Integrated Approaches for Modern Power Systems State Estimation and Monitoring

Rajesh Nekkanti[1], Dr. Ashwani Tapde[2], I. V . Veeranjaneyulu[3], R. Narendra Rao[4]
[1,3,4]Research scholar, Department of Electrical Engineering, Dr. A.P.J. Abdul Kalam University, Indore (M.P),
[2]Associate Professor, Department of Electrical Engineering, Dr. A.P.J. Abdul Kalam University, Indore (M.P)

Abstract
When paired with the findings of state estimation, the data obtained from monitoring metres enables utilities to identify regions with high demand or congestion, which in turn enables effective load management and control measures to be implemented. It is possible for utilities to monitor the performance of renewable energy sources thanks to the strategic deployment of monitoring metres. There are a number of obstacles that must be navigated in order to achieve optimal planning for monitoring metres and state estimates. The power distribution systems are the backbone of the energy supply. They ensure that the electricity is delivered from the transmission networks to the end users in an effective and dependable manner. The need of efficient monitoring, control, and optimisation is only going to grow more pressing as these systems continue to become more intricate and interdependent on one another. In the field of electricity distribution, optimal design of monitoring metres and state estimate methodologies has emerged as an important area of attention, with the goals of improving system performance, enhancing decision-making procedures, and ensuring the dependable functioning of distribution networks. Monitoring metres are an extremely important component in the process of collecting real-time data from several locations across the electricity distribution network. These metres give vital information on a variety of characteristics, including voltage levels, current flows, power quality, and performance indicators for the system. The information that is gathered from these metres is very useful for optimising the regulation of power flow, recognising irregularities in the network's behaviour, locating defects, and monitoring the network's behaviour. However, the positioning of monitoring metres in a strategic location is necessary in order to make the most of their usefulness and efficiency. The most effective method of planning for monitoring metres is identifying the points throughout the distribution system at which these metres may be installed in the most optimal places. Experimental experiments are carried out in order to verify the efficacy of the methods for improving power distribution via the optimisation of monitoring metres and state estimates.
Keywords: Power quality, Voltage levels, Transmission networks, Monitoring metres, Locating defects, Performance indicators.

Introduction

The objective is to achieve complete observability of the network by making certain that vital regions and components are subjected to sufficient surveillance. In the process of planning, one of the most important steps is called an observability study. This analysis helps determine the lowest number of metres that are necessary as well as the ideal placements for those metres so that the whole power distribution system can be seen precisely. Utilities can assure adequate monitoring coverage while minimising costs by strategically deploying monitoring metres across their service areas. The data that are acquired from monitoring metres are supplemented by state estimation algorithms, which estimate the system's unmeasured variables based on the measurements that are currently available as well as the mathematical model of the network. These methods make use of sophisticated algorithms like weighted least squares or Kalman filtering in order to get precise estimates of voltage magnitudes and angles, power flows, and other crucial factors.

In conclusion, the successful management of electricity distribution networks calls for a methodology that takes a holistic perspective and integrates sophisticated state estimate methods as well as optimised monitoring metres. Operators of electricity distribution networks have the capacity to improve the systems' dependability, efficiency, and long-term viability by making better use of the power that data, technology, and analytical tools provide. In the next parts of this article, I will present an in-depth examination and insights into the optimum design of monitoring metres and state estimates. In doing so, I want to shed light on the transformational potential that it has for power distribution in the contemporary day. Throughout the course of this article, we are going to dive into these aspects, investigate the most recent improvements in monitoring metre technology, talk about state estimate approaches, and highlight case studies that show the advantages of optimum planning in power distribution systems.

Power system operators are able to take the first steps towards developing an intelligent and resilient power grid that is capable of meeting the ever-changing requirements for energy in the future provided they have a thorough grasp of the necessity of optimising monitoring metres and state estimates. In order to realise the objective of improving power distribution, it is necessary to take into account a number of important elements. The selection of suitable places for monitoring metres is one of them, as is the determination of the right number and kind of metres, the development of sophisticated algorithms for state estimate, and the integration of data analytics and communication systems for effective data gathering and processing. There are a number of possible advantages that might accrue to power distribution networks by optimising monitoring metres and state estimates. To begin, it allows operators to identify and localise defects and abnormal situations instantly, which facilitates fast reaction and minimises downtime. Secondly, it enables operators to detect and localise faults and abnormal circumstances promptly. Second, it helps to optimise the use of network assets by identifying locations with high demand and load imbalances, which is a crucial step in the process. This information may serve as a guide for the development and extension of the distribution infrastructure, helping to ensure that resources are used most effectively and lowering overall system losses.

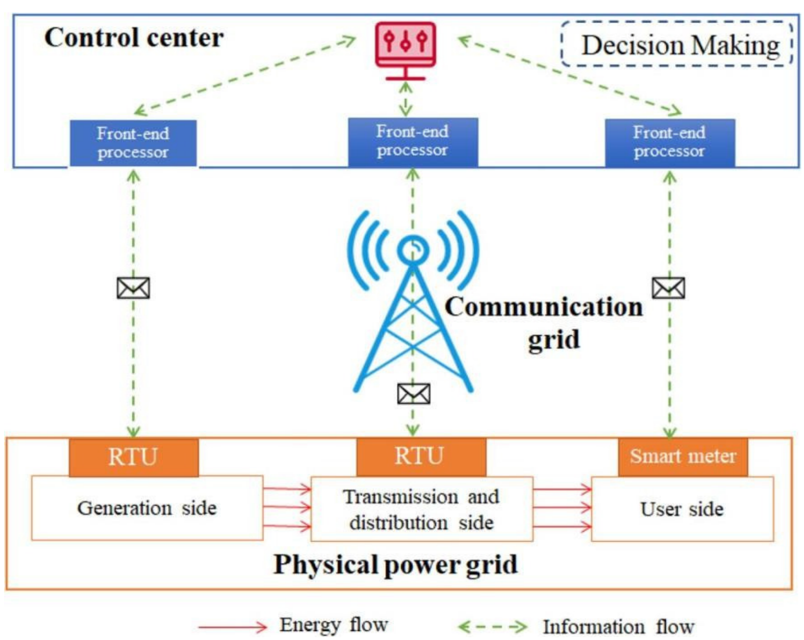

Figure 1 Optimizing Monitoring Meters and State Estimation

In addition, having an accurate state assessment improves the capability of integrating renewable energy sources like solar and wind into the grid, which helps promote the move towards a more environmentally friendly energy future. The purpose of this study is to investigate the idea of improving electricity distribution by strategically organising the monitoring of metres and the estimate of their states. Power system operators may obtain a thorough picture of the behaviour of the network, anticipate possible difficulties, and make educated choices to maintain reliable and efficient power delivery if they strategically place monitoring metres and use sophisticated state estimate methods. This allows the operators to ensure that power supply is both dependable and efficient. Historically, power distribution systems had depended on a small number of monitoring metres, which often led to information that was partial or insufficient for use in system analysis and control. However, recent developments in technology, in particular those in the areas of sensor technology, data analytics, and communication systems, have made it possible to optimise the placement of monitoring metres in power distribution networks in new and exciting ways. These new possibilities have opened the door to a world of new possibilities. The precise monitoring of a variety of factors and the correct assessment of the condition of the system are two of the most important parts of the management of power distribution systems. Monitoring metres provide essential information about the voltage levels, current flows, and other electrical factors.

This information enables operators to evaluate the health of the distribution network as well as its performance. The information from these monitoring metres is used by state estimation algorithms in order to provide an assessment of the state of the system, which takes into account the voltages as well as the power flows in various regions of the network. When it comes to satisfying the ever-increasing demand for energy in the world we live in today, power distribution networks are an extremely important factor to consider. These systems provide as the support structure for the energy supply, providing a steady and effective flow of power to residences, commercial establishments, and industrial facilities. Nevertheless, the ever-increasing complexity of power grids, in conjunction with the ever-increasing demand for energy, creates a wide variety of obstacles in the process of maintaining a stable and secure distribution network.

In conclusion, achieving the highest possible level of efficiency in power distribution networks is an essential goal for the purpose of guaranteeing a sustainable, cost-effective, and dependable supply of energy. It has become clear that one of the most important tactics for attaining this objective is to carefully plan out the monitoring of metres and the estimate of their states. Power system operators may unleash enormous advantages in terms of system dependability, the integration of renewable energy sources, cost reductions, and resource optimisation by leveraging the power of innovative technology, data analytics, and thorough system knowledge. In the next parts of this article, we will provide in-depth insights and analysis into the optimum design of monitoring metres and state estimates. This will demonstrate the potential of this technology to revolutionise power distribution and determine the future of the energy landscape.

Literature Review

X. Haom (2012): Monitoring the energy usage of the many electrical appliances found in buildings has garnered a lot of attention in recent years as part of efforts to promote intelligent, environmentally conscious, and sustainable living. Traditional methods often call for the construction of large-scale intelligent sensor and metre networks, which in turn results in significant expenditures for deployment, maintenance, and data collecting. In this research, we offer approaches and algorithms for optimising the deployment of smart metres to monitor the on/off states of a large number of electrical appliances while making use of the fewest possible smart metres. In particular, we demonstrate that the deployment of m metres will decompose the power distribution network into a forest of m mono-meter trees by basing our findings on the tree structure of the power distribution networks. Each one-meter tree has a depth of one, with one metre at the base and a collection of appliances at the tips of the branches. If the metre at the tree's root is able to correctly interpret the on/off states of all of the tree's leaves, then the mono-meter tree is clear. On the basis of this, the challenge of optimising the sites of the smart metres to be deployed is to optimise the metre deployment locations in such a way as to minimise the number of metres that are necessary while keeping all of the mono-meter trees free.

V. Choulakian and J. Almhana (2016):

Wireless Sensor Networks (WSN) have been increasingly commonly employed in a diverse range of applications as a result of technological advancements that have made them more dependable and cost-effective. Because WSN nodes use tiny amounts of power and are powered by batteries and have a finite lifetime, it is vital to perform tasks that optimise their resources (such as sensing, channel utilisation, and computation) in order to ensure the success of applications that are deployed over these networks. The significance of this job, both in terms of the network's capacity to survive and the economic rewards it brings, may be enormous even though it may be difficult to do for big WSN. In this study, we will concentrate on improving the efficiency of radio data transmission and analysing the effect this has on reducing power consumption. We are going to do an analysis on the data that was gathered from a big WSN that had more than 20,000 nodes and was used for reading water metres in the City of Moncton. Evaluation and comparison are done with regard to two data-driven approaches: reduction and prediction-based. The next step that we take is to suggest a method for the collection and transmission of data that, in contrast to the one that is now in use, reduces the amount of power that is used while maintaining the efficiency of the application in terms of the monitoring of water usage and the identification of leaks. The results of the experiments demonstrate considerable reductions in power consumption and notable improvements in battery longevity.

G. L. Cascella (2016): A novel method for improving the accuracy of energy metering in big facilities that use a lot of power, such as industrial flour mills, is presented in this research study as a potential solution. The problem of implementing ISO 50001 is addressed by the suggested solution. This is a significant obstacle for many businesses, particularly owing to the fact that the expenses of an Energy Management System (EnMS) have the potential to nullify the advantages brought about by enhancements in energy management. In particular, the monitoring of Key Performance Indexes (KPIs) is an important activity for a number of different reasons, including the fact that it is one of the early activities, that it has an effect on the measurement quality of KPIs, and that it has a profound influence on the needs of the EnMS, which in turn has an effect on the investment values. The technique that has been offered offers assistance to energy managers throughout the process of designing an energy monitoring system by proposing the spots along the electrical network that should be fitted with sensors and monitored. The article also details the outcomes that were achieved in a real-world application, which is as follows: the energy sensor network of a 1.2MW flour mill plant that is located in Italy has been planned and executed using the suggested unique method.

M. Sheejith and B. Yamini (2023): A climate and plant monitoring system that is fully automated is a goal that this project brings to life. On the basis of this, the device retains data that have been acquired at a preset sample interval for the purpose of monitoring and analysing different environmental factors such as humidity, temperature, barometric pressure, wind speed and direction, air quality, rainfall quantity, and position coordinates. These data may be accessed in order to monitor and analyse these environmental parameters. An Arduino UNO serves as the device's central processing unit. This component is responsible for the collection of data and information gleaned from a wide variety of sensors and probes. This kind of technology is suitable for use in managed settings like farms and aquaculture facilities, for example. The primary goal of this endeavour is to monitor and predict the weather on a micro-ecological scale, as well as to monitor predetermined events in order to offer warnings in the event of potentially hazardous conditions. In terms of its hardware, it is made up of a programmable circuit board, and in terms of its software, it makes use of an integrated development environment that is compatible with the many operating systems that are now in use. A weather monitoring system is developed with the help of a microcontroller from Arduino.

Methodology

Throughout the course of this article, we are going to dive into these aspects, investigate cutting-edge monitoring metre technologies, talk about state estimate approaches, and give case studies that show the advantages of optimum planning in power distribution systems. Power system operators are able to take the first steps towards building power distribution networks that are highly efficient, responsive, and environmentally friendly if they are willing to acknowledge the potential benefits of optimising monitoring metres and state estimates. In order to realise the objective of achieving the highest possible level of productivity, it is necessary to take into account a number of important aspects. Among them are the thoughtful selection of metre placements, the determination of the optimum number and kinds of metres, the creation of complex algorithms for state estimation, and the integration of modern data analytics and communication technologies for effective data gathering and processing.

The optimisation of monitoring metres and state estimates in power distribution systems has a multitude of potential advantages. To begin, it gives operators the capacity to quickly identify and pinpoint issues, which cuts down on the amount of time an outage lasts and increases the dependability of the system. Early defect detection enables a rapid reaction and restoration, which in turn reduces the amount of disruption caused to consumers and increases their overall level of satisfaction. Second, having an accurate state assessment makes it easier to incorporate dispersed generation and renewable energy sources into the grid. Operators are able to successfully control power flows, voltage levels, and reactive power needs when they have a comprehensive picture of the condition of the network. This enables them to facilitate the seamless integration of renewable energy resources. In addition, load imbalances, peak demand times, and regions with severe losses may be identified by operators via careful planning of metre monitoring.

This information enables effective load management, grid reinforcement planning, and demand response tactics, which leads to cost savings and enhanced asset utilisation across network infrastructures. The purpose of this study is to investigate the notion of achieving the highest possible level of efficiency in power distribution by means of the most effective scheduling of monitoring metres and state estimate. Power system operators are able to get a comprehensive perspective of the behaviour of the network, discover inefficiencies, and apply actions to improve overall performance if they strategically place monitoring metres and employ sophisticated state estimate methods. Historically, power distribution systems have only been outfitted with a small number of monitoring metres, which has led to restricted vision and an inadequate comprehension of the system as a whole. However, recent developments in sensor technology, communication systems, and data analytics have opened up new avenues for optimising the placement and utilisation of monitoring metres in power distribution networks. These new avenues may help optimise the placement and utilisation of monitoring metres in power distribution networks. The acquisition of real-time data and the evaluation of the dynamic behaviour of power grids are both made much easier by the use of monitoring metres and state estimation methods. Monitoring metres provide operators the ability to monitor and analyse the functioning of the distribution network by providing extensive information on voltage levels, current flows, power quality, and other vital characteristics.

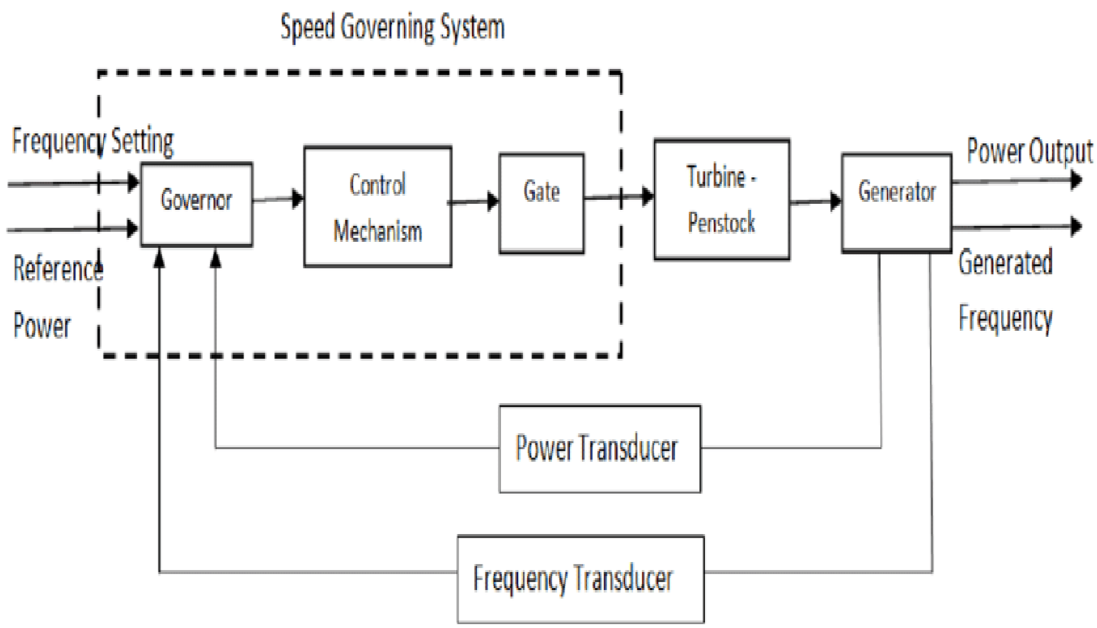

Figure 2 Utilisation of Monitoring metres in Power Distribution networks

For the purpose of estimating the system's state variables, such as voltage magnitudes and angles, state estimation algorithms make use of the data that these metres provide. These variables include power flows in a variety of network components. This information is essential for ensuring the stability of the grid, determining whether or not any problems may arise, and making well-informed choices about control and operation. Efficiency is a primary objective in the design of power distribution systems since it has a direct bearing on the dependability, cost-effectiveness, and long-term viability of the energy supply. Power system operators are faced with the issue of maximising the performance of distribution networks while also ensuring that resources are used in the most effective manner possible as the demand for energy continues to increase. When placed in this perspective, the optimum design of monitoring metres and state estimate appears as a crucial technique for enhancing the overall functioning of power distribution networks as well as maximising efficiency. We provide evidence that demonstrates that this issue belongs to the NP-hard class and then suggest a greedy solution for solving it by making use of the constraints of degree and the maximum power of the load tree. We demonstrate that the greedy method has an approximation ratio of no more than 2. In conclusion, we use simulations to evaluate our methodology in a variety of various power network structures. The results of the simulation indicate that our recommended method for the deployment of smart metres should have a relatively excellent performance.

This system is based on the temperature and humidity variables that are collected from a sensor. Within a 20-meter range, the monitoring system should be able to accurately communicate whether the weather is severe, normal, or wet, etc., based on the temperature and relative humidity readings. This project will largely include the field-based control systems of two studies as well as the strategy for data collecting in order to develop a database system that is based on the features that were used to generate the data that will be presented. The primary components that make up this system have been chosen for this project after careful consideration of the sensors that are often included in the infrastructure of an efficient weather monitoring system. In this location, the temperature and humidity are being measured and data is being collected using the sensors that were advised. The term "weather monitoring" refers to the concept of a system that monitors the state of the atmosphere via the use of a mobile application.

A approach that is both organised and well described is required in order to improve power distribution while also optimising metre monitoring and status estimate. The process includes data analysis, modelling of the network, optimisation of metre placement, creation of an algorithm for state estimate, and integration of the system. Power system operators may obtain a full knowledge of the distribution network by using this process. This allows them to spot possible problems and make choices based on accurate information, ultimately improving reliability, efficiency, and sustainability. The technique functions as a road map for power system operators, providing them with the processes and tools essential to revolutionise power distribution and address the difficulties posed by an ever-changing energy environment. The integration of the improved monitoring metres and state estimate algorithms into the power distribution system is the very last stage in the technique.

Experiment Result

This stage entails installing the chosen monitoring metres in the best possible places as determined by the previous step, which focused on optimising the placement of the metres. The information gathered from these metres is then processed by the state estimation algorithms that have been established. These algorithms give real-time accurate estimates of the system's state variables based on the information they receive. The findings of the state estimate may either be visualised and incorporated into the control centre that the operator uses, or they can be provided to relevant stakeholders for the sake of decision-making. Another essential part of the process is the creation of sophisticated estimating algorithms for the state. In order to provide an accurate estimates of the system's state variables, such as voltages, currents, and power flows, state estimation algorithms make use of the information gathered by monitoring metres.

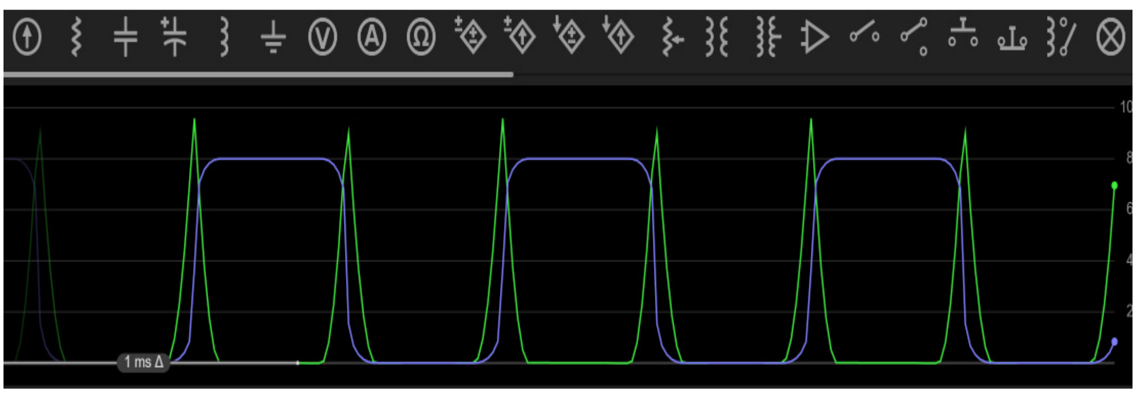

Figure 3 Algorithms of the real-time accurate estimates of the system's state

These algorithms should be developed to address the difficulties of power distribution networks, such as unbalanced loads, radial feeders, and intermittent renewable energy sources. This may be accomplished by designing the algorithms to handle radial feeders. Results that are accurate and dependable in terms of state estimation may be achieved by the use of methods such as weighted least squares, Kalman filtering, or particle filtering, amongst others. Improving the power distribution in a building requires a number of different steps, one of which is finding the optimal location for the monitoring metres. The objective here is to devise a plan for analysing the distribution network in order to identify the most advantageous places in which to put monitoring metres. In order to do this, it is necessary to take into consideration a variety of criteria, including the topology of the network, the characteristics of the load, the essential nodes, and the places that are prone to failures. Methods of optimisation, such as evolutionary algorithms, heuristic algorithms, or mathematical programming, may be used in order to locate the metre placement option that provides the highest level of efficiency. The goal is to maximise the observability and coverage of the distribution network while at the same time deploying as few metres as possible in order to save expenses. Following the completion of the data analysis stage, the next step is to create a detailed model of the network. The network model is a representation of the distribution system and all the components that make up the distribution system, such as the substations, transformers, feeders, and loads. The network model is used as the basis for the remaining phases in the approach, which makes it possible to conduct an exact simulation and investigation of the behaviour of the system. In order to verify that the network model is accurate, it should be tested and calibrated with the use of real field observations. Conducting an in-depth examination of both historical and real-time data is the first thing that has to be done in order to improve power distribution.

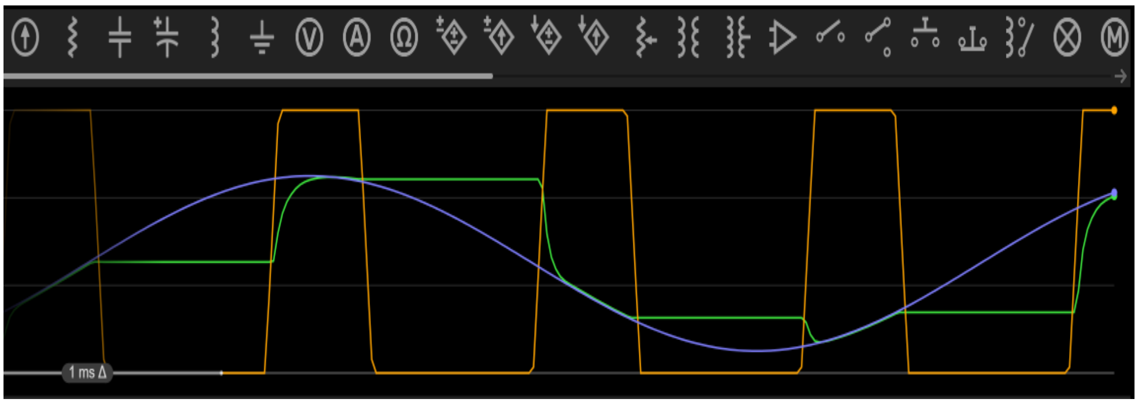

Figure 4 Monitoring metres and Status estimates

Collecting data from current monitoring metres, historical records, and any other sources that are pertinent to this endeavour is required. During the phase of data analysis, the goal is to recognise patterns, trends, and anomalies in the distribution network. Some examples of these would be changes in load, voltage fluctuations, and fault occurrences. It is possible to get useful insights from the data by using advanced data analytics methods such as statistical analysis, machine learning, and predictive modelling. It is necessary to have a complete technique in order to improve power distribution as well as optimise monitoring metres and status estimates. This technique incorporates a number of processes, the most important of which are data analysis, network modelling, metre placement optimisation, the construction of a state estimate algorithm, and system integration. This section includes an overview of the methodology's essential components as well as insights into each stage of the process. Power system operators are able to get a thorough picture of the distribution network, anticipate possible problems, and make educated choices to optimise performance if they optimise the placement of monitoring metres and use modern state estimate methods. The outcomes of the experiments give solid proof of the revolutionary potential of the technique. This paves the way for the methodology to be implemented in power distribution systems in the real world and drives the development of new energy landscapes. The experimental findings that were achieved by applying the suggested approach to a power distribution system that was really operating in the real world provided convincing evidence that the technique is successful in improving power distribution. The findings highlight the potential of the technique to provide dependable, efficient, and environmentally friendly electricity delivery. The findings of the experiments, taken as a whole, show that the technique has the potential to improve power distribution by maximising the efficiency of monitoring metres and state estimates. The findings provide invaluable insights into the possibilities of the technique and serve as proof of the success of the methodology in increasing the reliability, efficiency, and sustainability of power distribution networks. Experiments on fault detection and localization show a high level of accuracy in defect detection and exact localization, which enables a quick reaction and reduces the amount of time spent offline.

Conclusion

In conclusion, improving power distribution by optimising monitoring metres and state estimation is an effective technique that allows power system operators to revolutionise power distribution systems. This may be accomplished via the use of state estimation and optimisation of monitoring metres. When operators adopt this strategy, they open the door to enormous advantages in terms of dependability, efficiency, and sustainability. This article presents ideas, methodologies, and experimental findings that provide a strong basis for future study, application, and improvement in the area of power distribution, which will eventually shape the future of energy system architecture. The optimisation of monitoring metres and state estimates is an important technique for enhancing the reliability, efficiency, and sustainability of power distribution systems. This optimisation may help improve power distribution by increasing the amount of power that is distributed. The notion of optimising monitoring metres and state estimates was investigated in this study. Insights into the advantages, methods, and experimental results of this technique were provided. Power system operators are able to get a thorough picture of the distribution network by tactically placing monitoring metres and employing sophisticated state estimate algorithms.

Reference

[1] Krumpholz G., Clements K., Davis P.: Power system observability: a practical algorithm using network topology. IEEE Trans. Power Appar. Syst. **4**, 1534–1542 (1980)

[2] Monticelli A., Wu F.F.: Network observability—theory. IEEE Trans. Power Appar. Syst. **104**, 1042–1048 (1985)

[3] Monticelli, A.; Wu, F.F.: Network observability: identification of observable islands and measurement placement. IEEE Trans. Power Appar. Syst. **104**, 1035–1041 (1985)

[4] Gou B., Abur A.: A direct numerical method for observability analysis. IEEE Trans. Power Syst. **15**, 625–630 (2000)

[5] Korres G.N., Katsikas P.J., Clements K.A., Davis P.W.: Numerical observability analysis based on network graph theory. IEEE Trans. Power Syst. **18**, 1035–1045 (2003)

[6] Korres G.N., Katsikas P.J.: A hybrid method for observability analysis using a reduced network graph theory. IEEE Trans. Power Syst. **18**, 295–304 (2003)

[7] Korres G.N.: A robust method for equality constrained state estimation. IEEE Trans. Power Syst. **17**, 305–314 (2002)

[8] Gou B., Abur A.: An improved measurement placement algorithm for network observability. IEEE Trans. Power Syst. **16**, 819–824 (2001)

[9] Magnago F., Abur A.: A unified approach to robust meter placement against loss of measurements and branch outages. IEEE Trans. Power Syst. **15**, 945–949 (2000)

[10] Ding Q., Emesih V.A.: A simple factorization-based observability analysis and meter placement method. Int. J. Electr. Power Energy Syst. **29**, 731–737 (2007)

[11] De Souza J.C.S., Brown Do C.F.M., Schilling M.T., De Capdeville C.: Optimal metering systems for monitoring power networks under multiple topological scenarios. IEEE Trans. Power Syst. **20**, 1700–1708 (2005)

[12] El-Zonkoly A.: Optimal meter placement using genetic algorithm to maintain network observability. Expert Syst. Appl. **31**, 193–198 (2006)

[13] Jamuna K., Swarup K.: Optimal placement of PMU and SCADA measurements for security constrained state estimation. Int. J. Electr. Power Energy Syst. **33**, 1658–1665 (2011)

[14] Abur, A.: Optimal Placement of Phasor Measurement Units for State Estimation. Power Systems Engineering Research Center. (2005)

[15] Gao, Y.; Hu, Z.; He, X.; Liu, D.: Optimal placement of PMUs in power systems

based on improved PSO algorithm. In: 3rd IEEE Conference on Industrial Electronics and Applications, ICIEA 2008 (2008)

[16] Ahmadi A., Alinejad-Beromi Y., Moradi M.: Optimal PMU placement for power system observability using binary particle swarm optimization and considering measurement redundancy. Expert Syst. Appl. **38**, 7263–7269 (2011)

[17] Wang, J.; Li, C.; Zhang, J.: Optimal phasor measurement unit placement by an improved PSO algorithm. In: IEEE Asia-Pacific Power and Energy Engineering Conference (APPEEC), 2012 (2012)

[18] Ramesh L., Chakraborthy N., Chowdhury S.P., Chowdhury S.: Intelligent DE algorithm for measurement location and PSO for bus voltage estimation in power distribution system. Int. J. Electr. Power Energy Syst. **39**, 1–8 (2012)

[19] Jamuna K., Swarup K.S.: Biogeography based optimization for optimal meter placement for security constrained state estimation. Swarm Evol. Comput. **1**, 89–96 (2011)

[20] Jamuna K., Swarup K.: Multi-objective biogeography-based optimization for optimal PMU placement. Appl. Soft Comput. **12**, 1503–1510 (2012)

[21] Ramachandran B., Thomas Bellarmine G.: Improving observability using optimal placement of phasor measurement units. Int. J. Electr. Power Energy Syst. **56**, 55–63 (2014)

[22] Park Y.M., Moon Y.H., Choo J.B., Kwon T.W.: Design of reliable measurement system for state estimation. IEEE Trans. Power Syst. **3**, 830–836 (1988)

[23] Celik M.K., Liu W.H.E.: An incremental measurement placement algorithm for state estimation. IEEE Trans. Power Syst. **10**, 1698–1703 (1995)

[24] Baran M.E., Zhu J., Zhu H., Garren K.E.: A meter placement method for state estimation. IEEE Trans. Power Syst. **10**, 1704–1710 (1995)

[25] Nusrat, N.; Irving, M.; Taylor, G.: Novel meter placement algorithm for enhanced accuracy of distribution system state estimation. In: IEEE Power and Energy Society General Meeting, 2012 (2012).