Power System Balancing Issues in India

Power balancing methods and solutions

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***Abstract* - There are seven Renewable Energy (RE) rich States in India. RE sources are targeted to grow massively by 2022, including a doubling of wind power capacity and an almost ten-fold increase in solar power from today. Renewable generation have intermittent nature and depend on weather condition. Hence, higher penetrations of RE require more flexibility in power system with predefine balancing mechanism. It is a high time to decide on the balancing mechanism in rapidly, straightforwardly and economically fashion. This paper describes feasible solution for balancing of power in view of high penetration of RE on Indian prospective.**

Keywords-component; power balancing methodologies, its utilization, issue, solution, way forward

INTRODUCTION

Integration of renewable energy in the grid has become one of the crucial challenges in Indian power scenario. Renewable generation is an eventual need in power sector to overcome future challenges such as limited availability of fossil fuels, carbon emissions & climate change, prevents damage to environment and ultimately Public health.

At bird's view, renewable generation directly influence conventional power plants and grid operation, which needs to be addressed by various balancing mechanism. However, in absence of proper balancing mechanism in India, it is very crucial to manage the grid with high penetration of RE. Hence, it is urgent need to contemplate about the balancing mechanism so that techno-commercial impact on conventional power plant and grid operation would be resolved and renewable energy would have unrestricted access in the present grid system.

PRESENT CHALLENGES AND PRACTICE TO ADDRESS VARIABILITY OF RENEWABLE ENERGY GENERATION

Indian power system is having five regions i.e. Northern region, Northern Eastern region, Eastern region, Western region and Southern region. Northern region is generally deficit region and demand is highly weather sensitive. It has snow fed run of the river hydro. Northern Eastern region has very low demand and high hydro potential and has power evacuation problem. Eastern region is having low demand and high coal reserves and pit-head base load plants. Whereas, western region is generally consider as a surplus power region and has high industrial and agriculture load. It has monsoon depended hydro plant. Southern region has also high agriculture load and monsoon depended hydro plant. There are seven RE reach state in India. I.e. Rajasthan State in Northern region, Karnataka, Tamil Nadu and Andhra Pradesh States in Southern region, Gujarat, Maharashtra and Madhya Pradesh States in Western region. Looking to the overall phenomenon of India power structure, the quantum of renewable energy is requiring to be accommodated with proper balancing solution.

Present practice in India is to absorb variation of renewable generation by available conventional sources in the system or shed load or even backing down renewable generation. Gas base generations are basic source followed by hydro generations then after thermal generations are utilized for balancing mechanism.

TABLE I. SCENARIO OF TOTAL INSTALLED CAPACITY (MW) IN INDIA AS ON JUNE 2017

Region	***Coal***	***Gas***	***Diesel***	***Total Thermal***
Northern	52649	5781	0	58430
Western	70164	11059	0	81223
Southern	43382	6474	762	50617
Eastern	27778	100	0	27878
North Eastern	580	1771	36	2387
Island	0	0	40	40
Grand Total	**194553**	**25185**	**838**	**220576**
Percentage (%)	**59**	**8**	**0**	**67**

(Sources: CEA Website)

Region	***Nuclear***	***Hydro***	***RES***	***Grand Total***
Northern	1620	19312	11713	91075
Western	1840	7448	18412	108923
Southern	3320	11739	26891	92567
Eastern	0	4834	994	33706
North Eastern	0	1282	281	3950
Island	0	0	13	53
Grand Total	**6780**	**44614**	**58303**	**330274**
Percentage (%)	**2**	**14**	**18**	**100**

(Sources: CEA Website)

TABLE II. BREAK-UP OF RENEWABLE ENERGY INSTALLED CAPACITY (MW) IN INDIA AS ON JUNE 2017

Energy Sources	***Wind power***	***Solar Power***	***Small Hydro power***	***Bio Power***	***Total***
Installed Cap.	32508	13115	4385	8296	58303
Percentage (%)	56	22	8	14	100

(Sources: CEA Website)

TABLE III. SCENARIO OF TOTAL INSTALLED CAPACITY (MW) IN GUJARAT AS ON JUNE 2017

Conventional Energy Sources	***Thermal***	***Gas***	***Hydro***	***Nuclear***
Installed Cap.	14188	4934	779	559
Percentage (%)	52	18	3	2

Non-conventional Energy Sources	***Solar***	***Wind***	***Mini Hydro***	***Bio-mass***
Installed Cap.	1262	5405	9	41
Percentage (%)	5	20	0	0

TABLE IV. RE (WIND) VARIATION IN A DAY IN GUJARAT AS ON JUNE 2017

Variation of Wind Generation in MWH in a day	***Nos. of day in Year***			
	2013-14	***2014-15***	***2015-16***	***2016-17***
More than 1500	6	10	12	26
More than 1000	267	257	247	146
More than 500	82	94	116	292

Solar Generation is highly ramp up and down at morning and evening. Further, extremely variable during monsoon and cloud cover.

Variable, intermittent and uncertain renewable generation poses certain key issues in the power system like as high renewable generation leads to overloading of transmission elements whereas low renewable generation results in underutilization of transmission elements. The variation in renewable generation deteriorated voltage profile, resulting in reactive power management issue. In current scenario, the conventional power plants accounted for renewable generation variability. Due to seasonal variability of renewable generation, it is not so easy to plant conventional generation schedule / outages for long term and due to intermittency of renewable generation, it is challenging to honor ISGS schedule and compliances of Deviation Settlement Mechanism (DSM) regulation. Further, uncertainty in renewable generation, it is difficult to plan conventional generation schedule in real time as well as day ahead. Such frequent pick up and back down of conventional power plant affect its performance.

Issue: Thermal generating stations are not so flexible which response variation of renewable generation. Further, Gas station and hydro station having adequate ramp rate but most of the gas base generators are kept under reserve shut down due to Merit Order Despatch concept and inadequate hydro generation in RE rich State. Hence, gas and hydro station would not support as balancing power.

POWER BALANCING METHODS

There are certain methodologies utilizing for balancing the RE generation. Most probable methods are:

I. RE generation forecasting with role and responsibility of each stake holder

a) Method: Each RE pooling station has to submit generation forecast in Day ahead as well in real time nearer to realistic. The challenge of today is to have accurate forecasting model in a block of 15 minutes in synchronism with DSM mechanism. Renowned agencies from worldwide for renewable energy forecasting are in market, which is forecasting by physics-based and statistical model by utilizing various static, variable data and weather input sources. In view of FSPs (Forecasting Service Provider), real time availability of weather data and generation data of each wind mill and solar plant have a key role in forecasting. Some of FSP also argue that substantial experience for each RE station, covering every season, is essential to forecast the trend nearer to realistic. As far as concern to the RE developer, forecast for each RE station is not being availed by State Load Despatch Centre (SLDC) and if it is so that then again, accuracy of forecast is not so prominent.

b) Issue: Real time data of each windmill / panel cannot be made available to FSP, in absence or / and not implementation of regulation for RE developers in RE rich States. Some old RE developers have not provision to provide data at least plant wise. Further, accuracy definition in regulation for RE forecasting shall not make sense to RE developer for accurate forecasting and resulting state shall be deviate from its ISGS schedule and attack penalty.

c) Solution: Each stakeholder of power system has to comply technical requirements of CEA (Central Electricity Authority) / CERC (Central Electricity Regulatory Commission) Regulations for enabling RE Integration in the existing grid. All the grid connected renewable generators has to provide and maintain real time data to respective REMCs (Renewable Energy Management Centre) /SLDCs/ /RLDCs/NLDC (State / Regional / National Load Despatch Centre). All RE developer should undertake accurate forecasting of RE generation. Every State Control Centre has to implement the accurate load / demand and RE forecasting mechanism and capturing real-time data off all generators in the system. State has to support the strengthening of REC market and effective fulfilment of RPO targets.

II. Introduction of ancillary services

a) Method: Ancillary services in power system operation means services necessary to support the power system in maintaining power quality, reliability and security of the grid. Ancillary services principally regulate the generators. The system operator uses ancillary services over various time frames to balance load and generation i.e. Extreme weather conditions, generating unit or transmission line outages, Trend of load met, Intimation of any abnormal event, congestion in the grid, frequency etc.

b) Issue: Ancillary services were introducing at national level with the help of regulation but it would not replicate up to state level and not exclusive for renewable energy balance. Further, cyclic operation / load ramping capabilities of machines of different age and technology will pose difficulties in dealing with the impact of renewable generation variation. Frequent variation in loading of machine would affect the residual life of machine. This may lead to increase in number of break downs of equipment, tube leakage, line leakages, fatigue, creep etc. with impact on R&M cost of machines. Part load operation would adversely impact the heat Rate. Cheap Gas availability is a key issue in providing high ramping services from gas fired plants.

c) Solution: Ancillary service would be introducing in the RE reach states and it should be link with RE variation so that conventional generation can be utilized as an ancillary, in case of wide fluctuation in RE generation. Also the generators which will be contribute, would be offer attractive price.

III. Spot Power market

a) Method: The present power exchange provides platform for buying and selling on day-ahead basis. It has also provided platform for operation of intraday /contingency market for same day and next day delivery. Such more frequent market clearing, real time markets may provide a platform for selling power or buying power.

b) Issue: The above is yet to be exploited in a major way by the market players. It is expected that DISCOMs also operate in a 24 x 7 manner to reap the advantages from these extended market sessions.

c) Solution: Spot power market particularly for RE power would be developed with the regulation. RE generators bound to absorb its deviation with respect to schedule with the help of power market.

IV. Pump mode hydro station

a) Method: Pump mode hydro station shall be effective solution to manage the variation of renewable generation, also gap between forecast and actual RE generation. Pump hydro plant can store the energy in form of water, pumped from a lower elevation reservoir to higher during off pick or high RE generation and generate electricity during peak period or low RE generation.

b) Issue: At present, certain pump storage hydro stations are not in operation due to one or technical or commercial issues. The CEA report on 'Large Scale Grid Integration of Renewable Energy Sources' says "9 Nos. of pumped storage schemes with aggregate installed capacity of 4785.6 MW are in operation in the country. Out of these, only 5 No. of plants with aggregate installed capacity of 2600 MW are being operated in pumping mode. The details of these schemes are given below:"

TABLE V. STATUS OF PUMPING MODE OPERATION

Status	***Installed Capacity***	***Nos. of Plant***	***State-wise Installed Capacity in MW***
Existing	4785.60	9	Gujarat (GJ), Maharashtra (MH), Andhra Pradesh (AP), Tamil Nadu (TN), West Bengal (WB), DVC
Working	2600	5	TN (400), MH (400), AP (900), WB (900)
Non-Working	2185.6	4	GJ (1440), AP (750), DVC(40)

Some of pump storage plants around 1080 MW (Uttarakhand (1000), MH (80)) are under construction and 2600 (TN (500), MH (1100), WB (1000)) are under survey and investigation.

TABLE VI. STATE WISE - PLANT WISE BIFURCATION OF PUMPED STORAGE PLANT

State	Name of Project	Installed Capacity	Pumping mode operation
Gujarat	Kadana St. I&II	240	Not Working
Gujarat	Sardar Sarovar	1200	Not working
Andhra Pradesh	Nagarjuna Sagar	705.60	Not Working
Andhra Pradesh	Srisailam LBPH	900	Working
Tamil Nadu	Kadamparai	400	Working
DVC	Panchet Hill	40	Not working
Maharashtra	Bhira	150	Working
Maharashtra	Ghatgar	250	Working
West Bengal	Purlia PSS	900	Working

c) Solution: Expedite Non-working Pump mode hydro stations put back in service and create a regional / national pool of pump mode hydro stations and same will operated only to absorb RE generation variability as per State request.

V. Development of Renewable Energy Management Center (REMC)

a) Method: REMC is a worldwide accepted concept which can fulfilment the requirement of balancing of power at large extent. Renewable Energy Forecasting, scheduling and real time data monitoring for plant wise, area wise is key functionality of REMC.

b) Issue: Yet in no RE reach state REMC is functioned full flange. The balancing sources shall still require to maintain the system operation at stage of abnormal predefine scenario of renewable energy generations and other conventional generation availability at that time plus any other uncertain grid parameters like over generation / under generation / line overloading / line underutilization / tripping etc.

c) Solution: In India, development of REMC is under process in RE reach states, regions as well national level. REMC will mainly comprise of Static Data details, collection & maintain RE Energy data, fetching of real time RE generation data at control centre and monitoring of forecasted Vs real-time RE generation data at station wise, area wise and State as a whole. However, balancing sources can well support the REMC functionalities.

VI. Installation of Energy Storage Technology

a) Method: Installation of energy storage technology is one of the options for balancing power so as to store the energy when demand is low and same can be utilized when demand is high. Energy storage Technology can be installed at the RE stations of above 100 MW installed capacity. Energy storage technologies are: Pump storage, Various types of battery (Lead acid battery, Nickle chromium battery, Redox flow battery, Sodium Sulphur battery, Nickel Manganese Spinal (NMS) cathode based battery etc.), Compressed Air Energy storage (CAES), Flywheel, Fuel cells and Gravity power.

b) Issue: There are certain limitations of Energy Storage Technologies. I.e. Costly, most of the technologies are under development stage so having limited capacity in KW, Not possible at MW level. Further, Technology has required large space. At present, there is No regulation for energy storage in India and key point is "Distribution Company has to accept / absorb the store energy at the same PPA (Power Purchase Agreement) rate if it is injected in the grid when required."

c) Solution: Energy storage technology development is optimal option for balancing of power. However, it is expensive. Further, more reliable and efficient storage technology is under process and likely to get cheaper and also, higher capacity energy storage technology in near future. Many countries have started using in their utility / distribution companies.

WAY FORWARD

All above discussed methods may take considerable time to be operationalize but till that time following are the best option for balancing mechanism, which can be put in operation within short span.

A. Flexible operation of Thermal plant:

Flexible operation of coal based thermal units embedded in state (55% Technical Minimum) to be mandated with suitable commercial signals. In future, Special fund with commercial agreement to be issued for modification in design of conventional power plant. Clear roadmap is required for availability of primary control/response and implementation of Automatic Generation Control (AGC) for secondary control in all the state generating units.

B. Availability of gas

The available gas stations are to be deployed as balancing by waving of merit order. Also, special APM gas allocation for a limited quantity to high RE potential State may also help to overcome RE variations. In future, developing gas based generating station with RE station so that variation can be balanced to some extent.

C. Hydro operation

All the operative hydro stations will be pooled at national level and its dispatch will be controlled by NLDC. Also NLDC has to publish capacity on website with relevant tariff plus other impact up to State periphery and then only needy State shall able to avail.

D. Pump mode Operation:

The safe, secure and reliable operation for power system with increasing of renewable energy integration, the pump mode storage is most reliable, convenient and reasonable source. At this instant, the operation / utilization of balancing plant of other State should be materialized with mutual agreement and RLDC should encourage without any additional charges up to transmission capacity. In future, existing idle / inoperative pumped storage projects to be made operational on highest priority with plant wise follow up and monitoring. Time band program to be finalized for each non-working pump mode hydro station including station to be commissioned. Each to be framed and implemented with progress monitoring by highest authority of Central and State without further delay. Also, Special focus on large size balancing with multi State beneficiary either of existing / inoperative / under construction project is MUST. A research work may be entrusted to IIT like institute for converting conventional hydro in to pump mode by change in turbine, additional tail race etc. which shall be mandatory in future.

It is suggested to pool such sources at regional level and use them in the grid as and when required. In a way, RE generation to be given status of national asset and such pump storage scheme would act as a balancing mechanism of the grid. The operation of balancing plant in State or for other State, policy to be finalized. However, it should not be happened that once all pump hydro available but it cannot be utilized for RE balancing in absence of regulatory / commercial mechanism.

E. Energy Banking

The energy banking between two State without any financial transaction is seems to be very viable solution. Only RLDC need to be flexible encourage such transaction. Special intervention of higher / appropriate authority to RLDC with suitable arrangement for ease of transmission with energy banking philosophy between States is required or otherwise Hon'ble regulatory consider a real time product of energy trading (banking) between utilities which needs to be flexible (allowing changes in schedule in 4 time blocks) unlike the present rigid STOA (Short Term Open Access) regulations. Such contract should be direction specific and stipulate the precise period for transaction.

KEY TECHNICAL BENEFITS OF BALANCING POWER

The proper balancing of power results in technical benefit in the system. i.e. Grid stabilization, Grid operational support (frequency regulation services, contingency reserves, voltage support and black start), Power quality and reliability, Load shifting, Supporting the integration of intermittent renewable energy sources, it shall reduce the frequent pick-up and back-down of conventional generators thus improving their performance and avoid its damages.

CONCLUSION

Many countries reflecting very different geographies, markets, and power systems are successfully managing high levels of variable renewable energy on the grid, such as from wind and solar energy. When India is having an ambitious target of 60 GW wind generations and 100 GW solar generations by 2020 - 22, solely monitoring of curtailment may not bring the result but immediate provision of balancing mechanism to be made available for reducing curtailment and owing Must Run status. Pump mode hydro and energy banking is reasonable and reliable balancing sources which can smoothly put in operation by modifying some of its mechanism by effective attempt.