Department of Electronics and Electrical Engineering

भारतीय प्रौद्योगिकी संस्थान- गुवाहाटी
Indian Institute of Technology
Guwahati, India

Detection and Elimination of Cyber Security Threats in Distribution System State Estimation

Name of Student: Dnyaneshwar Hanumant Patale, Roll No.: 214102103
Name of Supervisor: Dr. Sreenath J. G.

Abstract: *In this work, forecasting-aided state estimation(FASE) is implemented in power distribution systems utilizing various measurement devices. Measurement devices consist of micro-phasor measurement units(μPMU), remote terminal units(RTU), and smart meters(SM) which are taken into consideration separately.*

1. INTRODUCTION

- The electric power system has evolved over the past century to become one of the essential infrastructural systems. According to the operating conditions, a power system might be in one of three states: normal, emergency, or restorative. Utilizing specialized tools like load forecasting, state estimation, security assessment, and others, system operators continuously plan, monitor, analyze, and control the functioning of the power grid in order to keep it in a normal, secure state and meet consumer demands for dependable power as shown in the figure below.

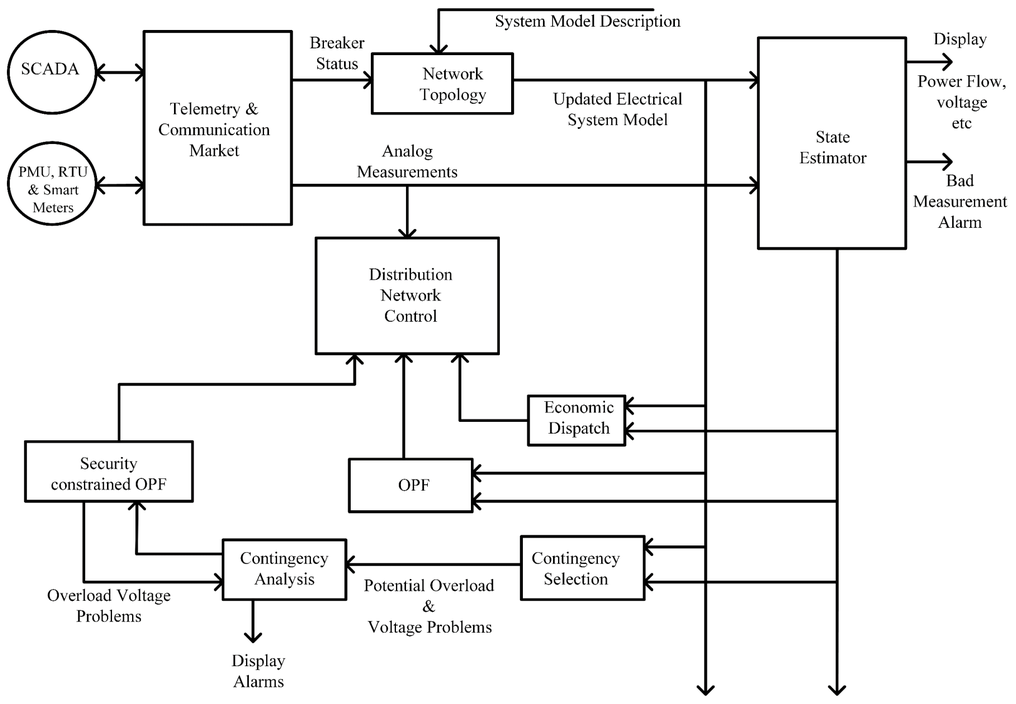

Figure 1: General block diagram for application of state estimation

2. MOTIVATION AND PROBLEM FORMULATION

- For continuous monitoring of the system, accurate state estimation of distribution systems with different distributed energy sources becomes more crucial. At the distribution system level μPMU, RTU, and SMs are used because more precise and synchronized measurements are required to execute the state estimation effectively.
- The various techniques employed in transmission system state estimation are not relevant to distribution system state estimation due to the system's unique properties. Distribution system state estimation considering the practical scenario

3. METHODOLOGY

- FASE is based on the Kalman filtering technique which is essentially a series of mathematical equations that implement a predictor-corrector type estimator that is optimal so that it minimizes the estimated error covariance

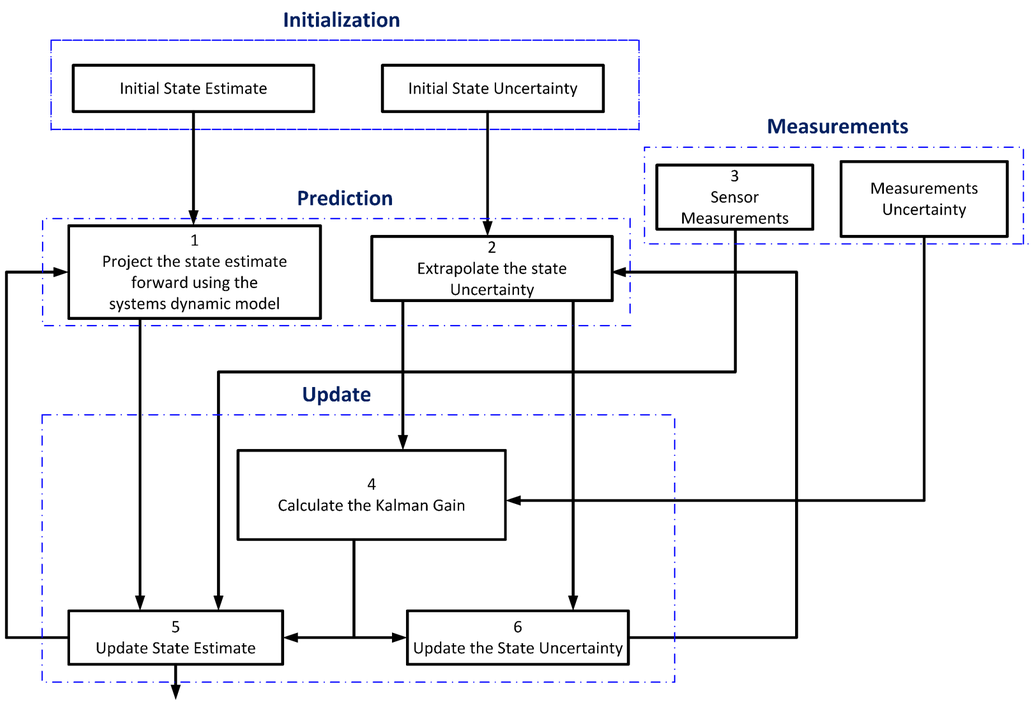

Figure 2: FASE algorithm

- Despite the initial predicted values being quite far from the true values and the measurement errors, the Kalman filter can estimate accurate values.

4. RESULTS AND DISCUSSIONS

- Measurements quantities for various devices are as follows
  - **μPMU**: Current and Voltage Phasors
  - **RTU**: Voltage Magnitude, Active and Reactive Power flow
  - **SM**: Active and Reactive Power Flow

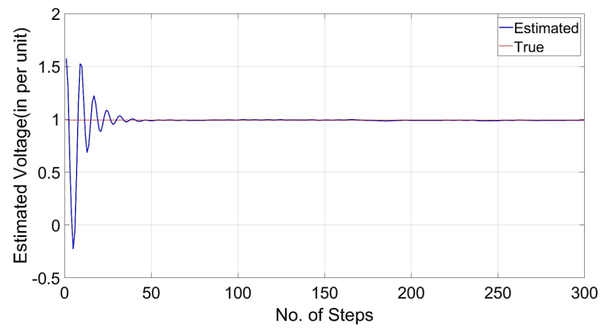

Figure 3: FASE tracking true value

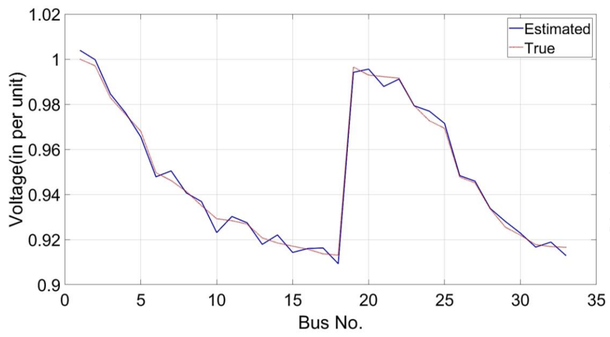

Figure 4 (a): Per unit voltage estimation with μPMU measurements

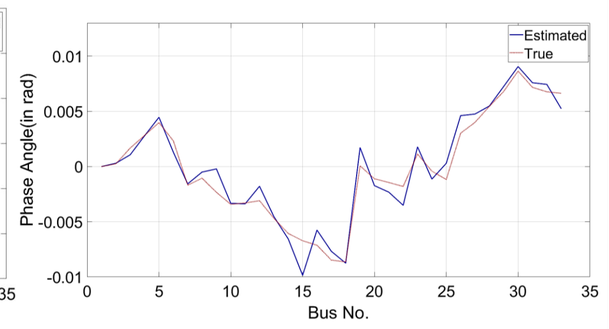

Figure 4 (b): Phase angle estimation with μPMU measurements

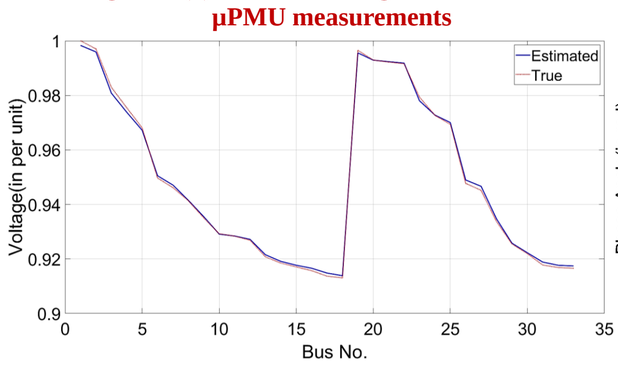

Figure 5 (a): Per unit voltage estimation with RTU measurements

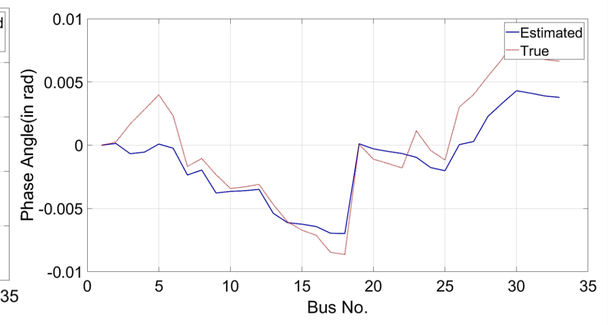

Figure 5 (b): Phase angle estimation with RTU measurements

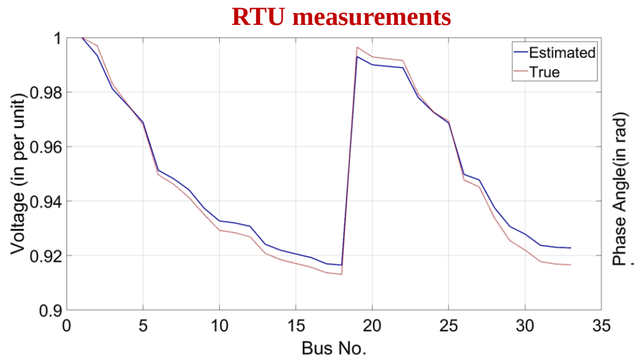

Figure 6 (a): Per unit voltage estimation with SM measurements

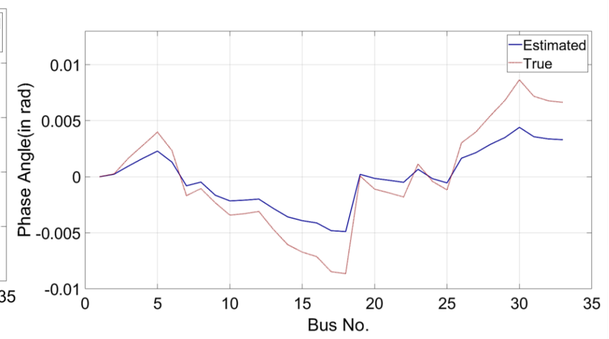

Figure 6 (b): Phase angle estimation with SM measurements

- For SM readings, voltage measurements are not present but the predicted value of the state can be taken as a voltage measurement and the same algorithm as that of RTU can be used.

5. FUTURE WORK

- All three measures must be taken together in the estimation algorithm to mimic this real-world system.
- Full observability does not imply a measurement device on every bus, hence the estimating technique needs to be enhanced to address this real-time condition.
- The viability of the approach should be verified against cyberattacks following the completion of FASE, which takes into account the majority of real-world situations

6. REFERENCES

- R. Dutta, S. J. Geetha, S. Chakrabarti, and A. Sharma, "An L-1 Regularized Forecasting-Aided State Estimator for Active Distribution Networks," in IEEE Transactions on Smart Grid, vol. 13, no. 1, pp. 191-201, Jan. 2022.
- M. Gol, "Incorporation of PMUs in Power System State Estimation," Northeastern University, 2014.
- M. Khan, M. Anees, and M. Rihan, "PMU and Smart Meters Assisted State Estimation in Distribution Grids," NTU Singapur, Feb. 2015.
- J. Zhao and L. Mili, "Robust Unscented Kalman Filter for Power System Dynamic State Estimation with Unknown Noise Statistics," IEEE Transactions on Smart Grid, vol. 10, no. 2, pp. 1215–1224, 2019.