Topic 3. Foundational Blocks for Smart Grid

Flexibility in Power System

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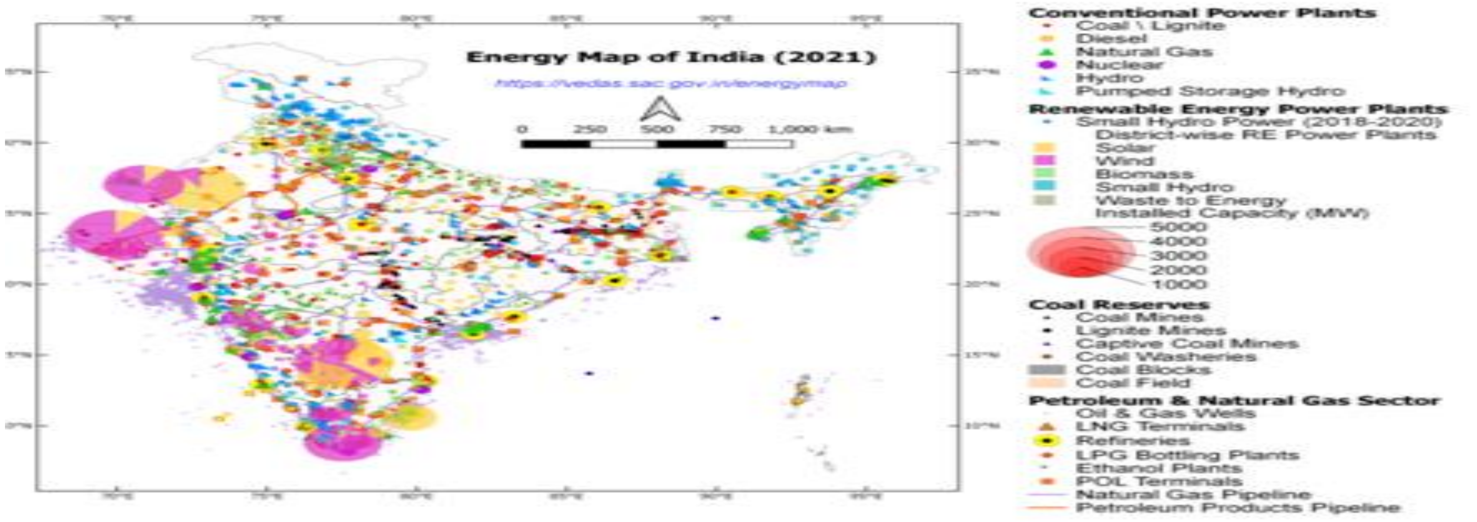
Introduction

1. Power System

i) **In the early 20th Century** , the centralization of electricity production made huge progress (economy of scale, improved plant efficiency & flexibility), whereas

21st Century laverages decentralization impeding challenges to create optimized ways leading access to system flexibility, reliability , green and resilient energy.

ii) Energy Map of India 2021 Status & State shares in Indian Energy.



iii) India Ambitious commitment during COP26(Nov 21)

- 500GW RES and CO_2 emission cut out by 1billion MT by 2030 {157.32GW (40.1%) on 10th Jan 22 (Solar /Wind/ Hydro = 48.55/40.03/51.34GW) and 175GW by 2022}

- Net Zero Carbon Energy by 2070

Flexibility & Flexibility Planning

2. Flexibility

i) Sync. rotating machines contribute kinetic inertia whereas Inverter-Based -Resources (IBR), Wind, BESS or HVDC not inherently provide an equivalent response and release stored energy immediately following an event. IBR is also called as Virtual Syn. Machine (VSM)

ii) Frequency control system designed for a certain level of inertia, frequency dynamics influence fast in power systems with lower inertia.

iii) DERs predictions of a 10-fold increase between 2020 and 2030 tend to increasing supply volatility. Counter-balancing via increased demand load flexibility and storage options are not of system balancing magnitude.

iv) Challenges posed by Reduced inertia - related directly to the loss of inertia and attribute more general reduction in synchronous generation (reduction in fault current and reactive power availability). M**itigation measures - provision of additional inertia & Fast frequency response** need to be evolved rather than simply developing **a like for like replacement of the lost synchronous generation.**

3. Flexibility Planning : 3 Steps [1]

Step 1: Assess current flexibility involving i) Production cost modeling and ii) Network studies

Step 2: Bridge gaps following least -cost approach involving i) unlock existing flexibility ii) Implement DSM scheme iii) Invest in new assets

Step 3: Assess future flexibility involving i) Optimizing VRE sitting using geospatial optimization, ii) Least cost capacity expansion to identify future assets and iii) Repeat Step1(Access of long -term plan identified on previous step)

Note: If gaps are identified in step1, go to Step 2, otherwise go to step 3

Renewables Impact on Power System-Studies

4. Studies Performed On Assessment and Impact of Renewable on Indian Power System.

i) CEA: Optimal Generation Capacity Mix for 2029-30 [2]

CEA mid-term Review: "**March 2018: National Electricity Plan (NEP) 2029-30**", assessed likely installed capacity **" Year 21-22"** and deploying **ORDENA Gen. Expanding Software** determined generation capacity mix by 2029-30 and Max VRE day absorption around 85.32 % on **3rd July, 2029** with minimum tech load of coal platform 55% to 50%, 45% and 40%, the RE Curtailment 14.68 to 12.94%,11.84% and 10.56% respectively.

ii) **IEA and NITI Aayog: *Renewables Integration in India*** [3]

IEA and NITI Aayog [8] inter-alia deployed Iea developed two newly detailed power sector production cost models 'the India Regional Power System Model' and 'the Gujarat State Power System Model' to illustrate flexibility challenges specific to the Indian context 2030 based on Power System Transformation Workshops deliberations mentioned share of solar & wind in ten Indian rich renewables states Karnataka (29%), Rajasthan (20%), TN (18%) and Gujarat (14%) significantly higher than the national average of 8.2%.

iii) **Developing a roadmap to a flexible, low-carbon Indian Electricity System' [4]**

TERI & NREL [9] thru case studies of TN (8.4GW wind) in 2018 to be more severe than in Karnataka (5.2GW) and observed both States to experience seasonal flexibility problem, etc.

Regions and States constituents to deploy standardized open platform for flexibility Models /studies till transition complete

iv) Pan India Lights Off Event (9 PM 9 Minutes) on 5th April 2020- Flexibility Capability [5]

Event 9PM 9min switching-off Residential lights [10] observed 'Underestimation Demand (Estimated 12-15GW & Actual 31GW)';'Highlighted need for modernization of methodology of demand forecast & its spatial demand composition and its accuracy'; 'Renewable generation resources forecast & rescheduling'; 'Loss of **C**ontrol Center' under COVID 19 situation; 'Recognize flexibility attributes, measurement of flexibility', etc.

Ancillary Services in India

5. Ancillary Services in India [6]

History: CERC (unscheduled interchange) mandated NLDC in 2009 and onward thru various notifications over a long journey from 2010, 2013,2015, 2018 and in 2021 issued latest draft: Ancillary Service Regulation 29th May 2021.

The draft Ancillary services briefly classified as under:

i)**Primary Reserve Ancillary Services (PRAS)** – Immediately responds thru governor action on sudden change in frequency.

ii**) Secondary Reserve Ancillary Services (SRAS,SRAS-UP & SRAS-Down)** : Second level of defense against sudden frequency changes, deployed by NLDC thru secondary control signal to replenish the primary reserves, provide min. response of 1 MW , capable of responding to SRAS signal within 30s and providing entire capacity obligation within 15 minutes and sustaining at least for the next 30 minutes; .

iii)**Tertiary Reserve Ancillary Services (TRAS- TRAS-UP & TRAS-Down)** : Capable of varying its active power output or drawl or consumption, as the case may be, on receipt of despatch instructions from the Nodal Agency within 15 minutes and sustaining the service for at least next 60 minutes. TRAS be activated to replenish the secondary reserve in case secondary reserve has been deployed continuously in one direction for 15 minutes for more than 100 MW and Such other Ancillary Services as specified in the Grid Code. The schedule for TRAS shall become effective from the time block starting 15 minutes after issue of the despatch instruction by the Nodal Agency

2. **CERC aims** to bring battery storage and pumped hydro storage (PHS) into the ambit of the frequency control and ancillary services (FCAS) market

3. **Auxiliary/ Ancillary Services in use in India [7]**

i) Ancillary services in full adoption are **Inertial** (1st few secs), **Slow Tertiary** (15-60min), **Generation Rescheduling / Market** (> 60min) & **Unit commitment** (hours-day ahead) and **Partly Primary** (few sec-5min) in India

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ii) AES and Mitsubishi Corporation :10 MW/ 10MWH for 1 hr grid-connected system, deploying Advancion energy storage platform from Fluence (a joint venture of Siemens and AES) located at Tata Power Delhi Distribution's sub-station in Rohini to protect critical facilities for TATA 2 million consumers. It will pave the way for ancillary market services for wider adoption of grid-scale energy storage technology across India, effective renewable integration and peak load management of Indian grids.

iii) CEA corresponding to 500GW 0f RES by 2030, has modelled requirement of around 27GW/108GWh of energy storage by 2030 and as such begun a process of creating rules to enable participation of energy storage and demand response in ancillary services markets to balance the grid.[B]

iv)Tata Power Solar Systems, has received a letter of award from SECI for EPC of 100 MW solar project with a 120 MWh battery in Chhattisgarh.

v) DOE Global Energy Storage Data Base-NTESS]© 2021, Sandia National Laboratories gives the List of 20 India Energy Storage out of which 15 are in operation and 5 are announced / never built. For details of Storage in operation, reference may be perused.

Ancillary Studies in Other Countries

6. Frequency Containment Reserves Requirements (FCR) Studies [8]

i) Survey

Particular	Definition Mini. Inertia Level	Min. Inertia Level Calculation Methodology	Freuency Containment Reserves	Fast Frequency Response	Other Mitigating Measures
Yes (%)	73	60	100	60	53
No (%)	27	40	0	40	47

ii) Studies

ERCOT for Elect. System of TexasC	Continental Europe 2030	Nordic System: 2030	EirGrid (Ireland) and SONI (North Ireland) : 2030	Sardinia Power System – connected to main land Italy via 2 LCC HVD Links (Ref [5 Chp 7 Para 7.10 for details]	National Electricity Markey (NEM) , Australia
Frequency containment & restoration attained thru adequate Control setting and Ancillary Service . Inertia dictates initial @ frequency change due to supply demand match 35GW new Renewable Gen as per Gen Interconnection Status Report 2017 Plus 10 GW (already approved)	As part of EU-SysFlex, Continental European Interconnection performed Project Frequency Security studies	Under EU-SysFlex, Project Frequency Security studies comprising Future scenarios 3 studies viz. 2 EU Core Scenarios,(Energy Transition & RES Ambition, and one Network Sensitivity developed for High Solar study	Under EU-SysFlex Project performed future operation study 2030 of system EirGrid 400, 220 &110kV system and SONI 275 & 110kV system as a single synchronous All-Island system 7GW (P. demand) connected to Great Britain thru 2 HVDC EWIC Links & Myole HVDC Interconnector	Inertia Requirement Cal: 2 stage method. Stage1 : Screening process to assess inertia sub-networks at risk inertia shortfalls & uses SMM of sub-network for study and certain assumptions around fast FCAS & relationship bet. inertia & fast FCAS. The Stage 2 assessment uses detailed RMS model of PS in PSCAD/ EMTDC to determine min. & secure levels of inertia but only applied if Stage 1 reveals a risk.	To support System Inertia & SC power, 2 Syn compensators (2x250 MVAr) operating since 2014 & 2 more be added. SC power concerns linked to ensure operation of SACOI & SAPEI HVDC links. Delayed response of FFR limits its ability to support freq. control to cases : --nadir/ zenith limited or -- RoCoF limited but FFR's full response time less than RoCoF measurement window ---continued

Ref. shown against each Operator (Country) viz Eskom (South Africa) [8 (Chp 1(B1)] , EirGrid (Ireland) [8 Chp1(B2,3,4,5,6,7)] , AEMO (Australia) [8 Chp1(B8)], ERCOT(Texas USA) [8 Chp1(B9)] , NORDIC System (Nordic Countries Europe) [8 Chp1(B10)] and ONS (Brazil) [8 Chp 1]

FCR and FFR Capabilities of Various Technologies

7. Summary of FCR (Frequency Containment Reserve/ Response) and FFR (Fast Frequency Response) capabilities of various technologies [8]

Technology	Synchronous Inertia	FCR Type	FCR Time to full response	FCR Sustained response#	FFR Type	FFR Time to full response	FFR Sustained response#
Synchronous Generator (incl. pumped hydro storage and CAES)	Yes	Droop respone (for pumped hydro only in gen mode)	10-20s	Yes	Droop Response*	2s	Yes
Load	Yes (if directly connected)	Droop response	few seconds	Yes	Step	0.25-0.5s	Yes
Smart Load	No	Droop response	few seconds	Yes	Proportional to Δf or RoCoF	0.5-1s	Yes
Synchronous Condenser	Yes	-	-	-	-	-	-
Wind Turbine	No	Droop response	few seconds	Yes (depending on wind)	Step or proportional to Δf or RoCoF	0.5-1s	Few seconds with re-covery phase. Ineffec-tive at low wind speed.
Solar PV	No	Droop response	few seconds	Yes (depending on sun)	Step or proportional to Δf or RoCoF	0.5-1s	Yes (depending on sun)
Battery Storage	No	Droop response	few seconds	Yes (depending on SoC)	Step or proportional to Δf or RoCoF	0.2-1s	Yes (depending on SoC)
Supercapacitor	No	-	-	-	Step or proportional to Δf or RoCoF	<0.2s	Only a few seconds (depends on size)
Flywheel	Yes (if directly connected)	Droop response	few seconds	Yes	Step or proportional to Δf or RoCoF	<0.01s	<15 min
Pumped Storage w. variable speed	No	Droop response	10-20s	Yes	-	-	-
HVDC VSC	No	Droop response	few seconds	Yes	Step or proportional to Δf or RoCoF	0.2 – 1s	No, depends on availa-ble energy buffer

* EirGrid and SONI procure FFR with a response time of two seconds from synchronous machines, full response of FCR from these machines is expected at 5 seconds (faster than most utilites require), thus the availability of FFR from synchronous machines will depend upon existing capabilities and FFR definition

\# Note, curtailment of renewable resource will allow sustained response depending on primary energy source variations(e.g. sun, wind).

Key Takeaways

1.Power systems tending green thereby loosening system inertia and necessitating compensation deploying synthetic inertia as also performing Flexibility studies at Regional & State levels catering for frequency disturbances and comparatively **drive more comprehensive & expansive compensation** in the areas of minimum Inertia for smaller electrical size systems, islanded from other parts of the grid, etc.

2. **CEA determined Optimal Generation Capacity Mix for 2029-30** and Max VRE day absorption 85.32 % on **3rd July, 2029** with min. tech load of coal platform 55% to 50%, 45% and 40% and RE Curtailment 14.68 to 12.94%,11.84% & 10.56% resp. **deploying ORDENA Gen. Expanding Software**

3.IEA & NITI Aayog study illustrated flexibility challenges & solutions specific to Indian Power System 2030 in 'Regional Power System Model' and 'Gujarat State Power System Model'. The study identified solar & wind share Karnataka (29%), Rajasthan (20%), TN (18%) and Gujarat (14%) significantly higher than the national average of 8.2%. Similarly, TERI & NREL case studies-2018: TN (8.4GW wind) more severe than Karnataka (5.2GW) and observed both States to experience seasonal flexibility problems, etc. P**roposed to deploy standardized open platform for flexibility Models /studies till Renewable energy transition is completed**

4. CERC Latest draft Ancillary Service Regulation -2021 categorize services as Primary Reserve Ancillary Services (PRAS) ii) Secondary Reserve Ancillary Services (SRAS,SRAS-UP & SRAS-Down and Tertiary Reserve Ancillary Services (TRAS- TRAS-UP & TRAS-Down)

5. CERC aims to bring battery storage and pumped hydro storage (PHS) into the ambit of the frequency control and ancillary services (FCAS) market

6. Other Countries South Africa (Eskom), Ireland (EirGrid) , Australia (AEMO) , Texas USA (ERCOT), Nordic Countries Europe (NORDIC System) and Brazil (ONS) have performed **Frequency Containment Reserves Requirements (FCR) Studies**

7. GB Grid Code wef 14^{th} Feb 22 approved wind, wave and solar generators capable to offer kind of stability services (grid forming or VSM capability) traditionally delivered by conventional generators thereby setting a new market in stability services, unlocking the potential for renewables to support the grid [9].

Thank You

For discussions/suggestions/queries email: www.indiasmartgrid.org
www.isgw.in
Links/References (If any)

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