Stability Analysis of Dedicated Green Energy Corridors and Enhancement of Renewable Energy Evacuation

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Abstract. This paper aims to analyze and investigate the influence of RES on 400kV transmission system in Tamil Nadu state which has the highest amount of Wind/Solar generation installed in India and huge addition of other RES, has been considered to study the impacts of increasing Renewable Energy Resources on proposed TN - Green Energy Corridors with regards to stability of the system and to suggest the improvements required to enhance the of the Corridor. Quantification of maximum power transferred from remote areas where renewable sources are predominant to Load centers through Green Energy Corridors also observed. Increasing Renewable Energy penetration in a power system means that RERs substitute the conventional power plants that traditionally control and stabilize the power system. Further, this project also covers the importance of Dedicated Transmission Corridors to facilitate large scale integration of renewable into the grid and identify the possibilities to evacuate the RES generation to the Load centres which ensures maximum RES usage and reduction in RES curtailment. Renewable Energy Management Centre (REMC) equipped with advanced Forecasting Tools, Smart Dispatching solutions & Real Time Monitoring of RE generation, can closely coordinate with the Grid Operations team for safe, secure and optimal operations of the overall grid.

Keywords: Green Energy, Power Grid, Renewable Energy

1. Introduction
As the worldwide use of Energy in utility scale applications continues to increase, it is important to assess the impact on the grid and conventional generation. The recent advances are with the
incorporation of Wind and Solar in to the Green Corridor to minimize the Carbon footing effect. This improves and maintains the environment in a safer mode. When large scale of RES sources mainly Wind/Solar, are being considered, they would be physically located where weather conditions are high enough to produce the amount of energy needed for reliable and profitable supply. With the integration of such distantly located Renewable Energy with utility's power grid, issues related to integration such as voltage stability, voltage control, transients, reactive power compensation, power quality assumes great importance.

India is a country of continental size and can integrate the entire targeted 175 GW of renewable energy into the national electricity grid based on projected power system plans and regulations according to a study conducted [1]. The report confirms the technical and economic viability of integrating 175 GW of renewable energy into India’s power grid by 2022, and identifies future course of actions that are favorable for such integration. Also, it was found that power system balancing with 100 GW of solar and 60 GW of wind is achievable at 15-minute operational timescales with minimal reduction in renewable energy output [2].

The corresponding intra-state and Inter-state transmission systems have already been planned, especially Green Energy Transmission corridors has been taken up for evacuating green energy from states such as Tamil Nadu, Gujarat, Rajasthan and Jammu & Kashmir. Further, a coordinated scheme for wind and solar forecasting stations, communication system and Renewable Energy Management Centres (REMC) are also planned to harvest maximum RES potential [3-5]. In this paper, a case study in respect of RES influence [6][7] on 400kV transmission system in Tamil Nadu state has been considered to study the impacts on EHV Grid operations.

2. Present Scenario in Tamilnadu

2.1 Installed Capacity

The total installed capacity in the state, (including own generating stations, IPPs and central allocation) is 24,433 MW. The share of thermal stations in the installed capacity stands at 51%. The State sources contribute to 31% of installed capacity (51% excluding RE Sources) as in Figure 1, whereas the private sector comprising of mostly RE sources contributes 39% of the installed capacity. The peak demand of the state is expected to increase from 14,533 MW in 2016 to 17,651 MW in 2019.

![Figure 1. Tamilnadu – Installed Generation Capacity](image)

2.2 Analysis of Renewable Sources

Presently the state has total RE based installed capacity of 9,687 MW which includes 1,155 MW of solar energy-based projects and 7,642 MW of wind-based capacity. The state has an estimated potential of 15,000 MW in Solar and 14,000 MW in wind [4]. As per projected estimate, 5,000 MW of RES including solar power of 3000MW and Wind Power of 2000MW is expected to be added
through RE Sources before 2019. As per projected estimate, 5,000 MW of RES including solar power of 3000MW and Wind Power of 2000MW is expected to be added through RE Sources before 2019.

The peak wind generation in a State occurs in a different season as compared to the months of peak requirement of the State. The variation of month-wise generation from wind and demand for Tamil Nadu is shown below in Figure 2.

![Figure 2. Projected month wise solar and wind generation](image)

The main wind season in Tamil Nadu is from June to September. During this season, wind contributes about 30-35% of the total energy consumption in Tamil Nadu. Tamil Nadu has four passes through which wind blows, viz., Palghat, Shencottah, Aralvoimozhi and Kambam. Wind generators fed from these passes are connected to pooling stations majorly at 110kV and 230kV levels through which power is injected into the grid.

### 2.3 TN - Green Energy Corridors

In Tamil Nadu, following schemes are under development as per 12th plan [2], in phase manner as part of its endeavor to create transmission infrastructure for evacuation of green power:

**Phase I**
- Establishment of Kanarpatti 400 KV SS
- Establishment of Kayathar 400 KV SS
- Allied Transmission Network

**Phase II**
- Establishment of 400 KV SS at Thappakundu.
- Establishment of 400 KV SS at Anikadavu
- Establishment of 400 KV SS at Rasipalayam
- Allied Transmission Network

In this research paper, a case study of Tamil Nadu state, which has the highest amount of wind power installed in India, has been presented to study the various impacts of increasing Renewable Energy Resources [8][9] on proposed 400kV TN - Green Energy Corridors with regards to stability of the system is analyzed with the use of ETAP software and explore the stability enhancement of the Corridors. The maximum levels of RES penetration [10][11] depends on the amount that can be integrated without causing problem to the stability [12][13] of the network. To increase the stability margin, excitation systems and dynamic compensation devices such as UPQC/STATCOM have been used.

### 3. Network Modelling

Simulation of Tamil Nadu 400kV Network [4] is considered and is simulated in the ETAP
software as described in figure 3. Current scenario of 400kV Grid has been considered for the study. The conventional generators of capacity 4200MW (Thermal/Nuclear Power: MTPS – 600MW, NCTPS – 1200MW, Vallur - 1500MW and Koodankulam – 900MW) connected in 400kV Substations are modeled as Synchronous machines and the Central power shares are presented as power sources at various 400kV Buses to match present Network power flow.

Each Wind/Solar farm with projected capacity of 3000 MW (Solar – 1000MW and Wind – 2000MW) is considered as power sources with fixed active/reactive power connected to the point of connection at 400kV Buses at RES richness Sub-stations. Originally, these Wind/Solar generators are integrated at different voltage levels 11 kV, 33 kV, 110kV and 230 kV in TN Grid. Loads of are taken as Lumped one and distributed at all the 400kV Buses to match with physical load demand.

Load flow studies and optimal dispatch studies have been carried out for the TN 400kV Network to analyze stability of the system and the network is tested for various contingencies such as outage of conventional and Wind/Solar generations and line outages.

Figure 3. ETAP Model of 400kV Tamilnadu grid
4 Power Flow Analysis

4.1. Case I
The power flow studies are modeled to match with present operating condition. In the operating scenario considered, VAR compensation of 2898 MVAR (2 X 64 MVAR at all 400kV Bus) has been added to ensure the bus voltages are within permissible limits. The total generation in the system for scenario studied at 400kV Network is of 6439MW out of which conventional generation is 5239 MW (MTPS – 584.20MW, NCTPS – 1200MW, Vallur - 1500MW and Koodankulam – 900MW plus Central share – 1054.81 MW) and RES generation is 1200MW (40 % of the Estimate injection) at various 400kV Buses as shown in Table 1.

Table 1. Thermal Units share for Case – I scenario

| ID          | Rating/Link | MW    | Amp | % Generation |
|-------------|-------------|-------|-----|--------------|
| MTPS GEN    | 600 MW      | 594.20| 587.3| 97.4         |
| NCTPS GEN1  | 1500 MW     | 500   | 982.2| 100          |
| NCTPS GEN2  | 1500 MW     | 500   | 982.2| 100          |
| VALLUR GEN1 | 1500 MW     | 500   | 981.8| 100          |
| VALLUR GEN2 | 1500 MW     | 500   | 981.8| 100          |

4.2. Case II
The output from RES generation which is limited to around 40% in the load flow scenario is further increased upto 80% by keeping the same Network configuration, to check the system stability with increased levels of RES penetration. It is observed that sensible reduction in conventional generation and is used only 4039 MW (MTPS – 464.152 MW, NCTPS – 720 MW (60%), Vallur – 900 MW (60%) and Koodankulam – 900MW with fixed Central share of 1054.81 MW) and the RES penetration is 2400MW (80 %) as seen in Table 2.

Table 2. Thermal Units share for Case – II scenario

| ID          | Rating/Link | MW    | Amp | % Generation |
|-------------|-------------|-------|-----|--------------|
| MTPS GEN    | 600 MW      | 494.15| 807.6| 77.4         |
| NCTPS GEN1  | 600 MW      | 360   | 577.4| 60           |
| NCTPS GEN2  | 600 MW      | 360   | 577.4| 60           |
| VALLUR GEN1 | 500 MW      | 300   | 491.1| 60           |
| VALLUR GEN2 | 500 MW      | 300   | 481.1| 60           |
| VALLUR GEN3 | 500 MW      | 300   | 481.1| 60           |

Table 3. Thermal Units share for Case – III scenario

| ID          | Rating/Link | MW    | Amp | % Generation |
|-------------|-------------|-------|-----|--------------|
| MTPS GEN    | 600 MW      | 494.15| 817.6| 67.4         |
| NCTPS GEN1  | 600 MW      | 240   | 304.9| 40           |
| NCTPS GEN2  | 600 MW      | 240   | 304.9| 40           |
| VALLUR GEN1 | 500 MW      | 200   | 320.8| 40           |
| VALLUR GEN2 | 500 MW      | 200   | 320.8| 40           |
| VALLUR GEN3 | 500 MW      | 200   | 320.8| 40           |
4.3. Case III
In this case output from RES generation increased to 3000 MW capacity, by keeping the same Network configuration with projected levels of RES injection into the Grid. It is clearly visible that major reduction in conventional generation utilized only 3439 MW (MTPS – 404.153MW, NCTPS – 480MW (40%), Vallur – 600 (40%) and Koodankulam – 900MW with fixed Central share of 1054.81 MW, due to the large-scale penetration of RES energy as seen in Table 3. Load flow analysis for all the three cases are successfully converged and the variations in power flow due to the influence of Large-scale integration of RES Sources in the 400kV Network is studied and performance of the dedicated Green Energy Corridors also observed as shown in Figure 4.

Figure 4. Thermal Units & RER Power Share Chart

Optimal Power Flow (OPF) analysis for the Tamilnadu 400kV Network was carried to study the power system load flow along with optimized system operating conditions and ensured system operating constraints such as bus voltage, Transmission power flow are not violated. The optimized system will reduce the operating cost, improve system overall performance, and increases its reliability and security. Also, as part of stability studies, loss of RES generations, outage of conventional Generators, Central power share and line outages are simulated and confirmed the network stability.

5 Conclusion
The result of the study has been helpful to optimize the Thermal generation levels of large thermal plants and support unit commitment decisions and ensures economical dispatch of Thermal Units with the aid of accurate forecasting techniques [14]. Also, quantifying the RES penetration levels in the EHV network and to strengthen the transmission network to evacuate the RES generation to the Load centers which ensures maximum RES usage and reduction in RES curtailment. Further, integration of large-scale Renewable Energy Resources has considerably altered [15] the power system performance and system operating conditions. Major impacts on System planning and operating conditions are as follows:

- Reduction in the cost of power system planning and operation.
- Reduction in fuel requirements for coal and gas and in CO2 emissions
- Reduction in generation levels of large thermal plants and helps in optimum unit commitment and economical dispatch.
- Apart from reduction in total energy cost saving, additional RES generation places stress on the transmission system with increase in time under congestion and changes in trading patterns.

To improve the operational flexibility and to manage the large-scale RES variability due to change
in weather conditions, the Network must be optimized with adequate spinning reserves from Hydel, Gas power plants, dynamic VAR compensators and Storage Elements of suitable capacity. As a future scope, the same Network can be simulated to analyze its capability of 'Transient stability' in order to improve the performance of Green Energy Corridors.

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