



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 12, December 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.524

 9940 572 462

 6381 907 438

 ijirset@gmail.com

 www.ijirset.com

Effects of Unobservable Bus States on Detection and Localization of False Data Injection Attacks in Smart Grids

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ABSTRACT: The research is structured to first provide a comprehensive review of existing state estimation, detection, and localization models, emphasizing data-driven temporal analysis methods. It then delves into an in-depth experimental evaluation to assess how unobservability influences the accuracy and reliability of these models. The insights from these experiments are intended to inform utilities about the potential impacts of network unobservability on cyber-attack detection, contributing to a broader understanding that may support future PMU placement strategies.

The principal finding of this synopsis is the identification of a direct correlation between the number of unobservable buses and the efficiency of attack detection and localization performance. As the count of unobservable buses escalates, there is a noticeable decline in the performance of both state estimation and detection and localization models. Accordingly, this study proposes an estimated threshold for the number of PMUs required to maintain model effectiveness before a critical decline in performance occurs. Moreover, the research delineates that certain buses exert a more significant influence on detection and localization outcomes than others, suggesting that strategic placement of PMUs at these buses can enhance detection capabilities. Additionally, this thesis evaluates the efficacy of detection and localization models under various common PMU placement strategies, concluding that, despite an increase in system observability, these strategies may not optimally support attack detection. The impact of clustered unobservability on detection models is also explored, providing insights into how it affects model performance.

KEYWORDS: Phasor Measurement Unit (PMU), Smart Grid.

I. INTRODUCTION

The transition towards smart grids marks a significant paradigm shift in the evolution of power systems, driven by the need to address modern challenges such as energy efficiency, reliability, and the seamless integration of renewable resources. Smart grids epitomize an advanced infrastructure that elevates control and monitoring capabilities through sophisticated digital technology, resulting in substantial improvements over traditional grids. In stark contrast to the latter, which are limited by unidirectional communication and static management, smart grids are characterized by their dynamic bidirectional energy flows and the proactive engagement of consumers in both energy production and consumption. This transformative shift is essential for the effective incorporation of distributed energy resources, including renewables, thus enhancing the grid's resilience to outages and cyber-attacks. The intrinsic value of smart grids is amplified by their flexibility to accommodate diverse power source structures, significantly reducing the likelihood of widespread blackouts and augmenting the overall economic efficiency of power supply by curtailing costs, minimizing energy consumption, and decreasing emissions.

For instance, the smart grid encompasses a variety of components as illustrated in Figure 1.1. Moving beyond the traditional linear system of generation, transmission, and distribution to the end-user, the smart grid paradigm

introduces bidirectional power flow, integrating an array of Distributed Energy Resources (DERs), microgrids, and electric vehicles. It empowers utilities to monitor and manage the system with greater efficiency, thereby reducing energy waste and enhancing economic value through initiatives like demand response programs. This complex system is underpinned by a robust communication network, essential for coordinating the diverse elements within the smart grid architecture and ensuring optimal performance. Such a sophisticated communication system results in introducing new threats and challenges in smart grids [3].

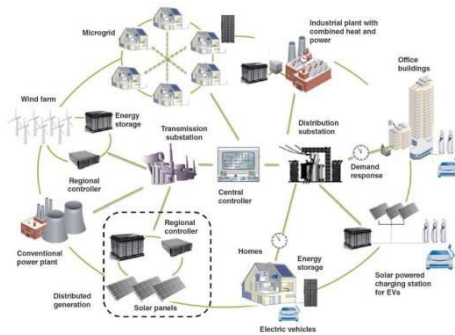


Figure 1.1 Smart grid components. From “Smart grid governance: An international review of evolving policy issues and innovations,” by M.A. Brown, S. Zhou, & M. Ahmadi, 2018, WIREs Energy and Environment, e290. Used with permission [3].

II. LITERATURE SURVEY

[1] Zhou, J., He, L., Li, C., Cao, Y., Liu, X., & Geng, Y. (2013). What's the difference between traditional power grid and smart grid? From dispatching perspective. Hunan University, Changsha, China. The development of smart grid requires higher renewable energy penetration as well as power supply reliability and economy. Traditional power grid dispatching cannot meet the demand. This paper analyzes the difference between smart grid dispatching and traditional power grid dispatching from several aspects, including bulk power grid dispatching, small and micro power grid dispatching, interruptible load management and supporting technology for power grid dispatching. This paper expects to make some contribution to a stable, secure, environmentally friendly and resource-saving power grid.

[2] Brown, M. A., Zhou, S., & Ahmadi, M. (2018). Smart grid governance: An international review of evolving policy issues and innovations. WIREs Energy and Environment, e290. The electric power systems of many industrialized nations are challenged by the need to accommodate distributed renewable generation, increasing demands of a digital society, growing threats to infrastructure security, and concerns over global climate disruption. The “smart grid”—with a two-way flow of electricity and information between utilities and consumers—can help address these challenges, but various financial, regulatory, and technical obstacles hinder its rapid deployment. An overview of experiences with smart grids policies in pioneering countries shows that many governments have designed interventions to overcome these barriers and to facilitate grid modernization. Smart grid policies include a new generation of regulations and finance models such as regulatory targets, requirements for data security and privacy, renewable energy credits, and various interconnection tariffs and utility subsidies.

[3] Kabalci, Y. (2016). A survey on smart metering and smart grid communication. Renewable and Sustainable Energy Reviews, 57, 302–318. The smart metering and communication methods used in smart grid are being extensively studied owing to widespread applications of smart grid. Although the monitoring and control processes are widely used in industrial systems, the energy management requirements at both service supplier and consumer side for individuals promoted the evolution of smart grid. In this paper, it is aimed to disclose in a clear and clean way that what smart grid is and what kind of communication methods are used. All components of a smart grid are introduced in a logical way to facilitate the understanding, and communication methods are presented regarding to their improvements, advantages, and lacking feature. The developing generation, transmission, distribution and customer appliances are surveyed in terms of smart grid integration. The communication technologies are introduced as wireline and wireless classification where the key features are also tabulated. The security requirements of hardware and software in a smart grid are presented according to their cyber and physical structures.

[4] Ahmed, M. M., Amjad, M., Qureshi, M. A., Imran, K., Haider, Z. M., & Khan, M. O. (2022). A Critical Review of State-of-the-Art Optimal PMU Placement Techniques. *Energies*, 15(6), 2125. <https://doi.org/10.3390/en15062125>. Phasor measurement unit (PMU) technology is a need of the power system due to its better resolution than conventional estimation devices used for wide-area monitoring. PMUs can provide synchronized phasor and magnitude of voltage and current measurements for state estimation of the power system to prevent blackouts. The drawbacks of a PMU are the high cost of the device and its installation. The main aspect of using PMUs in electrical networks is the property to observe the adjacent buses, thereby making it possible to observe the system with fewer PMUs than the number of buses through their optimal placement. In the last two decades, exhaustive research has been done on this issue. Considering the importance of this field, a comprehensive review of the progress achieved until now is carried out and the limitations of existing reviews in the literature are highlighted. This paper can be seen as a major attempt to provide an up-to-date review of the research work carried out in this all-important field of PMU placement and indicates that some perspectives of optimal PMU placement still need attention. Eventually, the work will open a new standpoint for the research community to fill the research gap.

III. METHODOLOGY

To explore the influence of unobservability on detection models, various detection models were developed, adapting and modifying architectures from the literature to suit our specific problem. This thesis evaluates both supervised and unsupervised detection models, aiming to identify the most effective approach; nevertheless, both models will be used when conducting the unobservability experiments to study the commonalities and differences between the two different approaches.

First, start by developing various models under the unsupervised model category. These models can be divided into 2 categories:

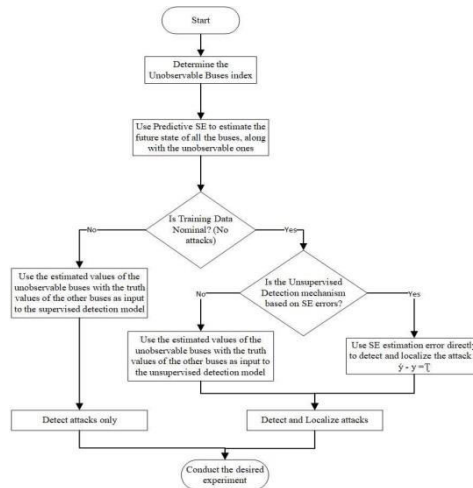
- State Estimation-Based Models: These include LSTM, GRU, Stacked LSTM, Stacked GRU, and Hybrid Stacked models.
- Non-State Estimation-Based Models: This category comprises LSTM-Autoencoders and LSTM-OCSVM models.

Chapter 5 will delve into the intricacies of these models. It is noteworthy that state estimation-based models possess a distinct advantage over their non-state estimation counterparts, as they can function in scenarios with unobservable buses by estimating their readings. In contrast, non-state estimation-based models require full observability, necessitating a preliminary state estimation to approximate the readings of unobservable buses before data input into the detection model.

Following the development of unsupervised models, our attention shifted towards creating supervised models, including Stacked LSTM, Stacked GRU, BiDirectional LSTM (BiLSTM)- based, and CNN-LSTM models. Like the unsupervised non-state estimation models, these too are limited by the need for full observability, thereby requiring SE before data input.

The state estimation models, initially paired with unsupervised state estimation-based models, are now solely tasked with estimating the state of unobservable buses. These estimated states, combined with the actual values for the observed buses, feed into the detection models.

Figure 3.1 illustrates the process flow in this mechanism. The process starts with the application of state estimation, utilizing the most effective model, which will be detailed in Chapter 4. The next step involves determining whether the training data are nominal (no attacks) or anomalous, meaning they contain cyberattacks. If the training data are found to be nominal, unsupervised learning models are used for further analysis. In the case that these unsupervised models are based on state estimation, an attack is indicated if the prediction error exceeds a specific threshold (τ). For models that do not use state estimation, attack detection hinges on whether the reconstruction error from LSTM-AE or the output from LSTM-OCSVM surpasses the threshold.



IV. CONCLUSION

It was demonstrated through many experiments with different parameters that the number of unobservable buses affects the detection and localization of the attacks. The work presented can give insights to the utilities on the minimum number of PMU units that must be installed in order to ensure system security and reliability. Moreover, through comprehensive experimentation, it was demonstrated that not all buses and regions within the grid hold equal significance in terms of maintaining system security. Specific buses and regions were identified as crucial nodes whose observability significantly influences the grid's ability to detect and localize attacks effectively..

REFERENCES

- Hossain, E., Khan, I., Un-Noor, F., Sikander, S. S., & Mudasser, M. (2014). A review of smart technology: Smart Grid and its features. Proceedings of 2014 1st International Conference on Non-Conventional Energy (ICONCE 2014), Kalyani, WB, India. IEEE.
- Zhou, J., He, L., Li, C., Cao, Y., Liu, X., & Geng, Y. (2013). What's the difference between traditional power grid and smart grid? From dispatching perspective. Hunan University, Changsha, China.
- Brown, M. A., Zhou, S., & Ahmadi, M. (2018). Smart grid governance: An international review of evolving policy issues and innovations. WIREs Energy and Environment, e290.
- Kabalci, Y. (2016). A survey on smart metering and smart grid communication. Renewable and Sustainable Energy Reviews, 57, 302–318.
- Ahmed, M. M., Amjad, M., Qureshi, M. A., Imran, K., Haider, Z. M., & Khan, M. O. (2022). A Critical Review of State-of-the-Art Optimal PMU Placement Techniques. Energies, 15(6), 2125. <https://doi.org/10.3390/en15062125>.
- Yang, Z., Liu, H., Bi, T., Li, Z., & Yang, Q. (2020). An adaptive PMU missing data recovery method. International Journal of Electrical Power & Energy Systems, 116, 105577. <https://doi.org/10.1016/j.ijepes.2019.105577>.
- Hossain, M. J., & Rahnamay-Naeini, M. (2021). Data-driven, multi-region distributed state estimation for smart grids. In 2021 IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe) (pp. 1–6).
- Hyacinth, L. R., & Gomathi, V. (2021). Optimal PMU Placement Technique to Maximize Measurement Redundancy Based on Closed Neighbourhood Search. Energies, 14(16), 4782. <https://doi.org/10.3390/en14164782>.
- Yuill, W., Edwards, A., Chowdhury, S., & Chowdhury, S. P. (2011). Optimal PMU placement: A comprehensive literature review. In 2011 IEEE Power and Energy Society General Meeting. IEEE.
- Hossain, M. J. (2022). Data-Driven State Estimation for Improved Wide Area Situational Awareness in Smart Grids. USF Tampa Graduate Theses and Dissertations. Retrieved from <https://digitalcommons.usf.edu/etd/9783>.
- Dehghanpour, K., Wang, Z., Wang, J., Yuan, Y., & Bu, F. (2019). A Survey on State Estimation Techniques and Challenges in Smart Distribution Systems. IEEE Transactions on Smart Grid, 10(2), 2312.
- Primadianto, A., & Lu, C.-N. (2017). A Review on Distribution System State Estimation. IEEE Transactions on Power Systems, 32(5), 3875.



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