

Extracts from email by Sh. Mata Prasad to POSOCO

Email dated 5.8.2014

1. In view of the fact that TTC between New Grid and Southern Region has increased to 2000 MW since 1st August 2014 due to expected commissioning of 800 kV Sholapur-Kolhapur lines, the additional ATC was declared as 1250 MW. Out of this TTC of 2000 MW, a chunk of 750 MW has been kept as Transmission Reliability Margin on Sholapur -Kolhapur 800 kV 2*SC lines resulting into ATC of 1250 MW being made available. Finally the quantum of LTA was computed by PGCIL as only 308 MW after taking into account due to vacation of power by Corporate Power Ltd.
2. Surprisingly it was seen that quite number of figures of quantum of power as TTC, ATC and LTA have been indicated on various Drawings, tables and Exhibits with various assumptions of late commissioning of 800 kV Transmission lines in the respective power corridors and this has compounded the confusion. I had expected that the studies done by PGCIL should have also worked out the credible cases on the system stability of both types that is Angular and Oscillating State Stability covering monotonic state as well
3. The main issues of Transmission Margin and ATC were required for resolution.
4. In this regard I had indicated my views in the above meeting which are being elaborated in step-by step mode for clear understanding by all concerned as under:
 - o The Thermal Rating of the 800 kV single circuit line is around 4500 MW and that is the limit governed by maximum possible conductor temperature and should be kept at least with a compromised figure of 3000 MW with adequate voltage support and other means.
 - o The load flow studies and line outage studies have been done but no document for stability tests on faults with various scenario of critical line outages have been presented. It is presumed that these studies have not been done. I suggest

that besides base case stability studies, some credible fault studies for stability indices should be done

- It is to be noted that the Transmission Assets created through investment in the 800 kV Lines has been executed with maximum available loadability limits of 4500 MW with SIL of 2250 MW and consequently all possible actions are required to be taken by power utilities in optimizing the maximum use of its loadability limits by properly extending these limits to ensure fair action plans on tariff structures. With adequate Reactive Power Support and Management at every level it would be possible to effectively wheel the power down from Generation to Distribution via Transmission. However it appears to be a Herculean task
- The Surge Impedance Loading as indicated above for uncompensated lines is calculated as 2250 MW. At this loading the line experiences a power flow at unity power factor
- The charging MVA of 800 kV line is quite large at 2.25 MVA per KM, it produces very high steady state overvoltages going beyond specified limits of +/- 5% due to Ferranti Effect on energisation or on line switching and this has to be controlled or contained
- The normal practice is therefore to compensate such lines with shunt reactors directly connected (called Un-switched Compensation) on the 800 kV lines to compensate 50-60 % of the charging MVA produced by the lines
- However the bad effect of such reactive compensation is that it reduces the SIL of the line by 30 to 40 %. resulting into modified SIL with such compensation, as 1575 MW and 1350 MW respectively.
- This will mean that if the loading on the compensated line is increased beyond 1350 MW, say theoretically to the level of original SIL Limits of 2250 MW, the system will need extra capacitive vars of the order of at least 800 MVAR approximately to be provided in the system
- If such compensations are not provided, the system will experience voltage drop and could lead to voltage collapse and security of the system will be jeopardized.

- The world practice is normally to provide shunt inductive compensation at the planning stage to the tune of 120 % of the total summated Vars generated by the lines and such reactive compensation distributed normally as 50% on the line as unswitched and 30-40% switched on the busbars and the rest on tertiary terminals of ICTs
- As we see, the two 800 kV circuit lines under reference are 284 KM long each and provided with 240 MVAR Shunt Reactors with breaker controlled Compensation on each line.
- This gives a degree of compensation of 75% (if this figure is correct) considered to be extremely high degree and may give rise to creation of "poles" at the receiving end leading to uncontrolled voltage rise.
- Thus this corridor between Sholapur and Kolhapur with a total 960 MVAR Shunt reactor provided will prohibit the usual power flow.
- It would be thus seen that 800 kV Lines have been *virtually* blocked to carry more power flow.
- The present dilemma of power flow can therefore be attributed the excessive inductive compensation and this must be corrected.
- It is to be pointed out that the circuit breakers provided to control the shunt reactors should be effectively used to maximize the power flow. There could be different control strategy to remove the breaker-switched shunt reactors from then lines
- With fully developed system at both ends with higher short circuit power at the Bus terminals, it is felt desirable to switch-off these shunt reactors after the lines have been charged. The Controlled Switching scheme assisted by suitably dimensioned Surge Arresters normally provided by PGCIL should take care of load rejection overvoltages. If needed the rejection overvotlages can be calculated through Network Studies.
- There were other means also to extend the loadability limits of 800 kV line back to SIL:

- Use Reactor-Transformer Scheme instead of conventional Shunt Reactors as have been used by Hydro Quebec at Laurentides Substation
 - Use Controlled Shunt Reactors (CSR) instead of conventional shunt reactor as PGCIL has more than 8 years experience of such reactor installed at Itarsi 400 kV Substation that was developed and tested by Dr. Alexandrov and manufactured in India by BHEL .
 - I do not know why PGCIL has shown lukewarm interest in using such CSR more in their network while MSETCL has already commissioned three such CSRs of rating between 50- 80 MVAR (ordered on BHEL) in their 400 kV systems If required these could be be imported.
 - Same is the case of using Quadrature Boosters that so effectively manages the control of power flow in paralleled 220 kV and 4 00 kV as also 800 kV and 400 kV running in parallel for control of congestion and reduction of line losses as well
 - Third alternative could be to adopt what FURNAS in Brazil has done for Itaipu Project where 800 kV lines with Unswitched Shunt Reactors have been supplemented by Series Compensation to augment the loadability of their 800 kV lines
- In view of above it may be taken that loadability of these two 800 kV single circuits Sholapur-Kolhapur could be at least 3000 MW instead of 4500 MW (twice the SIL) with good margin without any problem
 - This will take care of n-2 contingency of outage of 1000 MW Nuclear Unit at Kudamkulam, and also permit the generation Developers to get their shares of long or medium term access.
 - The other important point to note by PGCIL and CEA should not be satisfied by the addition 21 numbers Statcom sanctioned by CEA for dynamic compensation but to supplement the system by adding the Passive Compensation of required value to make Statcom really effective. Such Statcoms are normally working in and around Zero reactive

Var but are continuously active to support the network within a response time of 10 millisecond or less.

- It is felt that PGCIL and CEA should keep a close watch on the efficient use of these transmission assets employed in the system and take appropriate action in time to supplement and manage the Assets through up-rating and up-gradation of the network. This has been discussed extensively in all the international conference with positive action plan adopted by utilities in Americas and Europe.
 - The biggest problems affecting the mismatching of Generation and Transmission are due to delay in development and approval of generation projects in Hydro, Thermal and Nuclear. Power Plant and of late solar and wind energy mission network has to be planned ahead of commissioning of generation projects of Indian System Planning
5. In view of above, I am of the opinion that existing network with breaker-controlled 240 MVAR shunt reactors on 800 kV lines is quite strong and versatile enough to take care of designated contingency with enough margin required by the system and other developers .
 6. PGCIL should carry out such studies to find out any further constraints if any

Email dated 6.8.2014

I have never insisted that the lines should be or could loaded to their thermal or SIL Limits without any add-ons.

To take full advantage of the available line carrying capacity, the power utilities in Europe and Americas have taken appropriate bold measures to work out the revised loading conditions by continuous monitoring of conductor

temperatures and ambient conditions prevailing during the peak load conditions

I had tried to explain in the meeting about the unrestricted loading till the thermal limit that will need several associated action plans. As an operation philosophy even if you had provided SC or TCSC that increases the loadability but you can not always go to the maximum limit. The case in HVDC is slightly different as with proper proliferated controls and reactive power support from AC and DC filters as well as from the grid including generators, the loading can go to the full with overload capacity. This has been provided for, as has been done for NER-A UHVDC system where rated capacity of 6000 MW but with 33% continuous overload the system operator can go to the level of load of 8000 MW over this UHVDC system. This provision of 33% overload was specific for NER-A project while the CK UHVDC project has only 10 % overload rating.

It has to be noted that if the lines are provided with breaker switched Shunt reactors normally connected on permanent basis and to be removed only under specific conditions, then the loadability of lines will be governed by modified SIL compounded with liberal reactive power support. That means the 800 kV line with 50% compensation will have modified SIL as 1575 MW, with 60% compensation this will be 1423 MW and with 70% compensation this will further reduce to 1237 MW. It is quite normal that if you wish to increase the loading beyond the above modified SIL limits then you have to add quite a good amount of reactive power in the system to achieve the desired power flow over the said line. Further to enable the above one should be prepared with integrated controls controlling action for inter-tripping etc.

Although **POWERGRID** had indicated the provision of 240 MVAR Shunt Reactors on the Sholapur-Kolhapur (? or some other destinations) 284 KM (please check whether this line is Sholapur-Kolhanpur (?) or some other destinations and the length is 284 KM. However I am not sure whether these reactors are at both ends of 284 KM lines. If line length is 284 KM and shunt reactors are provided at both end then the degree of compensation may cross 75% that is too high. If the shunt reactors are provided at only one end then the degree of compensation reduces to dangerously low figure of 37%. This may kindly be rechecked as my comments are related to 800 kV lines with 240 MVAR Shunt Reactors

I request you to kindly go into the system details from HQ, AEP and ESKOM and Furnas about the role of breakers switched shunt reactors on the line and their operability. The picture becomes better and better with increasing short circuit power at sending/receiving ends.

You had mentioned about the line protection deficiency on Series compensated line. It is well known that the line protection on such lines has to be either replaced or modified to suit the TCSC/SC to take care of by-passing of series capacitors and reinsertion. You will be surprised to know that ABB distance protection provided on 800 kV or 400 kV lines does not meet the above requirements and even ABB had advised to replace their protection by SIEMENS or other protection from Basler or SEL. I am not aware whether this has been done

I personally feel that once you have entered into such fascinating levels of EHV, UHV AC upto 1200 kV and UHVDC system upto +/- 8000 kV and 6000 MW rating and have also embarked upon the All-India-Synchronous Grid covering all the five regions PGCIL and POSOCO you must be fully armed with all the controls that you have been talking all through. If that is not done the system operation will remain sub-optimal and will be suffering from congestion and outages. That will also mean the whatever we have invested in such gigantic projects will not be fully realized and will leave the system with ROW Constraints as chronic ills .

Email dated 7.8.2014

"These two circuits have been provided with 240 MVAR Breaker-Switched Shunt Reactors at each end of the lines. Earlier I had mistaken the inter-connectors as of 284 KM lines.

Now I have to submit as under:

1. Breaker-switched shunt reactors provided on the 800 kV lines will facilitate better power flow than with unswitched ones
2. The sequence of operation of these lines, in my opinion, should be as under:
 - o The circuit wise energization of the 800 kV lines will normally done from 800 kV Raichur Substation

- The breaker controlling the 800 kV, 240 MVA shunt reactor at receiving end will be closed first. The 800 kV 240 MVAR breaker-switched Shunt reactor at Raichur substation will remain off. This will ensure a degree of reactive shunt compensation as only 52 %.
 - Thereafter the 800 kV Breaker controlling 800 kV line at Raichur will be closed followed by closing of receiving end breaker to be synchronized or switched on and after this action the power flow would start
 - Closing both the breaker-switched shunt reactors and keeping them closed in service
 - will increase the degree of compensation for 204 KM line to about 105% and this level of compensation is far above the a maximum of 70 % normally employed. This high level of compensation would prohibit any 1100 MW as assumed by PGCIL
3. With TRM of 750 MW as fixed by you the permissible power flow would now be around 800 MW per circuit on these line with one circuit out and largest nuclear unit tripped requiring power flow from Raichur to down South and will ensure appropriate power flow demand by the developers in the region area.
4. In case you need any further clarification we may discuss the same at appropriate time

I may repeat that consideration of switched and unswitched inductive reactive power compensation will need optimization of load flow and fault studies

For small length 204 KM of 800 kV line, the reactors on the line at only one end seems better than at both ends. The provision of bus reactor would have been better. The provision of 33 kV shunt reactors at tertiary level should be considered by PGCIL as per international practice to control the voltage profile.

Email dated 11.8.2014

I had indicated the Transmission system has large amount of investments for maximum loadability of Thermal to SIL ratios as 1.6 to 2 for 400 kV lines and 2-2.2 800 kV lines. You may be surprised to know that ratio of SIL and per unit impedance of the line is virtually constant and lies between 900-1000 irrespective of line voltage from 220 kV to 1200 kV

I had never advocated that one should go to thermal limits but we must know what are the limits and in what way these are affected. Depending upon the climatic conditions all the capability has been stretched by all leading utilities in the world and since 2000 this topic has been a great forum for discussions in CIGRE and IEEE . In ENEL Italy, EdF and National Grid UK ,the maximum loadability has been adopted as 1500 to 1700 MW by several means of conductor monitoring, and effective dynamic supports as also sometimes replacing the conductors as well.

In India the summer thermal rating is say 800 MW in worst climatic conditions but it could be run at 1200 MW under the winter season when the temperature is around 10-15 degree Celsius. However at this loading the utility has to provide special reactive power supports. This aspect has been extensively discussed in all the international fora and efforts are in force to effective utilization of ASSETS. My efforts have been centered around this aspect.

My efforts through my carrier and till date to be aware of the latest techniques in the power system engineering.

I have also appreciated the view of MrDevenderChoudhary AS when he suggested to involve some foreign consultants to optimize our software, modelling and studies based on latest thinking on the subject of system planning and studies.

Email dated 9.8.2014

My point-wise views are given below:

1. The system planning takes into account the Load Generation Balance and related to expansion of Transmission Expansion to meet with Generation Growth **keeping in mind that there would be slippages and** that is the part of system planning criteria all over the world. It should be kept in view that transmission lines should not get fully loaded immediately after the commissioning. A growth period of 3 to 5 years is quite normal. The overall economics actions would take care of this while working out the feasibility studies.
2. Indian Power Network had been divided and operated successfully with five Electricity Regions. The All India Grid was established as soon all the four regions were connected asynchronously in mid-nineties with further supplementing of high capacity Bulk Power HVDC systems

in the North, East, West and South. Further interconnecting all the five Regional Grid in Synchronous mode must have been dictated by Grid Security and better operational flexibility.

3. The most disturbing aspect of such interconnections (intrastate or interstate or inter regional) is the presence of negative damping and upsurge of low frequency oscillations of in-plant mode or inter-area mode and more specially the inter-area mode of oscillation between 0.2 to 0.8 between 0.2 to 0.5 and from. You had yourself indicated the presence of inter area mode of oscillations that should be a cause of worry unless suitably damped. There would be more such pockets of inter are mode of oscillations in the other grids in the north-east and west-south corridors as well. Such low frequency oscillation may grow in amplitude and may create grid collapse and the result could be harmonic-resonance created problems and must be attended immediately through the tuning of POD of HVDC projects, Excitation System of Power Plants and by strong reinforcement of active filters at appropriate nodes
4. After the major grid collapse two years back CEA PGCIL realized the urgent need of installing as high as 22 STATCOM in the grid all over INDIA. Her I wish to remove a misplaced notion of optimizing the Passive and Dynamic Compensation of Reactive Power in the grid. What was required to first complete the deficit of passive reactive power in the grid commensurate with power factor of the load especially in T&D sector owned by SEB/States. It must be understood that dynamic compensation remains operational around Zero level and act only when demanded by system faults etc. As such the need of reactive power requirements must be met locally at 132 kV and below voltage levels that are not in the control of Central Sector like NTPC/PGCIL/NPC /NHPC etc. The gap in the requirement of passive reactive power is quite large and do not m appear anywhere in the operational records or system studies. The problems of Indian Grid can be easily resolved / handled through effective solutions of this reactive power. The basic distribution of reactive power supports provided by reactors and /or capacitors should have been optimizing by usefully utilizing the tertiary winding of all the ICTs
5. After creation of All India grid you had indicated that Stiffness Factor or Power Number defined as dP/df is around a very good figure of 5000 MW per Hz. This factor need be kept in view while deciding the power flow in the event of loss of a unit or even loss of a line/transformer. The

loss of a unit or loss of a line/transformer will deprive the system of 500-1000 MW and in this massive network this loss will be automatically adjusted by the grid lines associated with drop in system frequency by 0.2 Hz only.

6. The System Planner (CEA/PGCIL) and System Operators (POSOCO) of the Indian Grid will have to keep in view the strength of Indian Power Network and the inherent inertia and ability to handle such outages would definitely be able to withstand any such shocks or outages thereby removing the constraints or congestion
7. The Studies Report attached with the Agenda distributed by PGCIL pertains to "Import of Power to Southern Region through Sholapur-Raichur two single circuits at 800 kV lines- Brief Report". POWERGRID while presenting the case had indicated that SIL loading of 2250 MW will be reduced to around 1150 MW due to heavy compensation of 240 MVAR Reactors at both ends. I had pointed out that breaker controlled 240 MVAR shunt reactors will be utilized only during charging of these lines and afterwards will be switched out as the load flows. In that event the load ability of this line increases from 1150 to 1785 MW while with no reactors on the line the load flow will be full that is 2250 MW. This means the load ability of this line retains is 1785 MW per circuit as against 1150 MW per circuit limited by shunt reactors at both ends.
8. With this load flow pattern the power to southern region, in case of line outage or outage of largest unit there would not be any constraints to power flow to south in view of the fact that the grid is now all-India Synchronous Grid responding to such outages of 400 kV and 800 kV Line. As such there is no justification to imposing a load flow (ATC) to 308 MW
9. After this information you changed that the constraint is due to flow of power on ParliRaichur D/C line. The results of load flow and line outage studies indicate the flow level and voltage level at the busbars well within limit. The strength and inertia of the system will readjust to new level with readjustments of reactive power support and active power flow. With balanced voltage levels well above 360 kV I do not foresee any problem on this scenario.
10. It is rather surprising that the degree of constraints and level of congestion have been studied only by basic load flow followed by line outages without subject any fault studies as no such results such as frequency variation or swing curves and voltage profile as also criteria

has been indicated separately or along with this report. For the discussion being more meaningful it is essential that PGCIL should have created faults on critical and over-loaded lines with lower than normal voltage profile (380-420 kV) as has been the practice around the world before identifying and fixing the ATC for the developers who as a rule depend upon CTU to study the evacuation of power even for Developers

In view of the vastness of All-India Grid with massive interconnected nodes now under operation with more evacuations and Dynamic Reactive Power supports punctuated with passive compensation of required degree also under development it is strongly felt that keeping the restraints to 308 MW in the region appears to be unreasonable. With good voltage profile even after line outages, the system is practically normal within limits of 380-420 kV or even with 360 - 440 kV under controlled conditions. It is felt POSOCO, PGCIL and CEA should recognize the systems problems of low frequency oscillations in the network which may create partial or extensive blackouts in the future. .

I would suggest some practical action for the consideration of the Ministry of Power. There could be genuine insurmountable problems with the System Planners and Power Utilities in reducing and representing the power system in a scientific manner as practiced by the leading international utilities.

In this regard I would suggest the Power Ministry to create a Study Group supported by PGCIL and POSOCO Experts consisting of:

- Dr SN Singh/Dr SC Srivastava of IIT(K)
- Dr. K Parthasarathy/DrNagraj of PRDC Bangalore
- Dr Ram Adapa of EPRI USA
- Dr Adel Hammad Independent Consultant of Switzerland
- Dr. PrabhaKundur from Canada

The above experts are well known in their field and have been involved with Power Authorities in China and USA/Canada