

C2 Power System Operation & Control

PS 1 - System control room preparedness: today and in the future

Paper ID_10579

Re-establishing Functional Observability in a Control Center Under Total Loss of Normal Communications using Time-series Clustering

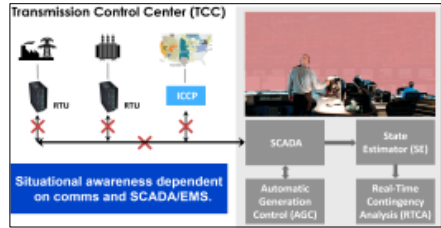
M. PATEL¹, P. DATTARAY², L. SUNDARESH¹, S. TRIPATHY¹, V. SINGHVI¹

¹Electric Power Research Institute

²Siemens Energy

Motivation

- In the event of loss of all normal communications to and from control centers, establishing some level of situational awareness for secure system operations is essential
- This work presents a method of restoring a functional level of situational awareness using sparse measurements reported by field personnel (Human RTUs – HRTU) from a small number of representative load locations (HRTU locations)



Methodology

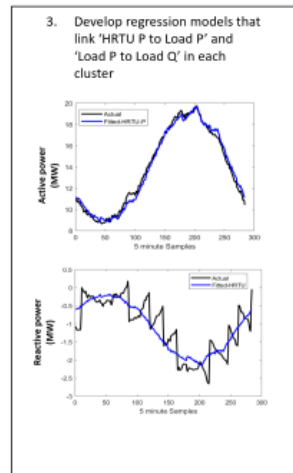
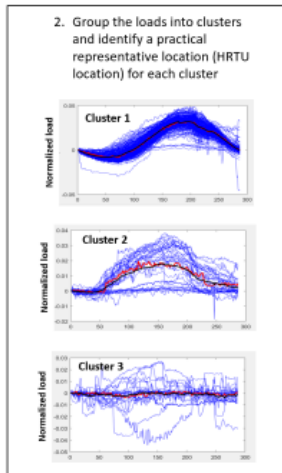
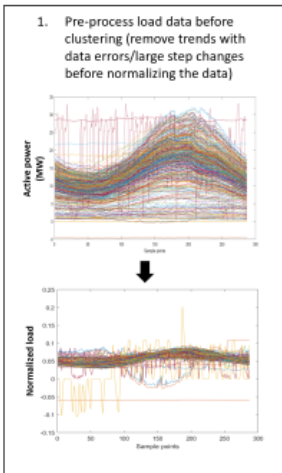
Offline procedures during preparedness stage

- Identify representative load locations (HRTU locations)
- Develop linear regression models to estimate remaining system loads from HRTU load measurements
- Time-series 24-hour load data archived at 5-6 mins resolution required

Online process during loss of communication event

- Use HRTU reported load measurements along with linear regression models to estimate rest of the system loads
- Update a study mode EMS case/power flow case, archived prior to the event, with estimated loads, reported generations and tie-line flows, and solve it to regain situational awareness

During preparedness stage (offline procedures)



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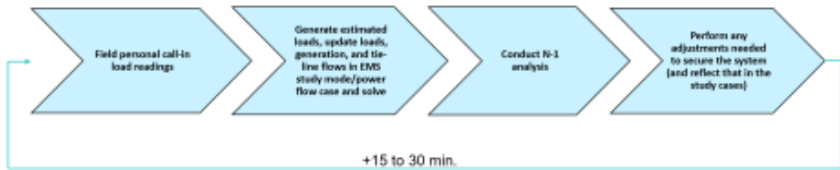
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During loss of communication event
(Online process)

Estimating system loads



Updating the EMS/Power flow case



Case Studies & Results

- Proposed approach demonstrated for a few US utilities

Offline procedure for utility #1

- In the archived load data, there were 450 loads of which 100 loads were industrial/mining loads, 18 loads had data issues
- Remaining 332 loads were grouped into two clusters with one representative HRTU location identified for each cluster (total 2 HRTU locations)
- Estimation models were developed for these 332 loads

Online procedure for utility #1

- A tabletop exercise was conducted to replicate the loss of all normal communications event
- Every 15 mins, reported measurements from the two HRTU locations were used to estimate 332 loads
- For the remaining 118 loads (industrial and ones with data issues), archived values were used
- An archived snapshot EMS case was updated and solved to obtain system states
- Contingency analysis was performed at every time step, and no voltage or flow violations were observed at the key buses or transmission corridors

Load estimation results from the tabletop exercise for utility #1

Time	Measured total load (MW)	Estimated total load (MW)
T+15 mins	3184	3172
T+30 mins	3244	3202
T+45 mins	3270	3209

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Summary of tabletop exercises conducted for a few US utilities
(Utility 2-5 Tabletop exercises were conducted post the Paper submission)

	Number of geographical regions	Number of clusters in each region	Total number of HRTU locations	Number of loads estimated	Actual aggregated load value (MW)	Aggregated load estimation error
Utility #1	1	2	2	332	3184	1%
Utility #2	3	2	6	~2100	18536	0.9%
Utility #3	3	2	6	1644	5596	5%
Utility #4	1	2	2	827	2479	2.7%
Utility #5	3	3	9	3366	14414	0.5%

Conclusion

- A method to establish situational awareness of the system during a total loss of communication was presented and demonstrated for a few US utilities
- Loads in the utility's footprint were grouped into a small number of clusters based on the similarity of trends and representative load locations (HRTU location) were identified in each cluster
- Linear regression models were developed to estimate rest of the loads in each cluster using HRTU load measurements
- A tabletop exercise was conducted to demonstrate the validity of the entire approach including the real time operation procedures
- Large number of loads (**3366 for utility #5**) in utility's footprint could be estimated using measurements only from a few (**9 for utility #5**) HRTU locations
- Aggregated estimated load values were within **5%** error margin compared to the aggregated measured (actual) load values
- The proposed approach was demonstrated to be useful for operators to establish and maintain situational awareness during extreme control center contingency with degraded communications and visibility