Session- Smart Grids for Smart Cities
Topic- Data Analytics enabled Inertia Volatility Assessment of Smart Grid in Enhancing Grid Resiliency in presence of DER

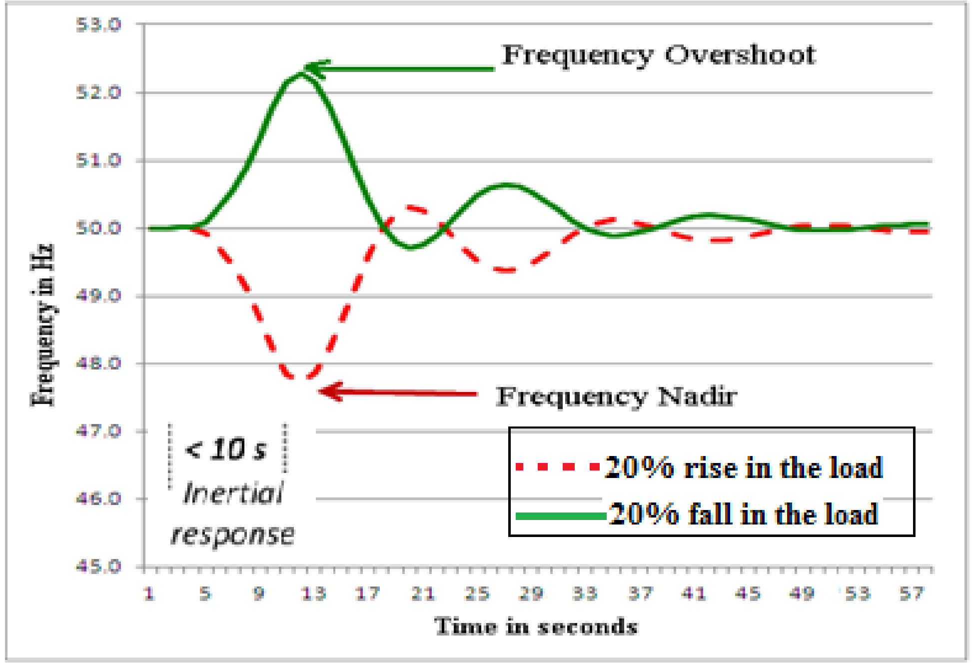
Speaker : Dr Surekha Deshmuh

Chair –PES India Chapters Council

Introduction

- Utilities transformation journey - Digitalization, Decarbonization and Deregulation
- Data-driven opportunities in leveraging the present digital enablers to address challenges of Grid.
- Today's smart grid, with large penetration of power from renewable sources has node-dependant, time-varying and more volatile "inertia", compared to the one post few decades
- Objective –
  - 1) Articulate the global challenge of utilities in maintaining grid resiliency
  - 2) How availability of diverse data of renewable generation, system load variation enable the assessment of inertia volatility
  - 3) Evaluate in turn the susceptibility of grid towards any perturbation.

Context- Grid Inertia & Resiliency



Digitalization and deployment of SCADA, IOT, AMI, PMU etc

- Access to the real time DATA of grid

-Giving opportunity to apply analytics to get the trend of behavior of grid

- Unlocking the potential solutions for techno-economical vulnerabilities

- When power grid is subjected to any step change of load ie perturbation, the system frequency will alter as a function of time (RoCoF)
- Grid with significant penetration of renewable generation has overall reduced inertia, influencing more system dynamics.
- It introduces frequency overshoot, frequency nadir and high rate of change of frequency for first few seconds. Hence this assessment is important to avoid possible relay mal-operation and de-synchronization.
- To get the total view of the network it is necessary to monitor

  - inertia-profile

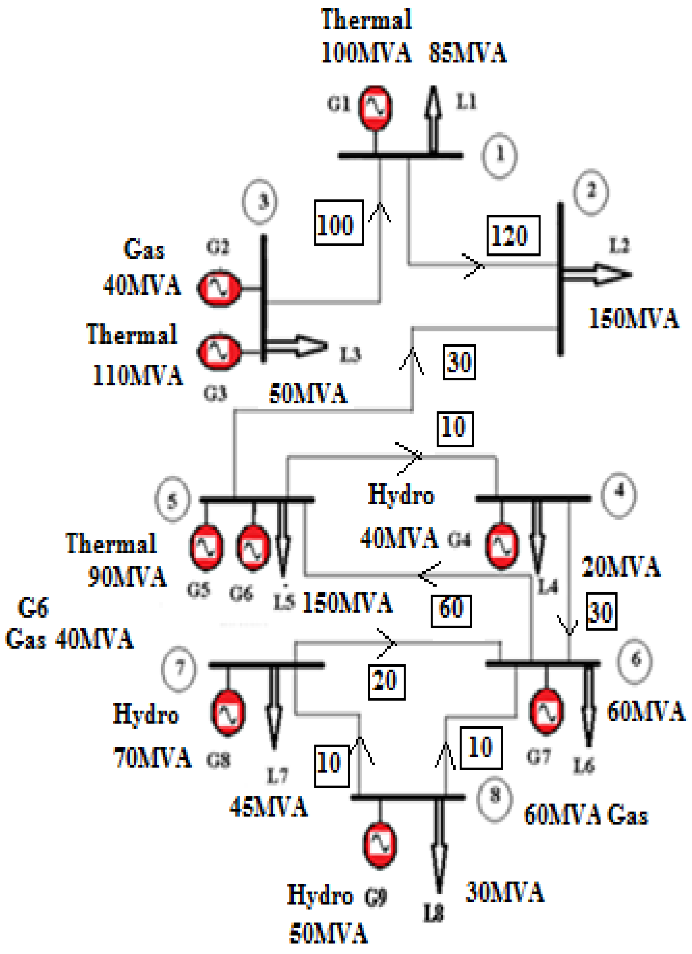
  - the way perturbation can penetrate through network

  - Perturbation Sustainability Level (PSL) at each node and total system

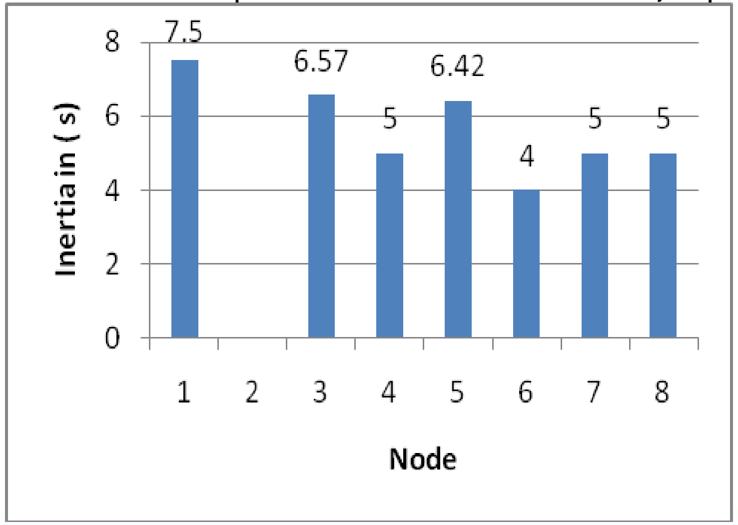
  - Aggregate Sustainability Level.
- insights – 1) Required inertia support to strengthen the grid

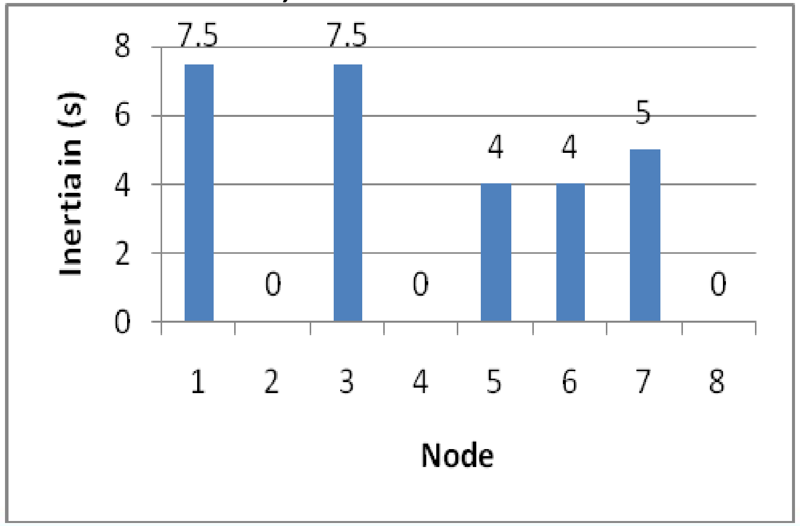
  2) Prescriptive guidelines on providing virtual inertia support

Relevance- Data Analytics for assessing Inertia Volatility



- Relevance – demo-grid has nine generators and total capacity of 600MVA and load 590 MVA1 slide
- Case1-All generators (Conventional generators with inertia constant)
- Case 2- Four generators, out of nine generators are replaced by Solar/Wind generators
- Inertia of node is $H = \frac{\sum_{i=1}^{n} H_i * S_i}{\sum_{i=1}^{n} S_i}$
- Where H_i –Inertia of i^{th} node, S_i –MVA at i^{th} node, n- Number of links.





Resiliency of Grid – Perturbation Sustainability Level (Node, system- aggregated)

- It is the ability of node to sustain perturbation. To evaluate Perturbation Sustainability level, rate of change of frequency is assumed to be 0.2Hz/sec as per standard. At each node Perturbation Sustainability Level(PSL) is calculated

$$\frac{df}{dt} = \frac{f\,\Delta P}{2HS} \qquad H = \frac{\sum_{i=1}^{n} H_i * S_i}{\sum_{i=1}^{n} S_i}$$

- System aggregated Inertia = 6.02 sec (Conventional), 4.21 sec(with DER)
- System Perturbation Sustainability Level – (S-PSL) = 4.81MW (Conventional), 3.37 MW (with DER)
- Observations -
- With increased penetration, the inertia of the node to which RE is connected is reduced.
- The rate of change of frequency profile (RoCoF) is decided by the profile of the inertia.
- More inertia support is required at nodes with more DER presence

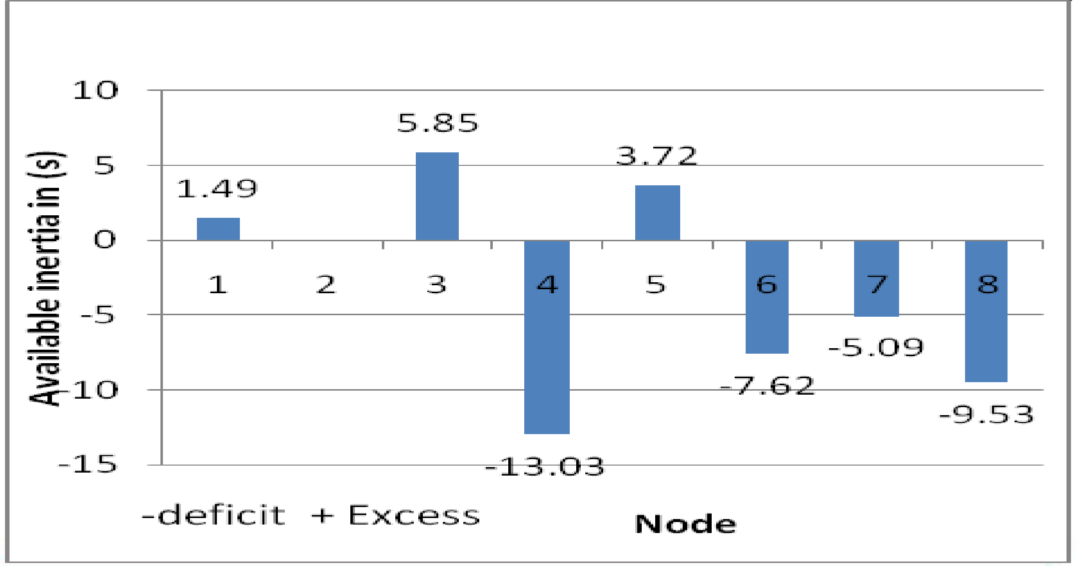
Node	Node inertia(s)	Perturbation Sustainability (MW)= case1
1	7.50	6.00
2	0	0
3	6.57	7.88
4	5.00	1.6
5	6.42	6.68
6	4.00	1.92
7	5.00	2.8
8	5.00	2

Node	Node inertia(s)	Perturbation Sustainability (MW)=case2
1	7.50	6.00
2	0	0
3	7.5	6.60
4	0	0
5	4	2.88
6	4	1.92
7	5	2.8
8	0	0

Inertia Support Required

- Occurrence of perturbation of 4.81MW, the requirement of inertia at each node is calculated to sustain the perturbation
- Node 4 being a sensitive node, requires 15.03 seconds inertia support which is large compare to remaining node. Similarly for node 8 inertia requirement is 12.03 seconds.
- Once the inertia requirement is known, the presence of inertia in the system can be leveraged as given below.
- To control RoCoF, the inertia support of 13.03seconds is required.
- Excess inertia of node 1,3 and 5 can be utilized to give support to weak nodes if required along with additional inertia support measures.

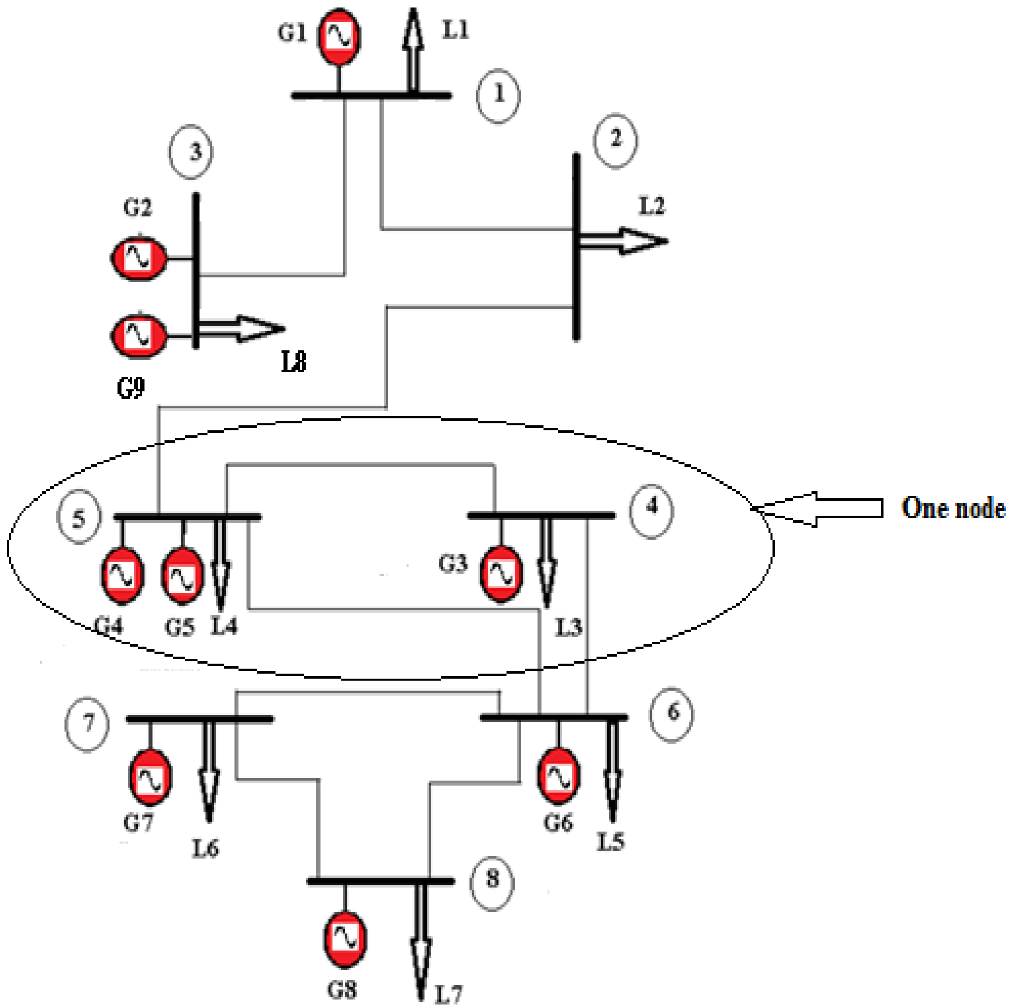
Node	Node inertia (seconds)	Inertia required to Sustain perturbations (s)	Inertia availability status (s) -deficit, +Excess	RoCoF (Hz/s)
1	7.50	6.01	+1.49	0.16
2	0	High	0	fast
3	9.86	4.01	+5.85	0.12
4	2.00	15.03	-13.03	0.60
5	8.35	4.63	+3.72	0.14
6	2.4	10.02	-7.62	0.50
7	3.5	8.59	-5.09	0.34
8	2.5	12.03	-9.53	0.48



Indicative approaches of Inertia Support

- *1) Transfer of inertia from one node to other connected node:*
- Inertia support to node 4 is given by transferring inertia of node 5 to node 4 as interconnected through transmission line
- H becomes 6.09s after connections. Similarly rate of change of frequency (RoCoF) at node 4 and 5 when independent was 0.6 Hz/s (very fast) and 0.14Hz/s is within the standard limit after connections

Node	Node Inertia H before support (s)	Node Inertia H after support (s)	RoCoF before support Hz/s	RoCoF after support Hz/s
4	2	6.09	0.6	0.2
5	8.35		0.14	



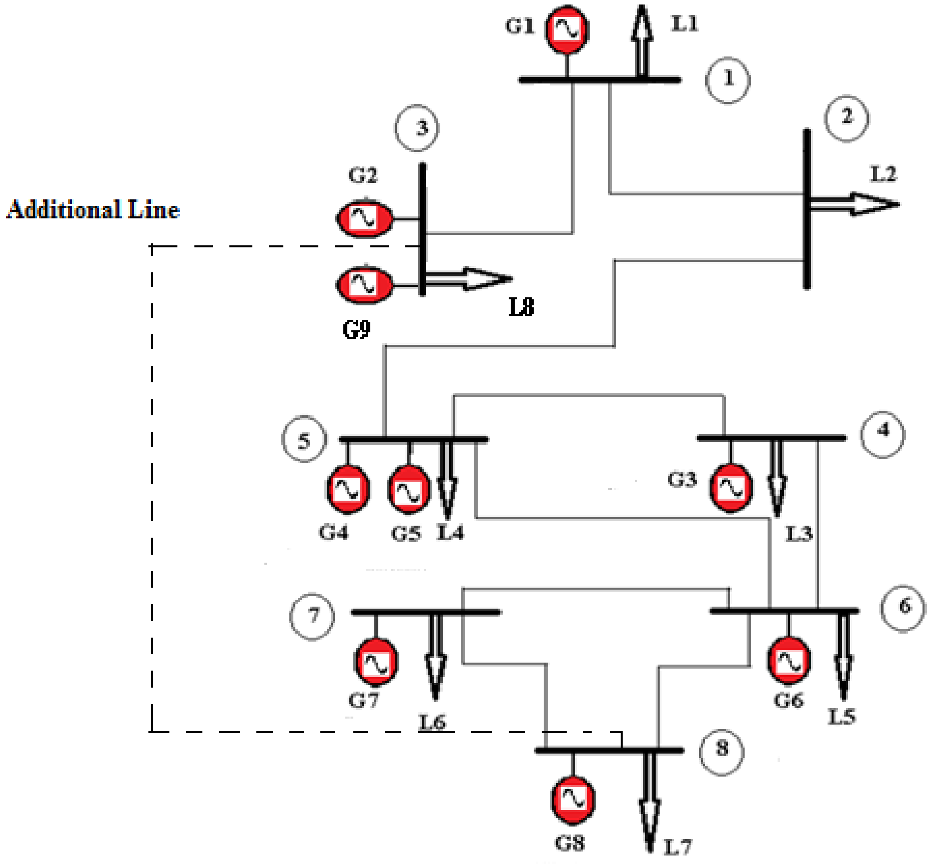
Indicative approaches of Inertia Support

2) Utilizing inertia of Renewable generators:

- Solar PV and wind generators are used as RE sources. Inertia from these sources can be utilized for inertia support to node 8

3) *Installation of new transmission line:*

- Excess inertia of node 3 can be provided along with other inertia support to node 8



Takeaways

- Green energy encouragement from regulatory commissions as well as governments increased investments into DER
- With digital transformation roadmap, Utilities are becoming smarter , in accessing, integrating and leveraging data across the grid for all techno-commercial decision making.
- This paper is articulated to present the potential of analyzing data to enhance the grid resiliency.
- As a known fact, penetration of RE generation not only reduces the inertia of the power system but results into node-dependent and time- variant inertia. Reduced inertia results in fast frequency dynamics.
- Hence an attempt is made in demonstrating how to create visibility and identify locations with high as well as low inertia in the grid.
- The frequency dynamics , RoCoF can be improved by harnessing inertia support within the system along with external inertia support.

Thank You

For discussions/suggestions/queries email: d_surekha@hotmail.com

Dr Surekha Deshmukh
Chair- PICC
IEEE R10 PES Chapters Rep – West
Execom member -IEEE Pune Section