A RESILIENT ALGORITHM FOR POWER SYSTEM MODE ESTIMATION USING SYNCHROPHASORS

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OBJECTIVE

- An efficient algorithm to detect and/or tolerate false data injection attacks against distributed mode estimation algorithms.
- Evaluating our method against various attack scenarios and noisy data

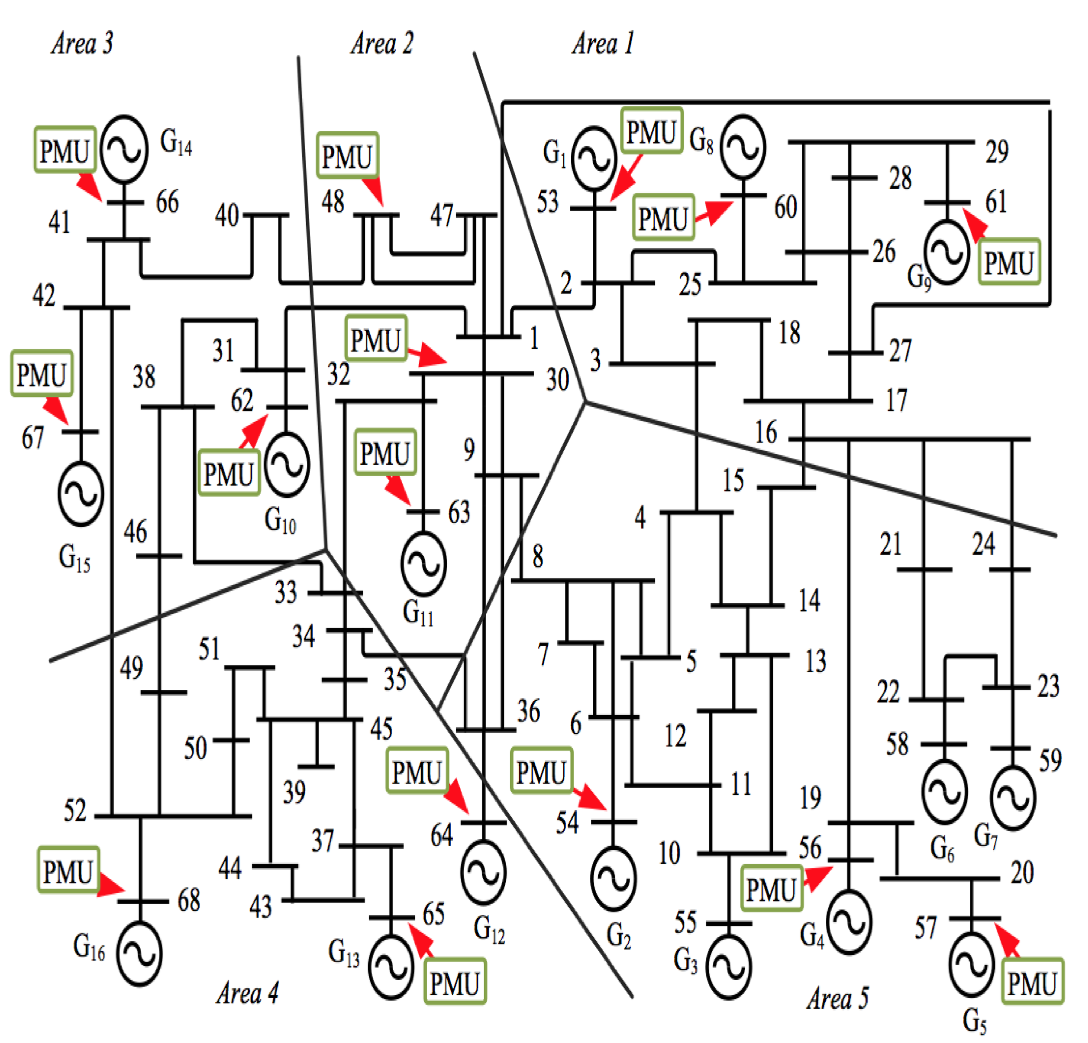
INTRODUCTION

Two types of mode estimation methods:

- Model-based (traditional) methods
- Measurement-based methods.

	Measurement-Based	Model-Based
time efficiency	✓	×
scalability	✓	×
on-line	✓	×
accuracy	×	✓
Topology Independency	✓	×

IEEE 68-bus power system:



PRONY ALGORITHM

Assume $y_i(n)$ is the n^{th} measurement of i^{th} Phasor Measurement Unit (PMU):

$$\underbrace{\begin{bmatrix} y_i(n) \\ y_i(n+1) \\ \vdots \\ y_i(n+l) \end{bmatrix}}_{C} = \underbrace{\begin{bmatrix} y_i(n-1) & \dots & y_i(0) \\ y_i(n) & \dots & y_i(1) \\ \vdots & & \vdots \\ y_i(n+l-1) & \dots & y_i(l) \end{bmatrix}}_{H} \underbrace{\begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_n \end{bmatrix}}_{a} \quad (1)$$

Let Z_i be the i^{th} root of following polynomial equation:

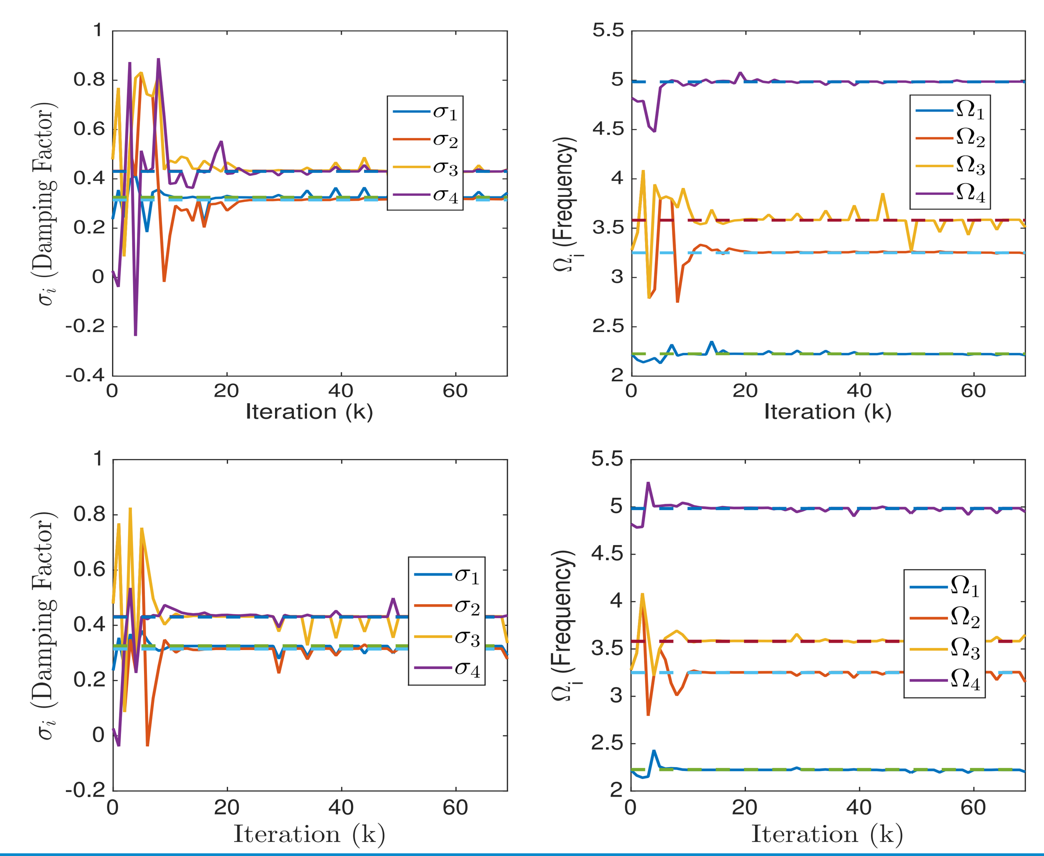
$$Z^n - a_n^* Z^{(n-1)} - a_{(n-2)}^* Z^{(n-3)} - \dots - a_1^* = 0$$
$$\frac{log(Z_i)}{T} = \sigma_i \pm j\Omega_i \quad (2)$$

σ_i, Ω_i and T are modes' damping factor, frequency and sampling period respectively

RESULTS

Adversary types:

- **Desired value attack:**
- **Random value attack:**
- **Periodic attack:**



PROPOSED METHOD

In S-ADMM mode estimation method:

- One semi-trusted central Phasor Data Concentrator (PDC)
- Set of Phasor Measurement Units (PMU) and one PDC in each area

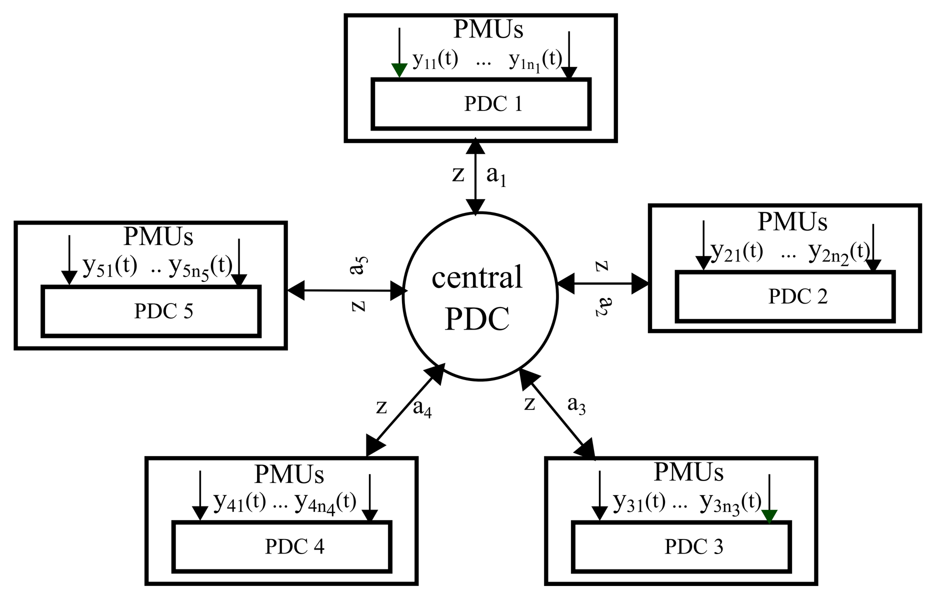


Figure 1: S-ADMM Architecture

Let $y_{ij}(t) = [y_{ij}(0) \dots y_{ij}(K)]$ be the measurements taken by j^{th} PMU in i^{th} area at times t.

$$H_i = \begin{bmatrix} H_{i1} \\ \vdots \\ H_{in_i} \end{bmatrix}, C_i = \begin{bmatrix} C_{i1} \\ \vdots \\ C_{in_i} \end{bmatrix} \quad (3)$$
$$f_i(a) = \|\hat{H}_i a - \hat{C}_i\|_2^2 + w_i^T(a-z) + \rho\|a_i - z\|_2^2$$

Algorithm 1 S-ADMM Algorithm

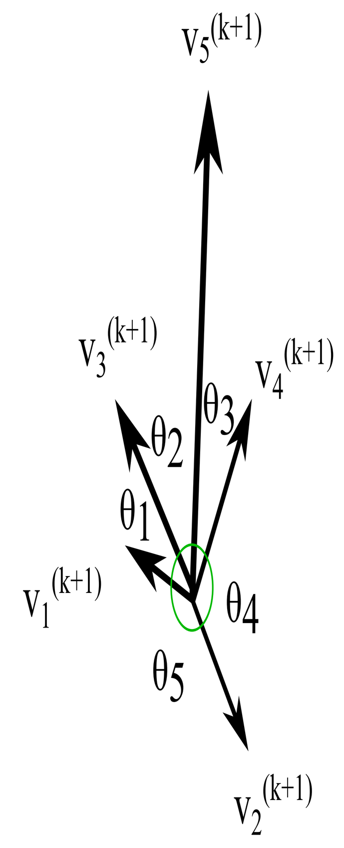
1: initialize $a_i^1, w_i^1, z^1, k = 1$
2: **while** $(\|z^{k+1} - z^k\| < \epsilon)$ **do**
3: **Areas:**
4: $a_i^{(k+1)} = (H_i^T H_i + \rho I)^{(-1)} (H_i^T C_i - w_i^k + \rho z^k)$
5: $w_i^{(k+1)} = w_i^k + \rho(a_i^{(k+1)} - z^{(k+1)})$
6: **Central PDC :**
7: $z^{(k+1)} = \frac{1}{N}(\sum_j a_j)$
8: $k++$
9: **end while**

Tolerance Step in Central PDC

- Computes $v_i^k = a_i^{k+1} - z^k$ and dissimilarity matrix M_{dis}:

$$M_{dis} = \begin{bmatrix} 0 & \theta_5 & \theta_1 & \theta_1+\theta_2+\theta_3 & \theta_1+\theta_2 \\ \theta_5 & 0 & \theta_4+\theta_2+\theta_3 & \theta_4 & \theta_4+\theta_3 \\ \theta_1 & \theta_4+\theta_2+\theta_3 & 0 & \theta_2+\theta_3 & \theta_2 \\ \theta_1+\theta_2+\theta_3 & \theta_4 & \theta_2+\theta_3 & 0 & \theta_3 \\ \theta_1+\theta_2 & \theta_4+\theta_3 & \theta_2 & \theta_3 & 0 \end{bmatrix} \quad (4)$$

- Add area with the most different v_i^k to the local memory.
- Removes the most repetitive area in local memory from z^{k+1} computation.



1	2	4	2	5	2	3

CONCLUSION

- We proposed a byzantine fault tolerant distributed mode estimation method based on S-ADMM [1].
- We evaluated our algorithm in presence of two intruders and different attack scenarios on 68-bus system.

FUTURE WORK

- Proposing a fully distributed attack tolerant tolerant mode estimation method and providing a formal analysis of our approach
- Applying machine learning methods to partition areas into non- faulty and faulty areas

REFERENCES

[1] Seyedbehzad Nabavi, Jianhua Zhang, and Aranya Chakrabortty. Distributed Optimization Algorithms for Wide-area Oscillation Monitoring in Power Systems Using Inter-regional PMU-PDC Architectures. *Smart Grid, IEEE Transactions on*, 6(5):2529–2538, 2015.

[2] Ermin Wei and Asuman Ozdaglar. On the O (1/k) Convergence of Asynchronous Distributed Alternating Direction Method of Multipliers. In *Global Conference on Signal and Information Processing (GlobalSIP), 2013 IEEE*, pages 551–554. IEEE, 2013.