Report of the CAC Sub-Committee on Congestion in Transmission

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June, 2015

R.V. SHAHI
Former Power Secretary, Govt. of India
Chairman, CAC Sub-Committee on
Congestion in Transmission

8th June, 2015

Dear Shri Pradhan,

CAC Sub-Committee on Congestion in Transmission set up by CERC

On behalf of the CAC Sub Committee, I have great pleasure in forwarding a copy of the Report. We are thankful to the CERC for entrusting this responsibility to this Group.

With regards,

(R.V. SHAHI)

Shri Girish Pradhan
Chairman
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Sub-Committee of Central Advisory Committee (CAC) on Congestion

Members

1. Shri R.V. Shahi, Former Secretary, Ministry of Power – Chairman
2. Shri Ashok Khurana, Director General, Association of Power Producers
3. Shri Hemant Sharma, CMD, GRIDCO
4. Shri R. N.Nayak, CMD, POWERGRID
5. Shri Vijayanand, CMD, APTRANSCO
6. Prof. S.C. Srivastava, IIT Kanpur
7. Shri Pankaj Batra, Chief Engineer (I/C)-FC&A, CEA
8. Shri Ravinder Gupta, Director (SP&PA), CEA
9. Shri A.K. Saxena, Chief (Engg.), CERC- Convenor

Special Invitees:

1. Shri S.K. Soonee, CEO, POSOCO
2. Prof. S.A. Soman, IIT Bombay
3. Shri A.M. Khan, Member, MERC

Acknowledgement

The sub-committee gratefully acknowledges the contribution made by Chairperson, Members and special invitees. The committee members not only spared their valuable time for the task at hand but also contributed immensely in the deliberations through detailed inputs as well as in-depth discussions. The sub-committee is thankful to the Chairperson for his contributions in steering the discussions through valuable suggestions and also providing guidance on critical issues. The sub-committee would like to place on record its appreciation for the detailed inputs provided by POSOCO in regard to the international position in respect of transmission capability, detailed account of SPS operation in the country and suggesting various measures in different time frames and also that of CEA for giving valuable inputs in the light of discussions held in National Reliability Council for Electricity. The sub-committee also acknowledges the painstaking efforts made by the CERC officers in collating, compiling and drafting the report from the inputs and voluminous material available from various source. The sub-committee is grateful to the Chairperson and Members of the CERC for entrusting this responsibility to and reposing confidence in the sub-committee.

Executive Summary

(i) In accordance with the National Electricity Policy, transmission system as an important infrastructure has to be in place ahead of generation capacity. In view of large capacity additions during last few years, though still short of targets, the transfer capability of transmission system has indeed emerged as a constraint.

(ii) It is also a fact that in the architecture of electricity sector, generation is delicensed and, accordingly, generation capacities have come up and will continue to come up based on technical and commercial feasibilities of these projects. Therefore, the contention that massive capacity additions, in a delicensed regime, pose a major challenge to transmission system planning and, therefore, this type of mismatch is inevitable, cannot be taken as an acceptable argument. In a situation of power sector being starved of generation capacity, delicensing have been a correct strategy and transmission system planners will have to devise strategy to cope with this.

(iii) The silver lining is that the gestation period for a typical coal based power project, and more so, for a Hydroelectric Project, will invariably be longer than transmission projects. However on the other hand the gestation period for renewable energy resources is lesser than gestation period for transmission. What is needed is a mechanism which could dynamically capture the emerging generation sources and enhance the ability of demand forecasts in different parts of the country. These two elements, along with other relevant factors should guide the planning process for transmission.

(iv) The present debate on transmission capacity and transfer capability has to be placed in right perspective. The debate has probably emanated from the statement of transmission capacity in the past. A

correct analogy would be the strength of a chain which is determined by the weakest link of the chain and not by the strengths of each link of the chain. It becomes very difficult to accept that transfer capability is in the range of 20 to 30 percent of the transmission capacity. In fact, there should be no need for expressing transmission capacity of the system if it has to be so vastly different from its ability to transmit power. The issue has become debatable in the context of stated transmission capacities. Transfer capability of transmission line is a complex property influenced by system voltage, loading, physical properties, system reactive capability & stability, therefore, it is correct to say that the capability of the system would be dependent on a number of factors and will definitely be not the sum total transmission capacities of different segments of the system.

(v) There is a need to have a balanced approach to address the conflicting concerns of – (a) a highly cautious operation to ensure safety and security of the Grid by reducing the loading of the system, and (b) allowing the system to carry as much of power as it can, thereby getting into somewhat unsafe regime from Grid security point of view. Either of the extremes needs to be avoided.

(vi) There is a convergence of view among the major players viz. POWERGRID/CTU, POSOCO, CEA, and others that enhancing the capability of the system is an ongoing process. Utilization of installed power generation capacity is an equally important consideration. During the period, in which various segments of the country's transmission systems are strengthened or re-laid to reach a comfortable level of redundancies, a goal which will obviously take some time, particularly in view of continuing generation capacity additions, instead of depriving the consumers from the benefits of increased availability of power, all areas of operational strategy, both in power plants and transmission systems, should be re-visited to provide higher level of confidence. Quite often, certain design

inadequacies are appropriately addressed through operational strategies. It is in this context that instrumentation and control systems – both hardware and software – could make a big difference in enhancing the transfer capability without jeopardizing the Grid security.

(vii) POSOCO and POWERGRID have identified specific special protection systems. This process should be extended to all such segments which are proving to be constraining the process of enhancing power flow duly keeping in view safety and security of the grid. Power Stations also need to be identified for similar dispensation. However, such System Protection Schemes (SPS) which are used for (N-1) security should be gradually phased out with commissioning of new transmission system and SPS should be actually deployed for (N-2) contingencies and beyond, which is not envisaged in the Planning Criteria but has a high impact in terms of cascading failures in case it happens. Meaning of (N-1) in HVDC means in case one pole of HVDC is out it should not affect generation and load. Reliability, selectivity, speed and sensitivity at each step of implementation of SPS is to be met.

(viii) IIT Bombay, IIT Kanpur and National Reliability Council for Electricity (NRCE) representatives have also suggested specific measures such as Phase Shift Transformer to enhance the transfer capability after necessary system studies. In all such existing cases where there is a scope for enhancing the transfer capability through this measure, immediate steps may be taken for implementation. In future this may be provided where needed at the planning stage itself. POWERGRID may carry out a comprehensive study jointly with CEA and NLDC for siting and sizing of PST.

(ix) Dynamic reactive power compensation devices such as SVCs, STATCOMs etc. needs to be expedited. As per studies conducted by

POWERGRID and CEA, twenty two (22) such schemes have been identified. In the next three to four years this number may rise to thirty five (35).

(x) POSOCO has indicated that MoP has identified about60 transmission systems which are being monitored with the target of completing them all by March, 2015. POSOCO has confirmed that completion of these will go a long way in addressing the present constraints being faced. It should, however, be recognized that such an exercise would not be a onetime initiative. In coming months and years, there would be new power generation capacities which would be getting added to the system bringing about yet new constraints in transmission. Therefore, short term measures would include an institutionalized mechanism to identify such problems in advance – well ahead of the likely commissioning of new generation plants – so that the short term actions which would include the identified transmission interconnections, sub-station strengthening and operation safeguards like SPS are all coordinated to converge with the likely time of the event, thus, addressing the emerging constraints in totality. It is suggested that CERC may consider putting a mechanism to monitor critical lines on a quarterly basis so that the short and medium term constraints are mitigated.

(xi) One of the reasons of this constraint has also been the fact that while in last ten years, private sector capacity addition has led to their share in the total generation capacity rising to 35 percent, ahead of Central Sector generation capacity, the private sector constitutes hardly 3 percent of the total capacity in Transmission. The process of transmission capacity enhancement through public as well as private sector routes has to be accelerated.

(xii) It may not be correct to conclude that the transmission constraints being experienced are only because of transmission system

development by POWERGRID lagging behind or because of POSOCO being too conservative for ensuring a totally safe operation. One of the main reasons of the constraint is also the inadequacies of State level transmission and sub-transmission systems. There are examples that power could be reached through National Grid into the State, but such transmission would be handicapped because the State level transmission and/or sub-transmission system may not be able to absorb. There is, therefore, a need for CTU, POSOCO, and CEA, to provide regular guidance to the State Utilities and authorities, and more importantly there needs to be a mechanism to monitor to ensure that the matching systems at State level are in place to coincide with the overall requirement. This is equally true for provisions related to SPS and dynamic control mechanism including SVCs, STATCOMs etc. in the State sector.

(xiii) Long term strategy would include assimilation of new technologies, and retrofitting of transmission lines and sub-stations to enhance their capacity, strengthening of transmission towers and conductors, apart from the new transmission systems with higher capacities to take care of right-of-way issues. CEA CTU and POSOCO could create a Task Force to identify exhaustively all possible areas of transmission capacity enhancement in the existing systems. This exercise should cover not only the Central transmission systems, but also the State level transmission and sub-transmission systems.

(xiv) On the planning and operations front, use of probabilistic and other simulation models to factor the uncertainty/risks on account of planned/forced outages in base case, opening of lines to control high voltage and protection surprises leading to contingencies greater than (N-1) would need to be gradually introduced against the present deterministic exercise being carried out.

(xv) POSOCO should in coordination with and full support of concerned SLDCs and DISCOMs prepare islanding schemes for major cities and towns (considering the criticality) which will aim at matching the local supply with important and emergency loads.

(xvi) Transmission system planning requires proper understanding and support of various agencies involved in this process. It has been observed usually that State Utilities favour a highly conservative approach, and it becomes a challenge to generate consensus for planning and development of new transmission systems. The consequence of such an approach finally is faced by these very State Utilities which quite often do not get electricity for their consumers even if electricity can be made available. CERC and Forum of Regulators could periodically organized discussions in this regard, so that the approach shifts towards a more liberal dispensation for transmission system development.

(xvii) In the context of a major shift in the Government's Policy for a quantum jump in developing renewable power generation systems, planning and operation of transmission system is going to pose - in fact, the problem has already started surfacing – a major challenge. It requires short and medium term solutions, but more importantly, it needs a long term planning fully integrated with the future plans of Ministry of New and Renewable Energy. In these cases, organizations like POWERGRID would need to be supported in view of the pattern of utilization of these transmission systems, by way of Viability Gap Funding/ Power System Development Fund (PSDF).

(xviii) Fluctuating load/generation in renewable and its impact on transmission planning needs to be taken care. There is a need to identify balancing capacity to manage the fluctuations.

(xix) North Eastern States have huge Hydro potential. It would be wrong to assume that all projects will be developed in the same time frame. It would also be a wrong strategy to develop transmission systems adequate enough only for the projects already under implementation. Long term planning would require development of transmission systems in a manner that they are normally underutilized in the initial years but later utilized well. Here again commercial organizations would need to be financially supported through instruments like Viability Gap Funding/ PSDF.

(xx) All such transmission Lines which are 765 kV and above and are expected to carry larger loads, particularly located in high wind and cyclone zones must be given adequate attention from design point of view with a view to completely obviating their possibility of their collapse. In the rare instance of such happening the planning considerations should also cover remedial backup

(xxi) CEA, CTU, POSOCO, and a number of other organizations have been discussing, for some time, about the General Network Access (GNA) Scheme, which aims at developing transmission system in a manner that available power can be smoothly transmitted. It would not be necessary to know in advance the destination of supply for a power generation plant. This is how it should be keeping in view the projected architecture of the electricity sector as per the Electricity Act 2003. It was noted that CERC has already brought out the Staff Paper which inter-alia includes GNA concept. The sub-committee expressed the need for an early decision by the Commission in this regard.

(xxii) The Sub-committee underlined the need for co-ordination of development of intra-state transmission system by CTU. CTU to submit quarterly report on augmentation of transmission system in the Country to CERC.

1. Background

1.1 Transmission infrastructure is backbone for operation of a competitive electricity market. The Inter-State Transmission System, which is the integrating backbone of India's vast National Electricity Grid, has over the years achieved tremendous growth. There has been a marked increase in growth of central sector transmission system and transformation capacity during the 11th Plan and it is expected to increase during the 12th Plan as well. However, transmission congestion in some parts of the grid underlines the need for emphasis on development of adequate transmission system.

1.2 'Congestion', according to Indian Electricity Grid Code, 2010, is a situation where the demand for transmission capacity exceeds the Available Transfer Capability.

1.3 The Total Transfer Capability (TTC), Available Transfer Capability (ATC) and Transmission Reliability Margin (TRM) have been defined in the CERC (Measures to relieve congestion in real-time operation) Regulations, 2009 as under:

"Total Transfer Capability (TTC)" means the amount of electric power that can be transferred reliably over the inter-control area transmission system under a given set of operating conditions considering the effect of occurrence of the worst credible contingency.

"Transmission Reliability Margin (TRM)" means the amount of margin kept in the total transfer capability necessary to ensure that the interconnected transmission network is secure under a reasonable range of uncertainties in system conditions.

"Available Transfer Capability (ATC)" means the transfer capability of the inter-control area transmission system available for scheduling commercial transactions through long term access, medium term open

access and short term open access) in a specific direction, taking into account the network security. Mathematically ATC is the Total Transfer Capability less Transmission Reliability Margin.

1.4 Congestion is more evident now in view of the fact that the State Utilities/DISCOMs plan for procurement of a specified quantum of power from the entities outside the State. However, relative price of power of their own generating stations vis-a-vis the same in respect of some of the stations from which the power can be availed by them is influencing the decision of DISCOMs, thereby resulting in congestion. In order to mitigate congestion in transmission and for a competitive market a robust transmission system is required. With Open Access in transmission, the role of transmission has changed from a mere infrastructure to an enabler in operation of a competitive power market.

Constitution of the Sub-Committee of CAC

1.5 The issue of transmission congestion was discussed in the 19th meeting of Central Advisory Committee (CAC) of CERC held on 12.5.2014. In the meeting consensus evolved that a Sub-Committee of CAC be formed by CERC to facilitate CAC with their recommendations on measures to ease transmission congestion. The Sub-Committee was formed vide CERC's Office Order dated 11.7.2014 and its partial modification vide Office Order dated 5.8.2014 with following composition:

a. Shri R.V. Shahi, Former Secretary, Ministry of Power – Chairman
b. Shri Ashok Khurana, Director General, Association of Power Producers
c. Shri Hemant Sharma, CMD, GRIDCO
d. Shri R. N.Nayak, CMD, POWERGRID
e. Shri Vijayanand, CMD, APTRANSCO
f. Prof. S.C. Srivastava, IIT Kanpur
g. Shri A.K. Saxena, Chief (Engg.), CERC- Convenor

Special Invitees

a. Shri S.K. Soonee, CEO, POSOCO

b. Prof. S.A. Soman, IIT Bombay

c. Shri A.M. Khan, Member, MERC

One copy each of the aforesaid CERC Office Orders is at ***Annexure-I & II*** respectively.

First meeting of the Sub-Committee

1.6 First meeting of the Sub-Committee was held on 22.8.2014. List of participants is at ***Annexure-III***. Gist of discussions held in the meeting is as under:

1.6.1 Prof. S. C. Srivastava of IIT, Kanpur mentioned that algebraic sum of Transmission Capacity of transmission lines or inter-regional transmission links cannot provide Total Transfer Capability due to various issues such as reactive power compensation, least resistance path and inherent characteristics of power system. He added that one of the major causes of the gap between Transmission Capacity (TC) and Available Transfer Capability (ATC) is lack of adequate reactive power compensation. He stressed that frequency of calculation of ATC should be increased and FACTS devices should be installed to improve ATC.

1.6.2 POWERGRID mentioned that transmission is a passive element and Available Transfer Capability is affected by generation and load profile. Various expected generations have not come up and matching upstream and downstream intra-state systems have also not been commissioned. These have lead to congestion.

1.6.3 Prof. Soman of IIT Bombay stated that as per study conducted by them, congestion in Mumbai system could be mitigated where ATC could be enhanced from 1800 MW to 3000 MW by use of phase shift transformers.

1.6.4 POSOCO presented international experience in regard to Transfer Capability which portrayed that the Transfer Capability in advanced countries is of the order of 21% of Transmission Capacity. An exhibit depicting the same is given as ***Annexure-IV***.

1.6.5 CMD, GRIDCO enquired whether there are any international benchmarks in regard to calculation of ATC or practices which could possibly be adopted to improve ATC. He also raised the concern whether it is an issue of improper transmission planning where consumers are paying for transmission system which is not used fully or is it an issue with management of transmission system that it is not put to optimum use and whether it could be done with better topology or reactive power management. He also sought more transparency in calculation of ATC and revision as per dynamic conditions.

1.6.6 Director General, Association of Power Producers (APP) mentioned that all the Developers share concern regarding congestion and whatever is feasible should be done. He also indicated that Ministry of Power had invited expert opinion from Shri Mata Prasad and wanted that a copy of the letter written by him to Ministry of Power in this regard be placed before the Sub-Committee.

1.7 Important extracts from correspondence between Mr. Mata Prasad and POSOCO are given in the ***Annexure-V***, where the issues of suitable reactive power compensation, need for stability studies, study of low frequency oscillations and its mitigation through power electronics devices have been highlighted by him in the context of line loadability. Thermal loading of lines has generally not been advocated.

1.8 POWERGRID confirmed that actions are being taken by them in regard to the above and the process would be further strengthened. POSOCO mentioned that the suggestions made by Mr. Mata Prasad are being taken care of.

1.9 POWERGRID and POSOCO were requested to furnish the reasons for congestion under various heads and suggest measures for reducing congestion in short-term, medium-term and long-term.

1.10 Chairman of the Sub-Committee suggested that audit check for working of requisite systems may also be institutionalized.

1.11 Association of Power Producers was requested to get data from generators regarding issues in dispatch of power plants.

1.12 A copy of presentations given by POWERGRID, POSOCO, and IIT Bombay is enclosed at ***Annexure-VI***. A copy of minutes of meeting is enclosed at ***Annexure-VII***.

1.13 It was also decided by CERC that the Sub-Committee while making its recommendations will also take note of C&AG Report (March 2013) on 'Planning and Implementation of Transmission Projects by POWERGRID and Grid Management by POSOCO' in so far as they are related to transmission congestion. Accordingly, the same was circulated to the members of the Sub-Committee through email dated 12.9.2014 (***Annexure-VIII***). A copy of C&AG report is available at www.cercind.gov.in.

1.14 In the first meeting of the Sub-Committee, it was decided to include one representative each from Transmission Planning Group of CEA & NRCE to be part of the Sub-Committee as members. A copy of CERC Office Order dated 12.9.2014 to this effect is enclosed at ***Annexure-IX***. CEA, vide its letter dated 17.9.2014 (copy at ***Annexure-X***), nominated following representatives as members of the Sub-Committee:

a. Shri Pankaj Batra, Chief Engineer (I/C)-FC&A
b. Shri Ravinder Gupta, Director (SP&PA)

1.15 In accordance with the decisions taken in the first meeting, POSOCO, APP and CTU submitted requisite information. POSOCO submitted reasons for congestion under various time frames and proposed measures to relieve congestion in short-term, medium-term and long-term. CTU submitted reasons for congestion and measures to relieve congestion in medium-term and long-term vide their letter dated 2.12.2014 and further email dated 26.12.2014. APP also submitted issues in dispatch of generators vide their letter dated 19.9.2014.

1.16 Various issues brought out by APP with regard to dispatch of generators due to transmission congestion are as follows:

a. **NR Import** - Northern Region is deficit in power almost for the whole year. The average Short Term requirement of power in Northern Region varies in the range of 1000 MW during winters to 3500 MW during summers / monsoon. Since the full requirement cannot be met through NR generators, NR States have to procure power from generators/suppliers outside the Northern region. The power procured on short term basis varies from 1000 MW to 2000 MW. As per NLDC data, there is no corridor margin available in WR – NR route and therefore the only option of getting power into NR is ER-NR route. The ATC in ER – NR route varies from 500 MW during winters to 1500 MW during summers / monsoon. As a result, the generators face huge short term transmission constraints for export of power to Northern Region mainly during the summer and Monsoon season.

b. **WR Import -** As per NLDC, ER – WR (W3) corridor on Short term is 0 MW around the year. As a result, there is no power flow from ER to WR on direct route. However, power from ER to WR is being scheduled via NR Route i.e. ER to NR to WR. This route is already experiencing congestion as mentioned above.

c. **SR Import -** As per NLDC, there is no corridor available in WR-SR and ER - SR route in advance basis on short term. Further, there is no corridor available under MTOA till FY 2016 for import of power

from NEW grid. There is no clarity on the status of LT Open Access applications which have already been submitted.

d. **NER Import -** NER States are also facing congestion during winter months as they face power deficit during this season and require import of about 200-300 MW power from outside the region. However the ATC is reduced to 100-150 MW.

1.17 A detailed report submitted by APP on Generation projects facing dispatch issues due to transmission congestion is attached at ***Annexure-XI***.

Second meeting of the Sub-Committee

1.18 Second meeting of the Sub-Committee was held on 18.9.2014. List of participants is at ***Annexure-XII***. Gist of discussions held in the meeting is as under:

1.18.1 CEA suggested the following:

a. Technology can be deployed to enhance capability of existing transmission system by including new conductors, new structures, FACTS devices, new transformers & phase shifters.

b. Dynamic line rating may be used to determine capability of lines. Emergency line rating can be up to 40% more for first few cycles. By considering lower temperature it is possible to increase transfer capability.

c. Discussions had been held in Reliability Committee on this and a copy of minutes of meeting will be shared (A copy of the minutes of meeting of the NRCE received from CEA subsequently is enclosed at ***(Annexure-XIII)***.

1.18.2 POSOCO suggested measures to be undertaken to reduce congestion in short-term, medium-term and long-term. In short term, SPS schemes already planned need to be implemented. In medium–term, various intra-state transmission systems and generation projects need to be expedited. In long-term, re-conductoring of short lines, expediting new transmission elements and General Network Access

need to be put in place. CEO, POSOCO also stated that settings of protection relays are not proper and they are also not operating as per standards. POSOCO was of the view that adequate ISTS is available for drawal; there is an imminent need to develop intra-state transmission system.

1.18.3 POWERGRID stated that congestion is also on account of the fact that generation is de-licensed and transmission is a licensed activity. Further, ROW is a reality and ROW related issues have been increasing over the years. POWERGRID suggested that future lines should be built with latest technology. In his regard, POWERGRID stated following technologies are being employed:

a. 6 nos. of Thyristor Controlled Series Compensation (TCSC) have been installed.

b. Meerut- Kaithal 400kV D/C line has been commissioned as high surge impedance loading line.

c. Farakka- Malda 400kV D/C was re-conductored with High Temperature Low Sag (HTLS) conductors.

1.18.4 POWERGRID further mentioned that based on the feedback from the POSOCO, lines are being identified where re-conductoring with high capacity conductor can be done and shall be taken up for the approval of constituents.

1.18.5 Chairman of the Sub-Committee opined that all possible measures to enhance transfer capability such as converting single circuit line to double circuit, upgrading 220 kV system to 400 kV, strengthening of existing towers, re-conductoring, and Loop in-Loop out of existing lines be studied. He suggested that CTU may explore the possibility of up-gradation of transmission lines of States. He also emphasized that sample audit of relays should be undertaken and heavy fine should be imposed for non-adherence to CEA Standards. Unallocated power available at the disposal of Ministry of Power may be suspended in such cases.

1.18.6 POSOCO stated that while the TTC/ATC computations are done as per the procedure approved by CERC, the following factors impact the

system security if one were to consider increasing the line loadability through concepts such as 'Dynamic Line Rating' and use of more and more SPS.

i. Maintenance practices including vegetation management on the transmission systems.

ii. Standards for planning, design and implementation of SPS ensuring reliability, selectivity, speed and sensitivity at each step of implementation.

iii. Proper operation of protective relays through timely fault clearance and correction of 'rogue' relay settings which has the potential to cause cascading effect.

iv. Absence of Fault Ride Through (FRT) capability of wind generators leading to large scale outage of wind generation in case of a fault close to the wind farm.

v. Delayed fault clearance close to HVDC systems leading to commutation failure and blocking of multiple HVDC links considering that all these would be in close proximity to the fault.

vi. Reduction in controllable devices in real time due to squeeze in margins on HVDC links as well as lack of dynamic reactive compensation devices.

vii. Lack of controls such as Automatic Generation Control enabling control areas to hold on to the schedule.

viii. Small signal stability problems for large grids and its mitigation through tuning of HVDC, FACTS and other Power Electronic Devices.

ix. Visualization and Situational Awareness at Control Centers through better availability of tools as well as real time data availability.

x. Regarding Dynamic Line rating it may be noted that the ambient temperature at several places in the country also crosses 45 degrees centigrade, the temperature mentioned in CEA Planning Criteria which would cause reduction in thermal limit during summers.

1.18.7 One copy of each of the presentation given by POSOCO and CEA is enclosed at ***Annexure-XIV & XV*** respectively.

Third meeting of the Sub-Committee

1.19 Third meeting of the Sub-Committee was held on 2.12.2014. List of participants is at ***Annexure-XVI***. Gist of discussions held in the meeting is as under:

1.19.1 CEA suggested following regarding deployment of SPS

a. SPS should not be deployed to take care of (n-1) contingencies but only for (n-2) contingencies.

b. N-1-1 is not required in every corridor and should be deployed only on critical lines.

c. International consultant may be involved for assessing requirement of n-1 since building more lines will lead to high voltages. Phase shifting transformers may be used to improve loading of lines.

1.19.2 Chairman of the Sub-Committee opined that it may be difficult to determine critical lines since it would be dynamic. The criterion to decide critical lines needs to be ascertained. He also enquired from CTU that why phase shifters have not been deployed yet and whether any study has been done to ascertain how much capability will improve with installing phase shifting transformer. He also stated that since the concept of (n-1-1) has been introduced in planning only recently, it will take some time to implement this. Till such time SPS may be deployed in all such cases where (n-1-1) is envisaged but not implemented and should remain till (n-1-1) criterion is satisfied. He further stated that planning and operational safeguards should be jelled together.

1.19.3 CTU stated that they have deployed TCSC in Raigarh-Raipur lines. CTU also informed that they had proposed to use phase shifting transformers (PSTs) in Raichur-Solapur line but same was not approved. A comprehensive study needs to be carried out to identify the feasible locations wherein Phase shifting Transformer can be installed, looking into the future perspective and power system

development. A joint study can be carried out by CTU, CEA and NLDC for the same at the earliest and it should be dynamically revisited to explore new areas and scope for enhancement.

1.19.4 Representative of Transmission Corporation of Andhra Pradesh (APTRANSCO) informed that they have done studies on some of their 400 kV and 220 kV lines regarding PSTs.

1.19.5 POSOCO stated that operationalisation of Balimela-Upper Sileru link can fetch additional 100 MW power in SR through WR-SR corridor. POSOCO informed that Andhra Pradesh shall be operationalising the line shortly.

1.19.6 Chairman also raised the issue of transmission planning for renewables especially in view of the fact that solar power will come quickly and building transmission will take some time. He stated that for planning for wind generation, data should be based on probabilistic estimate based on past experience. Besides this operational strategies are required for expected contingencies. CTU stated that they have planned Green Corridors ahead of generation. CEA stated that a Task Force has been set up in this regard. The important aspect regarding transmission planning is that the area where generation will be backed down on coal shall be different from the area where renewable is injecting power.

1.19.7 CTU proposed that CERC may have a meeting of MNRE with major solar developers, CTU, POSOCO and CEA for solar power expected in next 2 years.

1.19.8 POSOCO stated that generation cost should also be taken care of in transmission planning. CTU stated that presently transmission planning is carried out for different generating stations based on the Long Term Access requested by the applicant, keeping in view the present and future power transfer requirement. Adequate transmission capacity is planned to ensure that the system meets the reliability criteria as specified by CEA's Transmission Planning Criteria. However to take care of transmission system requirement to draw power by a state at a competitive price from different generating sources, each

state needs to indicate maximum export/Import requirement. For this change in regulation is required to take care of transmission planning based on the market requirement and commitment for payment of Transmission charges.

1.19.9 Chairman stated that extreme dispatch scenario should be envisaged and transmission should be planned accordingly. He asked POSOCO to ensure islanding of major cities and towns so that they could get isolated in case of grid collapse. He also asked POSOCO to submit details of how TTC/ATC calculation in our country has matured and what is the future outlook in this regard.

Fourth meeting of the Sub-Committee

1.20 Fourth meeting of the Sub-Committee was held on 29.1.2015. List of participants is at ***Annexure-XVII***. Some of the important points were discussed and finalized during the fourth meeting.

1.21 In the above backdrop, the report of the Sub-Committee has been structured covering the following aspects:

a. Long term planning procedure and mitigation of congestion.
b. Congestion: Near term perspective.
c. Reasons for large gap between transmission capacity vis-a-vis transfer capability.
d. Measures to improve visibility of the information system to facilitate stakeholders.
e. Audit check on working of system.
f. Other issues.
g. Conclusions and recommendations.

The deliberations in regard to the above and outcome of deliberations are presented in succeeding sections.

2. Long term planning procedure and mitigation of congestion

2.1 Planning of robust transmission System

2.1.1 In accordance with National Electricity Policy, CTU is responsible for planning and development inter-state transmission system.

"Network expansion should be planned and implemented keeping in view the anticipated transmission needs that would be incident on the system in the open access regime. Prior agreement with the beneficiaries would not be a pre-condition for network expansion. CTU/STU should undertake network expansion after identifying the requirements in consultation with stakeholders and taking up the execution after due regulatory approvals."

2.1.2 Regulation 3.4 (a) of Grid Code, brings out transmission planning philosophy as given below:

"CEA would formulate perspective transmission plan for inter-State transmission system as well as intra-State transmission system. These perspective transmission plans would be continuously updated to take care of the revisions in load projections and generation scenarios considering the seasonal and the time of the day variations. In formulating perspective transmission plan the transmission requirement for evacuating power from renewable energy sources shall also be taken care of. The transmission system required for open access shall also be taken into account in accordance with National Electricity Policy so that congestion in system operation is minimized".

2.1.3 Transmission Systems need to be planned accordingly so that congestion is minimized.

2.1.4 The detailed procedure framed under CERC (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-State Transmission and related matters) Regulations, 2009 (hereinafter

referred to as 'the Connectivity Regulations') specify the methodology for calculation of Total Transfer Capability (TTC) and Available Transfer Capability (ATC) for grant of MTOA and LTA. Relevant extracts from the detailed procedure are attached at ***Annexure-XVIII.***

2.1.5 MOP has, vide its Order date 15.7.2014, advised CTU to involve international consultant to calculate ATC/TTC. CTU informed that RfP for appointment of consultant was floated on 20.10.2014 and bids have been opened on 15.01.2015. The Sub-Committee underlined the need for revisiting the methodology for computation of ATC/TTC in the light of inputs from international consultant being engaged by CTU.

2.2 Procedure adopted by CTU for Long term planning

2.2.1 The procedure adopted by CTU for calculation of TTC and ATC includes the following:

a. The transmission planning for a particular time frame is initiated by drawing Load-Generation Balance for each State in a region.
b. Peak Load demand - 18th EPS
c. Intra-State Generation (State and Intra-State IPP)
d. Central Sector Generation
e. ISGS IPP generation
f. Load + Losses - Self Generation = Import of power from Grid
g. The above Import shall constitute
    i. Committed Share from Central Sector plus
    ii. Long term PPA with ISGS IPP plus
    iii. balance from Merchant generation
h. Aggregate of such import requirement of States in region gives Inter-regional power transfer requirement
i. The Inter-regional/Inter-State transfer requirement thus arrived is basically ATC required to be created
j. Margins are added on to this ATC for addressing various types of conditions as per Transmission Planning criteria

k. Therefore, power transfer requirement (i.e. ATC) + Reliability Margins = TTC

l. Tentative alternative systems are evolved for achieving above TTC

m. The systems are modeled for detailed load flow studies on which various normal and contingency studies are carried out

n. Results for various alternatives are analyzed to arrive at the most techno-economic alternative

o. The selected system is tested for other conditions like peak hydro, peak thermal, off-peak, etc.

p. The selected alternative is also tested for stability of system through dynamic studies.

2.2.2 On being asked about the details regarding TTC/ATC to be declared for next 4 years as provided under CERC Connectivity Regulations and difficulties being faced in compliance of the same, CTU submitted following:

a. TTC calculations are fairly accurate for a shorter time frame and beneficial for operation of the system where the actual availability of generation and transmission elements is known in advance. The number gets modified regularly depending on the availability viz. addition and outages of various elements.

b. The transmission planning is a longer time frame exercise and is associated with the need for transfer of long term committed power, considering availability of present, on-going and future parameters viz. generation, transmission lines, projected demand etc. expected to be in place under the inter-state as well as intra-state system in the time-frame of the study.

c. In fact, the new transmission elements are planned for enhancement of the TTC for the required power transfer on long term commitment basis as per present CERC Regulations. However, the proportional increase of TTC in actual operation may often get delayed due to mismatch in the commissioning of simultaneous projects/demand growth in the inter-state as well as intra-state

system. It may be mentioned that the transmission system expansion may not enhance TTC for unforeseen power transactions on 'opportunity basis' as this might indicate requirement of large scale system augmentation leading to sub-optimal development of transmission systems.

2.2.3 Keeping in view the necessity for transparency in declaration of TTC/ATC in planning horizon, the results of long term studies carried out by CTU should be made available on their website.

2.3 Reasons for Congestion

2.3.1 CTU indicated that the mechanism for development of transmission system worked well since starting in late 80's and a strong backbone of 400 kV network exists which is now being overlaid with 765 kV network. Till 5-6 years back there were hardly any instances of congestion. Recently large variation in development has been experienced as compared to assumptions in generation, transmission as well as demand. Salient ones at the macro level are:

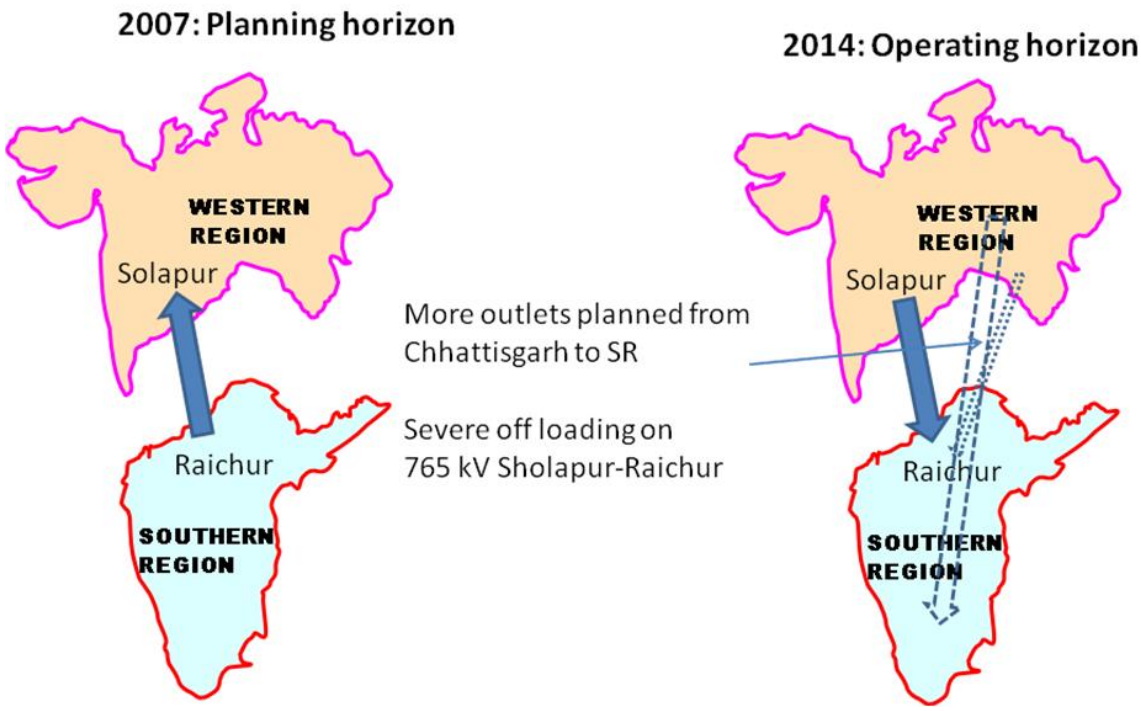
(1) Congestion in specific zones:

a. Raipur-Wardha due to forest clearance.
b. NR-WR: Gwalior-Jaipur due to delay in constitution of National Wildlife Board.
c. SR & NEW Grid: Gooty- Madhugiri-Salem line is held up due to ROW problem in Karnataka; Karnataka is asking for cost of land.

All the above lines are expected to come in next 3-4 months, but the associated 220 kV network in the States has not come up in many cases.

(2) CTU listed out additional reasons for congestion as follows:

a. Reversal of load & generation scenario in SR Grid vis a vis NEW grid.



b. Delay in commissioning of Intra-State or Inter-State generating stations
c. Large variation in power procurement from assumptions.
d. Delay in commissioning of parallel transmission network that inhibits power transfer; ROW in Karnataka, Kerala, Maharashtra, UP.
e. Commissioning of State generation without commissioning of planned transmission system- for example Tiroda (3300 MW), Ideal Energy (270 MW)
f. Skewed power flow due to market forces.
g. CLP Jhajjar (1320MW) & APCPL's Jhajjar (1500MW) in Haryana, Kayamkulam in Kerala, Gas projects, etc., planned as load centre based generation from stability point of view but being considerably under—utilised due to price considerations, thereby putting an extra burden on transmission.

Thus, due to variations in plans vis a vis the actual real time situations, temporarily planned system may appear to be under built or over built.

Thus, due to variations in plans vis a vis the actual real time situations, temporarily planned system may appear to be under built or over built. Further, different elements of transmission systems get commissioned progressively; the power transfers during the intervening period are less. Pockets of the transmission capacity which have been created have become partly or completely redundant/ idle contributing to the gap. The reasons for congestion submitted by POWERGRID are detailed at ***Annexure-XIX***.

2.3.2 POSOCO categorised the reasons for congestion mainly under the following heads:

a. Congestion due to non-availability of intra-state network - A detailed table listing such cases is enclosed at ***Annexure-XX***.
b. Congestion due to delay in commissioning of generating units- ***Annexure-XXI***.

2.3.3 Prof. Soman of IIT Bombay indicated that network inadequacy may be due to following:

a. Deficiencies in temporal and spatial dimension of load and generation forecasts
b. Optimisation tool used for network planning not being of good quality
c. Aggressive line and transformer loading limits having been used
d. Stochastic nature of load and generation not modelled, leading to lack of perception of risk measure
e. Lack of planning control devices

2.4 Measures suggested to mitigate congestion in Long term

2.4.1 Prof. Soman suggested following measures to mitigate congestion in long term:

a. Probabilistic load forecasts should be used.
b. Mixed Integer Linear Programming (MILP) based optimisation tool be used for network planning

c. AC load flow adequacies be assessed and mitigated by an automated tool which simulates all (n-1) scenarios.

2.4.2 Views of CTU in regard to the above suggested measures as follows:

1) Presently deterministic method is being followed for transmission planning. The load forecasting is done by CEA and CEA comes out with Electric Power Survey report. Further interaction is done with states regarding the load distribution. These projections are used for studies.

   For adoption of probabilistic method, long operating experience and availability of reliable statistical data regarding performance of system components, namely equipment failure rate, outage duration, etc. are essential. Such data are presently being compiled by a few utilities. Hence a comprehensive approach covering all aspects right from planning, role and responsibility of stakeholders are to be developed. An International Consultant can be appointed for the same.

2) Transmission planning is presently being carried out in accordance with Transmission Planning Criteria of CEA, January, 2013. The criteria clearly indicate the reliability criteria to be met and planning margins to be kept. The system is designed to meet the conditions as specified in the Planning criteria. Mixed Integer based Linear Programming (MILP) based optimisation tool are presently not being used but can be looked into.

3) CTU carries out Transmission planning using PSS/E of PTI Siemens well-accepted high-performance transmission planning software with meticulous and comprehensive modelling capabilities. The software can be used for carrying out load flow studies, short circuit studies, dynamics studies and automated contingency analysis to simulate contingencies like (n-1).

2.4.3 The Sub-Committee was of the view the use of Probabilistic load forecasts and Mixed Integer Linear Programming (MILP) based optimisation tool need to be considered for network planning. CEA and CTU need to explore the use of aforementioned tools.

2.4.4 Measure taken/to be taken by CTU to mitigate congestion in long term:

Following steps have already been taken by POWERGRID to mitigate congestion

(1) POWERGRID has taken up augmentation of system based on anticipated needs to accommodate power transfers under market mechanism as follows:

a. Implementation of 11 High Capacity Power Transmission Corridors after Regulatory Approval.
b. Planning and Implementation of Green Energy Corridor which is based on anticipated additions in renewable capacity.
c. System strengthening planned/ under implementation without any associated LTA request
   (i) Srikakulam – Vemagiri 765 kV D/c line
   (ii) Wardha – Nizamabad – Hyderabad 765 kV D/c line
   (iii) ±800kV, 6000 MW Raigarh – Pugalur HVDC bipole
   (iv) Warora – Warrangal 765 kV D/c line
   (v) Jabalpur – Orai – Aligarh 765 kV D/c line

(2) Operational feedback from NLDC forms important inputs for undertaking transmission augmentation. Large number of transformer augmentation and provision of reactors are result of such feedback. Besides many new transmission systems have been undertaken based on feedback which are in different stages of planning and implementation

a. Vijayawada – Nellore – Thiruvalem 400 kV D/c line - commissioned
b. Reconductoring of 400 kV Purnea-Binaguri Ckt 1 and 2

c. Mohindergarh – Bhiwani 400 kV D/c -TBCB
d. Addtiional strengthening for Sipat-TBCB
e. System strengthening for IPPs in Chhattisgarh and other generation in WR– TBCB.

(3) New technologies, as indicated hereunder, are being used by POWERGRID to improve execution time of transmission lines:
a. Provision of power line crossing section under live line condition, wherever applicable.
b. Use of sagging bridges/working platform.
c. Use of power operated winch machine for carrying out final sagging.
d. Panel wise dispatch of tower
e. Use of hydraulic rotary drilling rig for special foundation like pile foundation.

(4) Use of helicopter for erection is also being planned in future and mechanization for erection and stringing is being contemplated.

2.4.5 CTU mentioned that it has taken steps to convert many existing reactors to switchable line reactors and shifting/removal of reactors after LILO has been taken up. CTU further stated that line reactors help in controlling power frequency over voltages and secondary arc current through Neutral Grounding Reactor. Hence conversion to switchable line reactor has been taken up considering above aspects. Further new reactors where ever possible are being proposed with switching facility. CTU clarified that loadability of a line is primarily dependent on Thermal limit, Stability limit and Voltage of the system. If the system voltage permits then the line can be loaded irrespective of presence of reactor on it.

2.4.6 CTU suggested following steps which need to be undertaken to minimise congestion in future:

(1) Co-ordinated development of Transmission and Generation:

Focussed attention is required to ensure timely development/utilisation of generation and transmission system which are already under implementation.

(2) Matching development of intra-state transmission & distribution system:

Development of State transmission system is not keeping pace with the growing demand for power. Even though high capacity corridors are being constructed on target allocation basis, matching downstream networks are not being developed by the State Power Utilities. State Power Utilities need to plan matching intra-state transmission system in coordination with CEA & CTU. The development of intra-state transmission system needs to be regularly monitored in the Standing Committee meeting. During the 34th Standing Committee meeting of NR held on 8.8.2014, it was discussed that any new proposal under central sector in a state would be considered only when it is accompanied with identified underlying network along with undertaking for bringing the network matching with the commissioning of the Central Sector substation.

(3) General Network Access (GNA)

At present the transmission planning is carried out based on PPA (known beneficiary). In the 'General Network Access (GNA)' concept, Transmission System would be planned based on Generation/Demand quantum and their location without knowing the contracted source of purchase/sale. The generator and the States/Consumer could be given general network access to the Inter State transmission system for the agreed quantum of power (MW). This would not only optimize the shape and size of the transmission network but would also encourage the increasing market operation by providing flexibility in economic procurement of power. CEA has already submitted to MOP a concept note on GNA. CERC has also come out with a staff paper incorporating the concept of GNA.

2.4.7 The Sub-committee underlined the need for co-ordination of development of intra-state transmission system by CTU to submit quarterly report of augmentation of transmission system in the country to CERC. Further, CEA, CTU. POSOCO and other organisations have been discussing about General Network Access (GNA) Scheme which aims at developing transmission system in a manner that available power can be smoothly transferred. It was noted that CERC has already brought out the Staff Paper which inter-alia includes GNA. The sub-committee expressed the need for an early decision by the Commission in this regard.

2.4.8 POSOCO suggested following measures to mitigate congestion in long term i.e. in a time frame of more than 1 year.

(1) 67 elements being monitored by MOP (***Annexure-XXII***). Out of this, following 8 elements have been commissioned recently :

a. 765 kV Jharsuguda-Dharamjaygarh D/C
b. 765 kV Wardha-Aurangabad D/C
c. 400 kV Bhopal (MP)-Bhopal(BDTCL) D/C
d. 765 kV Raichur-Kurnool S/C
e. 765 kV Sholapur-Raichur S/C (RSTCL)
f. 400 kV Kalivindapattu-Pugalur D/C
g. 220 kV BTPS-Agia 2nd ckt.
h. 400 kV Derang-Anugul D/C

(2) Re-conductoring of short lines with High Temperature Low Sag (HTLS) Conductors: Details at ***Annexure-XXIII.***

(3) Other measures to improve transfer capability:

a. 98 lines can be shortened through suitable Loop-In Loop-Out (LILO)
b. Line reactors may be made switchable so that the same may be switched off during heavy loading of lines. Details at ***Annexure-XXIV***.

c. Zone-3 resistive reach may be set as per the recommendations of the V Ramakrishna Task Force.

Appendix 9.1 of the report of aforementioned Task Force guidelines for resistive reach considering load point encroachment. Extracts from the report are quoted below:

"In the absence of credible data regarding minimum voltage and maximum load expected for a line during emergency system condition, following criteria may be considered for deciding load point encroachment:

•Maximum load current (Imax) may be considered as 1.5 times the thermal rating of the line or 1.5 times the associated bay equipment current rating (the minimum of the bay equipment individual rating) whichever is lower.(Caution: The rating considered is approximately 15minutes rating of the transmission facility).

•Minimum voltage (Vmin) to be considered as 0.85 pu (85%)."

2.4.9 C&AG has in its report on 'Planning and Implementation of Transmission Projects by POWERGRID and Grid Management by POSOCO' (March 2013) made a few suggestions in regard to mitigating congestion. CTU has responded to those suggestions. Observations of C&AG and response of CTU thereon are given below:

(1) C&AG: PGCIL may initiate advance action to conduct detailed survey of forest stretches and submit forest clearance proposals before investment approval of the project.

CTU: Details of transmission lines delayed due to forest clearance and are attached as ***Annexure XXV***. The transmission lines planned in congested areas but delayed due to forest clearance are as below:

Name of the Line	Original Schedule	Actual/anticipated schedule	Remarks
765 kV S/C Gwalior- Jaipur – (under Rihand)	Nov.,'12	July,'15	Wild life sanctuary clearance received in Feb'15. Stage-I awaited for GIB forest.
765 kV S/C Gwalior- Jaipur – (under Orissa)	Mar.,'14	Aug.,'15	Involved Wild life sanctury clearance received in Feb'15. Stage-I awaited for GIB forest.
765 KV D/C Dharamjaygarh-Jabalpur Pooling Station	Dec.,'13	Jun.,'15	Stage-I Clearance received. Permission to work awaited
765KV S/C Ranchi New-Dharamjaygarh line	Apr.,'14	Sept.,'15	Stage-I Clearance received. Permission to work in forest awaited for Jharkhand portion.
765KV D/C Srikakulam Pooling Stn - Angul line**	Jul.,'15	Jul.,'15	Processing of forest case is very slow.
765KV D/C Aurangabad (PG)-Padghe (PG) **	May,'15	Dec.,'15	Forest clearance awaited and critical.
400KV D/C Aurangabad - Boisar line (Quad)**	Mar.,'15	Dec.,'15	Stage-I Forest clearance awaited. Critical. Severe ROW problem.

** Delay in forest clearance will lead to delay of the line.

Further, POWERGRID have already initiated following measures to minimize the delay in forest clearance.

a. Regions/Sites have been advised for initiating proposals for advance expenditure for survey work in forest and river crossing of all forthcoming transmission system soon after intimation of the transmission system by CTU group;
b. Submission of forest proposal within the stipulated period & has been made part of Internal MoU;
c. The forest clearance schedule has been made mandatory for all investment approval proposals considered by the Board;
d. Dedicated forest coordinates have been placed in all the regions for monitoring and facilitating early submission, processing and approval of the forest proposals.

2.4.10 The Sub-committee noted the measures already initiated by POWERGRID to minimise the delay in forest clearance and expressed the need for taking requisite steps in the right earnest. Sub-committee noted that this being major impediment in timely development of transmission systems, MoP may be approached to take up the matter with concerned State Governments either individually or in Power Ministers' conference so as to facilitate development of much needed transmission system.

2.4.11 C&AG: POWERGRID assesses need for interregional corridor only on 'Transmission Capacity' and does not monitor augmentation of total transfer capability.

CTU: It is misrepresentation of the fact. Planning of the transmission system is done based on totality and considering envisaged generation and load demand and transmission system needed to transfer the same based on CEA's Planning Criteria. The gap between the total transmission capacity of the system planned and TTC is mainly because envisaged generation is not there or sometimes distribution network to draw the power or non availability of parallel lines. For example, summation of Total Transmission Capacity between ER & NR is 14,000 MW. However, in the absence of envisaged generation in ER, other lines get critically loaded which was not designed for such power transfer and the TTC declared by POSOCO is only 3100 MW. The gap between total transmission capacity and transfer capability will narrow down, if planned generation is there and evacuation will be guided only by the factor of Reliability/Contingency margin like (N-1) as prescribed by CEA/ CERC. Reliability margin being considered for working out ATC is not being envisaged at the planning stage where (N-1-1) Criteria of CEA is adopted.

2.4.12 C&AG: Monitoring mechanism for implementation of transmission projects needs to be strengthened. Project review meetings were not held as per prescribed frequency of once in two months.

CTU: Regular reviews at Director/CMD level were held every fortnight which served the basic purpose of monitoring. With modern communication system in place, projects are being monitored through video conferencing with Regional head quarters/Site offices at regular intervals. Further Strengthening of monitoring mechanism for implementation of Transmission projects has already been taken up by POWERGRID. ERP has already been rolled out for SR-II, SR-I, Corporate Centre Deptts. ERP for balance Regions would be rolled-out and the complete system would be in place by end of FY 2014-15.

3. Congestion: Near term perspective:

3.1 Computation of TTC/ATC

3.1.1 Regulation 3(1) and 3(2) of the Central Electricity Regulatory Commission (Measures to relieve congestion in real time operation) Regulations, 2009 dated 22.4.2013 (herein after "CERC Congestion Regulations") provides as under:

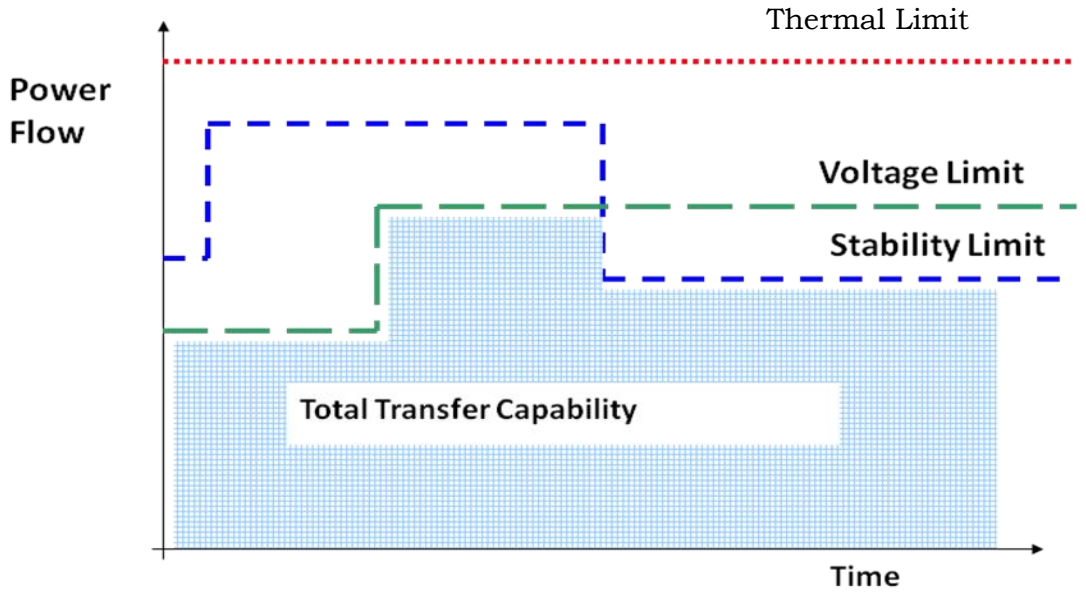
(1) The National Load Despatch Centre shall asses the Total Transfer Capability (TTC), Available Transfer Capability (ATC) and Transmission Reliability Margin (TRM) of inter-regional links / Corridors in consultation with Regional Load Despatch Centres, and revise, if necessary, the TTC, ATC and TRM declared by the Central Transmission Utility (CTU) as per the detailed procedure mentioned in the Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-State Transmission and related matters) Regulations, 2009 .

(2) TTC, ATC, and TRM along with the details of basis of calculations, including assumptions if any, shall be put up on the website of NLDC and RLDC at least three months in advance. The specific constraints indicated by the study would also be put on the website.

Thus, National Load Despatch Centre (NLDC) is required to assess the TTC, TRM and ATC of inter-regional links corridors for three months in advance for each month up to the fourth month as provided in *Detailed Procedure for relieving congestion in real time operation framed under Regulation 4 (2) of the Central Electricity Regulatory Commission (Measures to relieve congestion in real time operation) Regulations, 2009* (extracts attached at ***Annexure-XXVI***). It also requires display of real-time power flow in the corridor for which TTC has been declared alongside for comparison for monitoring the congestion.

3.1.2 The procedure adopted by POSOCO for calculation of TTC/ATC is attached at ***Annexure-XXVII***. A sample TTC/ATC report for September 2014 as declared by NLDC is also attached at ***Annexure-XXVIII***.

3.1.3 The Total Transfer Capability is being taken as minimum of thermal limit, voltage limit and stability limit.



Total Transfer Capability is the minimum of the Thermal Limit, Voltage Limit and the Stability Limit

3.1.4 CEA Transmission Planning criteria provide that the emergency thermal limits for the purpose of planning shall be 110% of the normal thermal limits.

3.1.5 National Reliability Council for Electricity (NRCE) was constituted on 21.02.2014 on the direction of the CERC vide Order dated 11.12.2013 in petition No. 188/SM/2012 for approval of Total Transfer Capability (TTC) calculated by POSOCO on a monthly basis. The status of computation/approval of TTC /ATC every month as per CERC's direction to NRCE vide Order in Petition No. 188/SM/2012 is as detailed below:

(1) The NRCE has so far held four meetings to deliberate on various issues related to approval of TTC. The NRCE also constituted a sub-Group for going into details of system studies for the purpose of determination of TTC. The sub-Group has also held four meetings. The agenda and minutes of meeting are available on the website of CEA. POSOCO was invited to attend the meetings as a Special Invitee to enable NRCE to understand the methodology being used by them for determination of TTC.

(2) From the deliberations during the meetings of the NRCE and its sub-group, it is confirmed that the system studies carried out by POSOCO and the data used for the same are as per the Detailed Procedure for Relieving Congestion in Real Time Operation approved by CERC. However, the operating margins on account of ambient temperature adjusted loadability of transmission lines, as provided in the CEA Transmission Planning Criteria, referred to in the Detailed Procedure, is not being used. Therefore, Operational Guidelines indicating the same are being issued to POSOCO for the same. These are in the nature of elaboration of the Detailed Procedure. Moreover, the Special Protection Scheme on each of the circuits of Agra-Gwalior 765 KV D/C line is set at 1250 MW, which is not as per the CEA transmission planning criteria for (N-1-1) contingency, which has been asked to be modified and which is likely to result in an increase in the TTC between Western and Northern region.

(3) The sub-Group is further studying the existing methodology of calculation of TTC, ATC (Available Transfer Capability) and TRM (Transmission Reliability Margin) vis-à-vis international best practices for the same, in order to see if the methodology can be made more efficient and accurate. Once the sub-Group arrives at a decision in this regard, NRCE would approach the Hon'ble Commission with the suggestions for change in Detailed Procedure.

(4) Since doing the system studies with the complete data of above 10,000 buses is a detailed exercise, it is not possible to verify the

data each month and do the system studies independently with the existing staff. Therefore, in the Annual Plan proposal for the year 2015-16, a proposal of NRCE has been sent to the Ministry of Power for hiring of consultants to do the system studies on a monthly basis independently. Moreover, since Special Protection Schemes affect the TTC, it is proposed to hire a consultant for reviewing all the System Protection Schemes in the Indian Grid, including the angular stability of the grid.

3.1.6 POSOCO was asked to submit details of how ATC/TTC calculation in our Country has matured since 2007, International practice(s) of calculating TTC/ATC and pros and cons of alternate methods. POSOCO has submitted a brief of international practices in calculation of TTC/ATC attached at ***Annexure-IV***. POSOCO is currently following Repeated Power Flow (RPF) method. In this method power flow equations are repeatedly solved for different operating points and for different load generation balance scenarios. This method is computationally expensive. For experienced personnel, this method is practically the most suitable method. This method is not suitable in those cases where robust power flow techniques are a necessity. This method is applicable when ATC changes need not be updated immediately after every transaction. This method becomes powerful with practical experience and historical data availability becomes an added strength.

3.1.7 The Sub-Committee opined that requisite exposure in regards to calculation of TTC / ATC will be an added strength and exposure be provided to CTU, CEA and NLDC / RLDCs/ SLDCs.

3.1.8 POSOCO has also detailed problems faced while calculating TTC/ATC and improvements which are possible are detailed below:

a. **Modelling/Network Topology:** For frequent calculation of TTC, snapshot model from the SCADA / State estimator has to be taken

as input to PSS/E. For this purpose, suitable interpreter has to be developed for converting bus-oriented model into a node-oriented model for running AC power flow.

b. **Input Data:** The states should declare their station-wise anticipated generation and properly forecasted load, for realistic assessment of TTC on day-ahead / month-ahead / three-month ahead basis node wise data. Currently the data is not available and hence TTC is therefore assessed for a month considering historical operational data like generation and load available with RLDCs for the same month of previous year scaled appropriately by the percentage increase in growth.

c. **Revision of TTC/ATC**: At present due to non-availability of suitable interface between SCADA and PSS/E, the revision of TTC in real-time is a tedious task. For this purpose, an interpreter has to be developed before going for hourly or frequent revision of TTC.

Further, such frequent revision of TTC and posting the balance ATC left at any point of time in public domain would be meaningful once we have an intra-day or intra hourly market.

The interplay between LTA/MTOA contracts and balance ATC is also important. If a generating unit supplying power under LTA/MTOA trips or gets synchronized, the schedules would be revised if the generator revises its Declared Capability (DC). This would have an impact on balance ATC and is basically an instance of change in the scheduling horizon. It calls for a high level of automation and a robust Market Management System (MMS) integrating the Short Term Open Access (STOA) window, Scheduling window, TTC/ATC declaration window as well as taking inputs from the Real Time System.

d. **Treatment of Loop Flows & Transit flows:** The loop flows & transit flows are being taken into consideration. If not considered, the same may affect the simultaneous TTC of a region. The effect of Loop flows are incorporated by calculating the TTC in a co-ordinated manner by RLDCs/NLDC instead of assessing individually. For this purpose, all India base case with full network is considered for checking loop flows and transit flows. The path-wise approval of short term transactions or re-routing of short term transactions should be phased out gradually in the current meshed scenario as the same is meaningless.

e. **Treatment of Counter Flows**: ATC can be increased by considering the counter flows. However, if transactions giving rise to counter flows are not executed by buyer/seller, then there would be congestion in real time.

Counter flow consideration in calculating the ATC should be decided from the historical record of the 'counter flow MTOA/STOA transactions'. Presently, the counter-flow transactions are not considered in case of contracts in the dominant flow direction. For instance, prominent direction of flow is Western Region to Southern Region. In case there is any contract from Southern Region to the NEW grid, then it will be difficult to incorporate this contract in the counter-flow direction while evaluating ATC from West to South. For if the power is not scheduled from South to West on any given day against this contract, there would be congestion in the West to South direction.

f. **Transmission Reliability Margin (TRM):** TRM should be risk based. The general method for setting the TRM is fuzzier in nature (high TRM denotes high security and less ATC). Because of the fuzzy nature of TRM, a proper basis for TRM should be set up. Peter Sauer [1] gives an excellent basis for deciding TRM. TTC could be assessed

for different likely scenarios that would occur for the period under consideration. Scenarios would cover a variety of load generation balance as well as the network topology. Since the TRM is designed to account for uncertainty in the model configuration and operating conditions, the alternate cases could be used to compute the TRM. The available capability for a given transfer can become smaller as more alternate (but not necessarily likely) cases are considered. If appropriately weighted by the likelihood of occurrence, this could be used to determine the TRM for this base case. This is one of the suggested approaches by Peter Sauer. IEGC regulations on TRM are broad in nature and need a sounder basis.

3.1.9 The Sub-committee opined that suitable interpreter needs to be developed at the earliest so that accuracy and transparency of TTC can be increased. Further loop flows, transit flows and counter flows should be considered for TTC / ATC calculations as considered appropriate by POSOCO. Congestion in real time be handled in accordance with the provisions in CERC Congestion Regulations. NRCE in consultation with POSOCO and CTU may explore alternative methods of calculation of TRM as suggested and provide to Commission for its consideration.

3.2 Measures to improve transfer capability in near term

3.2.1 Installation of System Protection Schemes:

(1) POSOCO has suggested that congestion may be mitigated in short term i.e. within 3 months time frame by installing various system protection schemes. An overview of number of System Protection Schemes in service, schemes to be made operational and the schemes under discussion, as per POSOCO, is given below:

S. No.	Region	No. of Schemes in service	No. of Schemes approved (yet to be operationalized)	No. of schemes under discussion	Remarks
1	Northern	14	10		Inclusive of ER-NR and WR-NR corridors
2	Eastern	5	1	1	Inclusive of ER-SR corridor
3	Western	19	0		Inclusive of WR-NR and WR-SR corridor
4	Southern	19	0	1	Inclusive ER-SR and WR-SR corridor
5	North Eastern	1			
	Total	58	11	2	71

A detailed list is enclosed at ***Annexure-XXIX***.

(2) POSOCO has furnished success rates of some of the inter-regional SPS deployed in India for the period 1st Jan 2014-30th Nov 2014 whereby there have been failures or unnecessary operations. A few concerns raised by POSOCO in this regard are enclosed as Annexure-***XXX.***

(3) POSOCO has expressed its concern over using SPS as a substitute for transmission (read N-1) would lead to insecure operating conditions. SPS would however be required for contingencies N-2 and above which are not factored in planning horizon due to low probability of such incidents but can have a high impact on the power system. Also, in view of the large number of instances of no response or inadequate response, POSOCO has expressed concern in its operational feedback to CEA and CTU as well as to the NRCE.

(4) The Sub-Committee is of the view that SPS planned needs to be installed within 3 months and the same be considered by POSOCO in calculation of ATC as deemed appropriate.

3.2.2 Dynamic Line Rating**:**

(1) CEA suggested that dynamic line rating may be used to enhance loadability of lines. Dynamic line rating enable system operator to determine capacity and apply line ratings in real time, based on actual operating conditions. In many power systems, static ratings are adjusted to account for significant differences in maximum ambient temperature. Line ratings may be adjusted daily, hourly, or even more frequently to reflect the maximum ambient temperature predicted during a particular period of time. The method of periodically adjusting a line's rating based on ambient air temperature is called ambient-adjusted rating. The impact of ambient temperature on line capacity is as detailed below:

NRCE has advised POSOCO to use ambient adjusted thermal rating to calculate the TTC & ATC.

Operating Conditions	Change in conditions	Impact on capacity
Ambient temperature	2 ^{0}C decrease	+ 2%
	10 ^{0}C decrease	+ 11%
Solar radiation	Cloud shadowing	+/- few percent
	Total eclipse	+ 18%
Wind	3 ft./S increase, 45^0 angle	+ 35%
	3 ft./S increase, 90^0 angle	+ 44%

(2) It was agreed that necessary action would be taken by POSOCO at the earliest as per advice of NRCE.

3.2.3 Use of Phase Shifting Transformer:

Prof. Soman of IIT Mumbai submitted that phase shifting transformers may be used to improve power flow. He mentioned that a study was conducted for Tata Power 2 X315 MVA 1:1 phase shifting transformers

on the 220 kV -MSETCL Tata Power line at Trombay. Mumbai transmission corridor is congested and there is reverse power flow from Mumbai to MSETCL. It was seen that import ability could be improved from 1800 MW to 3000 MW with angle of 12 degrees with phase shifting transformers. During 3rd meeting of the sub-committee, POWERGRID was asked to submit corridor-wise details of phase shifting transformers (PSTs) installed/ planned to be installed. POWERGRID subsequently communicated that it had proposed a Phase shifting Transformer on Sholapur-Raichur line for increasing the loadability of the line. The scheme was discussed in the 37th SCM held on 31st July 2014. However the same was not approved. POWERGRID proposed that a comprehensive study could be carried out jointly by CEA, POWERGRID and NLDC for siting and sizing of PSTs. CTU stated that use of Phase Shifting Transformer gets limited once generation comes up in the area. Prof. Soman indicated that as studies conducted by them for Mumbai revealed that Phase Shifting Transformer may be effective in enhancing ATC but if grid topology changes over a period of time and its effectiveness comes down, the transformer can be used as contingency measure.

3.2.4 Prof. Soman also suggested that St. Clair curve should not be used by operators since they are too conservative. Operators should use Dynamic Security Assessment (DSA) tool. POSOCO confirmed that after revision of the Transmission Planning Criteria in Jan 2013 and the revised procedure by CERC on TTC/ATC determination, POSOCO is no longer using the St Clair curve for filling the branch limits. Thermal limits are used as also verified by NRCE. Only seasonal ratings are yet to be applied and POSOCO has sought certain clarifications from NRCE.NRCE confirmed the clarifications sought by POSOCO during the fourth meeting held on 29.1.2015. POSOCO also stated that effective use of DSA necessitates a good quality State Estimator (SE) output from the Energy Management System (EMS) at NLDC/RLDCs/SLDCs. A high quality real time data in respect of digital status and analog values

becomes extremely important in this connection. RLDCs/NLDC have been making a lot of efforts in this respect and the difficulties have already been placed before the Honourable Commission in different petitions by RLDCs. Till a high level of confidence is gained in the SE output, effective use of DSA would be difficult.

3.2.5 Prof. Srivastava of IIT Kanpur suggested use of controllable devices like FACTS controller.

3.2.6 POSOCO suggested use of Damping controllers on HVDC/TCSC as well as PSS tuning to control oscillations. POWERGRID informed that it has six Thyristor Controlled Series Compensation (TCSC) devices and a Static VAR Compensator (SVC), FACTS devices, which provide damping features. Damping control features are also provided on all HVDC bipole and back to back links of POWERGRID. Further 16 nos. of SVC/STATCOM have been identified and procured which would provide both damping and voltage support. The list of STATCOMs/SVCs planned is attached at ***Annexure-XXXI***.

3.2.7 Congestion may be reduced by expediting commissioning of various intra-state transmission systems (***Annexure-XX***) and generating units (***Annexure-XXI***).

4. Reasons for large gap between transmission capacity vis a vis transfer capability

4.1 Reasons for variations between Transmission Capacity and TTC/ATC, according to POWERGRID, are as under:

a. The links are planned from future perspective of power transfer so initially system may not be capable to load it to full capacity

b. Mis-match between the commensurate development of Generation capacities and State's network; ideally "Transmission" should lead Generation and Load.

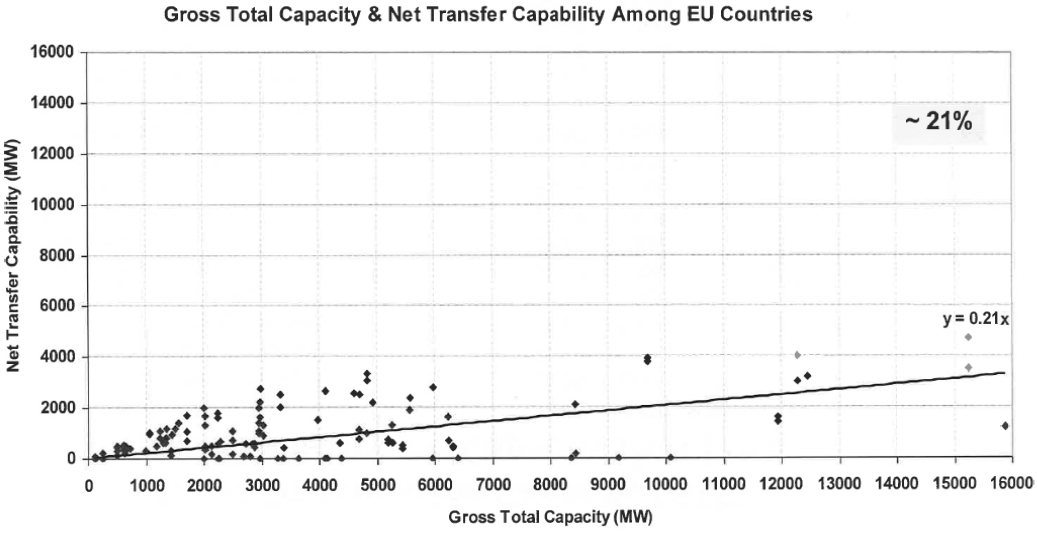
c. Lack of continual voltage correction devices that need to be essentially placed at State's network.

d. Capability progressively approaches Capacity with fulfilment of assumptions regarding Demand, Generation and Transmission Additions.

4.2 International experience in regard to transmission capacity vis a vis transfer capability.

POSOCO mentioned that loading of transmission lines decreases with increase in quantum of power to be transferred. Even in advanced countries, the loading is of the order of 21%. A sample graph for European Union Countries is shown below.

NTC Vs GTC Among EU Countries
For Corridors Up to 16000 MW



A list containing loading of lines in various countries is attached at ***Annexure-IV***. POSOCO also submitted similar computations for each state control area's import with respect to the transmission capacity connected to the state in its presentation during second meeting of the Sub-Committee held on 18.9.2014. A copy of the same is placed at ***Annexure-XIV.***

5. Measures to improve visibility of the information system to facilitate stakeholders

5.1 North American, Open Access Same-Time Information System (OASIS) provides information by electronic means about Available Transfer Capability for point-to-point service and a process for requesting transmission service on a non-discriminatory basis. OASIS enables transmission providers and transmission customers to communicate requests and responses to buy and sell available transmission capacity offered under the Open Access Transmission Tariff. PJM recalculates ATC once per hour for all valid paths posted on the PJM OASIS:

- Hourly (hours 1 to 168)
- Daily (days 1 to 35)
- Weekly (weeks 1 to 5)
- Monthly (months 1 to 18)

5.2 Development of similar information system for Indian System will facilitate efficiency in utilisation of ATC.

5.3 POSOCO has provided following details in Indian context with respect to information system:

5.3.1 Ever since the implementation of open access in the Inter State Transmission System (ISTS) in May 2004, RLDCs/NLDC has been posting relevant information on the website such as:

a. TTC/ATC on different inter-regional corridors and select zones facing congestion on a 3-month ahead basis which is updated on monthly basis as well as during the month. There were 237 TTC postings in 2013-14 and 155 in the first half of 2014-15 which indicates the dynamic nature of the network and its impact on transfer capability.

b. List of open access approvals granted by nodal RLDC

c. List of open access refusals by RLDCs and reasons thereof

d. Approved transactions scheduled on daily basis

e. Real time curtailments
f. Congestion Monitoring Page

Within a short span of time, the entire process has been made electronic so that the need for physical acceptance of applications does not arise. The whole process is such that there is no information asymmetry.

5.3.2 Further refinement of the process and extending it to intra hourly basis would necessitate the following:

(1) Appreciation of TTC/ATC in all time horizons starting from long term and extending to medium term, short term, day ahead, intra-day and intra-hourly basis. Currently the same is confined only to short term transactions. Frequent congestion in short term access implies that the same should be foreseen in the long term/medium term which is possible only if TTC/ATC computations are done in this time horizon.

(2) Another issue is the role of State Load Despatch Centres (SLDCs) in working out the TTC/ATC for their respective control areas as specified in the procedure approved by the CERC in June 2010 under the CERC Congestion Regulations. There are numerous intra state constraints which are rarely highlighted as there are no TTC/ATC postings by SLDCs. This gives an impression that constraints exist only in the Inter-State Transmission System (ISTS). There are many intra state generators which have been commissioned without the requisite intra-state transmission system; however as any restriction on such generation impacts the DISCOM of the state adversely, SLDCs remain passive rather than playing an active role and taking care of system security. This has potential to seriously endanger the network security.

(3) Establishment of intra-day market: Currently only Day Ahead Market (DAM) through power Exchanges exist. Despite the concept paper on having an Evening Market floated by the Commission staff, there has been a lukewarm response from the Power Exchanges.

(4) Perpetual reservation of corridor for long term customers even if they don't intend using the corridor. This had been raised by POSOCO in the CAC sub-committee meetings. 'Use it or lose it' policy would help else, the intra hourly TTC/ATC would be meaningless if the corridor has to be kept reserved for such long term customers throughout the day.

(5) High quality of real time data at control centres: Any computation of TTC/ATC closer to real time would necessitate using the snapshots of the system from the real time data and performing simulations using the same. This pre-supposes perfect network topology and good quality of measurands. Efforts are being made in this direction and the Honourable Commission is also seized of this problem. However it remains a challenge with fast expansion of the transmission system.

5.3.3 Based on CERC's directions, CEA has already constituted NRCE having a broad based representation of stakeholders which would inter alia examine the TTC/ATC computations etc. The NRCE could dwell further on this issue.

5.3.4 The Indian power sector is in a high growth phase as far as transmission expansion is concerned and the process involves a number of transmission system outages to facilitate construction. A few of such outages lead to reduction in TTC as stated above. However the overall impact of the same on reliability needs to be appreciated as the entire process of TTC assessment is based on (N-1) criteria and considering only those outages impacting TTC.

5.3.5 Apart from transmission system outages, communication improvement schemes through laying of optical fibre on many transmission lines is also undertaken. POWERGRID currently has a program of installing nearly 12500 km of fibre optic cable with a monthly target in the range of 350-400 km. This process necessitates taking the single pole auto-reclosure out of service. On an average 5-10 lines per day have their

single pole to ground auto-reclosure scheme kept off on this account having an impact on the overall reliability.

5.3.6 A related aspect is the number of transmission lines kept off to control high voltage. Details of these are given in the quarterly operational feedback report given by NLDC and available on its website. On an average 30-40 transmission lines are kept off which would have an impact in case of larger contingencies than (N-1). This aspect is not factored in the TTC/ATC assessment.

5.3.7 Protection related surprises have led to multiple element outages causing a Grid Disturbance (GD) or Grid Incidence (GI) as per CEA Grid Standards as per details tabulated below. This works out to 210 such instances in approximately nine (9) months or 23 incidents a month which is abnormally high. A brief description of each incident is placed at ***Annexure-XXXII***.

Log of Grid Incidences for the 2014-15 (up to Nov 2014)							
Region	Category as per CEA Grid Standards						
	GD-I	GD-II	GD-III	GD-IV	GD-V	GI-I	GI-II
NR	52					1	6
WR	17					10	11
SR	9						8
ER	47					3	6
NER	31	4	3		1	1	
All India	156	4	3	0	1	15	31

Against all the above uncertainties, the TTC/ATC determination is on a purely deterministic basis considering all elements in service.

5.3.8 The Sub-Committee opined that risks on account of all the above factors need to be quantified and incorporated in the simulations through probabilistic models. This is important in the context of the overall discussion on enhancement of TTC/ATC through Dynamic Line Rating and the assessment of TRM.

5.4 The Sub-Committee was of the view that transparency of data to stakeholders would not only help the utilities to plan their operation but would also avoid disputes and litigations. POSOCO being the apex organisation in regard to system operation & market operation in the country would take steps to make the information governing market operation as transparent as possible.

6. Audit Check on working of systems

6.1 It was suggested by the Sub-Committee that a mechanism like an audit to check working of the requisite systems as per requirements may be institutionalised. POSOCO has submitted that NERC follows reliability standards under the following areas.

S. No.	Area	No of standards
1	Resource and Demand Balancing (BAL)	14
2	Critical Infrastructure Protection (CIP)	22
3	Communications (COM)	6
4	Emergency Preparedness and Operations (EOP)	8
5	Facilities Design, Connections, and Maintenance (FAC)	11
6	Interchange scheduling and coordination (INT)	13
7	Interconnection Reliability Operations and Coordination (IRO)	19
8	Modelling, Data, and Analysis (MOD)	28
9	Nuclear (NUC)	2
10	Personnel Performance, Training, and Qualifications (PER)	5
11	Protection and Control (PRC)	32
12	Transmission Operations (TOP)	13
13	Transmission Planning (TPL)	5
14	Voltage and Reactive (VAR)	6
	Total	**184**

Details at ***Annexure-XXXIII.***

6.2 POSOCO further suggested that there are heavy penalties for non-compliance of reliability standards by FERC. A list of penalties imposed by FERC is detailed below:

Violation Severity Level								
Violation risk factor	Lower		Moderate		High	Severe		
	Range Limit		Range Limit		Range Limit	Range Limit		
	Low	High	Low	High	Low	High	Low	High
Lower	$1,000	$3,000	$2,000	$7,500	$3,000	$15,000	$5,000	$25,000
Medium	$2,000	$30,000	$4,000	$100,000	$6,000	$200,000	$10,000	$335,000
High	$4,000	$125,000	$8,000	$300,000	$12,000	$625,000	$20,000	$1,000,000

6.3 POSOCO also submitted a list of orders for non compliance of standards. Details are attached at ***Annexure-XXXIV***. POSOCO suggested that heavy penalties need to be imposed for non compliance of CERC Regulations. While the need for introducing Reliability Standards is recognised, framing of Standards relating to Communication system and protection system need immediate attention as it has maximum impact on reliable operation of the power system.

6.4 The communication system needs to cover speech, data as well as System Protection Schemes (SPS). COM series Reliability Standards of NERC could be examined further in this regard.

6.5 Protective systems need to be tested so that unintended operation due to 'rogue' relay settings are avoided as this is a time bomb that is ticking somewhere throughout the system and manifests itself only during a grid disturbance (often the triggering cause). The PRC series of thirty two (32) Reliability Standards could be examined further in this regard.

6.6 The Resource and Demand Balancing (BAL) series of fourteen (14) standards covering the responsibility of control areas or balancing areas is also extremely relevant for a large grid like ours.

6.7 In addition, balancing and frequency control standards, automatic generation control standards, as well as standards for calculation of

Available Transfer Capability are also equally important and should be brought out. NRCE was of the view that it could bring out these Standards, subject to approval of the Scheme of NRCE and capacity building through interaction with International Standard making bodies on regular basis. Sub-committee recognised the need for capacity building of NRCE in order to facilitate formulating of standards.

6.8 Sub-committee noted that the need for proper monitoring and strict compliance of existing regulations. The Sub-Committee opined that Protection Sub-committee of RPC should bring out a protocol for checking the settings, ensuring healthiness of existing protection system and periodicity of carrying out this exercise.

7. Other Issues

7.1 Generation from Renewable Energy Sources

7.1.1 The transmission planning for renewables needs to be done keeping in view the fact that solar power will come quickly and building transmission will take some time. Transmission Planning for wind and solar plants should be based on probabilistic estimate based on past experience. Besides this operational strategies are required for expected contingencies. CTU has already planned Green Corridors ahead of generation. CEA has also setup a Task Force in this regard.

7.1.2 Generation from Renewable energy source (RES) is variable, intermittent as well as unpredictable. Therefore while planning the transmission network for interconnection of large scale renewable generation RES needs to be embedded into with the system not only through strong grid interconnection but also integrated through other control measures.

7.1.3 This calls for planning of flexibility in all segments of Power system i.e. generation, transmission as well as distribution. Flexibility in generation can be introduced through fast-ramping generation like Gas, Hydro, Pumped Storage Hydro and other Energy Storage system. Transmission flexibility can be inculcated through Hybrid transmission system i.e. combination of HVDC & AC, controllability of power flow, provision of dynamic reactive compensation etc. Planning of flexible distribution can be through Smart Grid applications including Demand side management (DSM)/demand response (DR) etc. Further, State-of-the-Art forecasting of renewable generation, real time monitoring etc. are also necessitated. Transmission planning for RES integration should also cover enlargement of balancing areas through strong grid interconnections.

7.2 Development of Transmission System

7.2.1 North Eastern States have huge Hydro potential. It would be wrong to assume that all projects will be developed in the same time frame. It

would also be a wrong strategy to develop transmission systems adequate enough only for the projects already under implementation. Long term planning would require development of transmission systems in a manner that they are normally underutilized in the initial years but later utilized well. Here again commercial organizations would need to be financially supported through instruments like Viability Gap Funding/ PSDF.

7.2.2 All such transmission Lines which are 765 kV and above and are expected to carry larger loads, particularly located in high wind and cyclone zones must be given adequate attention from design point of view with a view to completely obviating their possibility of their collapse. In the rare instance of such happening the planning considerations should also cover remedial backup.

8. Conclusions and Recommendations

8.1 Reasons for congestion

8.1.1 Congestion has become prominent now due to advent of merchant power plants and evolution of electricity market where each buyer seeks to buy the least expensive electricity available and seller is ready to sell at competitive rates to the buyer. (Para 2.3)

8.1.2 The Congestion is/was prominent in specific zones as detailed in para. 2.3. Various reasons for Congestion have been detailed as inadequacy of matching intra-state network, delay in commissioning of generating stations and delay in commissioning of inter-state lines.(Para 2.3)

8.2 Transmission Capacity vis a vis Transfer Capability

Sum of transmission capacities of individual lines does not give Transfer Capability, which is a measure of the system capability. In a power system where power flow depends on least resistance path, voltage profile and reactive power compensation available, Transfer Capability continues to remain dynamic and will keep on changing depending on load-generation scenario. As the system becomes larger and larger and there are loop flows in the system, Transfer Capability decreases. It is not correct to compare Transfer Capability with sum of total the transmission capacities of individual lines since transmission capacity of individual line is applicable as a stand-alone line and not as a part of system where it is affected by various aforementioned factors. Even in advanced Countries Transfer Capability is of the order of 21% of transmission capacity. The inter-regional transmission capacity should therefore no longer be a yardstick of inter-regional transfer capability as it does not have relevance in a highly meshed system connecting the regional grids. (Para 4.2)

8.3 Computation of TTC/ATC

8.3.1 TTC/ATC is being calculated by CTU as detailed at para 2.2 herein earlier. TTC/ATC is also calculated by POSOCO as detailed at ***Annexure-XXVII***. Although both the agencies have been calculating TTC/ATC in accordance with prevailing Regulations, in order to have transparency in TTC/ATC calculation, CERC vide Order dated 11.12.2013 in petition no 188/SM/2012 directed CEA to constitute a NRCE with participation from CTU, CEA, RPCs/ State Representatives and IITs which shall approve computation of TTC for the month and further revisions shall be done by POSOCO. NRCE has already been constituted by CEA vide its Order dated 21.2.2014. It has been discussing on various aspects of TTC/ATC calculations. Minutes of four meetings of NRCE are enclosed at ***Annexure XXXV.*** (Para 3.1.5)

8.3.2 It is noted that POWERGRID, on the advice of MOP dated 15.7 2014, is in the process of engaging international consultant who shall calculate TTC/ATC for the entire Country (State-wise) – existing & required up to 2016-17 and suggestions for addressing the gap. The Consultant shall also provide methodology for optimum calculation of TTC/ATC. (Para 8.3.2)

8.3.3 It was also noted that POSOCO is also taking advice of a group of eminent Professors viz Professor Anjan Bose (Washington State University), Professor A. K. Sinha (IIT-Kharagpur), Professor S. A. Khaparde (IIT-Bombay) in regard to computation of TTC/ATC. CEA is proposing to hire consultants to do the system studies and verify TTC/ATC on monthly basis.

8.3.4 It is expected that the methodology for computation of TTC/ATC and its validation will be suitably addressed in the light of aforementioned efforts.

8.4 Way forward

8.4.1 To mitigate transmission congestion due to inadequacy of state network and delay in commissioning of generating unit

The gap between TC (Transmission Capacity) & ATC attributable to States should be found and needs to be communicated to them through appropriate discussions with States. The gestation period of transmission being generally shorter than generation, transmission planning needs to be sensitive to dynamic conditions unfolding in regard to generation. A mechanism should be institutionalised, (may be) by involving consultants to provide first hand information in regard to status of implementation of generation and transmission projects in the States. This would provide realistic data about gaps in execution so that one could navigate and re-plan. CTU should constitute a group for this purpose and conduct meetings every 6 months to monitor gaps in execution and replan accordingly (Para 2.3)

8.4.2 Improvements in long term (Para 2.4)

(1) Probabilistic Load forecasting/ Mixed Integer based linear programming (MILP) based optimisation tool may be used for planning. NRCE may look into suitable timeframe for including probabilistic load forecasting.

(2) All possible measures to enhance transfer capability such as converting single circuit line to double circuit, upgrading 220 kV system to 400 kV, strengthening of existing towers, re-conductoring, and Loop in-Loop out of existing lines be studied by CTU. CTU and POSOCO to create a Task Force to identify exhaustively all possible areas of transmission capacity enhancement in the existing systems within 6 months of issue of the report. This exercise should cover not only the Central transmission systems, but also the State level transmission and sub-transmission systems.

(3) Sample audit of relays/protection system to be undertaken by CTU for States within 1 year and heavy fine should be imposed for non-

adherence to standards. Unallocated power may be suspended in such cases.

(4) CERC to put a mechanism within 1 month to monitor critical lines on a quarterly basis so that the short and medium term constraints are mitigated.

(5) CTU, POSOCO and CEA, to provide regular guidance to the State Utilities and authorities, and more importantly there needs to be a mechanism to monitor to ensure that the matching systems at State level are in place to coincide with the overall requirement. This is equally true for provisions related to SPS and dynamic control mechanism including SVCs, STATCOMs etc.

(6) Fluctuating load/generation in renewable and its impact on transmission planning needs to be taken care. There is a need to identify balancing capacity to manage the fluctuations.

(7) Forest clearance being major impediment in timely development of transmission systems, MoP may be approached to take up the matter with concerned State Governments either individually or in Power Ministers' conference so as to facilitate development of much needed transmission system. (Para 2.4.10)

8.4.3 TTC/ATC may be improved in near-term by resorting to the following:

(1) Installing phase shifting transformers based on a comprehensive study to be carried out to identify the feasible locations wherein Phase shifting Transformer can be installed, looking into the future perspective and power system development. A joint study be carried out by CTU, CEA and NLDC for the same (Para 3.2.3).

(2) CTU/STUs to use controlling devices such as FACTS controllers and damping controllers (Para 3.2.6).

(3) Expeditious installation of Dynamic reactive power compensation devices such as SVCs, STATCOMs already planned by CTU (twenty two 22 nos.) (Para 3.2.6).

(4) Use of dynamic line rating within 1 month, after taking a confirmation from the equipment owner regarding the facility ratings (Para 3.2.2).

(5) POSOCO to take steps to develop Interpreter as a suitable interface between SCADA and PSSE to enable revision of TTC in real-time and declaration of TTC/ATC on hourly/ weekly/monthly basis as done by PJM.(Para 3.1.9.a)

8.4.4 Information dissemination to facilitate stakeholders

(1) Keeping in view the necessity for transparency in declaration of TTC/ATC in planning horizon, the results of long term studies carried out by CTU should be made available on their website. (Para 2.2.3)

(2) POSOCO being the apex organisation in regard to system operation & market operation in the country, would take steps to make the information governing market operation as transparent as possible. (Para 5.4)

(3) TTC/ATC to be declared by STUs for state network in planning horizon as well as operating horizon.

(4) There is a need for developing a common electronic platform with access to all market participants. Necessary protocols for information sharing and dissemination needs to be finalized by POSOCO in consultation with stakeholders.

8.4.5 Operational feedback by SLDCs to STUs be made mandatory through appropriate Regulations.

8.4.6 Reliability standards need to be planned for Indian Power System. To start with, NRCE may bring out Standards for "Protection System" and "Communication System"(Para 7).