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EDITOR'S NOTE

V.K. Kanjlia
Secretary & Treasurer
CIGRE India

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 24 members from different countries. It is a matter of pride for India that we are 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 from 2016-2018. Dr. Subir Sen, ED, POWERGRID was Chairman and Shri P.P. Wahi, Secretary of CIGRE AORC for two year during 2016-18.

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. 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 these 45 Abstract as per our quota, have been recommended to CIGRE HQ for their consideration.

The Membership of CIGRE from India is also on the rise and in the year 2018 we achieved membership count to 828 Nos.

We are bringing out this Journal on half yearly basis. The last issue was published in the month of January 2019.

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.

V.K. Kanjlia
Secretary & Treasurer CIGRE India

Overview and Key Features of +/- 320 kV, 2×1000 MW Pugalur-Trichur VSC HVDC Link

M. Vardikar, V. Singh, M.S. Rao, S. Bhattacharya, B.B. Mukherjee and Rakesh Kumar
Power Grid Corporation of India Limited

ABSTRACT

HVDC transmission links are most preferred solution for bulk power transfer over long distances from remote generation to load centres. Raigarh-Pugalur-Trichur HVDC scheme is such upcoming bulk power transmission scheme in India to transmit 6000 MW of power pooled from several generation plants at Raigarh, Western Region to Southern Region. Out of the 6000 MW transmitted power, 4000 MW shall be received at Pugalur, Tamil Nadu while 2000 MW at Trichur, Kerala in Southern Region.

To meet above requirements, an LCC HVDC link from Raigarh to Pugalur and a VSC HVDC link from Pugalur to Trichur are under implementation[1]. Pugalur is common converter bus for both the LCC HVDC link (normally operating as inverter) and VSC HVDC link (normally operating as rectifier). This configuration of LCC and VSC HVDC links is unique and limited literature is available for such configuration[3,4].

It is observed that common Pugalur converter bus is moderately strong (with Short Circuit Ratio of 3.3 for LCC HVDC link in Off-Peak case) and Raigarh-Pugalur HVDC link is of considerable size (15-20%) compared to power demand of Southern Region. Hence, it is vital to maintain stability and study the combined performance of the VSC and LCC HVDC links. Preliminary studies have been carried out for possible performance improvement of LCC HVDC link, recovery of LCC HVDC link for AC network faults and performance of combined scheme for commutation failures, temporary DC line faults[2].

This paper presents overview and features of Pugalur Trichur VSC HVDC link from utility perspective especially for combined performance of VSC and LCC HVDC links. The VSC HVDC scheme operates at ± 320 kV with 2x1000 MW power transmission capacity. The scheme consists of two symmetrical monopoles with half bridge configuration. It is based on Modular Multilevel Converter (MMC) topology. It is designed to transmit 2000 MW power from Pugalur to North Trichur over a distance of 179 km. The transmission scheme is a combination of overhead line (around 147 km) and underground cable (around 32 km). The transition station serves as interface between overhead line and cable.

The VSC HVDC link has 2 x(±330) MVAR reactive power capability at full load operation. With no active power transmission, 2 x (±550) MVAR reactive power support is available from VSC HVDC link at both Pugalur and Trichur. The VSC HVDC link has fast acting voltage control through reactive current modulation. It is well known that LCC inverter operation is sensitive to AC bus voltage. Hence it is envisaged presence of VSC HVDC at Pugalur would enhance performance of 6000 MW Raigarh Pugalur HVDC link.

The VSC HVDC link will have black start capability. It shall be possible to black start one converter station from other end via the DC line. After start up, the HVDC is able to restore a passive AC system by energizing the AC bus bar. In summary, the paper covers features of VSC HVDC link to have reliable operation and high availability.

***Keywords** : High Voltage Direct Current (HVDC), Line Commutated Converter (LCC), Voltage Source Converter (VSC), Multi-Infeed HVDC Systems, Commutation Failure*

1. INTRODUCTION

In India several bulk power transmission HVDC links have been installed in last three decades. The major requirement for such links is presence of large generation specific regions of the country far away from major load centres. Raigarh-Pugalur-Trichur HVDC scheme is such upcoming bulk power transmission scheme in India to transmit 6000 MW of power pooled from several generation plants at Raigarh, Western Region to Southern Region. Out of the 6000 MW transmitted power, 4000 MW shall be received at Pugalur,Tamil Nadu while 2000 MW at Trichur, Kerala in Southern Region.

Presently following HVDC links are under implementation:

Link-1: ± 800 kV, 6000 MW Raigarh Pugalur LCC HVDC link Link-2: ± 320 kV, 2000 MW Pugalur Trichur VSC HVDC link

In this scheme, Pugalur will have common converter bus between the LCC link (normally as inverter) and VSC link (normally as rectifier).

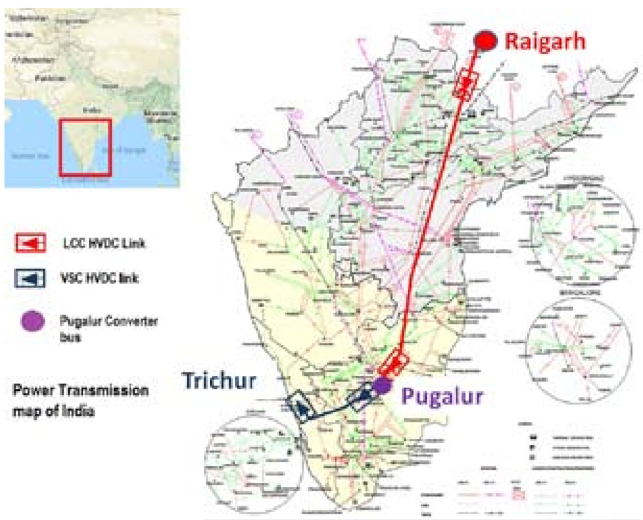


Fig. 1 : Raigarh-Pugalur-Trichur HVDC Transmission Scheme in Southern Region of India[2]

This combination of LCC and VSC links is unique and no similar configuration is available worldwide for assessing interaction between such configuration of HVDC links. This paper presents design considerations and features of Pugalur Trichur VSC HVDC link from Utility perspective especially considering presence of large LCC HVDC link.

2. OVERVIEW OF THE PUGALUR TRICHUR HVDC LINK

This is the first VSC HVDC transmission project in India. The VSC HVDC link shall operate at +/-320 kV with 2 x 1000 MW power transmission capacity. The link consists of two symmetric monopole systems in parallel with a rated power of 1000 MW each. The system is able to supply/ consume +/-330 MVAR of reactive power at full load referred to AC terminal. When no active power is transmitted (STATCOM operation) the available reactive power is ± 550 MVAR. The system is able to operate in reduced voltage mode with 80% power transfer. Figure 2 shows one Bipole of Raigarh-PugalurLCC (3000 MW) and One symmetrical monopole of Pugalur Trichur VSC (1000 MW) HVDC links.

2.1 AC Network Connected to Pugalur Converter Station

Eight no. of 400 kV AC lines are connected to converter bus apart from LCC and VSC HVDC links. The short circuit level of converter bus under light load condition is approximately 20 GVA. The only generation near to this converter bus is Neyveli Thermal power plant which is 3 buses away in 400 kV network.

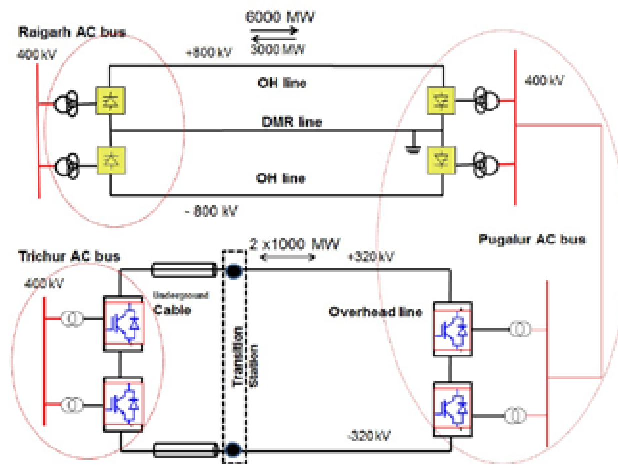


Fig. 2 : Common Pugalur Converter bus for Raigarh-Pugalur LCC and Pugalur -Trichur VSC HVDC Links

2.2 Performance Requirements

It is seen that Pugalur converter bus is moderately strong (Short Circuit Ratio of 3.3 for LCC HVDC link in Off-Peak case) and Raigarh-Pugalur LCC link is of considerable size (15-20%) compared to Southern Region. Hence dynamic performance of Raigarh-Pugalur scheme is vital to Southern Region.

The inherent reactive modulation functions of VSC HVDC link play an important role in supporting both the LCC link and associated ac system, during dynamic conditions such as

- AC system events
- Fault recoveries during DC line faults in LCC and VSC link.

In case of multiple contingency scenarios, Pugalur converter bus would become weak and interactions in such cases needs to be assessed. It is known that inverter voltage magnitude and waveform are vital for smooth operation of LCC links. Hence, VSC link shall help in maintaining stable voltage waveform such that the two HVDC links can be safely integrated in the system.

Following advantages VSC HVDC link adjacent to large LCC link are envisaged:

- Better commutation failure performance of LCC inverter due to dynamic voltage support from VSC
- Better fault recovery for single phase, three phase and LCC HVDC line faults
- Minimum control interaction leads to smooth integration and operation

3. VSC HVDC CONVERTER STATION

Pugalur Trichur VSC HVDC link consists of two parallel symmetrical monopoles with half bridge configuration.

Figure 3 shows overview diagram for a converter station for a monopole in Pugalur Trichur link.

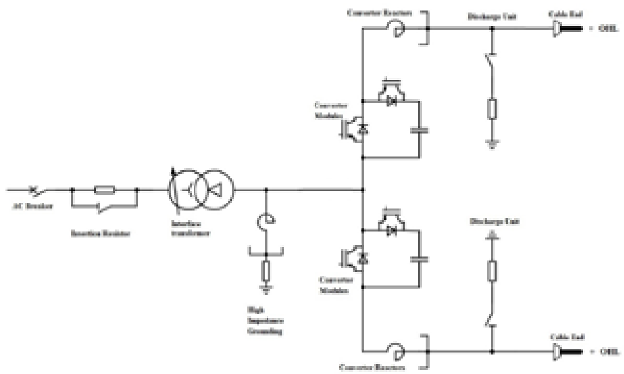


Fig. 3 : Overview Diagram for Converter station (Trichur end) for Pugalur -Trichur VSC HVDC Link

3.1 Converter Modules

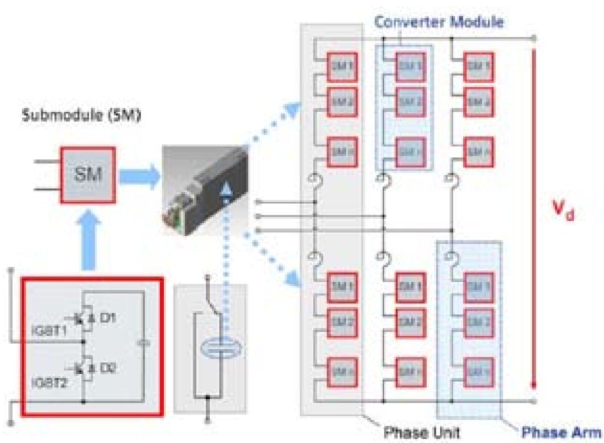


Fig. 4 : Typical VSC-HVDC multi-level topology[4]

3.2 Interface Transformer

Each Pugalur Trichur VSC HVDC link has 3 no. of Single phase two winding transformers of each rated for 367 MVA.

3.3 Insertion Resistor

In order to limit the voltage dip during pre-charging of the Converter, an insertion resistor is used. This resistor is inserted during pre-charging process of the Converter Modules and DCcircuit. The resistor shall be by-passed by a switchafterpre-charging.

3.4 Discharge Unit

To discharge the DC circuit a resistor is employed. The resistor will be connected via a discharge switch to the DC line. During normal operation the switch will remain open. In case the discharge of DC line is necessary the switch can be closed.

3.5 Converter Reactors

The converter reactors limit short circuit currents through the converter and decouple the Converter Phases from each other in case of minor unbalances in voltage. This will limit the circulating currents between the Converter Phases.

3.6 Transition Station

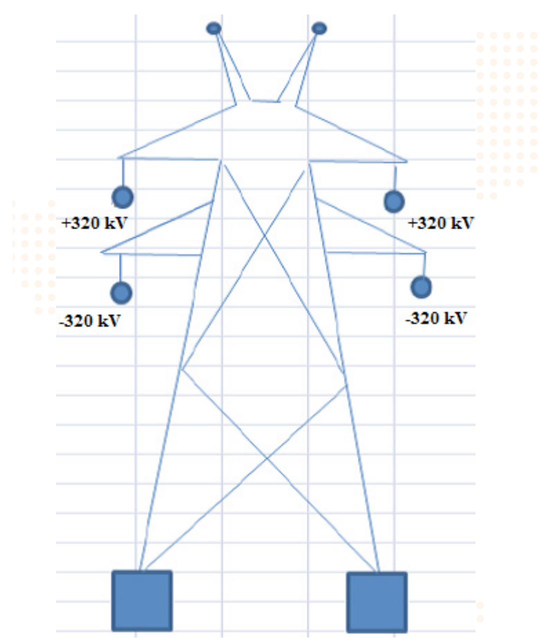
The transition station serves as interface between overhead line and cable as shown in Figure 2 earlier. The transition station consists of cable terminations, accessories, current transducers, surge arresters etc.

3.7 High Impedance Grounding

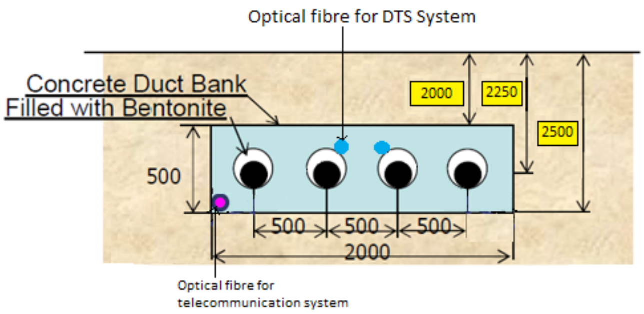
Due to presence of DC overhead line, leakage currents are anticipated during operation. Hence reactors with common star point grounding are provided at each converter station. Total leakage current will be shared between two station high impedance grounding arrangement. Further balancing control has been adapted to avoid any ground current between Pugalur and Trichur stations.

4. COMBINATION OF OVERHEAD LINE AND CABLE

The 2x1000 MW power shall be transmitted from Pugalur to North Trichur over a distance of 179 km. The transmission link is a combination of overhead line (around 147 km) and underground cable (around 32 km). The transition station serves as interface between overhead line and cable.



Overhead line configuration



Typical HVDC cable & Fiber Optic in Duct bank

Fig. 5 : Transmission Corridor for Pugalur Trichur Link[5]

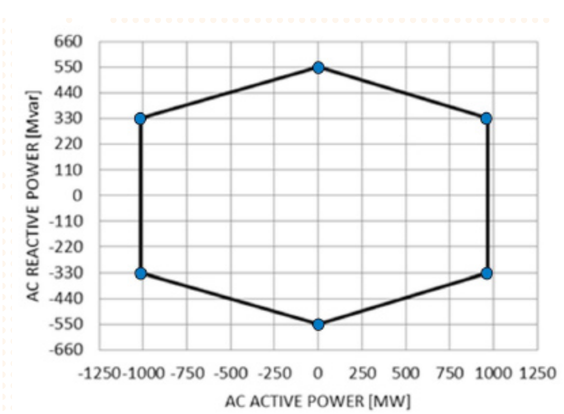
5. OPERATIONAL FEATURES

The parallel symmetrical monopoles can be operated independently (each 1000 MW, ±330 MVAR) or as a single link (2000 MW, ±660 MVAR). Unlike LCC HVDC link, VSC HVDC does not require reactive power for active power transmission. The reactive power requirement is generally 50-55% of active power transmitted in LCC HVDC link. Hence VSC HVDC is more suitable for connecting to weak AC networks. The real and reactive power capabilities of the link are described below:

5.1 Modes of Operation

- Active power flow in Forward direction with Reactive Power Support at each station Pugalur→Trichur 2 x (1000 MW, ±330 MVAR)
- Active power flow in Reverse direction with Reactive Power Support at each station Trichur→Pugalur 2 x (1000 MW, ±330 MVAR)

The above variation of real and reactive power is best depicted by the P-Q diagram below (for each monopole):



The above capability requirements are valid for AC system voltage between 380-420 kV. If AC voltage is outside this range then restrictions at some point may appear. The capability of converter varies based on following factors- AC system voltage, frequency and DC voltage.

5.2 Reactive Power Modulation Capability

The Pugalur-Trichur HVDC link has independent active and reactive power controls. There are additional converter reactive power modulation functions which contribute during abnormal grid conditions.

- *AC Voltage Sensitive Reactive power modulation*- This function supports during recovery after a network disturbance. Target ac voltage is achievable between the maximum and minimum grid voltage range. The control function has a slope of MVAR/kV which is settable. On sensing a deviation of abnormal ac voltage, converter absorbs/supply reactive power with the specified slope
- *Reactive Current Modulation* – This function provides instantaneous reactive current injection during transient under and over voltage conditions, upto 100% capability of converter to stabilise voltage during dynamic conditions.

5.3 STATCOM Capability

The VSC HVDC link is capable of operating in STATCOM mode at each Station (Decoupled mode) with 0 MW, ±550 MVAR for each symmetrical monopole. This capability may be utilised for dynamic voltage support requirement at Pugalur and Trichur.

5.4 Black Start Capability

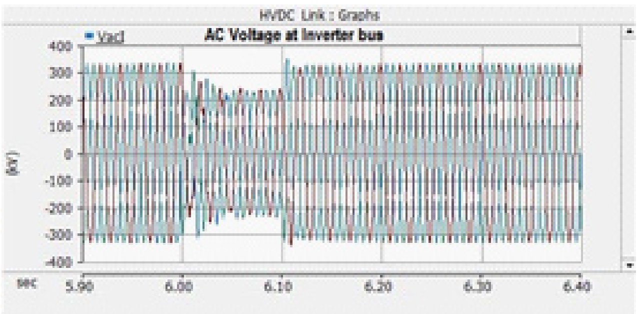
Black start capability in Pugalur Trichur VSC HVDC link allows restoration of network after partial or complete blackout occurs on that side. VSC HVDC link is able to energize passive network consisting of transformers, lines etc., provide start up power to generators and also stabilize the AC network during restoration within the capacity of the converters. The AC network on other end should be healthy with sufficient reserve to help the affected end of network where blackout has occurred. V/f Control mode in VSC HVDC link shall be utilised during black start.

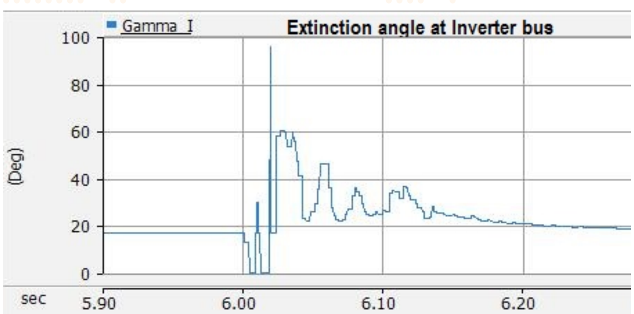
5.5 Combined Performance with LCC HVDC Link

Preliminary studies have been carried out to assess combined performance of LCC and VSC HVDC links[2]. In three phase and single phase fault cases, it is seen that VSC HVDC reactive power support (2 x +/- 330 MVAR) can contribute (though in limited amount) in improving LCC link performance at nominal short circuit levels (approx. 20 GVA) in vicinity of Pugalur.

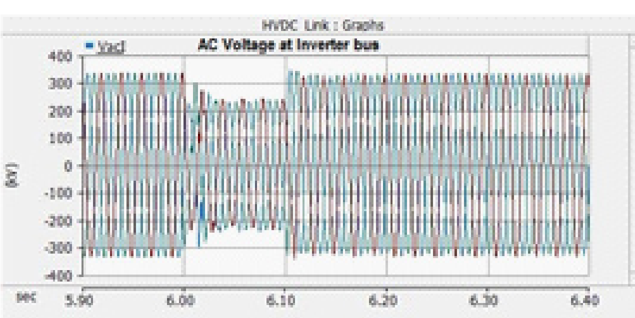
Plots for a three phase fault at Pugalur, with approx. 16% voltage drop are shown in Table I. It is seen that DC power and Extinction angle response of Raigarh Pugalur LCC HVDC are improved with presence of VSC HVDC link. The voltage drop at Pugalur with the presence of VSC is reduced from 16 % to 12%. Further recovery of DC power is smoother in case with VSC HVDC in service[2].

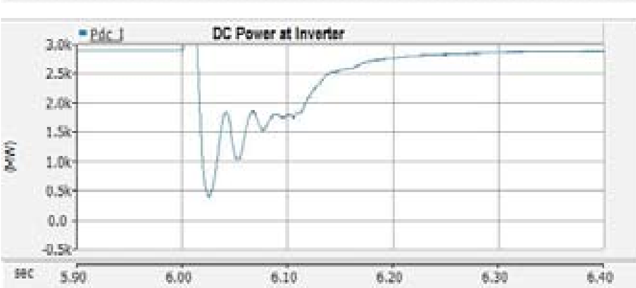
LCC HVDC plots without VSC HVDC in service





LCC HVDC plots with VSC HVDC in service





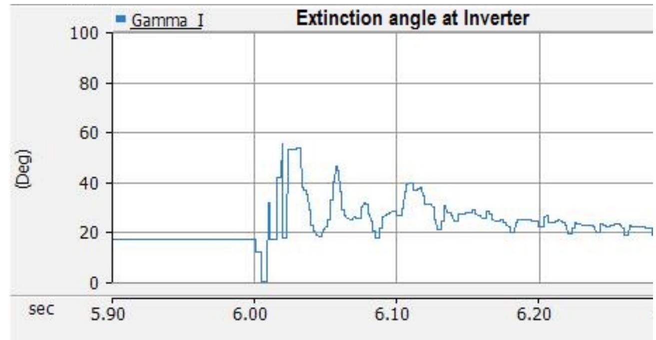


Table I. Comparison of LCC link performance, with and without VSC HVDC link in service, in case of three phase fault[2]

6. CONCLUSION

The paper has presented overview and key features of Pugalur Trichur VSC HVDC link. The link consists of two parallel symmetrical monopoles of each 1000 MW, ±330 MVAR capability. The transmission corridor is combination of overhead line (around 147 km) and underground cable (around 32 km).

Capabilities of the link in respect of reverse power transmission, STATCOM feature, reactive power modulation, black start feature etc. were highlighted in the paper.

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5. R. K. Chauhan, M.M. Goswami, B.B. Mukherjee, S. Bhattacharya, Puneet Tyagi and P. Chakraborty “Challenges in Planning and Design of Cable Transmission System of Pugalur North Trichur HVDC System- Users Perspective” SC-B1, CIGRE Delhi Colloquium, 2017 LCC HVDC plots with VSC HVDC in service

Zero Shutdown Uprating of the Transmission Lines : A New Technology in Indian Context

Shachidevi T.K., Rajat Sud and Madan G. Yadav
Sterlite Power Transmission Limited, India

ABSTRACT

In India, power demand is increasing in every region and at the same time we have many congested power transmission lines which may need to be augmented by new lines or by uprating the exiting lines.

Majority of the times, uprating using high temperature low sag (HTLS) conductor is preferred to increase the amperage using same towers due to non-availability of the right-of-way in many cities. During such change over of the conductor, the line must be shutdown and hence causing power interruptions.

This paper is about the possibility of uprating the transmission lines using live line techniques to avoid shutdown during the stringing and change over period and hence improving the reliability and uptime of the line.

Keywords *: Live line; Zero shutdown; current uprate; voltage upgrade*

1. INTRODUCTION

The uprating of the power transmission line with planned shutdown is a classical method followed for many years. However, in many countries like USA, Canada, South Africa, Australia and many more utilities uprating of the transmission lines are done without power shutdown to ensure uninterrupted power to the consumers using live line techniques.

In India, this will become very relevant in the coming days with increase in demand for the power from all sectors. We may have about 25% of congested lines in India needing uprating. When these lines are critical and hence congested line shutdown becomes difficult for uprating. New line building will also be challenging adjacent to such lines due to dense populations in such areas. This calls for zero shutdown methods during rebuilding the line and enhancing the capacity.

2. LINE UPRATING BY ZERO SHUTDOWN

The zero-shutdown reconductoring method can be defined as a process by which, reconductoring is done in the proximity of the energized lines using special conductor-handling tools and PPE by live line techniques trained linemen to overcome the induced voltage effect.

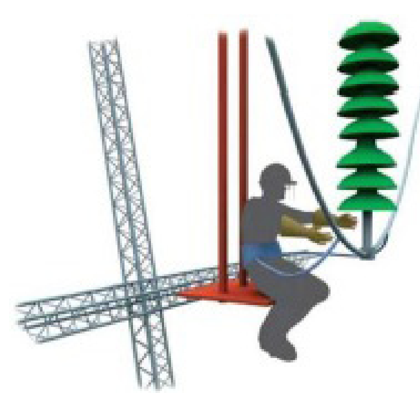
The need for such technique arises for the following conditions;

- When there is no parallel line to divert the load during uprating or change over to new conductor.
- Even when there is a parallel line, if redundancy is not adequate.
- When the loads connected are very sensitive to the repeated shutdown.
- New line building is not possible due to ROW issues and any one of the above.

3. ZERO SHUTDOWN OR LIVE LINE WORK

There are multiple methods to perform live line work. The most common tools for live line work involve fibre glass ladder, conducting suit, hot sticks, rubber gloves etc. A lineman equipped with all such tools can work using different methods namely, hot stick method, bare hand method, Helicopter technique or Ground based robots etc.

Method 1: Hot stick method



Method 2: Bare hand method

Method 3: Ground-based robots

Method 4: Helicopter technique

4. CASE STUDY OF ZERO SHUTDOWN RECONDUCTORING IN INDIA

This is a case study in India for uprating the line to enhance the ampacity taken by Sterlite Power Transmission Ltd. This line is not having any redundant or parallel path available to serve the loads.

This line has reached the thermal limits and carrying current which is much higher than desired due to rapid growth of the industries around. The increased thermal capacity has also weakened the conductor. This has resulted in conductor snapping. Since the line serves critical loads in the region, taking a planned shutdown is impossible for the utility.

Line passes through a very congested area where the residential and commercial buildings have encroaching the right-of-way. Hence, Sterlite proposed to do zero shut down live line reconductoring in this case.

In such cases, with zero shutdown, general methods used are; bucket truck or robotic arm for dismantling and holding the live line while reconductoring (ref: method 3) with the new conductor using live line techniques. However, space required for stationing the trucks will be more. Such techniques cannot be directly adopted for Indian highly populated areas with buildings, on both sides of the right-of-way as shown in the figures below in this case study.

Houses on both side with tower leg touching the compound of a building and Busy main road, the corner building has encroached ROW, Centre of the main busy shopping area.

Existing line data

Items	Unit	Value
Voltage	kV	66
Circuit	D/C	1
Rated current	Amps	330
Rated load	MW per circuit	35
Peak load demand	MW per circuit	36

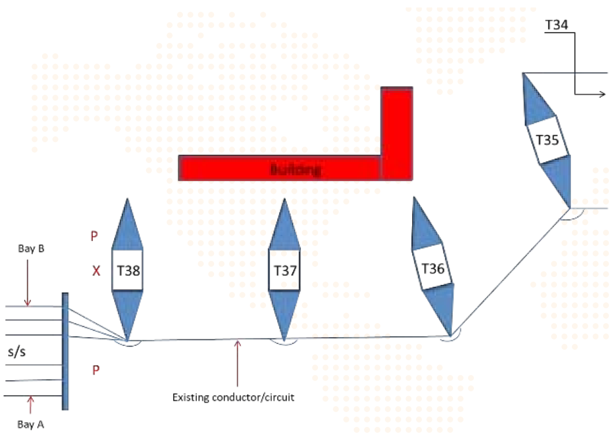
Utility Requirement is to double the ampacity using carbon composite, HTLS conductor.

This new conductor will provide better clearance from ground and hence is safer, compared to present ACSR by enhanced safety clearance from the building.

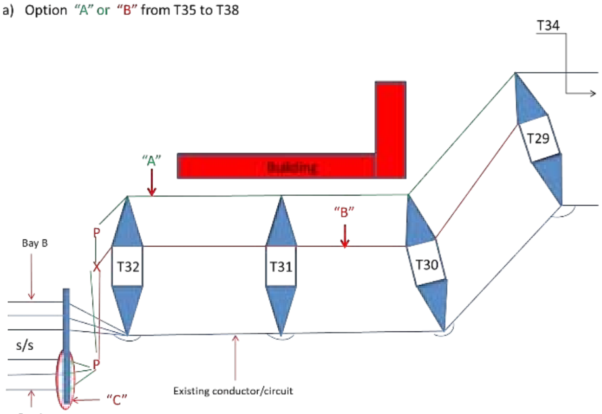
In such congested areas, no well-established methods like bucket truck or robotic arm could have been proposed. Hence, we adopted to create auxiliary phases on the tower for bypassing the load during reconductoring work. The auxiliary phases are nothing but a temporary cross arm or an insulator to hold the bypass conductor. This auxiliary phase created on the tower will be used temporarily during the reconductoring and later, the same is dismantled. This is a very compact neat method of working on live towers in congested corridors. This auxiliary phase is created on the body or cross arm after reviewing the tower strength and electrical clearances.

Additionally, electrical safety precautions like bypassing auto recloser circuit of the breaker etc. need to be addressed.

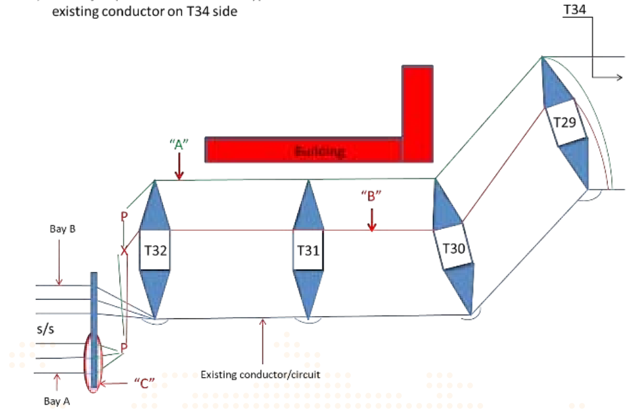
Below are the one among many alternates of doing zero shutdown or live line reconductoring;



Step 2
a) Option "A" or "B" from T35 to T38



Step 3
a) Install jumpers at T35 from the bypass line to the existing conductor on T34 side



5. CONCLUSION

Power sector in India foresees, continuous demand increases over next few years, and this will result in congestion of power transmission lines. Either new lines must be built or exiting lines must be uprated to decongest the lines for evacuating the additional power. The land available being limited for new lines, option of uprating & upgrading of existing lines are inevitable. The present technique discussed may provide a methodology to do such uprate of transmission lines without any load shutdown. This method is suitable for all voltage levels and also for many congested ROW.

This method takes slightly more time for execution as the work is carried out under energised condition. However, the advantage is that work is done without taking shutdown and hence uninterrupted power supply to the consumers.

The price is competitive over creating new line or having not able to shutdown the line at all.

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Use of Retired Hydrogen Cooled Generators as Synchronous Condenser

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BACKGROUND

In order to meet stringent green-house gas (GHG) emission target set in India, power sector is experiencing a big change. On one hand renewable power projects are being set up and on other hand inefficient thermal plants are getting retired. The retiring old plants which were planned in vicinity of load centres will deprive the network of VAR compensation, which was being provided earlier by these units. The introduction of solar and wind based generation scheme fed the power to grid through inverter. The reactive support from renewal plant is given at the cost of real power. It is important to note that in case of for 500 MW machine, the MVA output of Generator is 588 MVA. This machine can provide 310 MVA reactive support in addition to 500 MW. Whereas the output of 588 MVA inverter in renewable when connected to system at 0.85 power factor will deliver 500 MW real power and 310 MVAR reactive component. This 310 MVAR reactive component can be achieved by using a synchronous condenser, which will consume a meagre 700-800 kW to rotate the machine and enhance the real power output by 88 MW.

Thus operation of old generators connected to grid as synchronous condenser could compensate the VAR requirement as being fed to system prior to their retirement. The additional large scale VAR control requirement due to solar and wind addition has to be met by installing new VAR compensation equipments. The investment to install synchronous condenser is much lower as compared to alternative devices like STATCOM used for VAR support, besides offering better performance under dynamic conditions emerging from renewable generation variations.

ADVANTAGES OF USING OLD EXISTING GENERATORS AS SYNCHRONOUS CONDENSER

The use of existing retired spare generators as synchronous condenser could help us in improving the grid stability and also power quality. The synchronous condenser also has several advantages, which makes it a must for system with large scale renewable integration:

- Meet system MVAR requirements arising out of retiring generators
- Provide Inertia due to rotating heavy mass
- Support frequency and active power short time variations
- Low voltage ride through capability during peak condition
- Facilitates dynamic compensation
- To meet reactive MVA of HVDC
- To improve system stability for solar or wind plant weak isolated system
- Maintains power quality
- High reliability and
- Higher overload capability.

Synchronous condensers can be used at different locations to ensure power quality at consumer end and also ensure higher power transfer in existing network. At generation side the synchronous condenser can enhance the power output of wind farms and solar park by increasing the system power factor close to unity.

Accordingly Synchronous Condensers are to be installed near load points, EHV lines having over voltage issues, Solar and wind power plants. Whereas the grid transient requirements are met by static VAR compensators and STATCOMs, maintaining power quality as well as MVAR compensation under dynamic condition can be very well done by Synchronous condenser.

USE OF OLD EXISTING GENERATOR – DESIGN REQUIRMENTS

One of the important requirements of synchronous condenser is fast response, which is available in machines with static excitation system. The response time of static excitation system is 10-20 mS, whereas the machines with brushless excitation system are sluggish with response time up to 100 mS. The following points are to be ensured while using the existing spare generator in New Installation

(i) The Generator design should be suitable for high ramp up rate, which could be 100 MVA/minute. Large generators can very well meet this requirement.

(ii) Generators, where winding bar insulation is tested for temperature cyclic test as per IEEE 1310, are most suitable for cyclic loading condition.

(iii) Generator has to be provided with thrust bearing on drive end.

(iv) Generators provided with Static Excitation System (SEE) are suitable for Synchronous Condenser application. In case of machines with brushless excitation, an advance technology scheme has been discussed, which will ensure the response time of brushless scheme at par with Static Excitation System based scheme.

PROPOSED ARRANGEMENT OF SYNCHRONOUS CONDENSER

Existing old Generator needs to be accessed for healthiness of insulation system by conducting Residual Life Assessment (RLA) study prior to use as synchronous condenser. The other important aspects to be taken care are:

(a) The main generator bearing has to be changed to thrust bearing. The new bearing should be same as used in the test bed, when machine is not coupled to the turbine and run using Variable Frequency Drive (VFD) driven motor.

(b) The drive motor coupled to synchronous condenser will be fed from VFD.

The following equipments are required for synchronous condenser scheme:

(a) The bus bar connection between Generator, Generator Transformer Generator Circuit Breaker, Excitation Transformer, PT&SP Cubicle and LA&VT cubicle.

(b) Generator Circuit Breaker.

(c) The Surge Protection & Voltage Transformer (SP&VT) Cubicle, Lighting Arrestor and VT Cubicle.

(d) Protection monitoring & control system of Generator and auxiliary system.

(e) Necessary HT Feeder to run VFD drive motor is to be arranged.

(f) Necessary Low Voltage Switchgear and Air Conditioning System as per requirement.

(g) Generator Transformer Bank and

(h) HV equipment bay connecting GT bank to grid.

(i) Barring gear system and jacking oil system.

WHY OLD HYDROGEN COOLED MACHINES

It may be noted that hydrogen cooled machine insulation system deterioration is at very low pace as compared to air-cooled machines. The basic two factors which result in longevity of machine insulation system are :

(a) Absence of oxygen in hydrogen cooled machines, thus oxidation of insulation does not take place and insulation deterioration is solely due to mechanical failures, e.g. rubbing of bar insulation.

(b) The hydrogen pressure increases the breakdown voltage of machine insulation system, instead of machine insulation system designed based on 3 kV/mm, the machine insulation breakdown voltage raised to 6-8 kV/mm for 3-4 kg/cm^2 hydrogen pressure. Therefore the electrical stress seen by insulation system of these machines is similar to a case, when 11 kV generator is connected to 6.6 kV system.

In case the MVAR compensation requirement is low, after accessing the healthiness of insulation system, machine can be used as air and water cooled in consultation with OEM. This will reduce the complexity of hydrogen as well as sealing system. Whereas the cooling of stator winding is by water, the rotor cooling is critical as air is used for cooling medium instead of hydrogen. It may be noted that the electrical stress will be much higher on the winding in air medium as compared to that experience during its operation under pressurized hydrogen.

MODIFICATION IN EXISTING SYSTEM

The following modification job required to be carried out in old generator arrangement to use it as Synchronous Condenser:

(a) Brushless Exciter

The brushless exciter scheme is sluggish and the overall response time is about 100 mS. The issue has been addressed by newly developed scheme involve retrofitting of thyristor bridges in place of diode based rectifier wheel. Bluetooth technology is used to fire thyristors on rotating rectifier wheel. This scheme offers all advantages of brushless exciters and will also give high initial response similar to Static Excitation System.

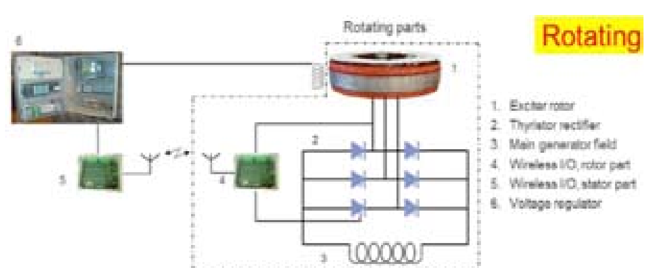

Fig. 1 : Typical arrangement to Use Bluetooth Technology to fire thyristors

(b) Static Excitation System

Static excitation System is necessarily to be used for better and reliable control of machines. The static excitation system is high initial response type to handle grid dynamic condition during sudden load variations seen with renewable generation.

(c) Drive Motor

Adequately sized 6.6 kV motor shall be used to synchronize the generator. The machine speed is increased to a speed more than 3000 r.p.m. and rated voltage is achieved by field control through excitation. After switching off the motor, machine is synchronised with the electrical network as and when rated speed is achieved.

(d) Thrust Bearing

Necessary thrust bearing is to be provided between the drive and generator.

(e) Generator Auxiliary System and Control panel - The existing generator auxiliary system and control panel are to be retained and healthiness of auxiliary system needs to be checked to ensure proper hydrogen pressurisation, perfect sealing and lube oil flow. Necessary AC supply to auxiliaries has to be ensured.

(f) LA & VT cubicle and SP&VT cubicle for Generator protection.

(g) Generator Transformer Bank – The GT shall be sized to meet the MVA as per Generator capability curve at 0-MW line, and designed considering the desired ramp rate of 100 MVA/minute.

(h) High voltage electrical system – All equipment coming in the generator bay are also provided in synchronous condenser scheme.

Suggested building layout of Synchronous Condenser Scheme is as in Figure 2.

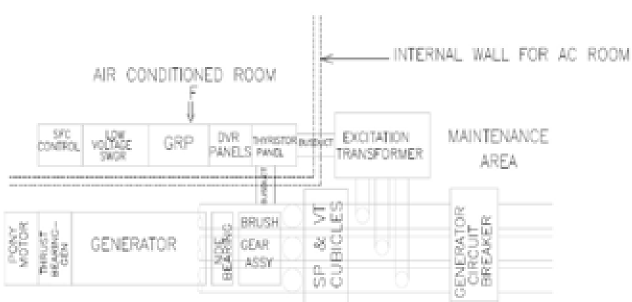

Fig. 2 : Synchronous Condenser Building – Equipment Layout

Typical Synchronous Condenser Scheme

The synchronous condenser requires high current bus-bar connection between the Generator, Generator Circuit Breaker and Generator Transformer. The high voltage side of Generator Transformer is connected with grid through a circuit breaker.

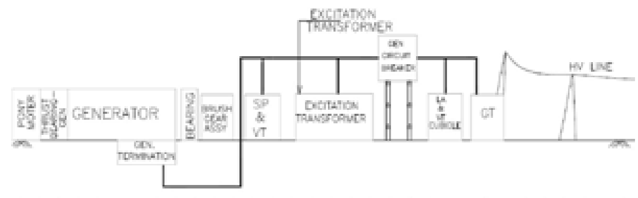

Fig. 3 : Synchronous Condenser Scheme

CONCLUSION

As discussed above, the Indian grid will be severely affected by large scale renewable integration. The sudden voltage and frequency variations expected on the grid will need a good planning to quickly add MW and MVAR as and when system need. The synchronous condenser could emerge as right solution to quickly add MVAR into the system. It will also ensure good power quality and help in maintaining the system inertia and voltage profile. This paper suggests use of advance technology for brushless exciter, which will reduce the response time making the excitation system high initial response type. The suggested use of existing old retired large hydrogen cooled generators will reduce the cost of installation to a great extent.

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New Approach to Reference Node Selection for Wide Area Situational Awareness Using PMUs in Large Grids

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ABSTRACT

Angular stability is one of the important factors in determining the integrity and stability of interconnected large power system. The angular separation between the various nodes in the power system provides the benchmark to decide the amount of safe power flow from one point in the grid to the other point keeping in view the credible contingencies. With the increased complexity and large size of the grid, it is important to monitor the wide area angular separation by the system operator. With the advent of Synchrophasor, the angular separation monitoring in real time has become a reality. However, its improved utilization and the better situational awareness to the operator is yet not been fully utilized due to some challenges. Among these, the selection of the reference node is one. This paper provides a practical approach for the selection of reference node during monitoring of wide area angular separation using PMUs for large grids. The criteria have been supplemented with practical case studies from the Indian power system.

Keywords *: Angular Separation, Angular Stability, Indian Grid, Synchrophasor, Wide area monitoring and control.*

1. INTRODUCTION

With increase in electrical demand and keeping a neck-to-neck balance between reliability and economy, the present power system transmission networks are being operated closer to its transmission capability limit. Transmission capability limit of any transmission line depends on three parameters: voltage at sending end & receiving end, the effective impedance of the transmission line and angular difference between the two ends. The voltage at sending and receiving end cannot be varied much due to design limitation. Further, the effective impedance between two ends is fixed as dependent on the design of the transmission line i.e. length of the line, tower configuration, conductor material, usage of Flexible AC Transmission System (FACTS) device etc. Therefore, angle difference or the angular separation between two nodes is the main factor behind the safe power flow between the nodes. Most of the grids are designed based on angular separation criteria of 30 degrees between adjacent nodes pair after an N-1 contingency. However, in the large interconnected system, even though all the adjacent node pair's angular separation are within the limit, there is a need for the wide area angular separation monitoring to access the overall stress of the power system. The wide area node angular separation is found to be effective in providing a precursor to the operator for increasing stress in the grid and may be warning for significant large disturbance, cascading event and blackouts[1].

System operator uses the State Estimator (SE) from the conventional Supervisory Control and Data Acquisition System (SCADA) for the monitoring of the angular separation in real time operation. The accuracy of the monitoring depends on the availability of all the real-time data of the system states from various locations in the grid. Further, it has its own limitations. State Estimator output cannot be used in dynamic state monitoring as it takes at least 3-5 seconds for each output. SE uses various analog and digital measurements for estimating power system states. But these measured data are not time synchronized. So estimated result is not accurate. In case of bad data or absence of data, SE program may not converge. On the other hand, the Wide Area Monitoring System (WAMS) utilizes the synchrophasor measurement for the dynamic angular separation monitoring between any two nodes having Phasor Measurement Unit (PMU) and has overcome these limitations of angular separation monitoring in real time.

The synchrophasor based angular separation monitoring between any two nodes in the grid has been very useful for the system operator across the globe. Wide area angular separation dynamic plot from synchrophasor provide the status of system stress, power flow across the corridor/flow gate/tie-line between areas, event detection, and oscillation monitoring[1]. However, there are certain challenges in its effective utilization for increasing the situational awareness of the grid operator. Among them, the most important one is the selection of reference node for wide area monitoring.

This paper discusses the importance and challenges in the selection of the reference node for the Wide Area Measurement System (WAMS). In addition, a practical approach on the selection of reference nodes based on the analysis of various case studies in Indian power system has been described in order to improve the monitoring and utilization of angular separation in the grid.

2. TYPES OF ANGLES MONITORED IN THE POWER SYSTEM

Power system has several types of angles and each one own importance. These angles can be broadly classified into four types[2]:

1. Phase angle
2. Power angle
3. Load angle
4. Torque angle

Phase angle is the angular separation between the current and the voltage waves at any node in the grid. While the power angle is the angular separation between the voltages at any two different points in Power System. Load angle is referred to the angular separation between terminal voltage (emf) and excitation voltage (emf) of a generating unit. On the other hand, the torque angle is the angular separation between the rotors's rotating magnetic field (mmf) and the rotating magnetic field (mmf) about the stator of the Generator. The synchrophasor data can provide the first two angular separations. For wide area monitoring, power angle is more important for real time grid operator. The high data rate (25 samples/second) of Synchrophasor data improves the visualization of angular separation during steady state as well as dynamic condition in the grid and thus provides detailed insight into the system behaviour.

Power System operators monitor the power angle from either State Estimator calculation or through WAMS in order to monitor the stress in the grid[1,3,4]. For system operator, the adjacent node angle pair monitoring is of importance in view of synchronization of any line so that angular difference between two ends is within the maximum allowable closing angle. Further, it provides the operator with better information about whether any corrective action is needed to reduce the angle within acceptable limits and when it is safe to close the line. Along with this, the wide area node pair angle separation is of importance to access the stress across the tie lines/ flow gates etc. It provides signatures during extreme events and based on baselining studies and help the operator in wide-area situational awareness.

Over and above this, the wide area angular separation for the entire grid is also monitored with WAMS in real time as it provides real-time assessment of grid stress for the entire grid. However, it requires a suitable selection of reference node PMU in order to provide the correct situational awareness to the operator. Figure 1 shows the All India Angular Separation with respect to one of the node. The perception of angular stability in system changes w.r.t. selected reference node. If the reference node is not selected scientifically and practically, then the incorrect detection of events, oscillation, angular stability etc. may arise which is not desirable in view of system security. The next section describes this aspect and the importance of selection of the reference node for the Wide Area Situational Awareness.

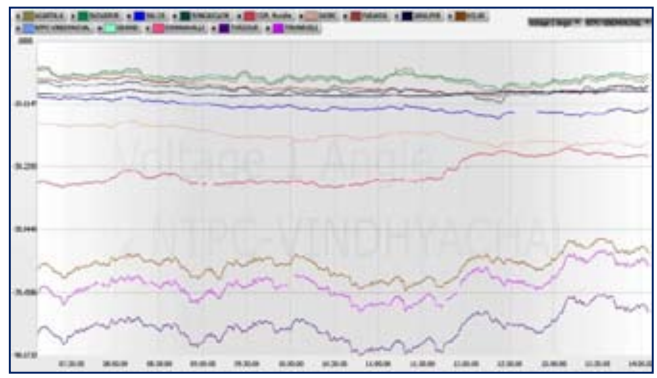

Fig. 1 : Angular separation monitoring of various nodes in the Indian grid with respect to one node from the WAMS system

3. IMPORTANCE OF REFERENCE NODE SELECTION FOR WAMS

Reference node selection plays a vital role in angular separation monitoring whether it is offline like load flow/transient simulation software or online like State Estimation in Energy Management System (EMS) and WAMS[3]. The monitoring of the wide area angle for the entire grid calculated with respect to one reference node provides the status of the entire grid and ongoing dynamic changes. With the advent of WAMS, the wide area angle is now available with Grid operator for real-time assessment.

The importance of Wide Area angular separation in power system can be illustrated with the help of Figure 1, which shows the angular separation in Indian power system measured by WAMS for a duration of 7 hours on a typical day. System operator can infer the following details from these plots:

1. **Maximum Angular Separation** : 100 degrees at around 10:30 AM (Indicating high load condition in the grid). This is also observed during highly skewed load/generation condition as well.
2. **Weekly and Strongly Connected System** : Angular separation indicates that some of the areas in the grid are strongly connected and their angular separation

is sturdy (top half of Figure 1) while some are weekly connected causing wide fluctuation in angular separation (bottom half of Figure 1).

3. **Reduction in Angular Separation** : It is indicative that either the power flow is reduced or the voltages have improved between these two points.
4. **Wide Area Angular Separation Alarm** : If the angular separation is beyond 90 degrees in Indian grid then it alerts operator the system is under stress and there is a need for voltage correction and load-generation re-distribution to reduce the overall angular separation
5. **Load or Generation Variation Around the Area** : Angular separation between various points denotes the power flow between them. If power generation increases near to points with a leading angle or power demand increases near to the points with the lagging angle, angular separation increases.

Therefore, it can be observed that how the wide area angular separation plot can provide the operator with the details of the long-term as well as the short time dynamic of the entire grid. However, the key point here is that the whole inference can change if the reference node for the visualization is not selected scientifically and practically[5]. So, in order to select the suitable reference node in the WAMS system, an exhaustive exercise of baselining of angular separation and operator inference was completed on 3 months data from the WAMS. The outcome of the exercise has provided six criteria, which can help in the proper selection of the reference node and is explained in the next section.

4. CRITERIA FOR REFERENCE NODE IN WAMS FOR WIDE AREA ANGULAR SEPARATION MONITORING

The reference node has a varied impact on the overall visualization of the power system angular separation. Its appropriate selection provides the robust alarms and alerts for real-time grid operation in offline as well as online dynamic monitoring of the system[5]. Out of many criteria developed based on the baselining of data, the major six conditions, which govern the selection of reference node for system operator monitoring and situational awareness, are described in this section one by one with case actual cases.

4.1 Weak Vs Strong Bus as Reference Node

Power system consists of buses having high fault levels, which are referred as strong buses. These buses have strong connectivity with the network owing to which any changes in transmission network due to contingencies do not affect their angular separation largely. Such high fault level nodes are generating complex with large capacity, pooling station where multiple generating stations are connected or substation having strong transmission connectivity with the system. Further, in terms of two grids, the buses in the grids having higher inertia are strong buses while in lower inertia are weak when they are synchronously connected through tie lines.

Based on baselining voluminous data on angular separation it was inferred that strong buses are more appropriate for reference nodes. In addition, if the strong bus is located in a grid having high inertia where multiple grids are synchronously connected with each other the angular separation provides a realistic overview of the system.

Figure 2 shows the Indian grid where five large grids are synchronously connected through AC tie lines. Among the five grids, four grids namely North, East, North-East and West Grid are strongly interconnected and called as NEW grid while Southern Region Grid (SR grid) is connected with few tie lines with rest of the NEW grid. So, the strong buses based on fault level were selected from both grids were selected as a reference for several numbers of cases and it was observed that angular separation monitoring is more sturdy and realistic for the bus located in the NEW Grid due to their high fault level and strong inter-regional connectivity compared to nodes in SR grid. Figure 3 and Figure 4 illustrate the above criteria.

Fig. 2 : Indian Grid shown as the synchronous interconnection of five regional grids. Nodes with PMU are shown in blue. Node with Event, HVDC Line, Varying High Hydro Generation Complex is highlighted for case studies reference.

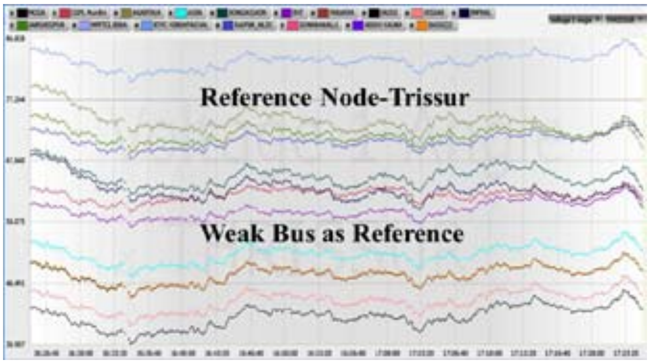

Fig. 3 : Weak Bus/Node in SR grid used as a reference for Wide Area Angular Separation Monitoring

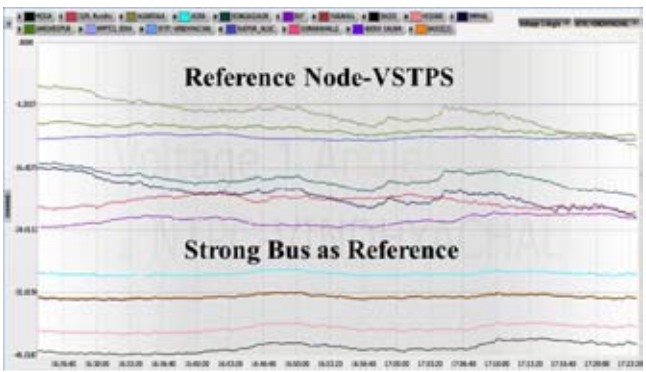

Fig. 4 : Strong Bus/Node in SR grid used as a reference for Wide Area Angular Separation Monitoring

This is due to the higher variation in the angle of the nodes located in the SR grid due to ongoing load generation changes and dynamics. This was the case when the inter-regional connectivity between the NEW and SR grids were limited, however, presently it has been enhanced manifolds and the similar situation does not arise.

4.2 Bus with Unreliable vs Reliable Communication as Reference Node

Communication is the key while using the real-time system like SCADA and WAMS. Thus, it is one of the important aspects while monitoring the angular separation from either SE or WAMS. Any non-availability of the reference bus PMU will result in non-availability of angular separation data from rest of nodes in the system. This can be observed in Figure 5 and 6.

Based on the baselining activity it was found that the Data availability, Data Quality, Time Synchronization is also one key factor in monitoring from WAMS. In addition, it provided two key inputs for future development:

1. The WAMS system should be able to discard the PMU with bad quality and flag the operator.
2. The WAMS system should have a list of reference nodes and when the data of one is not available then it should flag the operator and shift to the next reference node from the list. This will help in continuous monitoring without any interruption.

Fig. 5 : Reference node selected having unreliable communication causing non-availability of wide area angular separation from all nodes

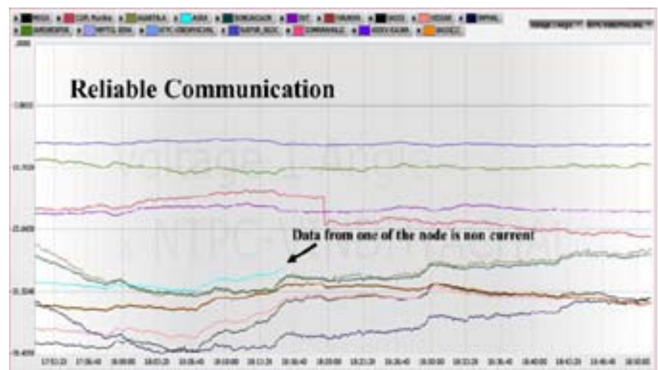

Fig. 6 : Reference node selected having reliable communication due to which all nodes angular separation monitoring is available except for the node having unreliable communication

4.3 Reference Node Near vs Far from Event Location

It is known that whenever any event/disturbance occurs at one of the nodes in the power system, then its angular separation varies by a large quantum compared to the rest of the nodes in the system. This helps in identifying the source of the event using WAMS system however at the same time it can also lead to mistaken situational awareness in wide area angular separation monitoring. If such nodes are taken as reference node then any large change in their angular separation will be reflected in all the nodes across the system and thus making the event look like a global event rather than local power system event.

Thus, it is better to select the reference node away from nodes, which are prone to power system event based on operator experience. Further, whenever any such large change in angular separation is observed, the operator must change reference node in order to know the type of event and get the correct knowledge on the event, its localization and impact.

This is illustrated with Figure 7 and 8 for one event at CGPL node in Western Grid in India. Figure 7 shows the CGPL node as a reference during the event and it can be observed that it has led to a large change in angle separation at all nodes. While when reference was changed to far away node from event location, i.e. another node VSTPS in the Western Regional grid, the angular separation changes only for CGPL nodes and rest of nodes remain largely unaffected in the Indian grid. Thus, it helped in localizing the event along with the correct situational awareness about the event characteristic, i.e., being local than global.

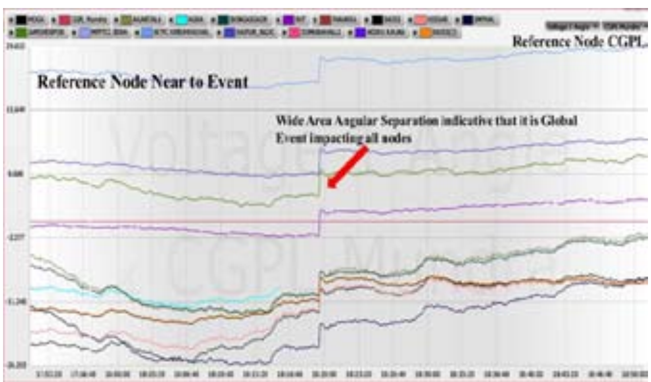

Fig. 7 : Wide area angular separation when the reference node selected near to event/disturbance location (here at the event location itself)

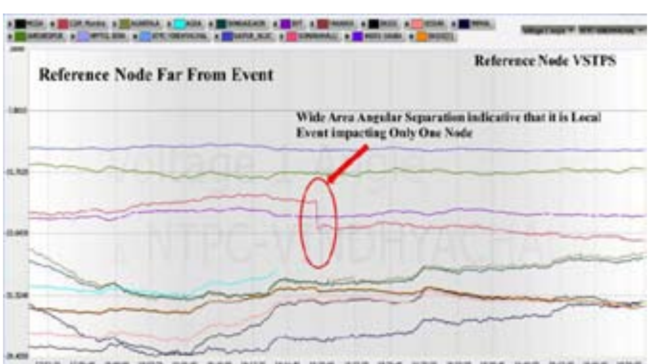

Fig. 8 : Wide area angular separation when the reference node selected far from the event/disturbance location

4.4 Reference Node Away from HVDC

During the baselining activity, it was observed that nodes having HVDC lines also influence the wide area angular separation monitoring to a good extent. As the set point of HVDC are changed throughout the day keeping in view of system security, minimization of system losses and voltage control, the angular separation also changes often. Thus, such HVDC nodes are not good as a reference for monitoring of wide area angular separation. However, if the angular separation reference node is kept away from such nodes, then during such changes of HVDC power order, angular separation of only nearby nodes changes. Figure 2 shows one HVDC connecting North East Grid with Northern Grid and it can be observed from Figure 9 that when reference node is far from HVDC the Angular separation provide a good description of the ongoing impact of HVDC on its nearby nodes.

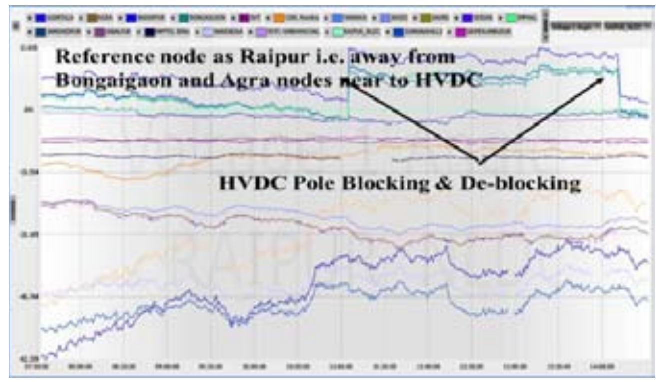

Fig. 9 : Wide area angular separation when the reference node is selected away from the HVDC Node

4.5 Reference Node Near to Varying Generation Complex

In line with the earlier case of HVDC, the baselining also highlighted that reference node location should be kept away from nodes like Hydro generation or Gas generation whose generation is varied during the day to cater the peak load and off-peak load for optimal dispatch. In Figure 2, Hydro generation rich node is shown in North East grid and if it is taken as reference (Refer Figure 10) then the change in the angular separation of such node gets reflected in all nodes giving a wrong interpretation of grid-scale changes.

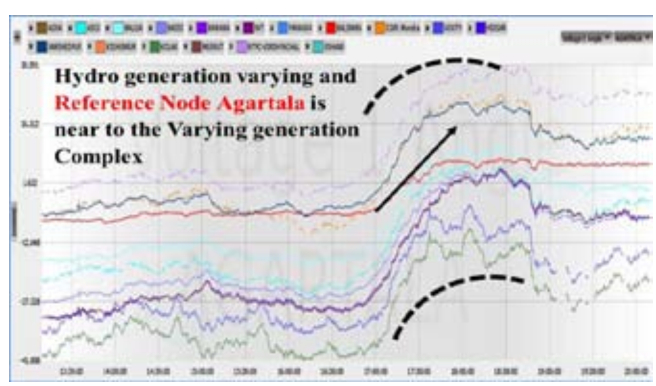

Fig. 10 : Wide area angular separation when the reference node is selected Near to the varying generation complex

Due to similar reason, PMU locations nearby to large renewable generation complex is not suitable for selection as reference node.

4.6 Reference Node Near to Low Frequency Oscillation Source

One most important aspect of angular separation was observed when the reference node has been taken at the node, which is the source of local mode oscillation. This is shown in Figure 11 where Thrissur node observed a local mode of oscillation and its angular separation was varying however when it was taken as a reference, the angular separation was observed in all the nodes just like for cases of event, HVDC and varying generation complex. In order to check whether the mode is local or global, Operator can vary the reference PMU. In this case, when VSTPS was taken as a reference as shown in Figure 12, then it can be observed that only a few nodes are observing the oscillation thus signifying its local nature rather than global. Therefore, it is advisable to avoid such nodes that are prone to low frequency oscillation (LFO). However, if such nodes are strong nodes and such LFO event occurs rarely, then in that case, the operator must be trained to localize the oscillation source by varying the reference node in visualization.

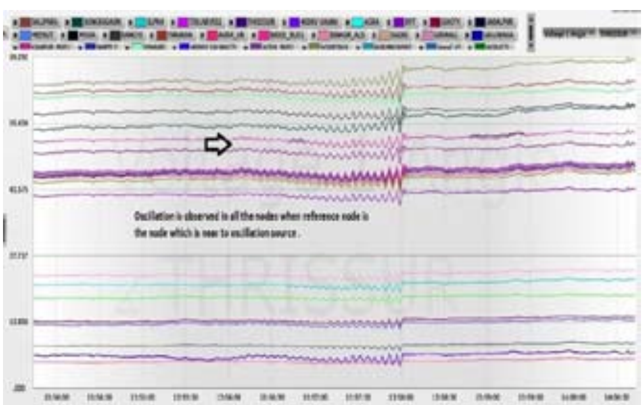

Fig. 11 : Wide area angular separation when the reference node is selected near to the source of LFO

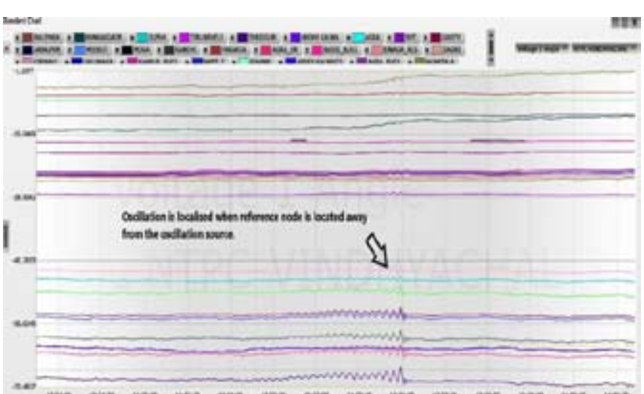

Fig. 12 : Wide area angular separation when the reference node is selected away from the source of LFO

5. SUMMARY OF CRITERIA FOR THE REFERENCE NODE SELECTION FOR WAMS

Based on the baselining activities and various case studies discussed in the paper, the criteria for reference node selection can be summarized as follows:

A. Preferred locations for the reference node

1. Node with strong Interconnections
2. Nodes with reliable communication
3. Node close to baseload Generation Complex
4. Node with High fault level
5. Nodes consistent with offline simulation/EMS studies
6. Should be system-wide available and reliable

B. Nodes to be avoided

1. Nodes with Low inertia, Weak tie lines, Low fault level,
2. Nodes located in Oscillation prone area (Difficult to ascertain),
3. Nodes near to HVDC Bus,
4. Nodes near to Varying Generation Complex

Based on the above, there is a need for preparation of reference look-up table that can be provided as input to WAMS in case of loss of data of any reference node. This will help the operator in stress monitoring of grid using wide area angle and decision-making. The above criteria are theoretical as well practical, and their relevance was observed valid for both the regional as well as national grid. Thus, it can be said that these criteria are applicable to WAMS system deployment and visualization in small as well as large power systems across the world. This important exercise of baselining and preparation of reference node are very much required to be completed beforehand while providing the system operator with wide area visualization from the deployed WAMS.

Based on these criteria, reference nodes have been prepared for all regions as well as National Grid and this list is being reviewed periodically and depending on the requirement of visualizations and applications.

6. ADDITIONAL BENEFIT

The above exercise of determination of criteria for the reference node has also provided several added benefits, which are as follows:

1. Utilization of Angular separation for event detection and localization.
2. Observability of Oscillation as a local or global mode.
3. Priority of availability of multiple communication links from nodes based on important reference nodes.

4. Provided system operator with clear demarcation and importance of reference nodes selection and its impact of human cognitive and perception in real time.

7. CONCLUSION

The paper has discussed one of the most important aspects faced while deployment of WAMS system and associated visualization in real time, i.e., Reference node selection criteria. This aspect of reference nodes criteria presented here is based on baselining exercise of three months angular separation data. This is illustrated with various case studies in Indian power system and shown how it is not only applicable to one system but for all such power systems.

Acknowledgement

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Life is a Combination of
Success and Failure
Both are Needed

Energy Storage Systems for Wind and Solar Power Integration to Grid

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ABSTRACT

It is recognized that renewable energy sources need to be part of the energy mix for a sustainable future. With the rapid growth of renewable energy sources, it will be a big challenge to operate the power system with high wind or solar power penetration securely and reliably due to inherent variability and uncertainty associated with these resources. With the flexible charging-discharging characteristics, Energy Storage System (ESS) is considered as an effective tool to enhance the flexibility and controllability not only of a specific Solar or/and wind farm, but also of the entire grid. The paper gives a brief overview on the importance of Energy Storage Systems for wind and solar power integration to grid.

Keywords *: Renewable energy (RE) sources, Energy Storage System (ESS), Battery Energy Storage System (BESS)*

1. INTRODUCTION

Currently, the dominant source of energy for power generation and transportation is fossil fuel. Most of the countries are depending upon the imported fossil fuel, and therefore, the countries need to face financial instability when the price of the fossil fuel changes in the international market. Renewable sources of energy such as wind and solar, have gained attention over the last few decades as key components to building a clean electric grid.

The greater presence and implementation of intermittent renewable technologies such as wind and solar power means that it is necessary to develop electric power storage capacity as the best solution to improve the quality of the energy generated, facilitate its integration into the grid and provide a reliable and secure response to the technical demands of the smart power grids.

The smart grid transforms the current grid into the one that functions more responsively, economically, and cooperatively. The sources of generation are fossil fuel-generators, renewable energy sources, and battery energy storage systems. The power consumers can be industrial loads, residential loads, commercial loads or batteries to store excess energy for later use as per customer requirement.

This paper is organized as follows, Section 2 presents a review of Energy storage technologies, Section 3 gives benefits of Energy Storage Systems (ESS) in integration of Renewable Energy (RE) sources to grid, and Section IV gives a review of the Energy Storage system planning for integration of renewable energy sources to grid. Section V concludes the paper with the ESS technology that is suitable for integration of RE sources to grid

2. ENERGY STORAGE TECHNOLOGIES

Since the discovery of electricity, we have sought effective methods to store that energy for use on demand. Over the last century, the energy storage industry has continued to evolve and adopt to changing energy requirements and advances in technology.

Energy storage systems provide a wide array of technological approaches to managing our power supply to create a more resilient energy infrastructure and bring cost savings to utilities and consumers.

This increasing importance of energy storage devices has forced the researchers to put great effort into achieving highly efficient and cost-effective storage devices. However, there are many other factors associated with the energy storage devices, which include energy storage capacity (MWh), power capacity (MW), device cost, and maintenance cost. The charging and discharging process of the storage devices require adequate control strategies to perform reliable operation of grids even during the peak demand.

There are different types of energy storage technologies[5] (Figure 1), each having distinguished characteristics in power and energy, depends on the nature of power required and delivered.

Figure 2 categorized the ESS technologies by the nominal discharge time and rated power. Figure 3 compares the power and energy density of the systems.

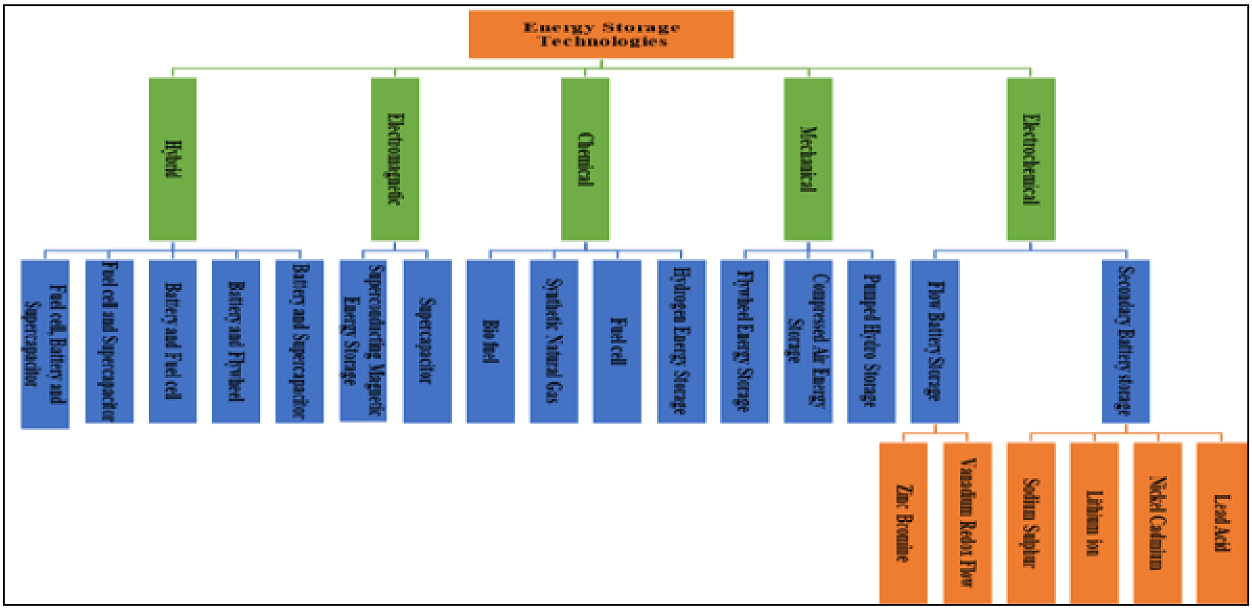

Fig. 1 : Classification of Energy Storage Systems

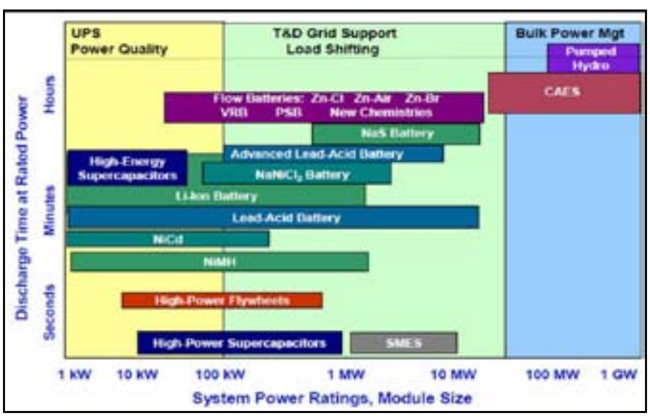

Fig. 2 : Power rating and rated Energy capacity[05]

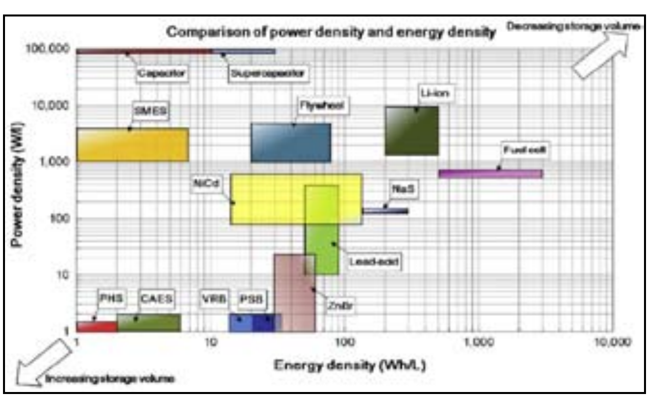

Fig. 3 : Comparison of Power and Energy density[05]

From the characteristics of various Energy Storage Technologies, Battery Energy Storage Systems (BESS) benefits with reasonably high energy density and power densities. It also can provide discharge/charging times ranging from seconds to hours. This differentiates the BESS systems from the other storage technologies to support with fast and slow transients associated with the integration of renewable energy sources to grid.

3. RENEWABLE ENERGY SOURCES INTEGRATION WITH ESS

As use of Renewable Energy (RE) generation increases, there is a commensurate need for electric resources that can address the unique characteristics of renewable energy fueled generation. The key challenges that storage can address include accommodating RE generation's[1,2,3]:

3.1 Output Variability & Ramp Rate Control

Most importantly, storage is expected to enable effective and reliable integration of RE generation whose output is variable and somewhat uncertain. The challenge of variability is primarily related to wind and solar. Example of solar generation variability is shown graphically in Figure 4.

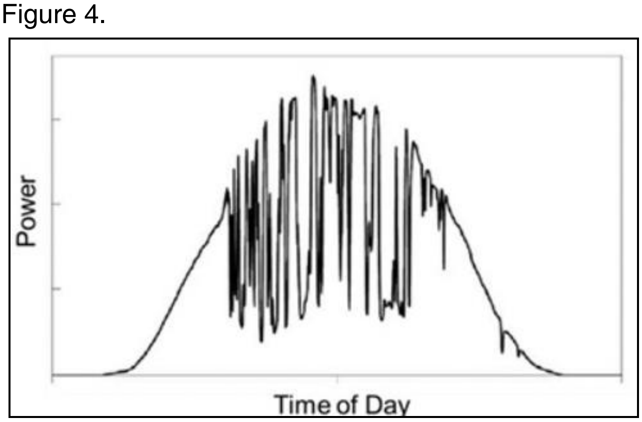

Fig. 4 : Power output from solar during a typical summer day having random cloud cover

RE generation's output variability can be categorized as (a) short-duration or (b) long-duration. Short duration variability-lasting a few seconds to many minutes-is caused by wind speed variability or sometimes significant moment-to-moment variations, and rapid fluctuations of solar energy due to clouds. Long term variability may occur throughout the day. Storage can be used to address both short-duration and long-duration variability.

With respect to short-duration variations, wind generation output power is proportional to the cube of windspeed, meaning that even a modest windspeed fluctuation may result in significant variation of power output from the wind turbine. Similarly, solar generation output can vary rapidly as clouds pass overhead. These rapid variations of output are called ramping. To perform ramping, ESS output changes its output power in such a way that it cancels out the RE generation's variability. For example, if wind generation output drops due to lower wind speed or solar power output diminishes due to numerous passing clouds then storage output is increased by the amount needed to compensate for the rapid reduction of output from RE generation. Similarly, if RE generation output increases rapidly, storage output is reduced accordingly. An example of ramping is shown graphically in Figure 5.

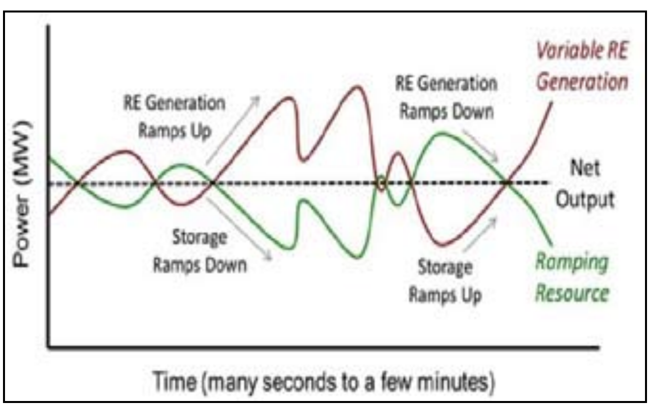

Fig. 5 : Variable RE and Storage Ramping

If storage is used in lieu of generation for ramping, then the benefit is related to combination of (1) reduced need and cost for generation equipment to provide ramping service, and (2) reduced variation of generation output.

3.2 Peak Shaving

From the Figure 6, as the significant portion of wind generation output occurs in night or early mornings, when the energy demand is low, the system operators must either shutdown (curtail) wind generation. With storage that "off-peak" energy from wind generation can be stored and used during the day, reducing (1) the need for generation capacity (equipment) and (2) operation during peak demand periods (thereby reducing air emissions, fuel use, maintenance costs).

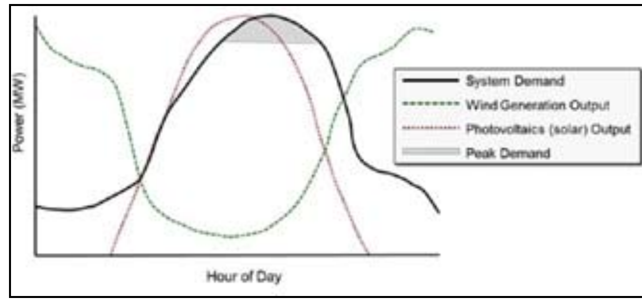

Fig. 6 : Wind and Solar Generation Output and System demand profiles, not including ramping.

3.3 Uncertainty Regarding Weather Forecasts

One challenge associated with RE generation is that there is always some uncertainty about prevailing weather conditions-wind speed and cloudiness – when RE generation is expected and the results can be somewhat dramatic, especially for wind generation because wind can be somewhat to very different than forecasts would indicate, especially when the forecast is a day-ahead.

When unexpected shortfalls of RE generation output occurs, some other resource is needed to make up the difference. Storage could be a valuable and flexible resource for addressing this challenge by providing "back-up" when RE generation is significantly less than expected.

3.4 Ancillary Services

In some cases, the distributed solar or wind produces an amount of power that exceeds the local demand. In such situations the excess electricity must be transferred to other sections of the distribution systems, or even to other regions. Storage can be used to address many PQ related challenges from RE generation by absorbing, filtering or otherwise offsetting many power quality anomalies. For example, when the voltage on a local distribution system varies too much, the storage can absorb excess power and even some types of abnormal power, such as current surges. Storage can also provide "real power" or "reactive power" to improve the voltage.

From the above-mentioned synergies and benefits, it is quite reasonable to assume that energy storage is likely to play a significant role in more sustainable, cleaner, variable and distributed electricity grid future by (1) offsetting negative effects on the grid from RE generation variability (2) increasing the value of variable RE generation output, and (3) enabling more variable RE generation deployment

4. ENERGY STORAGE SYSTEM PLANNING

4.1 ESS Type Selection

The rated capacity of the modern wind and solar farms can reach to several hundred MWs. For the energy management purpose, large-storage medium should be applied, such as BESS, PHS and CAES. Since PHS and CAES are limited by topographical constraints, the BESS is considered as a more competitive option for large-scale ESS application due to high power and energy density. Scalability, fast response, simple maintenance requirement and high cycle life for both technical and economical consideration.

For the power quality improvement purpose, the response time and ramp rate capability are the main concerns. The high energy density storage medium, normally BESS, is adopted for low frequency fluctuations mitigation, and the high-power density storage mediums, which can be super-capacitor, super conducting magnetic energy storage and flywheel energy storage are used for smoothing high-frequency fluctuations.

4.2 ESS sizing

Once the ESS type is determined, the optimal sizing can be solved by balancing the benefits and cost. The sizing problem includes the determination of both power rating and the energy rating.

The ESS sizing problem can also be modeled as an optimization problem. The factors related to the sizing of the BESS, application purpose, control strategy and economical aspect, can be quantified and taken into the optimization formulation as constraints. Based on the State of Charge (SOC), current constraints and charging-discharging rules, the power reference for next hour/minute can be generated to minimize the cost.

The cost function can also be formed as the service life of the energy storage system. The dispatch strategy can be proposed to ensure the BESS goes through full charging-discharging cycle and thus maximized the energy storage potential of the BESS.

4.3 ESS Siting

Some large-scale ESS types, such as PHS and CAES are heavily dependent on topographical conditions whereas BESS can be installed not only on-site with solar and wind farms, but also at different locations in the power system with different purposes, like differing or avoiding transmission capacity upgrade, reducing transmission and distribution losses, and improving system stability. Currently, only few publications have addressed the optimal placement of the BESS in a power system with large scale solar and wind integration[10].

For the on-site installation of the BESS with Renewable Energy sources, the ESS can be placed either at point of common coupling (PCC) i.e., AC coupling or can be connected to the DC, which is then connected to a common converter which converts DC to AC or vice versa.

CONCLUSION

The ESS specifically battery energy storage systems are considered as an effective solution to handle the reliability and stability challenges of future power systems with large scale renewable energy source integration.

BESS can be used for different applications required by specific wind/solar farms, grid operators or consumers. For the generation side, it can aim to improve the grid-friendliness of the RE sources to dispatch energy such that they could be controlled like conventional power plants. For the grid-side roles of the ESS, it can provide ancillary services to mitigate variability and uncertainty of the entire grid.

For the BESS planning, it is important to properly select the BESS type, and determine the size and site of the BESS. The size of the BESS including both power and energy capacity can be determined by several methodologies, including the method of historical wind/solar profiles, the probabilistic method based on wind/solar forecast error etc. The sizing problem can be formulated as an optimization problem with different cost functions. The siting of the BESS without topographical limitations can be installed either on-site or other locations to achieve high controllability

The recent research of the BESS operation and control focuses on the daily dispatch scheme of the BESS with wind/solar farms and fluctuation mitigation. Different factors, including wind/solar power forecast error, technical constraints, market rules, and energy price are taken into consideration to determine the optimal operation strategy or single or multiple ESS.

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Micro Grid Control and Protection

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ABSTRACT

With the increasing awareness of environment aspects, limited use of fossil fuels and need to feed power in remote areas, distributed generation is gaining popularity. Microgrid allows integration of Renewable Energy Generation such as Photovoltaic, Wind and Fuel Cell generations. Microgrid can be used for optimum use of generated energy, storage, and use of the same near load centers itself. Microgrid can operate in grid-connected or islanded mode and provides flexibility in managing power system. When microgrid operates in grid connected environment, this provides flexibility in drawing power from grid or supplying energy to grid in times of excess power availability besides better voltage and frequency control. In island mode of operation, microgrids can operate independently to provide electricity to the remote locations or to keep providing power in emergency situations like grid fault.

With the increasing penetration of distributed generation power sources, some technical challenges in network operation and system stability are imposed.

Since microgrids have relatively smaller capacity, they are vulnerable to random variation in generation and load which may cause operational stability. Due to relatively smaller capacity distribution generation sources, active and reactive power requirement to be monitored in island mode of operation and may require to be compensated, if required.

Conventional distribution systems are normally supplied through one source and has unidirectional power flow. However, in distributed generation systems there can be scenarios of bi-directional power flow and this creates complexity in protection system with respect to discrimination and selectivity.

This Paper will provide overview on challenges in microgrid operation in grid connected and island mode operation. Paper will cover required control and protection measures to take care of these challenges and for reliable operation of microgrid in grid connected as well as island mode of operation.

1. INTRODUCTION

Microgrid is referred to well defined area of an Electrical distribution network which constitutes of Distributed Energy Resources (DERs) besides localized loads. Distributed Energy Resources are relatively small-scale generation which may include Solar, Wind, and Fuel Cell generation besides energy storage devices that interface with low voltage or medium voltage distribution network. Microgrid is normally capable to be operated in grid-connected mode of operation or in island mode.

The concept of microgrid has emerged remarkably to integrate sustainable energy sources in the Electrical network besides various other considerable benefits as mentioned below:

- Potential to integrate various renewable resources into the Electrical Power System
- Localized power distribution
- Reduces grid investment due to lower network capacity requirement
- Ability to isolate itself from grid in island mode during utility grid disturbance
- During peak load, support grid by exporting power
- Environmental benefits due to very less or zero emission generation
- High energy efficiency due to combined heat and Power (CHP) technology
- Improved power quality
- Better reliability due to proximity between generation and consumption

Despite the advantages, microgrid has various challenges to distribution network with respect to control and protection. Distributed Energy Resources (DERs) are required to collectively control the network voltage and frequency, properly sharing the power demand, sustaining grid fault and disturbances, seamless transition from the grid connected mode of operation to the island mode of operation, and vice versa.

Technical challenges for microgrid operation are mainly due to requirement of sustained stable operation in grid connected mode of operation as well as in island mode. Challenge in grid connected mode of operation is affected by number and type of generating sources, and interconnection points of microgrid with the other power system.

Besides the control part, other major challenge is from protection point of view – protection system should be sensitive enough for both, utility grid faults as well as micro grid faults. Various protection concerns are required to be handled for integration of Distributed Energy Resources with distribution level network due to change in fault current level in grid connected and island mode of operation, reduction in reach of distance relays, and relay coordination. In island mode of operation, the major challenge is because of inverter based sources where the limiting factor is due to power electronics devices. Challenges pertaining to bidirectional power flow in microgrid system, low fault current levels due to more inverter-based sources, can be mitigated by adaptive protection mechanism with advanced communication system.

2. ARCHITECTURE

The main component of microgrid are Distributed Energy Resources (Wind Turbines, Solar PV plants, Fuel Cells, etc.), distributed energy storage devices like Flywheel, Batteries, etc. and Centralized Local Loads. Distributed Energy Resources can be mainly grouped in two types of categories – rotating machine-based generation and other is inverter-based generation sources. First category mainly comprises rotating machines which are directly interfaced to the network through transformers; however, second category utilizes Power Electronics converters (Photovoltaic system or Wind energy generation …) as interface media with the grid. From control point of view, methodologies are significantly different for inverter based interface system in comparison to conventional rotating machine generation. Further, from system stability and protection point of view, current rating of silicon devices being used in inverter-based systems are relatively less in comparison to conventional rotating machine-based system.

Distributed Energy storage devices are used in microgrid to provide the back-up to compensate for any power shortage, and mainly used in island mode of operation. Further due to larger time constant of rotating machines, response time against system swings is sluggish and this may cause in system instability during transient disturbances. Digital Energy storage device acts as a controllable AC voltage source and fast output characteristic of these devices help to response against any transient disturbance in the system.

Figure 1 represents single line diagram of typical microgrid that constitutes traditional rotating generating source, variable speed wind turbine, Fuel Cell, and battery energy storage unit. Distributed Energy Resources are through power-electronic converters, however rotating generator

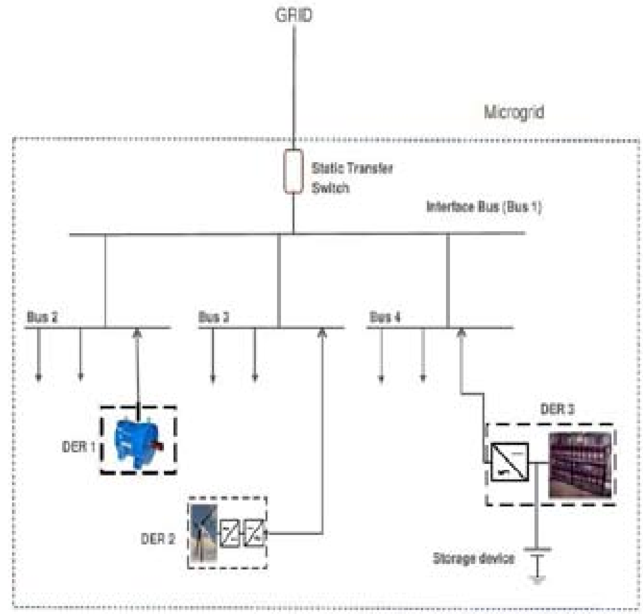

Fig. 1 : Single Line Diagram for Typical Microgrid

is directly coupled at bus. Microgrid is interfaced with the utility grid at Bus 1 through Static transfer switch.

Microgrid normally operates in grid connected mode - during this operation, Distributed Energy Resources (DERs) delivers constant real and reactive power to the distribution network, balance real and reactive power need is compensated by utility grid. In case of any fault in the utility grid, static transfer switch will disconnect microgrid from utility grid to enable microgrid to operate in island mode. Microgrid shall be able to resynchronize itself to the utility grid and seamlessly transition to the grid-connected mode of operation.

3. TECHNICAL CHALLENGES IN MICROGRID CONTROL AND PROTECTION

3.1 Technical Challenges in Microgrid Control

Most important challenge for microgrid control is that this should be capable to manage voltage, frequency, and system stability in both the operating scenarios – grid connected mode as well as island mode of operation.

In the grid connected operation, Distributed Energy Resources (DERs) operate in a constant real and reactive power control mode means that DERs exchange pre-specified power within distribution network with the objection to keep minimum import of power from utility grid.

In island mode of operation, control system must control local network voltage and frequency besides meeting immediate real or reactive power requirement of distribution network. Hence, appropriate voltage and frequency regulation schemes are required to maintain system stability.

Increase penetration of Distributed energy Resources in microgrid system may impose technical issues for stable operation of the microgrid due to steady state or transient voltage swing at interface bus, increase in short circuit levels and power quality problems.

Impedance between Distributed Energy Resources in microgrid is relatively lesser than the impedance in large Power system of utility grid – considering this the accuracy of voltage set points are important, as small error in set point may cause large circulating current within the DERs.

3.2 Technical Challenges in Microgrid Protection

Microgrid concept have several concerns from system protection point of view, mainly because of adaptive protection settings and functions for both – grid connected as well as island mode of operation.

Some of the key challenges for microgrid protection system are:

- *Fault Current Level*

  When large number of small Distributed Energy Resources using rotating generators/motors are connected to network, this changes fault current level as rotating equipment contribute to system fault current.

  When inverter based Distributed Energy Resources are used, fault current is limited to relatively lower value. Due to lesser fault current than load current, even some of the protective relays may not operate. During grid connected mode or island mode of operation, the fault current seen by relay will be different – during grid connected mode of operation, fault will be fed by both (utility grid as well as Distributed Energy Resources). However, in island mode of operation fault current will only be from Distributed Energy Resources which would be quite less than the fault being fed in grid connected mode of operation.

- *Discrimination*

  In the power system network that has generating sources at the end of network, fault current decreases with increase in distance due to increase in impedance. In these types of systems, variation in fault current magnitude is used for discrimination.

  However, in island mode of operation, where microgrid will have mainly inverter interfaced generating sources, fault is limited to lower value and fault level will be constant irrespective of location. Due to this, traditional current based protection coordination which is normally done based on fault current value needs to be adapted for proper discrimination.

- *Sympathetic Tripping*

  Spurious tripping may occur when protective device operates for faults in an outside protective zone. Distributed Energy resource may feed the fault and relay may operate even for fault which is not within the protective zone. As shown in Figure 2, if fault is in line 2, since DER 1 will also be feeding the fault – relay on DER 1 or line 1 may spuriously operate which is not intended.

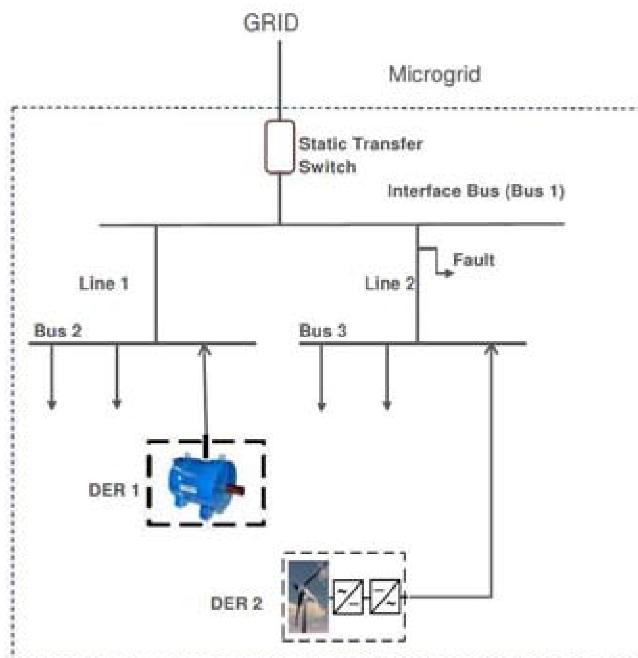

Fig. 2 : Sympathetic Tripping

- *Island Mode Protection*

  Inverter based Distributed Energy resources have limited fault current capability – therefore, fault currents are relatively lesser in the island mode of operation in comparison to grid connected mode of operation. Further, within the microgrid due to significant difference in power contribution by rotating sources and Inverter based sources, the fault current magnitude can vary within the islanded microgrid. Due to fault limiting this behaviour, conventional over-current protection system may not work for island mode of microgrid operation.

- *Single Phase Connection*

  Some Distributed Energy Resources like small PV panels generate single phase power. These type of DERs may create unbalance in the distribution network and can be the reason of stray earth currents in the system. This may impact overloading in the system besides risk to personnel safety.

- *Selectivity*

  Selectivity is the basic requirement of any protection system – system is selective, if the protective device closest to the fault operates to isolate the faulty system from the healthy system.

  Without Distribution Energy Resources, power flow in the system is only in one direction in both the scenarios, during normal operation as well as in the fault situation. By using conventional over-current protection scheme, proper protection coordination can easily be ensured to achieve the necessary sensitivity.

  However, when various Distributed Energy Resources are integrated in microgrid, conventional over-current and coordination may not work. There is possibility of disconnection of healthy feeder because this can feed the through fault. Further, bidirectional power flow which cause the conventional over current protection system to lose sensitivity.

  Renewable energy sources connected in microgrid may generate fluctuating power - setting for overcurrent relays are always based on maximum possible operating current. Due to randomness in generation levels, fault current may be lesser than in minimum operating mode in comparison to maximum operating mode and different fault level currents in both modes may cause relay losing the sensitivity.

  Considering the above-mentioned concerns on protection aspects for microgrid, in brief the main challenge arises from the fact that in microgrid where multiple Distributed Energy Resources are connected, power flow can be bi-directional in each feeder of the network. Other important area is the planning of suitable system which can adapt both the scenarios – grid connected mode of operation as well as island mode.

4. MICROGRID CONTROL SYSTEM

As discussed earlier, microgrid can operate in two modes – grid connected mode and island mode. Proper Control techniques are important to have stable operation of microgrid in either of the operating modes.

Significant points which needs to be taken care in Microgrid control system are:

- Voltage and frequency regulation in both operating modes
- Proper load sharing between various Distributed Energy Resources (DERs) and within DERs and utility grid
- Power flow control between microgrid and Utility grid
- Microgrid islanding in case of unstable utility grid and resynchronization with utility grid
- System stability against transient disturbances and restoration the normal conditions while switching between modes

Microgrid control system can be mainly categorized into three levels:

1. **First Level of Control (Primary Control)** to maintain voltage and frequency stability of the microgrid subsequent to go into island mode from grid connected mode of operation.

   Besides maintaining voltage and frequency stability, control mechanism needs to ensure proper real and reactive power to loads. Power sharing control needs to avoid any circulating current within various Distributed Energy Resources and respective buses.
2. **Secondary Control** to compensate for any deviation in voltage and frequency due to primary control operation and restoration of stable voltage and frequency synchronization stage.
3. **Third Level of Control** is to manage power flow between microgrid and utility grid and to facilitate economically optimal operation

Control system for microgrid needs to be designed to ensure:

- Voltage and frequency stabilization post islanding – Subsequent the isolation of microgrid from utility grid, microgrid can lose voltage and frequency stability (during grid connected mode of operation, voltage and frequency is mainly being governed by utility grid)
- Considering various Distributed Energy Resources (DERs) are there in microgrid, main objective of primary control system is to ensure proper real and reactive power sharing within DERs
- To mitigate circulating current within various DERs and respective buses

Control system work based on reference and loop control mechanism, this particular control mechanism is implemented in active/reactive (PQ) mode or voltage control mode.

Distributed Energy Resources (DERs) operate in constant real and reactive power (PQ) control mode to share pre-specified power within the distribution network.

In island mode of operation, control mechanism need to control local network voltage and frequency and to take care the instantaneous real and reactive power. Hence, appropriate voltage and frequency regulation requirement are important in island mode of operation from system stability perspective.

4.1 Grid – Connected Mode Control

The grid connected mode of control is employed when the microgrid is connected to the utility grid and voltage and frequency is being dictated by utility grid voltage and frequency. In this particular case, the main control requirement is to regulate real and reactive powers that Distributed Energy Resources (DERs) share and feed to distribution network.

If the real and reactive power output of a DER is controlled independent of other DERs and loads, it is non-iterative grid connected mode of control. However, in case where real and reactive power of a particular DER is used as a reference and used as a command for controller, the control mechanism is iterative grid connected mode control.

This means that in non-iterative mechanism, the controller act for constant power delivery mode in grid connected mode of operation and as voltage/frequency controller act as dispatchable power delivery mode with real and reactive power support in grid connected mode of operation and in load sharing (Droop control) mode in island operation in island mode of operation.

Inverter based Distributed Energy Resources are interfaced with the network through power-electronics converters.

Interface Converters provide additional conversion and control, along with fast dynamic response. Control mechanism of invert based DERs are different than the conventional rotating machines control.

In grid connected mode of operation, real and reactive power inverter based Distributed Energy Resources can either be controlled by voltage mode control or current mode control.

4.2 Island Mode Control

Islanding of microgrid can take place either due to some outage in the utility grid or even can be planned due to some maintenance requirements.

In island mode of operation, since utility grid is not there, significant requirement of control system is to ensure voltage and frequency regulation. Therefore, control mechanism needs to be built in such a way that the voltage and frequency can be maintained within pre-specified limits and microgrid is protected against real and reactive power oscillations.

If Distributed Energy Resources (DERs) supply the required real and reactive power besides regulating voltage and frequency of island microgrid, this is known as non-interactive island-mode control mechanism. On the other side, if microgrid have two or more DERs in the system which can share the load requirement, an interactive control mechanism is the recommended. By this, load sharing can be ensured along with voltage and frequency regulation.

5. MICROGRID PROTECTION

As explained above, due to the fact that multiple Distributed Energy Resources are connected on microgrid network, power flow can be bi-directional in each feeder of the network and for stable operation in grid connected mode of operation as well as island mode, conventional over current protection may not provide the proper protection coordination.

Microgrid protection system needs to be designed in such a way that:

- System is suitable for both grid connected as well as island mode of operation
- Adaptable for any type of Distributed Energy Resource and variable generation level
- Augmentable so that any new addition of Distributed Energy Resource can be taken care

Different solutions can be applied to take care the challenges as highlighted for microgrid operation either in grid connected mode or in island mode of operation.

5.1 Adaptive Protection System

Adaptive relays can be used to take care of the challenges the variation in fault current – in this adaptive protection system can be used - where settings, characteristics or logic functions can be adapted on-line by externally generated signals or control logics.

The adaptation of microgrid protection setting is required to adapt the settings based on actual state of the microgrid with respect to Distributed Energy Resource generation level and load requirement.

There can be various control logics which can be built to adapt the relay settings:

- Adjust the current-time characteristic based on the difference in voltage drop response that would be in short circuit or in over-load situation
- Use of directional over-current protection relay, for which settings can be parameterized based on various operating scenarios
- Setting adjustment based on comparing the system impedance to microgrid impedance

Adaptation in the protection settings can be achieved by using IEDs with directional over-current protection function and with multiple setting groups.

Communication Infrastructure using standard protocol like IEC 61850 can be used to exchange information between IEDs and centralized setting coordination unit.

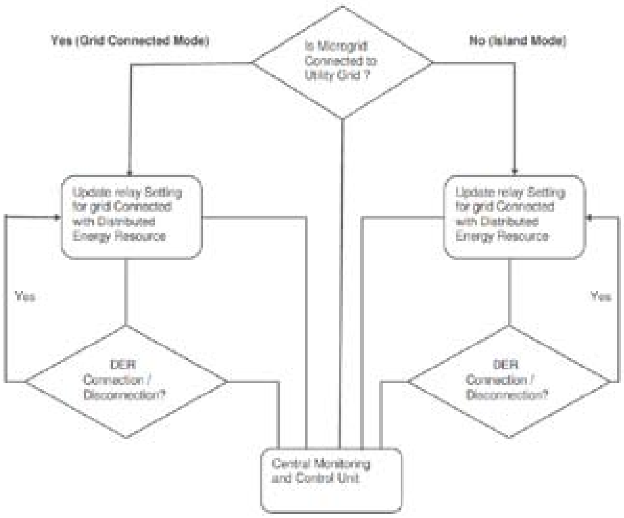

Fig. 3 : Microgrid Protection based on Different Relay Setting Groups

5.2 Protection of Inverter Interfaced Distributed Energy Resources

Since the fault current fed from inverter based DERs are quite less, conventional protection system may not provide the protection coverage for the faults.

Energy storage device like batteries in the system may be useful as these will feed the fault as well. Other possible solution can be to use a higher rated inverter which can provide sufficient fault current or use of pilot wire differential protection where communication can be from both ends of the line to sense the fault and initiate the tripping command, as required.

6. CONCLUSION

This paper outlines the different challenges in microgrid operation in parallel with utility grid and in island mode of operation. Challenges are highlighted for both. Microgrid–control and protection.

Challenged for control are mainly for the different control modes and requirement in grid connected mode of operation and in island mode of operation. Besides the control from protection point of view, the major challenges are due to bidirectional power flow, reduced fault level from inverter based Distributed Energy Resources, spurious tripping, protection blinding, discrimination and desires selectivity of the protection system.

The paper also elaborated the possible solutions like use of pilot wire differential protection, adaptive protection system, smart protection system using the standard communication protocol.

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Transmission Planning for Renewable Energy Zones

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ABSTRACT

India faces the trilemma of achieving objectives of energy access along with energy security and sustainability. Our country possesses abundant Solar and wind energy potential which can meet above requirements. Accordingly, in order to fulfil India's need of secure, affordable and sustainable energy demand to support rapid economic growth, growing population and rapid urbanization, the Government is promoting development of renewable generation through an attractive mix of fiscal and financial incentives as well as conducive policy environment.

Government of India has set a target of establishing 175 GW renewable capacity by 2022, which includes 100 GW from Solar and 60 GW from Wind. Renewable Generation has short gestation period (15-18 months) vis-a-vis development of transmission (24-36 months). This necessitates planning & implementation of transmission system in advance to match difference in gestation period. However, this requires identification of RE complexes which may come up on the priority basis based on availability of land, quality resources, developmental cost etc.

In this regard an exercise was carried out to prioritize Renewable Energy Zones along with their quantum for development in next 2-3 years. SECI/MNRE in discussion with NIWE/SNAs/RE developers, finalized potential wind/Solar complexes that may be developed in next 2-3 year in various RE resource rich states. NIWE/SNA carried out detailed analysis on developable potential of wind energy zones considering various parameters as well as already harnessed potential in that complex. CTU also shared information on applications from various RE applicants in diffèrent wind complexes. Subsequently, Wind Developers//IPPs provided inputs on the wind potential zones based on the feasibility of wind farm development considering availability of resources (Wind/Land etc.), land cost, ROW, existing and planned STU transmission system in complex as well as present regime of competitive wind bids scenario. Likewise, Solar potential zones were also prioritized by SECI/MNRE in consultation with NISE & Solar developers.

Based on corroborations of all inputs, realistic wind (16.5 GW) & solar (50 GW) potential was identified for development in next 2-3 years in different pockets of seven (7) RE rich state viz. Tamil nadu, Karnataka, AP, Gujarat, Maharashtra, MP and Rajasthan. Accordingly, Transmission planning studies were carried out to identify transmission requirement for grid integration of above envisaged Potential Renewable Energy Zones to national grid. For this, system studies were carried out for various load generation scenarios, i.e., RE maximized as well as peak demand scenario for 2021/22 time frame. All India demand is considered as per the 19th EPS of CEA (2021-22). Ministry of Power in consultation with Ministry of New and Renewable Energy notified the long term trajectory of renewable purchase obligation (RPO) for non solar as well as solar, uniformly for all states/UTs (10.5% solar & 10.5% non-solar) by 2021-22. From the Present and envisaged RE capacity and RPO targets of states, it was analyzed that Eastern, North eastern and Northern region states (except Rajasthan) may import RE energy from RE rich states. Some of the other non RE rich states of western and southern region, i.e., Chhattisgarh, Kerala may also fulfill their RPO by importing power from RE rich states. Considering envisaged RE (wind & solar) capacity addition and to achieve Load-generation balance, Thermal generation dispatch is reduced upto 55%, wherever required. Based on above, comprehensive transmission system requirement was evolved for grid integration of above Renewable Energy Zones (66.5 GW).

The paper deliberates on approach to identify transmission infrastructure for grid integration of envisaged potential renewable energy zones.

Keywords *: Renewable energy zone, solar energy zone, wind energy zone, Transmission*

1. PRESENT POWER SCENARIO

The Indian power sector is one of the most diversified in the world. The Sector has been continuously progressing in generation capacity addition through conventional viz. coal, gas, hydro and nuclear as well as non-conventional/ renewable sources viz. wind, solar, small hydro, Biomass etc. Presently total installed generation capacity in the country is about 349 GW (Dec'18) out of which about 79% capacity is contributed by conventional sources and balance 21% from renewable sources. The Conventional generation mix comprises of Coal (198 GW), Gas (25 GW), Nuclear (6.8 GW) and large hydro (45.4 GW). Out of balance 74.1 GW Renewables, Wind & solar generation contribution is about 48% & 34% respectively. Present generation capacity along with their resource composition is shown in Figure 1 & 2.

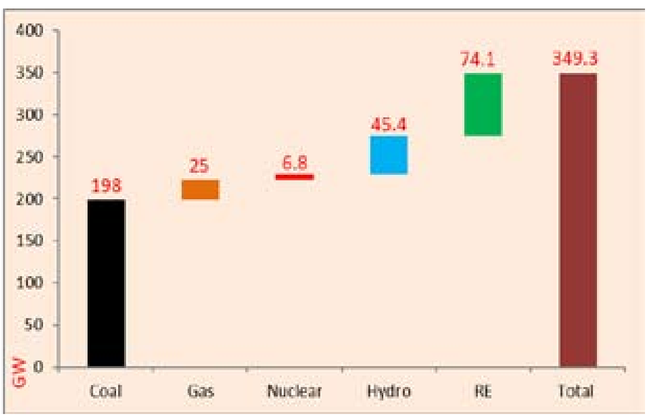

Fig. 1 : Installed Generation Capacity

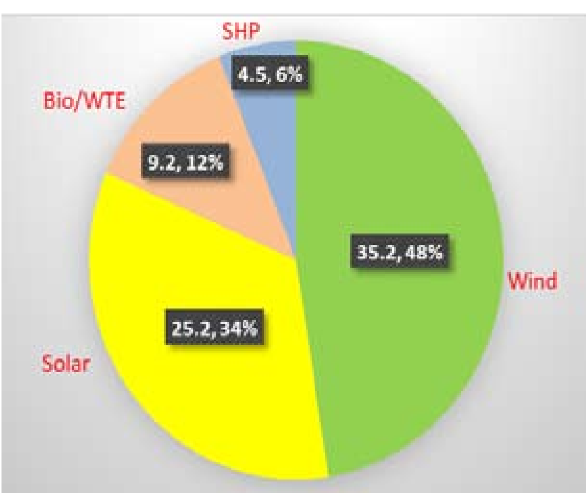

Fig. 2 : Renewable Generation Capacity

Source: CEA

2. RENEWABLE POTENTIAL IN INDIA

India's renewable energy (RE) potential is huge and largely untapped. National Electricity Plan-CEA estimated 275 GW renewable generation by 2027 comprising of 100 GW wind, 150 GW solar and 25 GW from others. Many researchers across the globe have estimated RE potential in India of more than 1000 GW.

NIWE also estimated wind potential of 302 GW at 100 meter hub height. NIWE wind potential map at 100 meter hub height. Out of total potential of 302 GW, 97% wind potential exists in six wind resources rich states viz. Gujarat, AP, Tamil Nadu, Maharashtra, Karnataka & Rajasthan as shown in Fig 3.

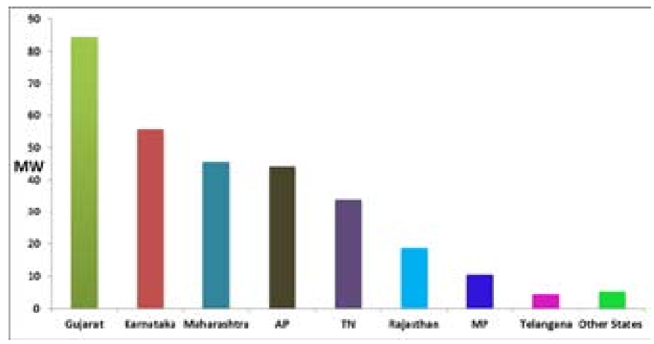

Fig. 3 : Wind potential at 100 m hub height (Source:NIWE)

Unlike wind, solar potential is distributed in most of the Indian states. As per assessment done by National Institute of Solar energy, India has about 749 GW of solar potential. Figure 4 depicts the states each having more than 20 GW solar potential.

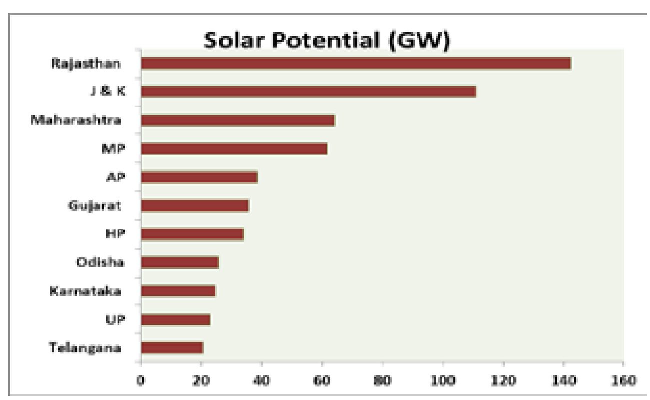

Fig. 4 : State wise Solar Potential in India (Source: MNRE)

3. GREEN ENERGY CORRIDORS- GRID INTEGRATION PLAN OF RENEWABLES

To integrate renewable capacity addition in 12th Plan (by 2017) in Seven (7) RE resource rich states, a comprehensive plan comprising transmission infrastructure at Intra as well as Interstate level and control infrastructure was identified as a part of "Green Energy Corridors" in 2012. Based on approvals, transmission as well as control infrastructure schemes like REMCs, were taken into implementation. Intra state transmission system is being implemented by respective state transmission utilities whereas Interstate transmission scheme of Green energy corridor is being implemented by POWERGRID. Part Inter state transmission scheme is already commissioned & balance are under implementation. Green Energy Corridor-transmission system was planned from good quality Wind/Solar Pockets of RE resource rich states.

During the course of development of Green Energy Corridor (Fig. 5), about 10,000–11,000 MW quantum of long term access RE applications have bene received at various pooling stations in GEC are received. This demonstrates the success of transmission corridor planning from good quality RE pockets.

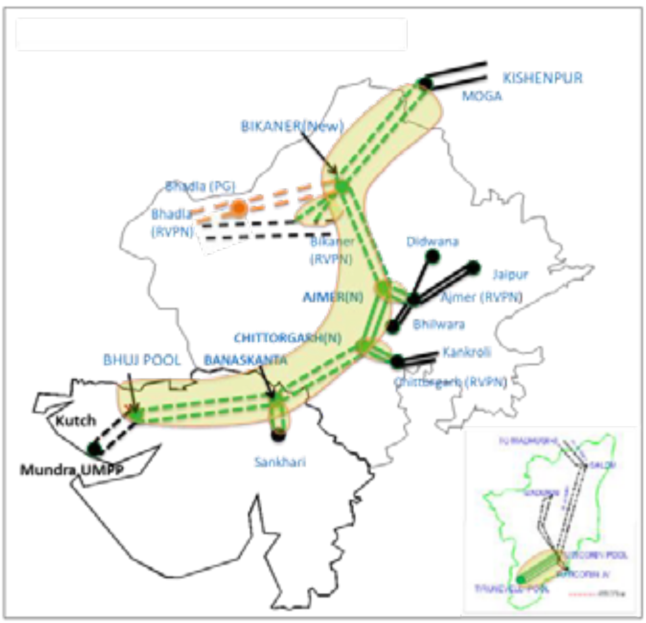

Fig. 5 : Green Energy Corridor - ISTS schème

POWERGRID is also establishing Renewable Energy Management Centers (REMCs) as part of control infrastructure for renewable integration. REMCs comprises of RE forecasting & RE scheduling systems, integrated with existing SCADA co-located with SLDC/RLDC/NLDC at 11 locations [Tamil Nadu, Andhra Pradesh, Karnataka, Gujarat, Maharashtra, Madhya Pradesh & Rajasthan, SRLDC, WRLDC, NRLDC & NLDC] for real time monitoring. The SR, WR and NR REMC packages are already awarded with commission schedule progressively from March 19.

Government of India has also set Solar capacity targets of 1,00,000 MW includes at least 50 nos. solar power parks (40,000 MW) in various states. In first phase, Solar Power Parks of about 20,000 MW capacities in Twenty one (21) states were identified in 2015/2016. Out of this scheme implementation of transmission scheme for seven (7) solar parks viz. Ananthapur (1500 MW), Pavagada (2000 MW), Rewa (750 MW), Bhadla-III (500 MW), Bhadla-IV (250 MW), Essel (750 MW), Banaskantha (700 MW) has been taken up by POWERGRID as part of Green Energy Corridor-II scheme. Transmission scheme for Ananthapur (Gen comm :650 MW), Rewa (Gen comm :430 MW), Tumkur Ph-I (Gen comm :650 MW) is already commissioned.

4. GENESIS OF RENEWABLE ENERGY IN ISTS

Most of RE generation, at present is connected at Intra state and consumed by host states. However, such RE potential rich states have fulfilled their present renewable purchases obligation (RPO) targets and facing various challenges to accommodate more RE capacity within their states due to limited balancing reserves (Hydro/Gas).

To encourage increased RE capacity penetration in total generation capacity portfolio, Ministry of Power vide order dated 13.02.18, waived off Interstate transmission charges & losses on transmission of electricity through Interstate transmission system for sale of power by such wind & solar projects commissioned till 31.03.2022. This waiver shall be available for the period of 25 years from date of commissioning of project and available only for projects entering into power purchase agreements (PPAs) with all entities including distribution companies for sale of power for compliance of RPO. However such wind & solar project needs to be awarded through competitive bidding process in accordance with the guidelines issued by Central Government.

In Oct'16, Ministry of New and Renewable Energy (MNRE) notified "Guidelines for Implementation of Scheme for Setting Up of 1000 MW ISTS Wind Power Projects". The scheme was aimed at facilitating transfer of wind power to fulfill non-solar renewable purchase obligations (RPO) of various states as well as to boost investment in the sector so as to achieve the goal of reaching 60 GW of wind power capacity by 2022. The implementation of the scheme was assigned to Solar Energy Corporation of India (SECI) to carry out bidding/ auction for award to the wind projects. At present total 9840 MW capacity bidding is already completed by SECI/NTPC for wind.

SECI has also concluded ISTS Solar bids for 2600 MW capacity for which majority of PPA/PSA is signed. In addition SECI also completed 1200 MW solar bid recently. Further, NTPC has also concluded bids for 2000 MW solar capacity. MSEDCL has already concluded its 1000 MW Solar bid. SECI has also projected approx. 18 GW Solar and 10 GW Wind projects bidding by end of financial year.

It may be seen that above biddings have boosted the RE sector to the newer highs necessitating requirement of Inter state transmission system. However at the same time gestation period mismatch between RE and Transmission needs requirement of advance transmission planning as well as implementation.

5. IDENTIFICATION OF RENEWABLE ENERGY ZONES (REZs)

NIWE had identified potential of 302 GW at 100 m agl. Majority of wind potential is confined in wind resources rich states. To identify developable wind potential zones by 2022, several round of discussions were held in 2017-18 with all stakeholders viz. MNRE, POWERGRID, NIWE, STUs and SNAs of wind potential rich states & wind developers/IPPs for prioritization of potential wind energy zones (WEZ) for which Interstate transmission infrastructure requirement is to be assessed.

CTU has also received large no. of applications from wind developers in last 1-1.5 years seeking connectivity at Interstate level. Due to short gestation period of wind generation, quality wind energy zones/ pockets where wind capacity (quantum) can be developed by developer was needed to be identified well in advance.

For above analysis, NIWE provided district wise Wind potential data of various pockets/REZ (Out of total potential of 302 GW at 100 m above ground level based on Rank-I/II/III grading land) in wind rich states. Based on district wise Wind potential of various pockets/WEZ in wind rich states provided by NIWE and applications received by CTU, pockets are segregated in three (3) categories

1. *Category -I* Districts : With High NIWE Potential & High Quantum of Applications received by CTU
2. *Category -II* Districts : With High NIWE Potential & Less Quantum of Applications received by CTU
3. *Category -III* Districts : With Less NIWE Potential & High Quantum of Applications received by CTU

Out of above potential, SNA provided inputs for district wise total technical potential data (i.e., NIWE potential-land constraints/topography etc) as well as developable potential. STU provided information regarding pooling station wise sanctioned wind capacity in state. As the some sites (Rank-III sites) were on forest land and its total potential was also miniscule, therefore it was not considered in further analysis.

Subsequently, Wind Developers/IPPs provided inputs on the wind potential zones based on the feasibility of wind farm development considering availability of resources (Wind/Land etc.), land cost, ROW, existing and planned STU transmission system in complex as well as taking account of present regime of competitive wind bids scenario. Based on all above inputs, prioritized wind energy zones were identified for next 2-3 years.

Solar Energy Corporation of India (SECI) in association with MNRE and in consultation with RE power developers also identified Solar Energy Zones (SEZ) [50 GW] and wind energy zones (WEZs) [16.5 GW] in seven RE rich states (Andhra Pradesh, Karnataka, Tamil Nadu, Gujarat, Rajasthan, Maharashtra and Madhya Pradesh). Further to ease the implementation of transmission infrastructure, it was proposed to bifurcate the requirements in two phases. Accordingly, total of 20 GW solar & 9 GW wind projects were planned for Phase-I (up to December 2020) and 30 GW solar & 7.5 GW wind projects planned for Phase-II (December 2021).

Table 1 : Solar Energy Potential Zones

State/District	Taluk/Tehsil	Total
Rajasthan		
Jaisalmer	Ramgarh	4
	Fatehgarh	4
Jodhpur	Phalodi	3
Bikaner	Koyalat /Pugal	4
Barmer	Barmer	5
Subtotal		**20**
Andhra Pradesh		
Kurnool	Gooty	2.5
Ananthpuram	Urvakonda	2.5
Subtotal		**5**
Karnataka		
Gadag		2.5
Bidar		2.5
Subtotal		**5**
Gujarat		
Kutch	Rapar	5
Banaskantha	Vav /Tharad	2.5
Jamnagar	Lalpur	2.5
Subtotal		**10**
Maharashtra		
Solapur		2.5
Wardha		2.5
Subtotal		**5**
Madhya Pradesh		
Rajgarh		2.5
Khandwa		2.5
Subtotal		**5**
Total		**50**

Table 2 : Wind Energy Potential Zones

State/District	Taluk/Tehsil	Total(GW)
Tamil Nadu		
Karur		2.5
Tirunelvelli		0.5
Subtotal		**3**
Andhra Pradesh		
Kurnool		3
Subtotal		**3**
Karnataka		
Koppal		2.5
Subtotal		**2.5**
Gujarat		
Kutch	Bhuj	2
	Lakadiya	2
Dwarka		2
Subtotal		**6**
Maharashtra		
Osmanabad		2
Subtotal		**2**
Total		**16.5**

6. APPROACH FOR TRANSMISSION PLANNING AND STUDY ASSUMPTIONS

In order to evolve grid integration requirement for above identified Renewable Energy Zones, Transmission System planning Studies were conducted for various load generation scenarios i.e., RE maximized scenario as well as peak demand scenario for 2021-22 time frame. All India demand data was considered as per the 19th EPS of CEA (2021-22). For peak demand scenario, regional demand was considered as per the 19th EPS. Based on the discussions & past trends, for RE maximized scenario, demand was considered as about 90% of the peak demand of 19th EPS for various regions except for Northern region where it is considered as about 95% of the peak demand.

To achieve the target of 175GW RE capacity by 2022, the Ministry of Power in consultation with Ministry of New and Renewable Energy notified the long term trajectory of renewable purchase obligation (RPO) for solar as well as non solar, uniformly for all states/UTs (2016-17 to 2021-22). The long term trajectory of RPO of all states/UTs shall be 21% (10.5% solar, 10.5% non solar) by 2021-22. From the analysis of present, envisaged RE capacity and RPO targets of states, it emerged that Eastern, North eastern and Northern region states (excluding Rajasthan) may import RE energy from RE rich states. Non RE rich states of western and southern region i.e Chhattisgarh, Kerala shall also fulfill their RPO by importing power from RE rich states.

In the studies, all India transmission network up to 220 kV level was simulated. This includes, existing as well as under construction transmission network including high capacity transmission corridors and Green Energy Corridors. Considering envisaged RE (wind & solar) capacity addition and to achieve Load-generation balance, Thermal generation dispatch was reduced upto 55%, wherever required.

7. TRANSMISSION SCHEME FOR RENEWABLE ENERGY ZONES

(i) Northern Region

In Northern Rajasthan, 20 GW Solar generation potential is envisaged to be developed by Dec' 21 which includes 10 GW Solar generation in each Phase-I & Ph-II. The potential comprises in Jaisalmer (Ramgarh : 4 GW, Fatehgarh : 4 GW), Jodhpur (3 GW), Bikaner (4 GW) and Barmer (5 GW) districts of western Rajasthan. Based on above potential generation, detailed studies were carried out to evolve transmission system for both the phases. However subsequently, potential in Barmer (5 GW) was reallocated to other districts of western rajasthan i.e. Fathegarh/Jodhpur & Bikaner due to land issues and phase-I capacity was reduced to 9 GW vis a vis earlier 10 GW. Based on above RE generation potential, detailed studies were carried out to evolve transmission system for both the phases. Transmission system shall cater to the power transfer requirement from the above Renewable Energy Zones to various load centres.

Considering above requirements of Power Transfer from LTA applicants (3100 MW) as well as Solar potential (5800 MW) of various complexes in western Rajasthan i.e. Fatehgarh, Bhadla/Phalodi & Bikaner, the transmission system so evolved through system studies included establishment of high capacity 765 kV transmission corridors emanating from above complexes to various grid points in Northern region including load centers in Delhi. Therefore cumulatively, this caters to power transfer requirement of 8900 MW Solar generation from Western Rajasthan (Schematic at Fig 6 as under). This transmission scheme is under various stage of tendering now.

Fig. 6 : Transmission scheme for solar energy zones in Rajasthan (Ph-I :8.9GW)

(ii) **Western Region**

In Western region, 20 GW solar & 8 GW wind generation potential is envisaged to be developed by Dec'21 in Gujarat, Maharashtra and MP, which includes 7.5 GW Solar & 3 GW wind generation respectively in Phase-I (Dec'20). Further, 12.5 GW Solar & 5 GW and wind generation is also envisaged in Ph-II (Dec'21). The potential comprises in Kutch, Jamnagar, Banaskantha, Dwarka districts in Gujarat (Solar : 10 GW, Wind : 6 GW) and Solapur, Wardha and Kallam (Osmanabad) districts in Maharashtra (Solar : 5 GW, Wind: 2 GW). In Madhya Pradesh (Solar : 5 GW), potential comprises in Khandwa and Rajgarh districts. Based on above RE generation potential, detailed studies were carried out to evolve transmission system for both the phases. Transmission system shall cater to the power transfer requirement from the above Renewable Energy Zones to various load centres.

Considering requirements of power transfer from solar as well as wind potential of various complexes in Gujarat i.e. Kutch, Jamnagar, Banaskantha & Dwarka, the transmission system included establishment of 765/400/220 kV pooling station near Bhuj and Lakadiya in Kutch, and 400/220 kV Jam khambhaliya S/s in Dwarka and establishment of high capacity 765 kV transmission corridors emanating from above complexes to various grid points in Western region including load centers in Gujarat. This transmission scheme is under various stage of tendering now.

Transmission system in Maharashtra included establishment of 400/220 kV Sholapur, Wardha and Osmanabad and its 400 kV interconnections in Maharashtra (Fig. 7 : Transmission for Gujarat & Maharashtra REZ)

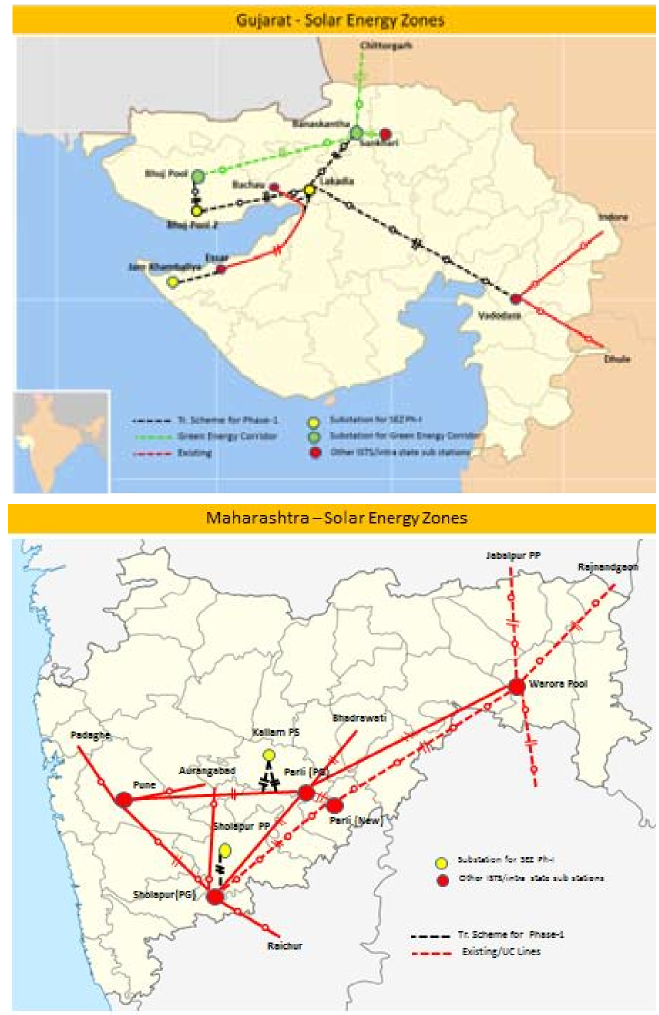

Fig. 7 : Transmission scheme for renewable energy zones in Gujarat (Ph-I: 6 GW) & Maharashtra (Ph-I : 3 GW)

(iii) **Southern Region**

In Southern region, 10 GW solar generation & 8.5 GW wind generation potential is envisaged to be developed by Dec' 21 which includes 1.5 GW of Solar & 8.5 GW of Wind generation in Phase-I (Dec' 20) and 8.5 GW of Solar in Ph-II (Dec' 21). The potential comprises in Koppal, Gadag & Bidar districts in Karnataka (7.5 GW), Kurnool & Anantapur districts in Andhra Pradesh (8 GW) and Karur & Tirunelveli districts in Tamil Nadu (3 GW)

Based on above RE generation potential, detailed studies were carried out to evolve transmission system for both the phases. Transmission system shall cater to the power transfer requirement from the above Renewable Energy Zones to various load centres.

Considering requirements of power transfer from solar as well as wind potential of various complexes, the transmission system included establishment of high capacity 765/400/220 kV Kurnool PS & 400/220 kV Koppal, Karur substations along with 765 kV & 400 kV transmission corridors emanating from above complexes to various grid points in Southern region for transfer of power to load centers (Fig. 8 & 9).

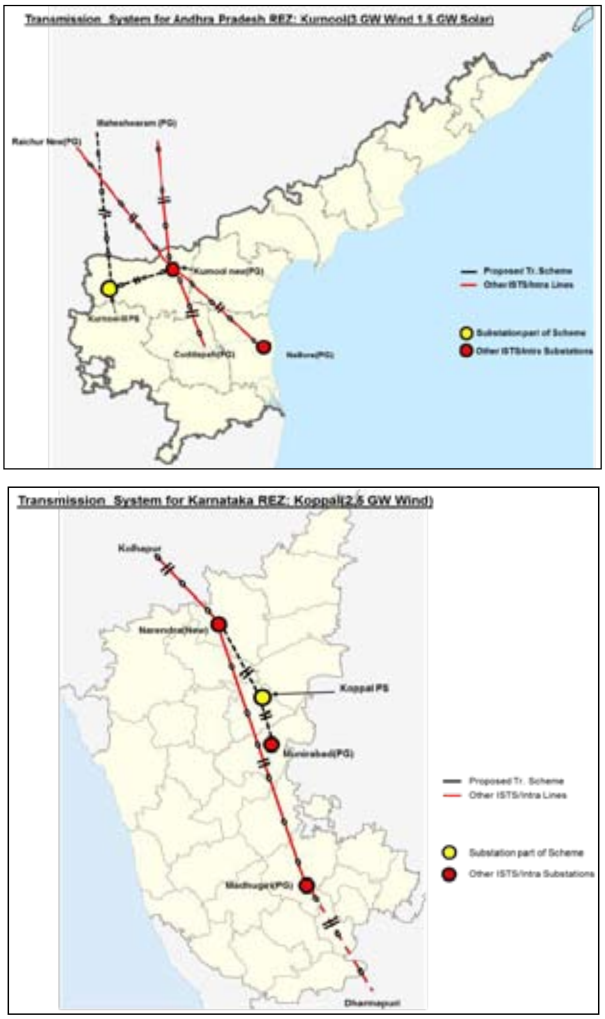

Fig. 8 : Transmission scheme for renewable energy zones in AP (Ph-I: 4.5 GW) & Karnataka (Ph-I: 2.5 GW)

8. CONCLUSION

India is bestowed with abundant Renewable potential, which offers an excellent solution to attain energy security, environmental sustainability & provide energy access. The gestation period for development of renewable generation is much lesser than time required for development of transmission system. Transmission planning for integration of large scale renewable generation is a major challenge vis-à-vis planning of transmission system for conventional generation.

Considering above a proactive initiative viz. evolution of Green Energy Corridor was earlier taken up, wherein transmission for high potential renewable zones was planned in anticipation for subsequent Renewable Generation development. However in view of Govt. of India target for RE capacity (175 GW), there was a need for advance planning of additional transmission corridors for grid integration of envisaged Renewables capacity. Future large sized wind generation projects & ultra mega solar power parks are more often located at distant location to load centers such as at Deserts, wastelands etc. would necessitate development of long distance transmission infrastructure in phased and modular way. This shall not only help in transfer of power from renewable resource rich states to other deficit States but also complement parallel transmission corridors of conventional generation projects/grid strengthening scheme for transfer of power as well as to maintain grid parameters.

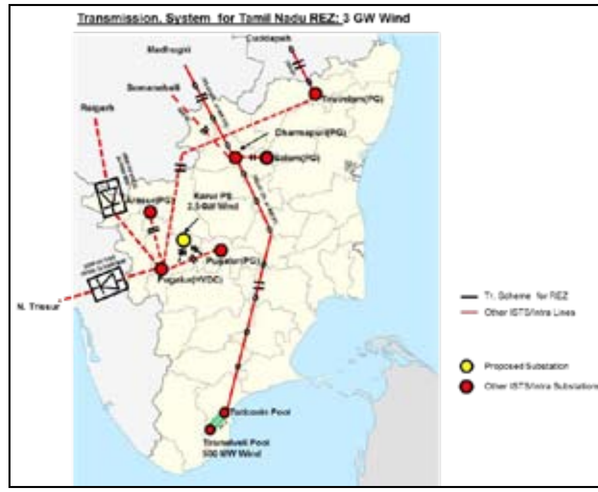

Fig. 9 : Transmission scheme for renewable energy zones in Tamil Nadu (Ph-I : 3 GW)

Acknowledgement

Authors are thankful to the management of POWERGRID for granting permission to present the paper. Views expressed in the paper are of authors only and need not necessarily be that of management.

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Powergrid's Experience on Best O&M International Practices

R.K. Tyagi, Manoj Kumar Singh and Vivek Sundariyal
Power Grid Corporation of India Limited

ABSTRACT

Power Grid Corporation of India Ltd. (POWERGRID) operate and maintain about 1,51,300 circuit kilometres of overhead EHV transmission lines spread over the length and breadth of the country involving about 2,70,000 no. of various configuration of towers. To operate such a huge network, inspection of each tower is to be carried out at a regular interval by skilled manpower for identification of any defects like missing (theft) tower members, damage to foundation/ conductor/ hardware/ insulator, hotspots/ infringing vegetation growth etc.

Manual inspection of transmission line towers is becoming more and more difficult due to large network coupled with difficult terrains across the country. For maintaining the large transmission network effectively, POWERGRID has adopted best O&M international practices like aerial patrolling of transmission lines using LIDAR (Light Detection & Ranging), thermal/ corona & high-resolution photographs, GIS mapping and application based patrolling which are reliable and cost effective.

Keywords *: Aerial patrolling, Corona/ thermal scanning, LIDAR mapping, App based patrolling, GIS mapping, POWERGRID*

1. AERIAL PATROLLING OF TRANSMISION LINES

Manual inspection of transmission line is a physical intensive work, which requires skilled manpower for defect identification. Also it is time consuming work. Based on these limitations, about 10-15 towers can be inspected effectively each day.

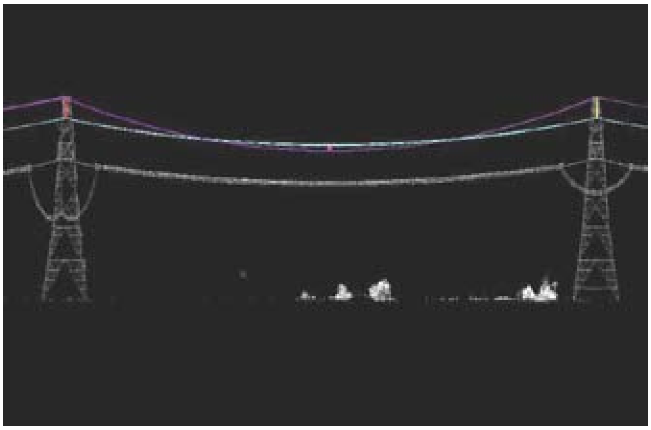
To overcome above limitation and early detection of faults in transmission lines, aerial patrolling of transmission lines using state of the art sensors like LIDAR (Light Detection & Ranging), high resolution digital still camera, high definition Video Camera, Thermovision Camera and Corona Camera was taken up by POWERGRID for the first time in India in year 2014. At present, aerial patrolling of about 15,000 route kms of transmission lines has been completed.

Aerial Patrolling of 400 kV Kaiga-Narendra line

The sensors used in aerial patrolling work can capture minute details of live line portion of transmission lines (conductor, jumper, insulators etc.) which can help in identification of faults/efects in incipient stage. Further, LIDAR sensor can map complete transmission line corridor in three-dimensional map, which can be used for determining any violation in electrical clearances between conductors with ground/ tree/ other phase conductors/ Earthwire/ Powerline Crossing etc. The information captured through aerial patrolling is very fruitful for planning the maintenance work as it provides authenticated information supported with 3D LIDAR maps, high-resolution imagery of tower, Thermal/ Corona signatures and video clips about transmission line corridor. Further, Aerial patrolling of transmission lines helps in mechanization of patrolling activity and has reduced manual intervention. In POWERGRID, application of Aerial Patrolling has helped in following areas:

1.1 Detection of Low Clearance Using LIDAR

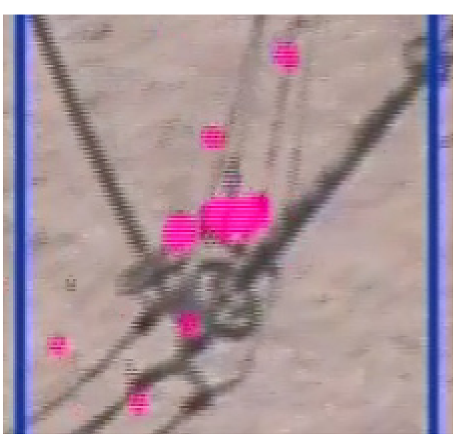
Recently LIDAR scanning of various lines was carried out for detection of electrical clearance violations. During analysis of LIDAR data, it was observed that at some locations, the vertical distance between Earthwire and top conductors at mid span is very less due to excessive sag. In some cases vertical distance has gone beyond zero level, indicating that EW/OPGW is at lower level than conductor which may cause tripping during high speed wind. Such kind of clearance issues are difficult to detect during ground patrolling and requires thorough examination by climbing the tower.



LIDAR image of line indicating high sag in Earthwire

1.2 Detection of Excessive Corona Signature on Insulators

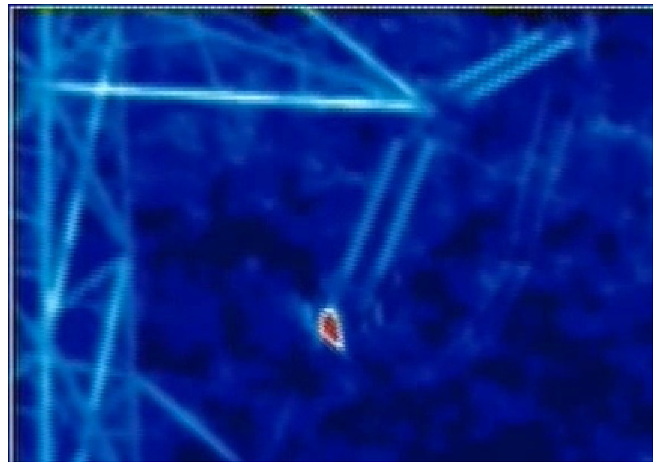
For smooth operation of transmission lines passing through polluted stretches, polymer insulators have been installed to reduce pollution related trippings. However, as per international experience, polymer insulators are susceptible to corona discharge. Aerial patrolling using corona sensors had helped in early detection of excessive corona discharge on polymer insulators. Based on the findings, preventive action had been taken to avoid any damage to polymer insulators.



Excessive corona discharge on insulators

1.3 Detection of Hot-spots in Jumper/Conductor Joints

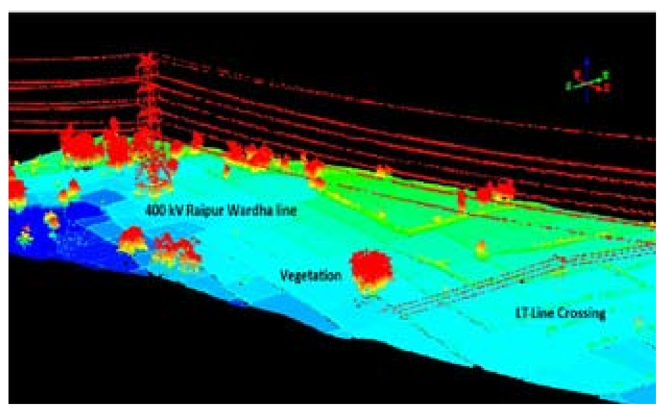
Aerial patrolling also includes use of highend thermovision sensor, which can detect any abnormal rise in temperature/ hot-spots in jumper / conductor joints, which can be rectified in incipient stage.



Hot-spot on jumper connection

1.4 Development of Complete Transmission Line Database

Aerial patrolling can also help in building a complete database of a transmission line having high-resolution imagery, corona/ thermal signature, LIDAR mapping of each tower and HD videography of entire line, which could be used as reference for comparing any change in condition of line elements in future.



LIDAR map covering every ROW corridor information

2. TRANSMISION LINE MONITORING USING GEOGRAPHICAL INFORMATION SYSTEM (GIS)

Geographical Information System (GIS) is virtual mapping of transmission system assets on satellite imagery on a platform which can be accessed by the concerned maintenance staff. GIS mapping for transmission system can help in detecting change in terrain, river course, and vegetation growth in the vicinity of transmission line towers.

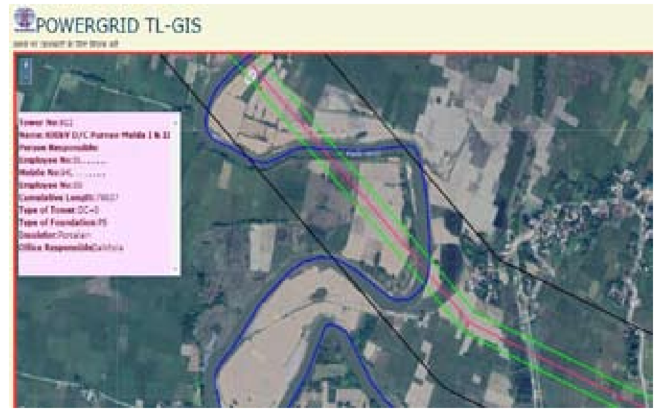
Mapping of POWERGRID line on GIS

POWERGRID's Experience on GIS Mapping

POWERGRID has taken initiative for in-house GIS mapping of it's transmission line assets which involves collection of GPS information of towers using ground based hand held GPS instruments, validation of data on satellite images, processing of data on desktop based GIS software and reprojection of the same on web based GIS portal. Different layers like land use, land cover, forest, river, transmission networks, railway network, road network etc. have been added on GIS platform simultaneously to provide complete information of the area.

Following information can be retrieved from POWERGRID's GIS platform:

- Vital historical information of towers like type of foundation, type of tower, type of Earthing, type of insulator, designed wind zone, forward span, and cumulative length from originating Substation.
- Right of Way corridor of transmission lines for identification of vegetation and its management



- Information regarding pollution sources in the vicinity of transmission line corridor like Brick Kilns, cement factories etc.

Identification of brick kilns near to transmission line

- Information regarding any change in terrain/river course in the vicinity of transmission lines over a period of time.

  Ex ±800 kV BNC-Agra line Location No 1788 River: Parmar

<table>
<tr><th>Bird Eye View</th><th>Zoomed Satellite image</th></tr>
<tr><td colspan="2">Date 26/02/2011 Tower Distance 85.86m</td></tr>
<tr><td></td><td>
</td></tr>
</table>

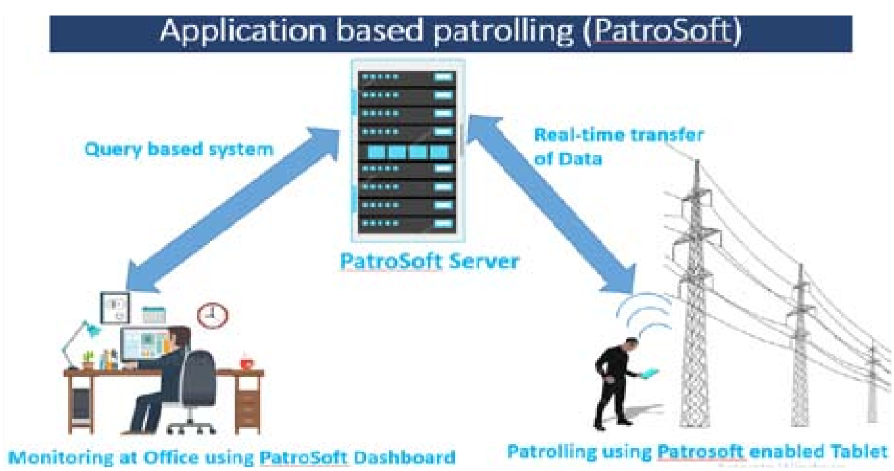
Date -25/01/2018 Tower Distance 33.33 m

3. SOFTWARE BASED PATROLLING OF TRANSMISSION LINES

In addition to aerial patrolling of transmission lines, emergency/ routine patrolling is also being carried out by POWERGRID maintenance staff for detection of any damages/ faults in transmission lines due to change in environmental conditions. Defects/ abnormalities observed during manual ground patrolling work were earlier recorded in different patrolling formats due to which compilation and analysis of data of 2.5 Lacs towers was difficult. Also there was a time lag between detection of defects at site and actual reporting of same through report.

To overcome above limitations, POWERGRID has adopted software based patrolling of transmission lines, which enables transfer of real time data recorded at site to concerned maintenance offices. Further, defect report is being generated automatically after submission of patrolling data on server, which saves precious time for planning the rectification works.

Thus, this application has helped in real time reporting of defects identified during patrolling and optimized the time and resources required for generation of MIS (Management Information System) report.



4. CONCLUSION

In POWERGRID, state of the art O&M practices have adopted for ensuring reliable operation of huge network. LIDAR has helped in identifying low electrical clearance in transmission line which otherwise are difficult to detect. GIS mapping of transmission lines assisted in detection of any change in terrain/ river course in the vicinity of tower based on which proactive corrective actions have been taken. Further, software based patrolling has helped in reducing the time lag between detection of defects at site and actual reporting of same to the concerned maintenance team.

Acknowledgement

Authors are thankful to POWERGRID management for sharing experience on operation and maintenance of transmission lines. The views expressed are not necessarily of POWERGRID management.

International Conference on Integration of Renewable with Synchronous Grid

(Conference 2 during Gridtech 2019)

In association with CIGRE SC C6

3rd - 4th April 2019, New Delhi, India

Inaugural Session of the Conference

CIGRE India with support of CIGRE SC C6, organized an International Conference on “Integration of Renewable with Synchronous Grid”, on 3-4 April 2019 at Pragati Maidan, New Delhi during GRIDTECH 2019.

The following technical subjects have been presented and discussed during the conference:

- Grid Integration of Large Scale Renewables - Requirements & Measures
- Grid Connectivity Challenges
- Integration Aspects of Distributed PV Generation in Distribution
- Smart Grid Application in Renewable Grid Integration
- Micro Grids (Grid Connected & Off Grid)
- Hybrid Renewable System and their Integration with Grid
- Solar & Wind Developer Experiences on Generation Development in India - Case Studies
- Evolving Technologies in RE Generation (Wind/Solar/Off shore wind)
- Renewable Forecasting Technology & Real Time Monitoring (WAMS) for RE
- Technical Standards Requirement for Renewables
- Green Energy Corridor - Uprating & Upgrading of Existing Transmission Line for Optimum Penetration of Renewable
- Utility, Regulator & System Operator Experiences on Existing RE (72 GW) Integration

- Energy Storage for Balancing and System Stability Including Pumped Storage and Batteries
- Experiences on Renewable Energy Certificate and Renewable Purchase Obligation Mechanism
- Experience on Ancillary Service in Indian Electricity Markets
- Modelling of RE Generators for Dynamic Stability
- Problem Related to Operation, Maintenance and Protection of RE

Dr. Christine Schwaegeri, Chairperson CIGRE SC C6 was the Conference Chair. In total 35 Nos papers from eminent experts were presented & discussed. About 200 delegates participated.

The following were the honoured Guests from CIGRE:

- Mr. Philippe Adam, Secretary General, CIGRE
- Prof. Christine Schwaegerl (Ms.), Chairperson, SC C6
- Prof. Nikos Hatziargyriou, past chair, CIGRE SC C6

TECHNICAL SESSIONS

Apart from the Opening Ceremony and session for Key Addresses, there were six Technical Sessions conducted over two days.

The following were the key speakers:

1. Dr. Subir Sen, ED, POWERGRID
2. Dr. P.C. Maithani, Adviser, MNRE
3. Prof. Nikos Hatziargyriou, past chair, CIGRE SC C6
4. Prof. Christine Schwaegerl (Ms.), Chairperson, CIGRE SC C6

The following six technical sessions were held :

Technical Session 1 *: Application of Smart Grid Technologies - Chaired by Mr. Vikas Saksena, President (Technical), ACME*

Technical Session 2 *: Energy Storage Technologies - Chaired by Mr. B.B. Chauhan, Managing Director, GETCO*

Technical Session 3 : Microgrid - *Chaired by Mr. Nikos Hatziargyriou, Past Chair CIGRE SC C6, CIGRE-Paris*

Mr. P.P. Wahi, Director, CBIP honouring Mr. Philippe Adam, Secretary General, CIGRE

Mr. P.P. Wahi, Director, CBIP honouring Prof. Christine Schwaegerl (Ms.), Chairperson, SC C6

Mr. P.P. Wahi, Director, CBIP honouring Prof. Nikos Hatziargyriou, past chair, CIGRE SC C6

Technical Session 4 : RE Integration - Forecasting, Real Time Monitoring, Transmission Planning and Market Participation - *Chaired by Mr. G.K. Gupta, Joint. Secretary, MNRE*

Technical Session 5 : Large Scale Renewable Integration - *Chaired by Mr. S.K. Mishra, Director,* Solar Energy Society of India

Technical Session 6 *: PV integration in Distribution Grids - Chaired by Mr. Sameer Mehta, Vice President, Bergen and Mr. Nihar Raj, Vice President, ABB*

DIGNITARIES ON DAIS DURING INAUGURAL SESSION

Mr. Praveen Kumar, Addl. Secretary, Ministry of New & Renewable Energy, Govt. of India

Mr. Philippe Adam, Secretary General, CIGRE

Mr. I.S.Jha, President, CIGRE - India

Prof. Christine Schwaegerl (Ms.), Chairperson, SC C6

Mr. R.P. Singh, CMD, POWERGRID

Prof. Nikos Hatziargyriou, past chair, CIGRE SC C6

Mr. Harish Agarwal, President, IEEMA

Mr. V.K. Kanjlia, Secretary, CIGRE-India

Technical Session : Key Address by Dr. P.C. Maithani, Adviser, MNRE; Dr. Subir Sen, ED, POWERGRID; Prof. Christine Schwaegerl (Ms.), Chairperson, CIGRE SC C6 and Prof. Nikos Hatziargyriou, past chair, CIGRE SC C6

Mr. P.P. Wahi, Director, CIGRE-India

Technical Session 1

Technical Session 2

Technical Session 3

Technical Session 4

Technical Session 5

Technical Session 6

The topics were very relevant to Indian power system context as based on power system planning and government policies. India is on the fast track to become RE rich country with integration of large scale Renewals. More and more RE penetration has created increased concern as well as awareness regarding challenges and to have planning for mitigation measures/techniques.

RECOMMENDATIONS

Looking to huge task of future requirement GETCO emphasized for formation of forum of industry stake holder and governing body for following

1. Stringent RE grid integration requirements
2. Mechanism for Promotion of Grid ancillary services – Pilot projects
3. Road map for promotion of new Grid support technologies – Pilot projects
4. Comprehensive program for building new skill level and competence

Visit of CIGRE Experts to Gridtech Exhibition 2019

CBIP has also responded and agreed to take the proposal further in forming a national expert group focusing on large scale RE integration requirements.

The presentations were very focussed, of high technical content but simple to understand. The presenters made every effort to make it easy for the participants to grasp the subject.

Closure of conference : As the last part of the conference, Mr. P.P. Wahi gave an official vote of thanks for all dignitaries who addressed the participants during Inaugural Session including the Honored Guest from CIGRE, Keynote Speakers, presenters, Chairman of Sessions and delegates and others involved with the conference. He made a special mention of Mr. Philippe Adam, Prof. Christine Schwaegerl (Ms.) and Prof. Nikos Hatziargyriou, for their excellent support and gracing the conference.

Welcome dinner & Cultural Program was also organised on 3rd April 2019.

View of the participants during the conference

International Conference on Energy Storage (including Pumped Storage)

27-28 June 2019, New Delhi

Shri P.K. Pujari, Hon'ble Chairman, CERC, Chief Guest (in the Centre)

(L to R) Shri P.P. Wahi, Director, CBIP; Shri K.V.S. Baba, CMD, POSOCO; Shri Aniruddha Kumar, Joint Secretary-Hydro, Ministry of Power; Shri Prakash S. Mhaske, Chairperson, CEA; Shri Gurdeep Singh, CMD, NTPC; Shri Sanjay Banga, CEO & MD, TPDDL; Shri Ved Mani Tiwari, CEO, Sterlite Power and Shri V.K. Kanjlia, Secretary, CBIP, during Inaugural Session

A REPORT & RECOMMENDATIONS

The International Conference on "Energy Storage (including Pumped Storage)" jointly organised by CIGRE-India and Central Board of Irrigation & Power on 27th & 28th June 2019 at Scope Complex, Lodhi Road, New Delhi, was a grand success.

This conference aims to discuss the following:

- Policy & Regulatory Matters w.r.t. Energy Storage
- Energy Storage Technologies
- Types of Energy Storage including Pumped Storage
- Role of Energy Storage for Utilities (Transmission, Distribution & Generation)
- Business Model & Industry Perspective
- Investment & Finance and Session for Manufactures etc.

We are honoured with the gracious presence of Top level dignitaries during Inaugural session of the conference. Shri P.K. Pujari, Hon'ble Chairman, CERC, was the Chief Guest and delivered Inaugural address. The Guest of Honour Shri Prakash S. Mhaske, Chairperson, CEA; Shri Aniruddha Kumar, Joint Secretary-Hydro, MOP also addressed the participants during Inaugural Session of the conference. Shri Gurdeep Singh, CMD, NTPC; Shri K.V.S. Baba, CMD, POSOCO, Shri Sanjay Banga, CEO & MD, TPDDL; Shri Ved Mani Tiwari, CEO, Sterlite Power also graced the dais during Inaugural Session.

Salient important Points highlighted in the Key addresses by the Chief Guest & Guest of Honour during Inaugural Session

1. Shri P.K. Pujari, Chairperson, Central Electricity Regulatory Commission

- CERC came out with a Staff Paper in 2017 on Electricity Storage Services. However, looking at how the market has moved in the past 18-24 months, it is time to update and revise the staff paper.
- CERC has recognised Energy Storage as an independent entity in the 7th Amendment to CERC Connectivity regulations.
- CERC developing a road map for primary/ secondary/ tertiary and fast response ancillary services.
- Internationally, BESS has been established as a most cost competitive fast response asset. But is still away from achieving grid parity.
- Pumped storage and hydro have traditionally faced development challenges which are unlikely to go away soon. Hence given rapid RE adoption, need for focus on other energy storage technologies.
- BESS needs a policy push, especially in view of the upcoming RE capacity targets for 2030 and initial hand holding required.
- It is important to demonstrate utility of BESS for a Discom. Need few more pilots as done by TPDDL.
- CERC in the process of drafting regulations for creating an enabling ecosystem and power market products for utilisation of BESS.

Shri P.K. Pujari, Hon'ble Chairman, CERC, delivering inaugural address as chief guest on the occassion

2. Shri P.S. Mhaske, Chairperson, Central Electricity Authority, addressed as Guest of Honour on the occasion and made a mention of following vital points on the subject :

- Storage a necessity to manage RE ingress.
- BESS prime candidate for balancing source with falling prices, improving technology and short gestation period.
- PSP to also play a key role – has advantages of long operational life, fast ramping, and huge potential.
- While PSP has come in focus in recent times, BESS is rapidly evolving in technology and price terms.
- Challenges with PSP are high tariffs, availability of land, long gestation period, clearances/ approvals etc.
- Need to explore Off-river PSP since they can circumvent few of these challenges.

Shri Aniruddha Kumar, Joint Secretary-Hydro, MOP, addressing during inaugural session as guest of honour

3. Shri Aniruddha Kumar, Joint Secretary (Hydro), Ministry of Power during his address as Guest of Honour on the occasion highlighted following important Points on the subject :

- CEA has conducted a study on optimal generation mix for 2030, estimating 136 GWh of storage capacity requirement.
- Out of 100 GW potential for Pumped Storage Projects (PSP), only 4.7 GW exploited till now.

- PSP potential re-assessed based on Satellite images, estimated as high as 400 GW.
- Cost of Storage remains a challenge, and therefore need for assessing appropriate business models.
- Ministry keen to promote Energy Storage Systems (ESS) including PSP.
- Consumer interest to be paramount in developing business models for ESS.

There were about 220 participants from more than 60 organizations including CEA, IREDA, SECI, PSUs, State Transmission, Distribution & Generation Cos., Regulatory Authorities, Indo German Energy Forum, World Bank, India Energy Storage Alliance and Technical Institutes, etc.

Total 31 Technical papers / Case Studies on the issues like Policy & Regulatory Matters w.r.t. Energy Storage; Energy Storage Technologies & Applications; Role of Energy Storage for Utilities (Transmission, Distribution & Generation); Business Model; Types of Energy Storage including Pumped Storage; Investment & Finance and session for manufactures were presented by Eminent Speakers in six Technical sessions.

Shri Prakash S. Mhaske, Chairperson, CEA, addressing during inaugural session as guest of honour

TECHNICAL SESSION 1

The technical session of the conference i.e., Key Speeches on Energy Storage – Global Perspective, started with presentation of base paper by Ms. Namrata Mukharjee of Sterlite on behalf of Organising Committee. This followed by the theme Presentation by

- Mr. R.N. Nayak, Former CMD, POWERGRID
- Dr. Rahul Walawalkar, President IESA & Chair, Global Energy Storage Alliance
- Prof. R. Venkat, IIT, Mumbai
- Mr. Marcel Schönleber, BU Energy Systems, Germany

Shri R.N. Nayak Chaired first Technical session

Shri R.N. Nayak, Former CMD, POWERGRID, chairing First Technical Session

TECHNICAL SESSION 2 AND 3

The Policies & Regulatory Matters w.r.t. Energy Storage and Energy Storage - Technologies & Applications was Chaired by Shri S.K. Soonee, Former CEO, POSOCO.

In this session there were presentations from : POWERGRID, GETCO, Sterlite, CERC, BRPL, TPDDL, CESC, CTR, BHEL, ERDA and Fluence Energy

Session chaired by Shri S.K. Soonee, Former CEO, POSOCO

DAY 2 : THEME ADDRESS BY DR. SUBIR SEN, ED, POWERGRID

The proceedings of the 2nd day Conference started with the theme address by Dr. Subir Sen, ED, POWERGRID and Chairman, CIGRE National Study Committee on Active Distribution Systems and Distributed Energy Resoures.

Theme address by Dr. Subir Sen, ED, POWERGRID

TECHNICAL SESSION 4

The Technical session on Business Models for Deploying Energy Storage was chaired by Shri R.S. Dhillon, Director, PFC and Shri R.K. Kaura, MD, Bergen Group of Cos. was the Co-chair for the session.

In this session there were presentations from : SECI, Sterlite, ICF, PFC and BERGEN

Session chaired by Shri R.S. Dhillon, Director, PFC and Co-chaired by Shri R.K. Kaura, MD, Bergen Group of Cos.

TECHNICAL SESSION 5

A separate Technical Session on Pumped Storage was also arranged which was Chaired by Shri Sanjay Srivastava, Chief Engineer, CEA.

In this session there were presentations from : CEA, THDC, ABB, PWC, WB and TERI

The last session of the conference was Panel Discussions wherein the draft recommendations of the conference were presented by Mr. Nishit Mehta of Sterlite Power on behalf of Organising Committee of the conference. Shri A.S. Bakshi, Shri S.K. Soonee, Prof. Venkat, IIT Mumbai were the panellist during panel discussions.

Session chaired by Shri Sanjay Srivastava, Chief Engineer, CEA

PANEL DISCUSSION

With the support of TPDDL and IGEF an optional technical visit to their energy Storage Plant at Rohini (New Delhi) was also organised for the participants on both the days.

The contribution of the Organising Committee of the conference headed by Shri A.S. Bakshi, Former Member CERC for their valuable guidance and excellent support in organisation of this important conference in effective manner was acknowledged by Shri P.P. Wahi during his closing remarks.

Shri Wahi also acknowledged the sponsorship support from Sterlite Power, Bergen Group of Cos. as platinum sponsor, POWERGRID & POSOCO as Gold sponsor & SECI, BRPL & CTR as silver sponsor for the conference.

Besides, the sincere thanks were conveyed to the Chief Guests, Guest of Honor, during inaugural session for sparing their valuable time and also to the participants, Speakers & Chairman of various sessions.

Panel Discussion

(L-R) Shri R. Venkat, IIT Bombay; Shri P.P. Wahi, Director, CBIP; Shri A.S. Bakshi, Former Member CERC; Shri S.K. Soonee, Former CEO, POSOCO and Nishit Mehta, VP, Energy Storage

A view of the participants

Shri V.K. Kanjlia, Secretary, CBIP, delivering the Welcome Address during inaugural session

Shri P.P. Wahi, Director, CBIP, delivering vote of thanks

RECOMMENDATIONS

1. Government of India should come out with Storage policy & Road Map with fiscal incentives like Tax holidays both Custom duty & GST for import of battery cells till it is manufactured in India. This should be available to only those projects awarded on competitive bidding by Discoms / at central level like SECI/NTPC/POWERGRID etc. for balancing purpose.
2. Specific Policy pronouncements required from Govt. of India, along with a 10-year road map for integration of Energy Storage as an essential element in Country's Power setup, especially with a view of the upcoming RE capacity addition.
3. Estimation of Grid Energy Storage requirement for Renewable Energy Integration for 2022, 2030 & 2040 to be prepared by the Government. This shall attract long term investors to prepare them for such investment.
4. CERC/CEA/POSOCO should work out the minimum storage capacity to be identified as Grid element for each State, Regional & National level and kept under Load Despatch Centre for grid management for balancing purpose. This may be socialised and recovered as Grid Element like other elements.
5. Policy and Regulatory environment need be conducive for supporting the Storage market should be created.
6. CERC should take up Market Design for Primary & Secondary Reserve product as Ancillary Services particularly (i) Frequency Regulation and (ii) Ramping Product as soon as possible to encourage storage projects.
7. CERC/ POSOCO to ensure stricter implementation of discipline adhering to frequency band by the Discoms / States and declare a Road map tightening of frequency band to International Class/Developed Countries.
8. CERC to ensure through Regulation that Unscheduled Interchange (UI) cannot be the source of power planning portfolio. This intends will force Discoms / States to be disciplined and look for Storage. This shall take us to a discipline, reliable and "International Class Grid"
9. State Regulators to approve power procurement plans of Discoms with Energy Storage System (ESS) as key source.
10. Assessment of lost load to be mandated by Regulators – Discoms to undertake cost-benefit analysis
11. Pilots of different technologies and options to be undertaken across Generation/ Transmission/ Distribution – for demonstrating value and optimal utilization.
12. Emphasis on power quality – stringent parameters for harmonics, voltage & frequency bands etc.
13. Energy storage be classified as Renewable energy which use RE for its operation/charging.
14. Govt. of India to expedite the planned Battery manufacturing of 50 GW.
15. Like Renewable Purchase Obligation (RPO), establishment of Solar Purchase Obligation (SPO) – to be categorically defined such as for Hydro, BESS etc.

16. Govt. of India to fund Research Institutions for Research & Development to localise most of the product progressively for energy security. Private or Public Private Partnership (PPP) R&D institutes should be promoted in order to expedite the development and Indigenization of technologies & product
17. Technical Standards to be defined for all essential aspects of Battery Energy Storage System (BESS) – Standardisation across charging, safety, equipment, among others.

RECOMMENDATIONS RELATING TO PUMPED STORAGE PROJECTS (PSP)

18. Re-assessment and optimal utilization of PSP potential in the Country be done. Out of 4700 MW Pump Storage Plants, only 50% are operational. The balance 50% to be made operational as soon as possible in a time bound manner. If required, this may fund from PSDF/such like fund as Grant to enhance flexibility in the Grid.
19. ESS including PSP be declared as a Grid Asset – as they enhance grid stability and security
20. Cost of ESS/PSP to vary depending on the application and to be shared between various utilities
21. Environmental / Forest and R&R Policies to be conducive to avoid time & cost over-runs in PSP

Group Photo of stalwarts in Power Sector and CBIP organisers

Activity Report of

CIGRE-INDIA AFTER CIGRE SESSION IN AUGUST 2018

CIGRE-India entered in Steering Committee (the top decision making body) of CIGRE

Steering Committee of CIGRE is the body made up of high level stakeholders and/or experts who provide guidance on key issues such policy and objectives, budgetary control, marketing strategy, resource allocation, and decisions involving large expenditures.

It is a matter of pride for India that we have got a seat in the Steering Committee of CIGRE and Shri I.S. Jha, President CIGRE India & Member, CERC is the member from India in this high level council of CIGRE.

This is going to help India taking maximum advantage of the activities of CIGRE at International Level for knowledge accentuation of professionals.

Shri I.S. Jha
President CIGRE India

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	:	Mr. I.S. Jha, Chairman & Member, CERC
Vice President	:	Mr. A.K. Gupta, Director, NTPC
	:	Ms. Seema Gupta, Director, POWERGRID
	:	Mr. Amitabh Mathur, Former Director, BHEL
	:	Mr. Harish Agarwal, President IEEMA
Technical Chair	:	Mr. R.P. Sasmal, Former Director, POWERGRID
Vice Chair-Tech.	:	Mr. N.N. Misra, Former Director, NTPC
Secretary & Treassurer	:	Mr. V.K. Kanjlia, Secretary, CBIP

CIGRE AORC

- CIGRE-India had a privilege to Chair CIGRE-AORC for 2016-18.

  Dr. Subir Sen, was, Chairman of CIGRE-AORC and Mr. P.P. Wahi was the 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.

MAJOR ACTIVITIES OF CIGRE INDIA

Growth of Membership

In the year 2016 - 594 nos. equivalent members and

In the year 2017 - 768 nos. equivalent members

In the year 2018 - 828 nos. equivalent members

Participation of CIGRE India at international level

- India got seat in Steering Committee (Executives Body) of CIGRE
- Delegates attended from India in CIGRE Session 2018 - 145 Nos.
- Total papers presented in 2018 session at Paris from India - 22, 1 paper under Intl. Category, and three papers by Young members.
- Exhibitors from India during Paris session
- Scope T&M - Stand No. 168
- CTR Manufacturing Co. - Stand No. 125
- KalkiTech - Stand No. 131
- Karamtara Engineering Pvt. Ltd - Stand No. 276 – did not present
- KSE Electricals - Stand No. 241
- Tag Corporation - Stand No. 169
- AORC Meeting convened & chaired by India and charge for next term handed over to Japan.
- Participation in CIGRE Study Committee meetings during Session (26th - 31st Aug. 2018) : As per

feedback received all the CIGRE SC Meetings during session were attended by Members/ their representatives.

- Presentations about preparations for SC Meeting & Colloquium in India in 2019 for SC A1- in Sept.; and SC A2, B2 & D1 in Nov. 2019 were made in respective Study Committee meetings.
- The proposal to host the SC meeting in India in 2021 for SC A3, SC B3, SC B5, SC C2 & C5 were submitted during respective SC Meetings.

SC A3	Tentatively agreed to hold in 2021
SC B3	Tentatively agreed to hold in 2023
SC B5	Tentatively agreed to hold in 2021
SC C2	Since 2021 is already allotted to Japan the request was register for 2023
SC C4	The proposal sent will be considered for 2023

- Mr. N.S. Sodha, Member of CIGRE SC D2 acted as Secretary for one of the preferential subject during Session and also selected as Member in SC D2 Advisory Group and SC D2 Africa Group.
- In Study Committee A1-India dominated the meeting of Advisory Group. Out of total seven working groups, convener for the three WGs is selected from India.
- CIGRE is looking at India for more and more technical contribution. The expectations from the Chairman of almost all the study committees were that, India should have representation in all the working groups.

Upcoming CIGRE Study Committee meetings in 2019 and participation from India

	Study Committee (SC)	2019	Attended by
1	A1 Rotating Machine	India (22-28 Sept. 2019)	-
2	A2 Transformers	India (18-23 Nov 2019)	-
3	A3 High Voltage Equipment	Bucharest Romania (7-13 Sept 2019)	Mr. R K Tyagi, CGM (AM), Power Grid Mr. Rakesh Kumar, Sr. GM (AM), Power Grid
4.	B1 HV Insulated Cables	Aalborg Denmark (3-6 June 2019)	-
5	B2 Overhead Lines	India (18-23 Nov 2019)	
6	B3 Substations	China	Mr. Rajil Srivastava, Sr. GM (NR 1), Powergrid Mr. Abhay Kumar, GM (Engg S/S), Powergrid
7	B4 HVDC Link and AC Power Electronic Equipment	Aalborg Denmark (3-6 June 2019)	Mr. R.K. Chauhan, Dir (Proj.), Power Grid Mr. B B Mujharjee, Sr. GM, Power Grid
8	B5 Power System Protection and Local Control	Norway (24-28 June 2019)	Mr. Abhishek Khanna, Manager, NTPC Mr. Debashish Dutta, Sr. Manager, NTPC Mr. Anand Pandey, Sr. Manager, NTPC
9	C1 Power System Planning and Development	Aalborg Denmark (3-6 June 2019)	Ms. Seema Gupta Dir (Operation), Power Grid Mr. Ashok Pal CGM (CTU), Power Grid
10	C2 Power System Operation and Control	Aalborg Denmark (3-6 June 2019)	Mr. KVS Baba, Chairman, POSOCO
11	C3 System Environmental Performance	Aalborg Denmark (3-6 June 2019)	Mr. B N De Bhowmick Executive Director, Power Grid

12	C4 System Technical Performance	Aalborg Denmark (3-6 June 2019)	Mr. B.B. Chauhan, Managing Director, GETCO
13	C5 Electricity Markets and Regulation	Canada (16-19th Sept 2019)	–
14	C6 Distribution Systems and Dispersed Generation	Aalborg Denmark (3-6 June 2019)	Dr. Subir Sen, COO (CTU Plg. & SG), Power Grid Mr. Rajesh Kumar, Sr. DGM (SG), Powergrid
15	D1 Material for Electrotechnology	India (18-23 Nov 2019)	–
16	D2 Information Systems & Telecommunications for System	Finland (11-14 June 2019)	Mr. N.S. Sodha
17	CIGRE AORC meeting	Bali (24-28 March 2019)	Mr. Lalit, COO, KEI Mr. Adish Kumar Gupta, Sr. GM (AM) Power Grid Mr. D.K. Karma, DGM - Dir (Proj.)-Sec

All the study committee meetings in 2019 are planned to be represented.

Participants from POSOCO, POWERGRID & GETCO in CIGRE Meeting, Aalborg

Mr Sodha, Chairman NSC D2 participated in SC D2 at Helsinki, Finland

Meeting of officers of CIGRE India with representatives of CIGRE (Paris)

Guests from CIGRE (Paris) welcomed by Mr. P.P. Wahi during GRIDTECH 2019 in India

Participation in CIGRE AORC meeting at Bali on (24-28 March 2019) – Shri Lalit Sharma COO, KEI and Chairman for CIGRE NSC B1 attended.

It was a matter of great pride for India to actively participate in the 14th Annual Conference of AORC CIGRE Panel B1 on 26th March 2019 at Bali, Indonesia.

CIGRE India NSC B1 Chairman – Mr. Lalit Sharma along with domain expert Mr. Ajay Garg participated in the conference and presented different activities of B1 group carried out in India. Mr. Lalit Sharma gave a comprehensive bird's eye view of CIGRE India Activities of SC B1 Business. Mr. Sharma not only discussed the common challenges faced during the installation of Underground Cable Systems; using his strong technical background and rich experience, he deftly explained how to overcome these challenges too.

The stage was then taken over by Mr. Ajay Garg who dealt with dexterity various tests that need to be carried out post installation of AC and EHV underground cable systems. Mr. Garg elaborated on several issues associated with these tests and how to address them.

True to the objective of exchanging technical knowhow and latest developments at a global platform regarding generation, transmission and distribution of electricity at high voltage, the session presented by Mr. Lalit Sharma and Mr. Ajay Garg- bore deep insight and were profoundly interactive, and hence highly appreciated by the learned audience.

CIGRE National Level Activities – after Dec. 2018

Meetings of NSC D2 in progress

- Regular Review Meeting with President CIGRE India & Technical chair.
- Regular Meeting of Governing Council of CIGRE india.

Events Held :

1. Conference on Modern Technology Trends in Power Transformers including OLTC, Bushings etc., 27-28 Feb. 2019, New Delhi
2. Workshop on Power System Protection and Automation, 4-6 March 2019, Patiala
3. Gridtech-2019- CIGRE International Conference on RE Integration – 3-4 April 2019 at Pragati Maidan.
4. Conference on Reliable & Quality Power, 30-31 May 2019, New Delhi
5. International Conference on Energy Storage including Pumped Storage, 27-28 June 2019
6. 7th National Conference on Advances & Innovations in Substations, 25-26 July 2019

CIGRE Events Planned in India in 2019

- Meeting & Intl. Conf. of SC A1 on Rotating Machines - proposed from 23 - 28 Sept. 2019 at New Delhi.
- Meeting & Intl. Conf. of three Study Committee i.e. SC A2 (Transformers)/ B2 (Overhead Lines) /D1 (Materials) – in 18-23 Nov. 2019 in New Delhi.
- CIGRE-India plan to hold minimum one event by each National Committee (tutorials /workshop/ conferences) in a year at National Level.

Strategy for participation in CIGRE Session 2020

- Submission of Quality Papers from India. Total 240 abstracts were reviewed.
- 45 abstracts have been recommended for approval of CIGRE for Session 2020 at Paris from 23-28 Aug. 2020.
- Maximum number of Participants for Session
- Planning for India Pavilion during Exhibition (Space for 150 sq. m. – plan for about 15-20 Exhibitors; like, CPRI, NSPTCL, POWERGRID, BHEL, Tata, & Pvt Cos.)

CIGRE Members from India in 2019

(As on June 2019)

Institutional Members

S. No.	Organisation
1.	Bihar Electricity Regulatory Commission
2.	Central Electricity Regulatory Commission
3.	CIGRE INDIA- COE,Centre of Excellence
4.	Delhi Electricity Regulatory Commission
5.	Electrical Research and Development Association
6.	H.P. Electricity Regulatory Commission
7.	IEEMA
8.	Indian Inst. of Technology Kanpur
9.	Jharkhand State Electricity Regulatory Commission
10.	Joint Electricity Reg. Com.-for Goa &Uts
11.	Malaviya National Inst. of Tech.- Jaipur
12.	Punjab State Electricity Regulatory Commission
13.	Ramelex Testing & Research Institute
14.	U.P. Electricity Regulatory Commission

Individual Members

S. No.	Name	Organisation
1	Gaurav Kumar Kasal	ABB
2	Sachin Srivastava	ABB Global Industries & Services Ltd.
3	Arvind Kumar Sharma	Adani Electricity Mumbai Limited - Trans
4	Niraj Agrawal	Adani Power Maharashtra Ltd.
5	Bipin B Shah	Adani Transmission Ltd,
6	Neeraj Khare	Adishaktyai- India
7	Ramesh Dattaraya Suryavanshi	Alfa Consultants
8	Venkata Krishna Marmavula Muni	Amara Raja Power Systems Ltd
9	Gopal Ji	Angelique International Ltd.
10	Usa Savadamuthu	Anna University
11	Srimanta Kumar Jana	Apar Industries Ltd.
12	Deepak Kumar Saxena	AVAADA Power
13	Ashish Bhatnagar	Bechtel India Private Limited
14	S. V.N. Jithin Sundar	BHEL
15	V K Kanjlia	CBIP
16	Virendra Kumar Lakhiani	Consultant
17	N S Sodha	Consultant
18	N N Misra	Consultant
19	Venkata Chalapathi Chendur Venkatarao	Consultant
20	R P Sasmal	Consultant
21	Krishnan S. Balasubramanian	Consultant
22	Dhananjay Kumar Chaturvedi	Consultant
23	Sanjay Patki	Consultant
24	Pramod Rao	Consultant
25	Subhash Sethi	Consultant
26	Dr. Burjupati Nageshwar Rao	CPRI
27	Devender Rao Karre	CPRI
28	T P Govindan	CTR Manufacturing Industries Ltd.
29	Abhijit Chakraborty	Damodar Valley Corporation
30	Ravi Kumar Puzhankara	DNV-KEMA
31	Rajesh Kumar Arora	DTL
32	Satish Chetwani	ERDA
33	K. Singaram Christian Johnson	Erode Sengunthar Engineering College
34	Hosalli Bhashyam Mukund	Free Lance
35	Mahesh Raman	GE T&D India Ltd.
36	Pandiyaraj Kalyani	GE T&D India Ltd.
37	Madhu Sudan	GE T&D India Ltd.
38	Santosh Kumar Annadurai	GE T&D India Ltd.
39	Pankajbhai Suthar	GETCO
40	Nikunjkumar Makwana	GETCO
41	Ashokkumar J. Chavda	GETCO
42	Venu Birappa	GETCO
43	Sachin D Patel	GETCO
44	Nishant Priyakant Shah	GETCO
45	Jalpesh Trivedi	GETCO
46	Alpeshkumar Jayantilal Soni	GETCO

47	Zulfikarali M Vijapura	GETCO
48	Vinay Rathod	GETCO
49	Rajeshkumar Amrutlal Patel	GETCO
50	Bhasmang N. Trivedi	GETCO
51	Bhadreshkumar B. Mehta	GETCO
52	Nilesh Sheth	GETCO
53	Rameshchandra P. Satani	GETCO
54	Bankim Pravinchandra Soni	GETCO
55	Dipak kumar Patel	GETCO
56	Chetan G Thakkar	GETCO
57	Bhadresh B. Chauhan	GETCO
58	Yogesh Vishnu Joshi	GETCO
59	Rakesh Thakkar	Gujarat Industries Power Co. Ltd.
60	Kaushik Tarafdar	Hindalco
61	Himanshu Bahirat	IIT-Bombay
62	Anchal Pahwa	India Infrastructure Publishing Limited
63	Sarasij Das	Indian Institute of Science
64	Joy Thomas Meledath	Indian Institute of Science
65	Udaya Kumar	Indian Institute of Science
66	Habib Chowdhary	J&K Power Development Department
67	Nitin Kumar Patel	Kalpataru Power Trans. Ltd
68	Pervinder Singh Chowdhry	Kalpataru Power Trans. Ltd
69	Milind Nene	Kalpataru Power Trans. Ltd
70	Lalit Sharma	KEI Industries Ltd
71	Aradhana Ray	Laxmi Associates
72	K. Kamlesh Murty	M.P. Power Transmission Co. Ltd
73	Udaybabu Ratanchand Shah	Mahati Industries Pvt.Ltd.
74	Ram Kumar Vaithilingam	Modern Insulators Limited
75	I R Rao	National Inst. of Technology Karnataka
76	Harshal Maelwar	North East Transmission Co.
77	Nagesh Kondra	NTPC Ltd.
78	Pravinchandra Mehta	Persotech Solutions
79	Deepal Shah	PFISTERER

80	Tony Martens	Polycab Wires Pvt. Ltd.
81	SUBHENDU MUKHERJEE	POSOCO
82	Santosh Kumar Jain	POSOCO
83	Shailendra Verma	POSOCO
84	K V S Baba	POSOCO
85	Vivek Pandey	POSOCO
86	Aditya Prasad Das	POSOCO
87	Rajiv Kumar Porwal	POSOCO
88	S.R. Narasimhan	POSOCO
89	Samir Chandra Saxena	POSOCO
90	Manoj Kumar Agarwal	POSOCO
91	Praveen Kumar Agarwal	POSOCO
92	Anantha Sarma Boppudi	Power Grid
93	Brijendra Bahadur Singh	Power Grid
94	Subhash C Taneja	Power Grid
95	Gyaneshwar Payasi	Power Grid
96	Abhay Kumar	Power Grid
97	R P S Rana	Power Grid
98	Subir Sen	Power Grid
99	Ravindra Kumar Tyagi	Power Grid
100	Seema Gupta	Power Grid
101	Arun Kumar Mishra	Power Grid
102	B N De Bhowmick	Power Grid
103	Biswajit Bandhu Mukherjee	Power Grid
104	Rajesh Kumar	Power Grid
105	Anish Anand	Power Grid
106	Bapuji Palki	PRDC
107	Vijayakumaran Moorkath	Primemeiden Ltd.
108	Pradeep Kumar Gangadharan	Protection Engg. & Research Laboratories
109	Dr. Daya Shankar Shukla	Raj Petro Specialities Pvt Ltd
110	Sushil Chaudhari	Raj Petro Specialities Pvt Ltd
111	Baburao Keshawatkar	Raj Petro Specialities Pvt. Limited
112	Jaspaul Kalra	Rajasthan Test & Research Centre
113	P. Kirushnaraj	Raychem RPG Pvt. Ltd.
114	Vinod Kumar Agarwal	Regen Powertech Private Limited
115	Alok Roy	Reliance Power Transmission Ltd
116	Vikas Shahaji Jagadale	Shreem Electric Ltd.
117	Santosh Vishwakarma	Silverline Electricals Pvt. Ltd.

118	Rashi Tyagi	SJVN Ltd.
119	Surinder Kumar Negi	SkipperSeil Ltd.
120	Sivaji Burada	Sleepwalkers
121	Rajesh Suri	Sterlite Power Grid Ventures Ltd
122	Parantap Krishna Raha	Sterlite Power Transmission Ltd.
123	Hrushaabh Prashaant Mishra	Syselec Technologie Private Limited
124	Vivek Thiruvenkatachari	TAG Corporation
125	Subhash Chandra Takalkar	Takalkar Powerr Engin&Consult. Pvt Ltd
126	Vishnu Agarwal	Technical Associates
127	Yogesh Telawne	Telawne Cromptek Electricals Pvt. Ltd.
128	Rajendra Vinayak Saraf	The Tata Power Co. Ltd.
129	Arogya Raju Pudhota	TS Transco
130	Jaywant Thorat	Vision Vidyut Engineers Pvt. Ltd.
131	Hillol Biswas	WAPCOS Ltd.
132	R C Anand	Ziv Automation India Pvt Ltd

Organisational Members

Sl. No.	Organisation
1	ABB India Limited
2	Adani Electricity Mumbai Limited - Tran.
3	Adani Transmission Limited
4	Associated Power Structures Pvt. Ltd.
5	Bharat Heavy Electricals Limited-Bangalore
6	Bharat Heavy Electricals Ltd, Bhopal
7	Bharat Heavy Electricals Ltd, Hyderabad
8	Bharat Heavy Electricals Ltd., Noida
9	Central Electricity Authority
10	Central Power Research Institute
11	CESC Limited
12	CTR Manufacturing Industries Ltd.
13	Easun-Mr Tap Changers (P) Limited
14	Karmatara Engineering Pvt. Ltd.
15	KEI Industries Ltd.
16	Larsen & Toubro Limited- Construction
17	LS Cable India Pvt. Ltd.
18	National High Power Test Lab. Pvt. Ltd.
19	NTPC - Dadri SSTP
20	NTPC Limited - Koldam
21	NTPC Limited, Bongaigaon TPP
22	NTPC Limited, H.Q.
23	NTPC Limited, Kahalgaon STPS
24	NTPC Limited, Kawas GPP
25	NTPC Limited, Kayamkulam
26	NTPC Limited, Korba STPS
27	NTPC Limited, Ramagundam STPS
28	NTPC Limited, Simhadri STPP
29	NTPC Limited, SIPAT STPS
30	NTPC Limited,Farakka STPS
31	NTPC Sail Power Co. Pvt. Ltd.
32	NTPC Limited, Vindhyachal STPS
33	POSOCO- ERLDC
34	POSOCO-NERLDC
35	Power Research & Develop. Cons. Pvt. Ltd.
36	Powergrid Corp. of India Limited-Patna
37	Powergrid Corp. of India Ltd, Bangaluru
38	Powergrid Corp. of India Ltd, Secunderabad
39	Powergrid Corp. of India Ltd, Shillong
40	Powergrid Corp. of India Ltd.,Jammu
41	Powergrid Corp. of India Ltd.-Maharashtra
42	Powergrid Corp. of India Ltd-Bangalore
43	Powergrid Corporation of India, H.Q.
44	Scope T&M Pvt Ltd
45	Supreme & Co. Pvt. Ltd.
46	Tata Power Delhi Distribution Limited
47	Techno Electric and Engineering Co. Ltd.
48	THDCIL
49	The Motwane Manufacturing Co. Pvt Ltd
50	Transformers & Rectifier (India) Ltd.
51	Transmission Corporation of Telangana Limited
52	Universal Cables Limited

Young Members

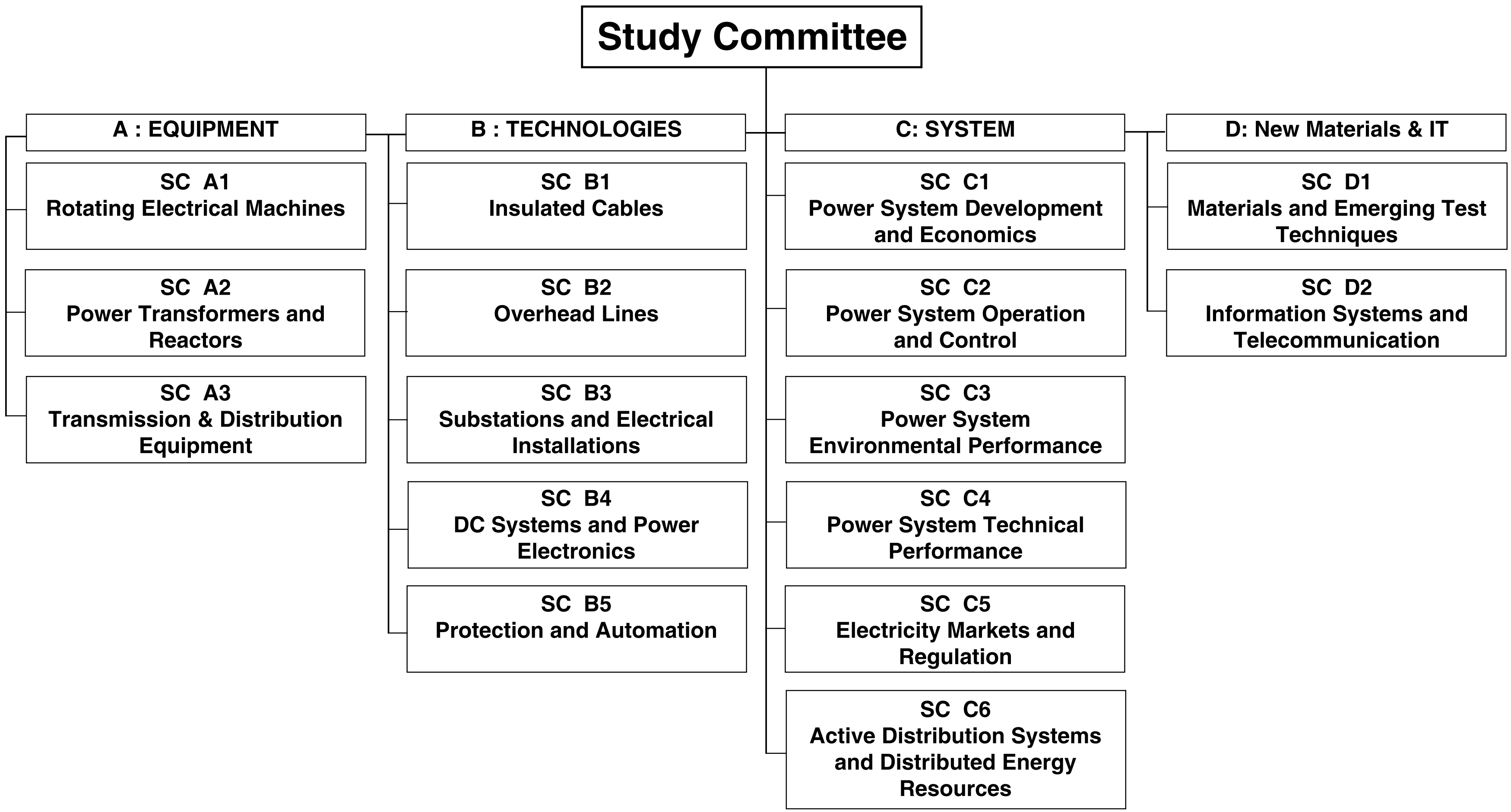
S.No.	Name	Organistaion
1	Animesh Moji	Adani Group
2	Mohan Vadivel	GE T&D India Ltd.
3	Aishwarya Dixit	Hyosung T&D India Pvt. Ltd.
4	Kummaragu K	Indotech Transformer Ltd.
5	Dony C S	Kerala State Electricity Board Ltd.
6	Atma Ram Gupta	NIT Kurukshetra
7	Harshvardhan Senghani	NTPC Ltd.
8	Gourav Mukherjee	POSOCO
9	Ankit Gupta	POSOCO
10	Saibal Ghosh	POSOCO
11	Dwaipayan Sen	Power Grid
12	Manash Jyoti Baishya	Power Grid
13	Ankur Kumar	Power Grid
14	Jeetesh Kumar	Power Grid
15	Amit Kuma	Power Grid
16	Lokesh Kumar Singh Chundawat	Power Grid
17	Amandeep Singh	Power Grid
18	Ankit Prakash Vaishnao	Power Grid
19	Madhav Beni	Power Grid
20	Priyanka Swain	Tata Consulting Engineers Limited

Student Members

S. No.	Organisation	Name
1	Indian Institute of Technology Kanpur	Anamika Dubey
2	Indian Institute of Technology Kanpur	J G sreenath
3	Indian Institute of Technology Kanpur	Aasim
4	Indian Institute of Technology Kanpur	Akhilesh Prakash Gupta
5	Indian Institute of Technology Kanpur	Vineeth V
6	Indian Institute of Technology Kanpur	Piyush Warhad Pande
7	Indian Institute of Technology Kanpur	P. Naga Yasasvi
8	Indian Institute of Technology Kanpur	Gaurav Khare
9	Indian Institute of Technology Kanpur	Priyanka Gangwar
10	Indian Institute of Technology Kanpur	Saurabh Kesherwani
11	Indian Institute of Technology Kanpur	Ankit Yadav
12	Indian Institute of Technology Kanpur	Avinash kumar
13	Indian Institute of Technology Kanpur	Rajarshi Dutta
14	Indian Institute of Technology Kanpur	Syed Mohammad Ashraf
15	Indian Institute of Technology Kanpur	Arindam Mitra
16	Indian Institute of Technology Kanpur	Bandopant Pawar
17	Indian Institute of Technology Kanpur	Anamika Tiwari
18	National Institute of Technology, Calicut	Amararapu Satish
19	National Institute of Technology, Calicut	Aswin Bhaskar P E
20	National Institute of Technology, Calicut	Cheemala Vaishnavi
21	National Institute of Technology, Calicut	Divya P
22	National Institute of Technology, Calicut	K Vamsi Krishna
23	National Institute of Technology, Calicut	Sarov Mohan S
24	National Institute of Technology, Calicut	Thalluri Chaitanya Sai
25	National Institute of Technology, Calicut	Vipul Kumar
26	National Institute of Technology, Calicut	Avinash Nelson
27	National Institute of Technology, Calicut	Gowrishankar S

28	National Institute of Technology, Calicut	Joyce Jacob
29	National Institute of Technology, Calicut	Emil Ninan Skariah
30	National Institute of Technology, Calicut	Jacob P Varghese
31	National Institute of Technology, Calicut	Lakshmi Tharamal
32	National Institute of Technology, Calicut	Anjitha V
33	National Institute of Technology, Calicut	Haritha G
34	National Institute of Technology, Calicut	Ravishankar A N
35	National Institute of Technology, Calicut	Athira Raju
36	National Institute of Technology, Calicut	Subin Koshy
37	National Institute of Technology, Calicut	Rahul S
38	National Institute of Technology, Calicut	Rinsha V
39	National Institute of Technology, Calicut	T S Bheemraj
40	National Institute of Technology, Calicut	Sanila P
41	National Institute of Technology, Calicut	Najda V M
42	National Institute of Technology, Calicut	Renuka V S
43	Indian Institute of Technology Bombay	Lokesh Kumar Dewangan
44	Indian Institute of Technology Bombay	Vatsal Kedia
45	Indian Institute of Technology Bombay	Santanu Paul
46	Indian Institute of Technology Bombay	Siba Kumar Patro
47	Indian Institute of Technology Bombay	Aditya Nadkarni
48	Indian Institute of Technology Bombay	Kaustav Dey
49	Indian Institute of Technology Bombay	Santosh V Singh
50	Indian Institute of Technology Bombay	Kavita Kiran Prasad
51	Indian Institute of Technology Bombay	Anees V P
52	Indian Institute of Technology Bombay	soumya Ranjan mohapatra
53	Indian Institute of Technology Bombay	Kevin Gajjar
54	Indian Institute of Technology Bombay	Rohit Thute
55	Indian Institute of Technology Bombay	B. Sai Ram
56	Indian Institute of Technology Bombay	Minal Chougule
57	Indian Institute of Technology Bombay	Soumya Kanta Panda
58	Indian Institute of Technology Bombay	Joel Jose
59	Indian Institute of Technology Bombay	Hemantkumar Goklani
60	Indian Institute of Technology Bombay	vinay chindu
61	Indian Institute of Technology Bombay	Gopakumar
62	Indian Institute of Technology Bombay	Patil Nikhil Suresh
63	Indian Institute of Technology Bombay	Pragati Gupta
64	Indian Institute of Technology Bombay	Suman Kumar Neogi
65	Indian Institute of Technology Bombay	Ajith J
66	Indian Institute of Technology Bombay	Makarand M Kane
67	Indian Institute of Technology Bombay	Annoy Kumar Das
68	Manipal University Dahmi Kalan Jaipur	Udayan Atreya

Four Group of CIGRE Study Committees



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 (March 2017)	As on 31.5.2019
THERMAL	218330.00	226279.34
HYDRO	44478.00	45399.22
NUCLEAR	6780.00	6780.00
RENEWABLE ENERGY SOURCES	57244.00	78359.04
TOTAL	**326832.00**	**356817.60**

Source : CEA

ALL INDIA REGION WISE INSTALLED CAPACITY

As on 31-5-2019

(Figures in MW)

Region	Thermal	Nuclear	Hydro	RES	Total
Northern	57721.46	1620	19707.77	14411.43	93460.66
Western	85155.11	1840	7547.50	23262.26	117804.87
Southern	53217.26	3320	11774.83	38940.34	107252.43
Eastern	27563.64	0	4942.12	1403.00	33908.76
N. Eastern	2581.83	0	1427.00	324.29	4333.11
Islands	40.05	0	0.00	17.73	57.78
All India	**226279.34**	**6780**	**45399.22**	**78359.04**	**356817.60**
Percentage	**63.42**	**01.9**	**12.72**	**21.96**	**100**

Source : CEA

SECTOR WISE INSTALLED CAPACITY AND GENERATION

As on 31-5-2019

Sector	Installed Capacity (MW)					Percentage Share	Net Capacity added
	Thermal	Nuclear	Hydro	RES	Total		During May 2019
STATE	72849.13	0.00	29878.80	2348.93	105076.86	29.45	0 MW
PRIVATE	87372.30	0.00	3394.00	74377.81	165144.11	46.28	
CENTRAL	66057.91	6780.00	12126.42	1632.30	86596.63	24.27	
TOTAL	**226279.34**	**6780.00**	**45399.22**	**78359.04**	**356817.60**	**100**	

Source : CEA

GROWTH OF TRANSMISSION SECTOR

	Unit	At the end of 12th Plan (March 2017)	As on 31.5.2019	During 13th Plan (up to May 2019)
TRANSMISSION LINES				47007
HVDC	ckm	15556	15556	
765 kV	ckm	31240	41862	
400 kV	ckm	157787	181240	
220 kV	ckm	163268	176200	
Total Transmission Lines	**ckm**	**367851**	**414858**	**47007**
SUBSTATIONS				
HVDC	MW	19500	22500	167643
765 kV	MVA	167500	213000	
400 kV	MVA	240807	318362	
220 kV	MVA	312958	354546	
TOTAL	**MW/ MVA**	**740765**	**908408**	**167643**

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 2018-19*	1181 kWh

**Provisional*

RE SECTOR IN INDIA: POTENTIAL AND ACHIEVEMENTS

GRID-INTERACTIVE POWER Sector	FY 2019-20 Target (MW)	FY 2019-20 Achievement (April-May 2019)	Cumulative Achievements (MW) (as on 31.5.2019)
Wind	3000.00	463.16	36089.12
Solar Power (SPV)	8500.00	1228.57	29409.25
Small Hydro (up to 25 MW)	50.00	10.60	4603.75
Bio Power (Biomass & Gasification and Bagasse Cogeneration)	250.00	28.00	9806.31
Waste to Power	2.00	0.00	138.30
Total (Approx)	**11802.00**	**1730.33**	**80046.73**
OFF GRID/CAPTIVE POWER (CAPACITIES IN MW_{EQ})	**411.00**	**1.29**	**1259.00**
Other Renewable Energy Systems (Biogass plants)	**86900.00**	**0.00**	**25561.00**

Source : MNRE

DHOOT TRANSMISSION ACQUIRES BENGALURU'S SAN ELECTROMEC

Dhoot Transmission has no immediate plans for further acquisitions but is open for any new opportunities.

In a bid to diversify its customer base, Aurangabad-based Dhoot Transmission, the second-largest Indian wiring harness maker for two wheelers, has acquired San Electromec, wire harness and control panel player that specializes in railways, defence, construction and specialty vehicle segment, for an undisclosed sum This is Dhoot's fourth acquisition after it bought Parkinson Harness Technology (UK), TFC Cable Assemblies (Scotland) and a JV into automotive switches & controllers with controllers with Carling Technologies of the USA. Dhoot bought into Carling, instead of carving out a separate firm.

Singhi Advisors, a global investment bank focused on niche mergers and acquisitions, advised Dhoot Transmission in the transaction besides Aeterno Partners, a boutique strategy consulting and investment banking firm with extensive focus on emerging technologies and industrial automation.

Dhoot Transmission has no immediate plans for further acquisitions but is open for any new opportunities. The company has set aside close to $70 million or Rs 500 crore for organic and inorganic opportunities for the next three to five years.

"Acquisitions help us to acquire customers in newer geographies and additional capabilities in our product portfolio. We have successfully integrated our 3 acquisitions and have seen the benefits of synergies both in technological and financial advantage," company's managing director, Rahul Dhoot, told ET.

Founded in 2001, Bengaluru-based San Electromec Industries has solutions from cabling systems, wiring harnesses and control panels. It counts Wirtgen, Volvo, Terex, Faiveley, BEMLNSE 0.86 % and Tata Motors as clients.

Source : ET Bureau, Feb 10, 2019

INDIA'S SOLAR CAPACITY AT 28 GW AT DEC-END: BRIDGE TO INDIA REPORT

The quarterly market report, titled 'India Solar Compass Q4 2018', gives a detailed analysis of capacity addition.

The country's total solar power generation capacity, including 3.85 gigawatt (GW) rooftops, stood at 28.05 GW while 17.65 GW was under implementation as on December 31, 2018, according to a report by Bridge To India (BTI).

The quarterly market report, titled 'India Solar Compass Q4 2018', gives a detailed analysis of capacity addition, tender issuance, market players, price trends for the past quarter and the whole year 2018.

India's total solar installed capacity and pipeline stood at 28,057 MW and 17,658 MW as on December 31, 2018, according to the report. This capacity is split between utility scale and rooftop solar as 24,202 MW and 3,855 MW, respectively.

It said only 1,446 MW capacity was added in the October-December 2018 period, 990 MW in utility scale solar and 456 MW in rooftop solar.

The utility scale solar capacity addition has been sluggish since the second quarter ended June 30, 2018, and is down 46 per cent over the fourth quarter of 2017. In contrast, the rooftop solar market is growing strongly and is up 47 per cent over previous year, it said.

In the December 2018 quarter, the highest capacity (200 MW) was added in Andhra Pradesh and Gujarat.

Karnataka (5,328 MW), Telangana (3,501 MW) and Rajasthan (3,081 MW) continued to be the top-three states by commissioned capacity for utility scale solar. In 2018, Adani (740 MW), Acme (720 MW) and Essel Infra (460 MW) were the top-three developers by commissioned capacity. GCL, Risen Energy and JA Solar (all Chinese suppliers) were the leading module suppliers, while Sungrow, ABB and Huawei were the leading inverter suppliers.

The EPC (engineering, procurement and construction) market was led by Sterling & Wilson and Mahindra Susten. Module prices have fallen to USD 0.20 per watt, down 44 per cent over the previous year. But, most of this fall has been offset by 25 per cent safeguard duty and 5 per cent GST as well as more than 10 per cent rupee depreciation. Moreover, prices are expected to harden in 2019 by 5 to 10 per cent, it added.

An unprecedented 51,118 MW of new tenders were issued in 2018, with 15 GW tenders in December 2018 quarter alone. However, tender design has not met market expectations -- 16,725 MW of tenders were cancelled in 2018 and another 9,238 MW of tenders were undersubscribed, the report stated.

Commenting on the report, Vinay Rustagi, managing director, BTI, said in a statement: "2018 was an extremely testing year for the solar market. Pretty much everything that could go wrong, did go wrong. Issues such as safeguard duty and GST created uncertainty for the entire industry, costs went up, execution challenges mounted and to make matter worse, discoms cancelled many tenders because of unrealistic tariff expectations."

"2019 is expected to be better but the new government will have to work hard to re-build investor appetite. Rooftop solar remains a bright spot but even this market has seen some serious policy reversals in the last few months," he added.

Source : PTI, Feb 19, 2019

MAJOR BOOST FOR 4 HYDRO PROJECTS WORTH RS 45,000 CRORE

The 2,800-mw Dibang multipurpose project was granted pre-investment approval in November last year.

The government expects a big push to hydropower sector having received clearances for four projects worth about Rs 45,000 crore. Last week, the project investment board (PIB) of finance ministry recommended NHPC's Rs 28,000 crore Dibang project and a proposal to acquire and complete Lanco Infratech's Teesta VI project worth nearly Rs 5,400 crore, a government official said.

NHPCNSE -0.85 % bagged the 500-mw Teesta hydro power plant under insolvency proceedings for Rs 907 crore. The project will require further investments of about Rs 4,500 crore for completion and will now be put before the Union cabinet for approval. NHPC has installed generation capacity of 7071 mw and another 3800 mw under construction. "The hydropower sector was almost written off due to the delays and languishing of the projects. The recent developments will revive investments in the sector.

Also, this is the first time that a government entity has bid for a project and bagged it in NCLT. While bigger PSUs are shying away from bidding in insolvency court, NHPC, a miniratna company with limited financial autonomy, has set precedence," said a government official.

The 2,800-mw Dibang multipurpose project was granted pre-investment approval in November last year. The National Green Tribunal had in its judgment on November 13 dismissed an appeal filed by appellant Pradip Kumar Bhuyan against the government for granting environment clearance to the project.

The tribunal upheld the environmental clearance accorded to the project in lower Dibang valley district. The tribunal had in the month of November also rejected an appeal filed by social activists against constitution of a three-member experts committee to study the 2,000-mw Lower Subansiri Hydroelectric Project on the border of Assam and Arunachal Pradesh.

The official said NHPC will shortly call bids to award turnkey contracts to build 70-meter high concrete dam on Dibang river. NHPC last week signed MoU with Jammu & Kashmir for 850-mw Ratle hydroelectric project. The project entails an investment of Rs 6,760 crore including interest during construction and will be set up on built, operate, own and transfer model.

Presently, NHPC holds 51% in the project. A joint venture was also signed for 624-mw Kiru hydroelectric project entailing an investment of Rs 4,500 crore. Prime Minister Narendra Modi laid the foundation stone of the Kiru project last week. The project will be built by Chenab Valley Power Projects Pvt Ltd, a joint venture between NHPC, JKSPDC Ltd and PTC Ltd. Kiru is a run-ofriver scheme that will be located 25 km upstream of the 390-MW Dulhasti Hydroelectric Project on the Chenab river in the Doda district of Jammu and Kashmir.

Source : ET Bureau

BHEL WINS RS 350 CRORE ORDER FOR RAILWAY LINE ELECTRIFICATION

The engineering, procurement and construction contract has been placed by Central Organization for Railway Electrification (CORE) for the sections.

Bharat Heavy Electricals Ltd has won Rs 300 crore order for electrification of 440 track kilometers railway line.

The engineering, procurement and construction contracthas been placed by Central Organization for Railway Electrification (CORE) for the sections; Birlanagar - Etawah, Bhandai - Udi and Farrukhabad - Shikohabad (including Mainpuri - Etawah) of North Central Railway, an official statement said. With this BHELNSE 1.10 % has made a foray into track electrification, it said.

BHEL's scope of work in the order includes supply and commissioning of 25 kV, 50 Hz, AC, single-phase electrification works including overhead equipment, traction sub-stations, Supervisory Control & Data Acquisition (SCADA) system, and associated civil and Signal & Telecom (S&T) works.

Source : ET Bureau, Feb 01, 2019

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)

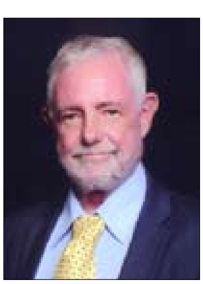
(II) Collective Members (II) - (Universities, Engineering Colleges,Technical Institutes and regulatory commission)

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

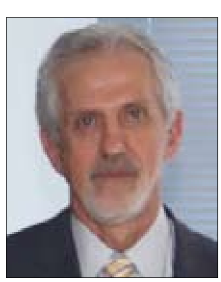
(IV) Young Members (Below 35 Years of Age) -
(In the engineering, teaching or research professions as well as of other professions involved in the industry (Lawyers, economists, regulators...)

CIGRE - HQ

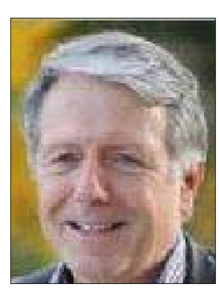
President
Rob STEPHEN (SA)



Chairman TC
Marcio SZECHTMAN (BR)



Treasurer
Michel AUGONNET (FR)



Secretary General
Philippe ADAM (FR)

INTERNATIONAL COUNCIL ON LARGE ELECTRIC SYSTEMS

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

MEMBERSHIP APPLICATION FORM – for the year 2019

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. 67,000/-	Rs. 79,060/-
2	Collective II (Universities & Regulatory Com.)	Rs. 26,500/-	Rs. 31,270/-
3	Individual	Rs. 8,000/-	Rs. 9,440/-
4	Young - below 35 years of age	Rs. 4,000/-	Rs. 4,720/-

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