q
31	NTPC Limited, Anta GPS
32	NTPC Limited, Auraiya
33	NTPC Limited, Bongaigaon TPP
34	NTPC Limited, Barh
35	NTPC Limited, Dadri SSTP
36	NTPC Limited, Faridabad
37	NTPC Limited, Farakka STP
38	NTPC Limited, Jhanor
39	NTPC Limited, Kudgi STPS
40	NTPC Limited, Kahalgaon STPS
41	NTPC Limited, Kawas GPP
42	NTPC Limited, Korba STPS
43	NTPC Limited - Koldam
44	NTPC Limited - Kayamkulam
45	NTPC Limited, Mouda STPP
46	NTPC Limited, Rihand STPP
47	NTPC Limited, Ramagundam STPS
48	NTPC Sail Power Company Pvt. Ltd.
49	NTPC Limited, Singrauli STPS
50	NTPC Limited, Simhadri STPP
51	NTPC Limited, SIPAT STPS
52	NTPC Limited, Talcher STPS
53	NTPC Limited, Talcher TPS
54	NTPC Limited, Tanda
55	NTPC Limited, Unchahar
56	NTPC Limited, Vindhyachal STPS
57	ONGC Tripura Power Company Ltd.
58	Olectra Greentech Ltd.
59	Polycab Wires Pvt. Ltd.

60	Power Research & Develop. Cons. Pvt. Ltd
61	POSOCO- ERLDC
62	POSOCO- NERLDC
63	POSOCO- H.Q.
64	POSOCO- SRLDC
65	POSOCO- WRLDC
66	Powergrid Corp. of India Ltd, Lucknow
67	Powergrid Corp. of India Ltd, Shillong
68	Powergrid Corp. of India Ltd.,Jammu
69	Powergrid Corp. of India Ltd., Delhi
70	Powergrid Corp. of India Ltd-Orissa
71	Powergrid Corp. of India Ltd-Nagpur
72	Powergrid Corporation of India, H.Q.
73	Powergrid Corporation of India, Bangalore
74	Powergrid Corporation of India, Kurukshetra
75	Powergrid Corporation of India, Secunderabad
76	Powergrid Corporation of India, Patna
77	Powergrid Corporation of India, Vadodara
78	Powergrid Corporation of India, WRTS-1
79	Powergrid Corporation of India, Kolkata
80	Powergrid Corporation of India, Guwahati
81	Siemens Ltd, EM TS
82	Sterlite Power Transmission Limited
83	Savita Oil Technologies Ltd.
84	SJVN Limited
85	Solar Energy Corporation of India Ltd.
86	Sanvijay Infrastructures Pvt. Ltd.
87	Sicame India Connectors Pvt. Ltd.
88	THDCIL
89	The Motwane Manufacturing Co. Pvt Ltd
90	The Tata Power Company Ltd.
91	Tata Power Delhi Distribution Limited
92	Transmission Corporation of Telangana Ltd.
93	Transrail Lighting Limited
94	Universal Cables Limited
95	UE System Imena Pvt. Ltd.

YOUNG MEMBERS

S.No.	Name	Organistaion
1	Power Grid	Ankur Kumar
2	Power Grid	Jeetesh Kumar
3	Power Grid	Amandeep Singh
4	Power Grid	Prasoon Tripathi
5	POSOCO	Nitin Yadav
6	POSOCO	Aman Gautam
7	Aditya Birla Insulators	Vikas Rai
8	POSOCO	K B V Ramkumar
9	POSOCO	Vishal Puppala
10	GETCO	Bhavesh Kumar Manubhai Rana
11	GETCO	Sanjay Jadav
12	GETCO	Vasantkumar Ramanlal Patel
13	Power Grid	Vinita Kumari
14	Power Grid	Ashish Kumar Singh
15	Power Grid	Ashutosh Digambar Rajurkar
16	Power Grid	Priyam Maity
17	Power Grid	Aman Bansal
18	Sterlite Power	Venkata Krishnaji Palasanipalli
19	Sterlite Power Transmission	Ashok D.K.
20	Power Grid	Vikas Bishnoi
21	Power Grid	Deepthy C Nair
22	Power Grid	Ankit Prakash Vaishnao

STUDENT MEMBERS

S. No.	Organisation	Name
1	College of Engineering	Rijo Ranjan
2	College of Engineering Guindy	Ramesh Rahul
3	Engineering College Banswara	Abhishek Bhoi
4	Engineering College Banswara	Manisha Bhuriya
5	Engineering College Banswara	Ajay Bunkar

6	Engineering College Banswara	Durgesh Bunkar
7	Engineering College Banswara	Ashish Chatwani
8	Engineering College Banswara	Bhavesh Kumar Gamot
9	Engineering College Banswara	Meena Bhushan
10	Engineering College Banswara	Meena Mahesh Kumar
11	Engineering College Banswara	Ashok Meena
12	Engineering College Banswara	Abhishek Mishra
13	Engineering College Banswara	Ajay Ninama
14	Engineering College Banswara	Avinash Yadav
15	Engineering College Banswara	Suraj Banjara
16	Engineering College Banswara	Ratan Lal Barad
17	Engineering College Banswara	Suresh Chandra Bhedi
18	Engineering College Banswara	Gautam
19	Engineering College Banswara	Ajay Katara
20	Engineering College Banswara	Ragineejoshi
21	Engineering College Banswara	Rahul Singh
22	Engineering College Banswara	Amit Singh
23	Engineering College Banswara	Yajan Joshi
24	Engineering College Banswara	Surbhi Singhale
25	Engineering College Banswara	Abhishek Tiwari
26	Engineering College Banswara	Adarsh Verma
27	Indian Institute of Technology Kanpur	Anamika Dubey
28	Indian Institute of Technology Kanpur	J G sreenath
29	Indian Institute of Technology Kanpur	Aasim
30	Indian Institute of Technology Kanpur	AKHILESH PRAKASH GUPTA
31	Indian Institute of Technology Kanpur	Vineeth V
32	Indian Institute of Technology Kanpur	Piyush Warhad Pande
33	Indian Institute of Technology Kanpur	P.Naga Yasasvi
34	Indian Institute of Technology Kanpur	Gaurav Khare
35	Indian Institute of Technology Kanpur	Priyanka Gangwar
36	Indian Institute of Technology Kanpur	Saurabh Kesherwani
37	Indian Institute of Technology Kanpur	Ankit Yadav
38	Indian Institute of Technology Kanpur	Avinash kumar
39	Indian Institute of Technology Kanpur	Rajarshi Dutta
40	Indian Institute of Technology Kanpur	Syed Mohammad Ashraf
41	Indian Institute of Technology Kanpur	Arindam Mitra
42	Indian Institute of Technology Kanpur	Bandopant Pawar
43	Indian Institute of Technology Kanpur	Anamika Tiwari
44	National Institute of Technology, Calicut	Amararapu Satish
45	National Institute of Technology, Calicut	Aswin Bhaskar P E
46	National Institute of Technology, Calicut	Cheemala Vaishnavi
47	National Institute of Technology, Calicut	Divya P
48	National Institute of Technology, Calicut	K Vamsi Krishna
49	National Institute of Technology, Calicut	Sarov Mohan S
50	National Institute of Technology, Calicut	Thalluri Chaitanya Sai
51	National Institute of Technology, Calicut	Vipul Kumar
52	National Institute of Technology, Calicut	Avinash Nelson
53	National Institute of Technology, Calicut	Gowrishankar S

54	National Institute of Technology, Calicut	Joyce Jacob
55	National Institute of Technology, Calicut	Emil Ninan Skariah
56	National Institute of Technology, Calicut	Jacob P Varghese
57	National Institute of Technology, Calicut	Lakshmi Tharamal
58	National Institute of Technology, Calicut	Anjitha V
59	National Institute of Technology, Calicut	Haritha G
60	National Institute of Technology, Calicut	Ravishankar A N
61	National Institute of Technology, Calicut	Athira Raju
62	National Institute of Technology, Calicut	Subin Koshy
63	National Institute of Technology, Calicut	Rahul S
64	National Institute of Technology, Calicut	Rinsha V
65	National Institute of Technology, Calicut	T S Bheemraj
66	National Institute of Technology, Calicut	Sanila P
67	National Institute of Technology, Calicut	Najda V M
68	National Institute of Technology, Calicut	Renuka V S
69	Indian Institute of Technology Bombay	Lokesh Kumar Dewangan
70	Indian Institute of Technology Bombay	Vatsal Kedia
71	Indian Institute of Technology Bombay	Santanu Paul
72	Indian Institute of Technology Bombay	SIBA KUMAR PATRO
73	Indian Institute of Technology Bombay	Aditya Nadkarni
74	Indian Institute of Technology Bombay	Kaustav Dey
75	Indian Institute of Technology Bombay	Santosh V Singh
76	Indian Institute of Technology Bombay	Kavita Kiran Prasad
77	Indian Institute of Technology Bombay	ANEES V P
78	Indian Institute of Technology Bombay	soumya Ranjan mohapatra
79	Indian Institute of Technology Bombay	Kevin Gajjar
80	Indian Institute of Technology Bombay	Rohit Thute
81	Indian Institute of Technology Bombay	B. Sai Ram
82	Indian Institute of Technology Bombay	Minal Chougule
83	Indian Institute of Technology Bombay	Soumya Kanta Panda
84	Indian Institute of Technology Bombay	Joel Jose
85	Indian Institute of Technology Bombay	Hemantkumar Goklani
86	Indian Institute of Technology Bombay	vinay chindu
87	Indian Institute of Technology Bombay	Gopakumar
88	Indian Institute of Technology Bombay	PATIL NIKHIL SURESH
89	Indian Institute of Technology Bombay	Pragati Gupta
90	Indian Institute of Technology Bombay	Suman Kumar Neogi
91	Indian Institute of Technology Bombay	AJITH J
92	Indian Institute of Technology Bombay	Makarand M Kane
93	Indian Institute of Technology Bombay	Annoy Kumar Das
94	Manipal University Dahmi Kalan Jaipur	Udayan Atreya
95	Indian Institute of Technology Delhi	Deep Kiran
96	Malaviya National Institute of Tech.	Sapna Ladwal
97	Malaviya National Institute of Tech.	Anil Kumar Kesavarapu
98	Malaviya National Institute of Tech.	MD Kaifi Anwar
99	Malaviya National Institute of Tech.	Rohit Bhakar
100	Malaviya National Institute of Tech.	Bhupesh
101	Malaviya National Institute of Tech.	Sandeep Chawda

102	Malaviya National Institute of Tech.	Debollena
103	Malaviya National Institute of Tech.	Sunil Jangid
104	Malaviya National Institute of Tech.	Jitendra Kumar
105	Malaviya National Institute of Tech.	Ajay Kumar
106	Malaviya National Institute of Tech.	Andru Tarun Kumar
107	Malaviya National Institute of Tech.	Prerna Kuntal
108	Malaviya National Institute of Tech.	Priyanka Kushwaha
109	Malaviya National Institute of Tech.	Parul Mathuria
110	Malaviya National Institute of Tech.	Yash Pal
111	Malaviya National Institute of Tech.	Arushi Relan
112	Malaviya National Institute of Tech.	Umesh Saini
113	Malaviya National Institute of Tech.	Shalini Kumari
114	Malaviya National Institute of Tech.	Sunanda Sinha
115	Malaviya National Institute of Tech.	Aniruddh Takshak
116	Malaviya National Institute of Tech.	Falti Teotia
117	Malaviya National Institute of Tech.	Rajive Tiwari
118	Malaviya National Institute of Tech.	Shefali Tripathi
119	Malaviya National Institute of Tech.	Shakti Vashisth
120	Malaviya National Institute of Tech.	Shivanjali Yadav
121	Malaviya National Institute of Tech.	Amit Kumar

122	Malaviya National Institute of Tech.	Archana
123	Malaviya National Institute of Tech.	Nilesh B Hadiya
124	Malaviya National Institute of Tech.	Chandra Prakash Barala
125	Malaviya National Institute of Tech.	Shivani Garg
126	Malaviya National Institute of Tech.	Sakshi Gupta
127	Malaviya National Institute of Tech.	Archee Gupta
128	Malaviya National Institute of Tech.	Bhavna Jangid
129	Malaviya National Institute of Tech.	Nitesh Kataria
130	Malaviya National Institute of Tech.	Gautam Raina
131	Malaviya National Institute of Tech.	Navneet Sharma
132	Malaviya National Institute of Tech.	Deepak Singh
133	Malaviya National Institute of Tech.	Yamujala Sumanth
134	Malaviya National Institute of Tech.	Dheeraj Verma
135	Malaviya National Institute of Tech.	Raj Kumar Yadav
136	Malaviya National Institute of Tech.	Anjali Jain
137	Malaviya National Institute of Tech.	Rohit Vijay
138	Manipal University Dahmi Kalan Jaipur	Udayan Atreya
139	MNIT, Jaipur	Sumanth Yamujala
140	NIT HAMIRPUR	SUCHANDAN DAS
141	RGPV University	Vishal Telang
142	M. S. Ramaiah Institute of Technology	Wajid Ahmed

Four Group of CIGRE Study Committees

Study Committee

A : EQUIPMENT
- SC A1 Rotating Electrical Machines
- SC A2 Power Transformers and Reactors
- SC A3 Transmission & Distribution Equipment

B : TECHNOLOGIES
- SC B1 Insulated Cables
- SC B2 Overhead Lines
- SC B3 Substations and Electrical Installations
- SC B4 DC Systems and Power Electronics
- SC B5 Protection and Automation

C: SYSTEM
- SC C1 Power System Development and Economics
- SC C2 Power System Operation and Control
- SC C3 Power System Environmental Performance
- SC C4 Power System Technical Performance
- SC C5 Electricity Markets and Regulation
- SC C6 Active Distribution Systems and Distributed Energy Resources

D: New Materials & IT
- SC D1 Materials and Emerging Test Techniques
- SC D2 Information Systems and Telecommunication

FIELDS OF ACTIVITY OF CIGRE STUDY COMMITTEES

Study Committees No.	Scope
A1	**Rotating Electrical Machines** : The SC is focused on the development of new technologies and the international exchange of information and knowledge in the field of rotating electrical machines, to add value to this information and knowledge by means of synthesizing state-of-the-art practices and developing guidelines and recommendations.
A2	**Power Transformers and Reactors** : The scope of SC A2 covers the whole life cycle of all kind of power transformers, including HVDC transformers, phase shifters, shunt reactors and all transformer components as bushing and tap-changers.
A3	**Transmission & Distribution Equipment** : The scope of the SC A3 covers theory, design, construction and operation for all devices for switching, interrupting and limiting currents, surges arresters, capacitors, busbars, equipment insulators and instrument transformers used in transmission and distribution systems.
B1	**Insulated Cables** : The scope of SC B1 covers the whole Life Cycle of AC and DC Insulated cables for Land and Submarine Power Transmission, which means theory, design, applications, manufacture, installation, testing, operation, maintenance, upgrading and uprating, diagnostics techniques. It has been focused on HV & EHV applications for a long time. Nowadays MV applications are more and more taken into consideration.
B2	**Overhead Lines** : The scope of the Study Committee SC B2 covers all aspects of the design and refurbishment of overhead power lines. The Study Committee's strategic goals include: increased acceptance of overhead lines; increased utilization of existing overhead lines; improved reliability and availability of overhead lines.
B3	**Substations and Electrical Installations** : The scope of work for SC B3 includes the design, construction, maintenance and ongoing management of transmission and distribution substations, and the electrical installations in power stations, but excluding generators.
B4	**DC Systems and Power Electronics** : The scope of SC B4 covers High Voltage Direct Current systems and Power Electronics for AC networks and Power Quality improvement. Overhead lines or cables, which may be used in HVDC systems are not included in the scope, but are the responsibility of SC B2 and SC B1 respectively. The members of B4 come from Manufacturers, Utilities, transmission system operators (TSOs), Consultants and Research Institutes. SC B4 is active in recruiting young engineers to participate in its activities.
B5	**Protection and Automation** : The scope of the Committee covers the principles, design, application and management of power system protection, substation control, automation, monitoring, recording and metering – including associated internal and external communications and interfacing for remote control and monitoring.
C1	**Power System Development and Economics** : The SC's work includes issues, methods and tools related to the development and economics of power systems, including the drivers to: invest in expanding power networks and sustaining existing assets, increase power transfer capability, integrate distributed and renewable resources, manage increased horizontal and vertical interconnection, and maintain acceptable reliability in a cost-efficient manner. The SC aims to support planners to anticipate and manage change.
C2	**Power System Operation and Control** : The scope of the SC C2 covers the technical, human resource and institutional aspects and conditions needed for a secure and economic operation of existing power systems under security requirements against system disintegration, equipment damages and human injuries.
C3	**Power System Environmental Performance** : The scope of this Study Committee is focused on the identification and assessment of electric power systems environmental impacts and the methods used for assessing and managing these impacts during the all life cycle on the power system assets.
C4	**Power System Technical Performance** : The scope of SC C4 covers system technical performance phenomena that range from nanoseconds to many hours. SC C4 has been engaged in the following topics: Power Quality, EMC/EMI, Insulation Coordination, Lightning, and Power systems performance models and numerical analysis.
C5	**Electricity Markets and Regulation** : The scope of the Study Committee is "to analyze the different market approaches and solutions and their impact on the electric supply industry in support of the traditional economists, planners and operators within the industry as well as the new actors such as regulators, traders, technology innovators and Independent Power producers.
C6	**Active Distribution Systems and Distributed Energy Resources** : SC C6 facilitates and promotes the progress of engineering, and the international exchange of information and knowledge in the field of distributions systems and dispersed generation. The experts contributes to the international exchange of information and knowledge by the rizing state of the art practices and developing recommendations.
D1	**Materials and Emerging Test Techniques** : The scope of Study Committee D1 covers new and existing materials for electrotechnology, diagnostic techniques and related knowledge rules, as well as emerging test techniques with expected impact on power systems in the medium to long term.
D2	**Information Systems and Telecommunication** : The scope of this SC is focused on the fields of information systems and telecommunications for power systems. SC D2 contributes to the international exchange of information and knowledge, adding value by means of synthesizing state of the art practices and drafting recommendations.

HIGHLIGHTS OF POWER SECTOR

GROWTH OF INSTALLED CAPACITY

(Figures in MW)

	At the end of 12th Plan (August 2017)	As on 31.12.2020
THERMAL	218330.00	231590.72
HYDRO	44478.00	45798.22
NUCLEAR	6780.00	6780
RENEWABLE ENERGY SOURCES	57244.00	91153.81
TOTAL	**326832.00**	**375322.74**

Source : CEA

ALL INDIA REGION WISE INSTALLED CAPACITY

As on 31.12.2020

(Figures in MW)

Region	Thermal	Nuclear	Hydro	RES	Total
Northern	60799.05	1620	20143.77	17581.99	100144.81
Western	86081.61	1840	7555	27933.96	123410.57
Southern	54699.99	3320	11774.83	43665.36	113460.18
Eastern	27387.05	0	4639.12	1568.11	33594.28
N. Eastern	2582.98	0	1685.5	369.17	4637.64
Islands	40.05	0	0	35.22	75.27
All India	**231590.72**	**6780**	**45798.22**	**91153.81**	**375322.74**
Percentage	**61.70**	**1.81**	**12.20**	**24.29**	**100**

Source : CEA

SECTOR WISE INSTALLED CAPACITY AND GENERATION

As on 31.12.2020

Sector	Installed Capacity (MW)					Percentage Share	Net Capacity added
	Thermal	Nuclear	Hydro	RES	Total		During Dec. 2020
STATE	74547.36	0	26958.5	2391.52	103897.39	27.68	369 MW
PRIVATE	86875.45	0	3493	87129.98	177498.43	47.29	
CENTRAL	70167.91	6780	15346.72	1632.3	93926.93	25.03	
TOTAL	**231590.72**	**6780**	**45798.22**	**91153.81**	**375322.74**	**100**	

Source : CEA

GROWTH OF TRANSMISSION SECTOR

	Unit	At the end of 12th Plan (August 2017)	As on Dec. 2020	Addition after 12th Plan (2017-22) (up to November 2020)
TRANSMISSION LINES				
HVDC	ckm	15556	19087	
765 kV	ckm	31240	44855	
400 kV	ckm	157787	186389	
220 kV	ckm	163268	183179	
Total Transmission Lines	**ckm**	**367851**	**433510**	**65659**
SUBSTATIONS				
	Unit	**At the end of 12th Plan (August 2017)**	**As on Oct. 2020**	**Addition after 12th Plan (2017-22) (up to October 2020)**
HVDC	MW	19500	27000	247708
765 kV	MVA	167500	234900	
400 kV	MVA	240807	343872	
220 kV	MVA	312958	382701	
TOTAL	**MW/ MVA**	**740765**	**988473**	**247708**

RURAL ELECTRIFICATION / PER CAPITA CONSUMPTION

Total no. of Villages	597464
No. of Villages Electrified	597464
% of Villages Electrified	100.00
No. of Pump-sets Energized (At the end of 12th Plan)	21212860
Per Capita Consumption during 2019-20*	1208 kWh

**Provisional*

RE SECTOR IN INDIA: POTENTIAL AND ACHIEVEMENTS

Sector GRID-INTERACTIVE POWER (CAPACITIES in MWp)	FY 2020-21 Target (MW)	FY 2020-21 Achievement (April-Nov. 2020)	Cumulative Achievements (MW) (as on 30.11.2020)
Wind	3000	689.8	38433.55
Solar Power (SPV)	11000	2282.7	36910.49
Small Hydro (up to 25 MW)	100	57.3	4740.47
Bio Power (Biomass & Gasification and Bagasse Cogeneration)	250	270.61	10145.92
Waste to Power	30	21	168.64
Total (Approx)	**14380**	**3321.41**	**90399.07**
OFF GRID/CAPTIVE POWER (CAPACITIES IN MW_{EQ})	**510**	**77.01**	**1253.59**
Other Renewable Energy Systems (Biogass plants) (capacity in Nos.)	**0.6**	**0.04**	**50.5**

Source : MNRE

NEWS

GOVT TO FOCUS ON LOSS-MAKING DISCOMS FOR NEXT 3-4 YRS TO ACHIEVE '24x7 POWER FOR ALL'

The government's spotlight will be on electricity distribution utilities or discoms, which are mostly state-run and cash-strapped due to losses, to achieve the goal of 24×7 power for all, a senior official said. There is stress in the power sector due to the inability of discoms to make timely payments for supply of power by gencos (power generating firms), which affects the entire value chain.

Participating in a webinar organised by the Institute of Directors, Ashish Upadhyaya, additional secretary in the Ministry of Power, said the major focus of the central government will be on the distribution sector for the next three-four years. Talking about the continuous losses of discoms, he said there is a gap between the actual rate of supply of power and the cost recovered from consumers. According to power ministry data, discoms' total outstanding dues stood at over Rs 1.42 lakh crore as of November 2020. Last year, the government announced aRs 90,000 crore liquidity infusion scheme for discoms which was later expanded to Rs 1.2 lakh crore. Earlier this year, some reports also suggested that the forthcoming Budget may unveil the second phase of the UDAY (UjwalDiscom Assurance Yojana) for revival of discoms.

The UDAY scheme was launched in November 2015 under which the discoms' financial performance was to be turned around in three years. Upadhyaya further pointed out that some states have not fixed tariff commensurate with the actual cost of supply for years, while expenditure on power generation has kept on rising. Participating in the webinar, Gujarat Energy Minister Saurabh Patel said the power sector can change if there is political will of the state governments. He emphasised on curbing transmission and distribution losses to make the power sector vibrant in the states. Citing Gujarat's example, he said there has not been a single year in the last 15 years in which the four discoms in the state did not report at least a minor profit. He exuded confidence that there would be 12 GW power generation capacity addition in the state in the next two years.

POWER GENCOS SEND PAYMENT DUE NOTICES TO STATE DISCOMS

Consumers across India could face power supply disruptions as central public sector undertakings (CPSUs) including NTPC NSE -1.30 %, NHPC and Damodar Valley Corporation have begun issuing regulation notices to state distribution companies for non-payment of dues.

On Thursday, NTPC issued notices to power utilities of Sikkim, Jammu & Kashmir, Puducherry and two discoms of Karnataka for discontinuation of aggregate 3,000-mw beginning next Friday. Government officials said all CPSU power generators have decided to issue similar

warnings threatening discontinuation of power supply to defaulting distribution companies. Officials in various electricity distribution companies said their financial positions deteriorated due to the impact of Covid-19 on power consumption and billing and collections. A senior NTPC official said more notices are likely to be issued to large defaulters such as Uttar Pradesh, Andhra Pradesh, Telangana Madhya Pradesh and Assam.

"The company has decided to take action against non-paying distribution companies starting Thursday with five utilities. More such notices to bigger states would be required to recover large amounts of receivables," the official said. NTPC has invoked insolvency proceedings against BSES Delhi discoms. "In spite of repeated follow ups at various levels in person as well as through letters beginning August 2020 the states have yet not liquidated the outstanding dues which are way beyond due dates. As per various agreements and CERC Regulations, in case of defaulting making payments of bills, NTPC has the right to discontinue or regulate the power supplies.

Power producers' total dues owed by distribution firms rose over 35% to Rs 1,41,621crore in November 2020. The total overdue amount stood at Rs 1,29,868crore Overdue of independent power producers and Central PSUs amounted to 34% each of the total overdue. Among the central public sector power generators, NTPC has an overdue amount of Rs 19,215.97 crore on discoms, followed by NLC India at Rs 6,932.06 crore, Damodar Valley Corp at Rs 6,238.03 crore, NHPC at Rs 3,223.88 crore and THDC India at Rs 2,085.06 crore.

The Union power ministry had in August 2019 mandated maintenance of bank guarantee by distribution companies in favour of power plants. State-run financiers Power Finance Corp and REC Ltd are offering Rs 1,20,000 crore conditional loans to discoms under Atmanirbhar Bharat scheme to help them repay the dues to power gencos. Of this close to Rs 68,000 crore has been sanctioned.

Source : ET Bureau, Jan 08, 2021

GOVERNMENT ASKS CERC TO RELIEVE POWER PLANTS DELAYED DUE TO FORCE MAJEURE FROM TRANSMISSION LEVY

The government has invoked special powers to direct electricity regulator to make changes in regulations freeing power plants delayed due to justifiable reasons from paying penalties to associated transmission projects. The penalties would now be borne equally by all beneficiary discoms of a generation project, as per the directions issued by the Union power ministry to the Central Electricity Regulatory Commission (CERC) under section 107 of the Electricity Act 2003. While power generation and transmission companies welcomed the relief, distribution companies said the move asking them to pay for delay in generation projects came as a shock to them.

"Penalties for delay in COD (commissioning) of generating stations, or for delay in completing transmission system, or operationalising the LTA (long-term agreement) shall invite penalties to be paid to CTU (central transmission utility). The penalties shall be equitable; and shall not extend to compensating either the Generation companies for power it could not despatch because of delay in transmission or to compensate the transmission company for the delay in generation or the associated transmission," the central government directions to CERC to amend Sharing of Inter-State Transmission Charges and Losses Regulations, 2020 said.

Power transmission projects attached to delayed generation plants are considered 'deemed commissioned' and are liable to compensation but the complexity in arrangement makes it difficult to claim any amount. In the present system, the CTU coordinates with transmission licensees on one hand and all other users on the other. There are back-to-back agreements between CTU, the transmission licensees and distribution companies and generation companies are outside these contracts. The power ministry is working to amend the structure to bring in transmission licensees and generators together. A senior government official said the directions are aimed at ease of process. "If the delay is not attributable to the parties, none of them should take the hit," he said. The directions said the entire burden of strengthening which will serve many procurer or power producers in the future cannot be levied on one party.

"Over 3-4 years, it is being realised that is possibility of mismatch in timelines in commissioning of generation companies and associated transmission lines. The regulators deny compensation since the line is not being used. Lack of agreement with generation companies closed hopes of compensation. The investors to these transmission lines have started worrying over collection of the charges. This is a very positive development," said an industry official.

Electricity distribution companies opposed the move calling it unfair to be penalised for no fault. "This will lead to passing of private losses to the general public and tariff shocks," an official said.

The directions said events of force majeure may be defined by CERC and provision included enabling the CTU to extend the commissioning of a generating station.

Source : ET Bureau, January 19, 2021

NEW POWER ISLANDING FOR DELHI PROPOSED TO PREVENT BLACKOUTS

The government proposes to put in a robust islanding facility for power supplies in Delhi to prevent the national capital to face electricity disruptions, especially for essential services, in case of grid disturbances.

Sources said the country's largest power producer NTPC has suggested a mix of its gas-based and coal-fuelled power units in the vicinity of the Capital for dedicated use for the city to create an island in the case frequency in the main grid collapses and there is real threat of a complete power breakdown. This, it has been suggested, will balance the frequency in case of grid collapses, ensuring that essential services in the Capital continues to receive uninterrupted supply electricity.

Sources said that though an islanding scheme for Delhi was developed by grid manager Power System Operation Corporation Limited (POSOCO) in 2017, it yet to be commissioned. Moreover, with over dependence of gas-based capacity to provide dedicated power to Delhi in the event of a sudden drop on frequency has created a situation where despite islanding infrastructure adequate electricity supply would be hard to maintain.

With most gas-based power plants dedicated to Delhi operating at around 30-35 per cent plant load factor (PLF) an eventuality still puts the national capital on the risk of a complete blackout as capacities would not be sufficient to ensure adequate frequency in the power systems.

"It is imperative to revisit the earlier planned islanding scheme for Delhi to prevent a repeat of what could not have happened in Mumbai and could happen in Delhi," said the sources. It is understood that a group in the power ministry is studying various upgradations that are required to build a robust islanding facility for Delhi and a decision on the same would be taken soon.

Sources said that NTPC is ready to keep at least two units of Dadri power plant and one unit of Jhajjar plant on bar at all times to take care of any grid disturbances. These coal-fired units would become critical in times of frequency collapse to ensure power generated from there helps to keep essential services running in the Capital.

"The question is whether we need to keep running coal-fired power plants in the vicinity of the capital as they are also a source of pollution the affects the region. But systems could be developed so that these units become critical in times of grid disturbances," said a former head of POSOCO asking not to be named.

Two severe power blackouts had affected most of Northern and Eastern India on 30 and 31 July 2012. The blackout on 31st July was the largest power outage affecting more than 62 crore people in Northern, Eastern, and Northeast India. Based on the recommendations of enquiry committee constituted under MOP, an Islanding scheme for Delhi was framed.

The Delhi Region is a part of Northern Grid and in case of any grid disturbance, this islanding scheme will isolate Delhi from rest of the grid. Once islanding is done, the demand is matched with the own generation. The priority is Delhi Metro, Railways, DIAL and the healthcare facilities. As per guidelines, each state has been given a share of load shedding which should contribute in case of any fall in frequency. When any grid disturbance occurs in the grid, there'd be an increase or decrease in frequency.

The Delhi Islanding scheme has incorporated load shedding at Flat frequency up to stage 48.6 Hz and df/dt slope stages of 0.1Hz/sec,0.2Hz/sec and 0.3Hz/sec for frequency less than 47.9Hz. In case the frequency fall beyond 47.9 Hz the Islanding of Delhi is initiated by tripping of Circuit Breakers at various locations.

On an average, typical daily electrical load in Delhi is around 3000 MW and internal generation is only around 500 MW. Due to low and uncertain gas allocations to CCGT Bawana, Pragati, Rithala and IPGCL GT station, it has become important to keep a minimum number of thermal coal-fired units on bar at all times.

This was also envisaged in the original islanding scheme for Delhi.

Source : IANS December 12, 2020

POWER CONSUMPTION GROWS 7.8% IN FIRST HALF OF NOVEMBER

India's power consumption grew 7.8 per cent to 50.15 billion units (BU) in the first half of November this year, showing rise in economic activities, as per government data. Power consumption in the country was recorded at 46.52 BU during November 1-15 last year, according to the power ministry data. For a full month in November last year, power consumption was 93.94 BU.

Thus, the extrapolation of half-month data clearly indicates that power consumption may witness year-on-year growth for the third month in a row, according to experts. After a gap of six months, power consumption recorded a growth of 4.4 per cent in September this year at 112.24 BU compared to 107.51 BU in the same month last year.

India's power consumption grew nearly 12 per cent to 109.53 billion units (BU) in October this year as against 97.84 BU in the same month last year. The growth in power consumption in the first half of this month showed that there is consistency in improvement in commercial and industrial demand due to easing of lockdown restrictions, experts said. The government had imposed the nationwide lockdown on March 25 to contain the spread of COVID-19. Power consumption started declining from March onwards due to fewer economic activities in the country. The COVID-19 situation affected power consumption for six months in a row -- from March to August this year. Power consumption on a year-on-year basis declined 8.7 per cent in March, 23.2 per cent in April, 14.9 per cent in May, 10.9 per cent in June, 3.7 per cent in July and 1.7 per cent in August.

The data showed that electricity consumption had grown by 11.73 per cent in February. It has shown an improvement post-lockdown easing for economic activities after April 20. Peak power demand met, the highest supply of power in the country in a day, in the first half of November was recorded at 160.77 GW (on November 3, 2020), 5.2 per cent higher than 152.77 GW on November 6, 2019. The peak power demand in the month of November last year was 155.32 GW.

The peak power demand met in October was recorded at 170.04 GW, 3.52 per cent higher than 164.25 GW in the same month last year. Peak power demand in September this year recorded a growth of 1.7 per cent at 176.41 GW, compared to 173.45 GW a year ago, the data showed. Peak power demand met had recorded negative growth from April to August this year due to the pandemic.

It had dropped to 24.9 per cent in April, 8.9 per cent in May, 9.6 per cent in June, 2.7 per cent in July and 5.6 per cent in August. In March, it was muted at 0.8 per cent.

Source : PTI, Nov 16, 2020

International Council on Large Electric Systems (CIGRE)

International Headquarters:

International Council on Large Electric Systems (CIGRE), 21 Rue d'Artois, 75008 Paris, France
Tel: **+33 1 53 89 12 90;** Fax: **+33 1 53 89 12 99**
Email of Secretary General: philippe.adam@cigre.org

Date of inception : CIGRE was founded in 1921 with its HQ at PARIS

Aims and Objectives:

CIGRE (International Council on Large Electric Systems) is one of the leading worldwide Organizations on Electric Power Systems, covering their technical, economic, environmental, organisational and regulatory aspects.

A permanent, non-governmental and non-profit International Association, based in France, CIGRE was founded in 1921 and aims to:

- Facilitate the exchange of information between engineering personnel and specialists in all countries and develop knowledge in power systems.
- Add value to the knowledge and information exchanged by synthesizing state-of-the-art world practices.
- Make managers, decision-makers and regulators aware of the synthesis of CIGRE's work, in the area of electric power.

More specifically, issues related to planning and operation of power systems, as well as design, construction, maintenance and disposal of HV equipment and plants are at the core of CIGRE's mission. Problems related to protection of power systems, telecontrol, telecommunication equipment and information systems are also part of CIGRE's area of concern.

Establishment of Indian Chapters:

CIGRE India was set up as society on 24.07.91 with CBIP as secretariat.

Membership:

(I) Collective Members (I) - (companies of industrial and commercial nature)

(II) Collective Members (II) - (Universities, Engineering Colleges,Technical Institutes and regulatory commission)

(III) Individual Members -

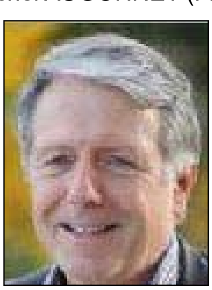
(In the engineering, teaching or research professions as well as of other professions involved in the industry (Lawyers, economists, regulators...)

(IV) Young Members (Below 35 Years of Age) -

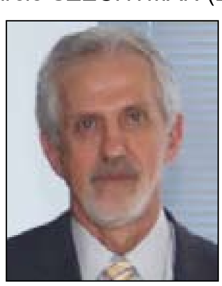
(In the engineering, teaching or research professions as well as of other professions involved in the industry (Lawyers, economists, regulators...)

CIGRE - HQ

President
Michel AUGONNET (FR)



Chairman TC
Marcio SZECHTMAN (BR)



Treasurer
Michael Heyeck

Secretary General
Philippe ADAM (FR)

THE COMMITTEE FOR INTERNATIONAL CONFERENCE ON LARGE HIGH VOLTAGE ELECTRIC SYSTEMS (CIGRE), INDIA

TO BE SENT TO NATIONAL COMMITTEE (i.e Central Board of Irrigation and Power)

MEMBERSHIP APPLICATION FORM – for the year 2021

Please fill in the column of the relevant MEMBER CATEGORY.

MEMBERSHIP RENEWAL ☐ **NEW MEMBERSHIP** ☐ **Membership Number** ________

☐ ***INDIVIDUAL MEMBER I*** ☐ ***INDIVIDUAL MEMBER II*** *(Young Member under 35 years)*	***COLLECTIVE MEMBER I*** *Administrative bodies, scientific and technical organisations, research institutes, public or private Companies industrial and/or commercial.*	***COLLECTIVE MEMBER II*** *Universities, Educational Bodies only.*
Family Name …………………… Forename …………………… Position, Dept. …………………… Company, Organisation …………………… Full Address …………………… …………………… …………………… TEL ………… Mobile no. ………… FAX ………… E-Mail : ………… Year of Birth …………	NAME of COMPANY …………………… …………………… Person or Department to receive ELECTRA journal. …………………… …………………… Full Address …………………… …………………… …………………… TEL …………………… Mobile no. …………………… FAX …………………… E-Mail……………………	NAME of UNIVERSITY …………………… …………………… Person or Department to receive ELECTRA journal . …………………… …………………… Full Address …………………… …………………… …………………… TEL …………………… Mobile no. …………………… FAX …………………… E-Mail……………………

S.no	Category	Fees	Fee incuding GST 18% to be paid
1	Collective I	Rs. 68,000/-	Rs. 80,240/-
2	Collective II (Universities & Regulatory Com.)	Rs. 28,000/-	Rs. 33,040/-
3	Individual	Rs. 8,500/-	Rs. 10,030/-
4	Young - below 35 years of age	Rs. 4,250/-	Rs. 5,015/-

Fee can be paid through cheque/ DD in favour of CIGRE India or through bank transfer

Vender Name	THE COMMITTEE FOR THE INTL CONF ON LHVES		
Bank Name & Branch	Canara Bank/ Delhi Diplomatic Enclave		
Branch Address	7/48, Malcha Marg, Chanakyapuri, New Delhi-110021		
IFSC code of branch	CNRB0000157	**MICR No.** : 110015007	**Account No.** : 0157101031491
Type of account	Special Saving Account		**PAN No.** : **AAAAZ0260A** **GSTIN : 07AAAAZ0260A1Z1**

For information pl contact – Vishan Dutt, CIGRE India, CBIP Building, Malcha Marg, Chanakyapuri, New Delhi – 110 021, Mobile – 9811431554 ; vishandutt@cbip.org; rohinithomas@cbip.org