Fault Detection and Notification Systems for Renewable Energy Remote Monitoring: A Case Study on The Future of Alert Systems

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Abstract

With the ever-growing use of real-time monitoring of systems in all aspect of technological advancement, the need for improving its implementation and operation is vital for it to adapt to the fast-changing challenges it faces. Integrating fault detection and notification systems for system optimization purposes to renewable energy set-up have seen a tremendous improvement in its efficiency, reliability and safety.

This study is intended to identify current technological advancement and breakthrough on the system optimization and predictive maintenance on battery energy storage and solar photovoltaic systems as renewable energy sources to various applications that needs to operate continuously. Monitoring systems are crucial on the overall impact on the operation and maintenance of these systems. Considering that remote management and control of these systems needs to be performed in real-time, it is critical that these monitoring systems should be up and running continuously to provide real-time situation update on these monitored systems for timely intervention if fault is detected.

Enhance fault detection and identification strategies that lowers operational and maintenance cost were the main discussion of this study. Included also are identifying the current challenges and concerns being faced in its implementation and how these challenges are met by recently developed and advanced technological solutions.

Keywords
alert systems, fault detection, fault notification, IoT monitoring systems, renewable energy, SDG7 Affordable and Clean Energy, SDG 11 Sustainable Cities and Communities

1 Introduction

Fault detection and identification is crucial in a system to ensure its continuous and safe operation. With this functionality, predictive maintenance can help in proactive decision making and on time reaction to serious situation and circumstances. System optimization is improved with the functionality of predictive maintenance added to the operation and management of a system.

For an accurate fault detection and identification, real-time data needs to be continually monitored and captured to help in analyzing significant information in designing optimized renewable energy systems which would help improve system reliability, improve system dependability, increase generated output energy and mitigate impact of uncertainty on energy generation. With the integration of these functions to the system, it would improve data analysis, decrease intervention and monitoring time, streamline network administration and do away with requirement for routine manual system maintenance [1]. There are three methods to identify and to detect faults in a system. First is the manual method that includes visual inspection, time-domain reflectometry, second is the semi-automatic method using thermal cameras, infrared or electro-luminescence imaging and the third method is the automatic method that uses data loggers and monitoring systems that collect data and implement fault detection algorithm to check its performance [2].

As processing and interpreting collected and recorded data becomes faster and more efficient, a more accurate fault detection and identification is achieved. With this great technical improvement, notification strategies are also enhanced resulting into a more optimized and improved monitoring system.

2 Alert Systems: Its Technologies and Methods

2.1 System optimization

Interconnected sensors in a network have transformed the way data is handled and gathered. Data from across a range of applications such as smart cities, industrial automation, weather monitoring, environmental monitoring, etc. needs to be collected and processed for further analysis in determining the performance of a system. These node sensors act as information collector agents of the digital world [3].

Optimizing system performance have shown an increased in the reliability of the system and a decrease in operational and maintenance cost. System optimization can be achieved through different optimization algorithms and technological and management strategies that identify system security and physical vulnerabilities. With optimized system performance, the possibility of security attack and system abnormality is reduced [4].

2.1.1 Fault and anomaly detection

Fault and anomaly detection has helped in making the system more optimized and reduced operational and maintenance cost. It has greatly reduced operational hazards, avoided unknown problems and minimized process downtime [5]. Implementation of sensors and the continuous monitoring of these devices speeds up real-time detection process and visualization of the battery state analysis can be done remotely and in real-time.

There are different strategies and techniques that detect fault and anomaly in a system. Some of the most common strategies are:

2.1.1.1 Fuzzy Logic

Network attacks on node sensor devices has been common because of their vulnerabilities that are being exploited by the hackers. Using fuzzy logic algorithms, it can detect anomaly within the network devices itself when the data received is inaccurate or uncertain. Fuzzy detection schemes can be classified as supervised learning-based schemes, semi-supervised learning-based schemes and unsupervised learning-based schemes. Anomaly detection methodologies can be categorized as host-based or network-based schemes [6], [7], [8].

2.1.1.2 Decision Trees

Machine learning processes are used to analyze results from node sensors and has the capability to predict and respond to faults detected on a system. Decision trees algorithm is a machine learning process where it identifies anomaly from preset identified data. Anomalies can be identified when there are changes to the data collected that are out of place or incompatible [9], [10], [11].

2.1.1.3 Support Vector

Support vector machines paired with deep neural networks have the capability to work together for unsupervised anomaly detection process. Cloud storage systems, particularly the cloud environment is prone to faults which results to negative impact on service quality and availability. To prevent such network disturbance, a proactive method should be implemented in order for the system to operate continuously [12]. This anomaly detection process can also be used to detect anomaly on various applications such as hybrid control unit [13] and electric power grids [14].

2.1.1.4 Bayesian Network

Wireless sensor networks are prone to experiencing unexpected anomalies due to accidental failure or from malicious sources. In this time of networked devises, collected data should be reliable and accurate. With Bayesian framework algorithm, it can identify multiple and different types of anomalies using estimation of common parameters within the sensor network environment. Intruder detection systems can identify using machine learning techniques can detect attacks on these devices [15], [16].

2.1.2 Fault diagnosis and mitigation

Utilizing machine learning solutions on fault diagnosis and mitigation has been part of intelligent maintenance on systems and is gaining ground in the industry 4.0 applications [17]. The current trend of the industry is becoming more integrated and intelligent. Accurately diagnosing faults is the result of a fault detection mechanism that is efficient and effective. The current and improved type of fault diagnosis includes hybrid approaches and fault prognosis processes [18]. Fault prognosis development is receiving more focus because of its capability to determine and estimate the process operation time before an abnormality occurs and preventive maintenance is performed. Technological advancement in artificial intelligence and with the availability of multiple machine learning tools, automatic and autonomous fault diagnosis and mitigation have improved the efficiency of systems and applications [19]. Self-healing for smart manufacturing through fault diagnosis and mitigation is also gaining traction in intelligent industry environment [20]. Self-Healing-Fault-Tolerant (SH-FT) strategy is encouraged to improve security issues, performance deterioration and productivity decline because of identified and detected faults and anomalies on systems and processes.

As fault diagnosis is made more accurate, corrective actions results into a more efficient and effective troubleshooting strategies. Advanced sensor technologies coupled with advanced machine learning algorithms results into an optimized and enhanced process of system fault management.

2.1.3 Predictive Maintenance

Predictive maintenance is focused on lowering down maintenance cost and reducing the unavailability of resources and operation. It is one of the most important factors in managing a system for it to achieve its optimized performance. It can also increase the competitive strength of an enterprise by utilizing analytical techniques in maximizing the schedule of maintenance intervention [21]. While fault detection act as the critical component of predictive maintenance, it is designing a maintenance plan when a fault is detected or predicted that is crucial [22]. In defining a maintenance plan, the cause of the failure should be identified, how did it happen, what are those that are affected, and how long will it take to recover if affected. The effectiveness of the response to such failure determines the successes of a predictive maintenance system.

System management is simplified specifically on the maintenance and troubleshooting strategies as fault in the system can be identified already before it can disrupt system operation. As the capability to identify faults are made more accurate, troubleshooting time is greatly reduced resulting into lesser downtime of the affected systems and reducing operational costs to the organization.

3 Fault Detection and Notification on Battery Storage Systems: Applications

Real time information regarding the current situation of a monitored system is very important in the maintenance and troubleshooting techniques for its improved performance and increased reliability. However, batteries' chemical composition is prone to dangerous situations which can lead to failure or worst potential disaster. Early and precise detection of faults is very much needed to ensure the safety of the system thus early warning and isolation of battery failure based on real-time battery parameters is very much needed [23]. In this process, alerts and notifications have been extended to remote applications of battery monitoring system through remote applications and systems [24].

An online battery monitoring management system based on with features that includes online monitoring, remote control, big data analysis, high-speed communication and fault diagnostics is necessary for safe operation of battery and enables predictive maintenance which reduces battery downtime [25]. With the integration of notification through early warning alarm system on detecting potential battery issues such as increase of temperature or low State of Charge on a battery monitoring system, safety measures are triggered, and notifications are sent as an alarm [26].

Sending data to the cloud for analysis which can be accessed anywhere will have the advantage of on time and informed decision regarding the status of the system. In potential hazardous situations, the need for fault detection and notification is crucial [27]. Identifying problems within battery inter-cell connections, loose connections and corrosion problems, abnormal conditions can be detected at an early state thus extending battery life and enabling preventive maintenance of the battery [28].

For safe and reliable operation of batteries on electric vehicles, an online monitoring of the battery state is necessary [29], [30], [31]. Monitoring battery parameters such as temperature, State of Health, State of Charge, Depth of Discharge continuously through remote sensor nodes is essential. Integrating a battery fault detection method is integrated for assessing and improving the reliability of the system. Implementing a notification method through an alarm when abnormal condition of the battery is observed enhances the safety of the system. Based on the battery parameter reading, the system can automatically adjust charging and discharging parameters thus ensuring that the battery is charged to its optimal level minimizing the risk of overcharging and over-discharging.

4 Fault Detection and Notification on PV Systems: Applications

Finding fault in the photovoltaic system has been crucial in the effective maintenance and troubleshooting strategies for improved performance and overall operation of the system. Sometimes uncertain fluctuations and failures due to either manufacturing or environmental aspects will certainly affect the supply of energy [32]. Fault detection and notification are an important mechanism in self-regulated decision-making systems to update its behavior, performance and other criteria which provide real-time scenario on existing systems regarding its operation [33].

A smart monitoring and maintenance management of photovoltaic systems using both fog and cloud storage for data analysis is beneficial to the real-time and informed management decisions during normal and unusual operation of a system [34]. Fault identification, fault classification and immediate analysis of the different collected parameter values in real-time are important to be integrated into the system. A monitoring and alert system with the purpose of supervising and optimizing the efficiency of a PV system can be installed within an existing system with ease [35]. Node sensors are used as data collectors then uploaded to cloud server for monitoring and alerts notification. During system abnormality like power outage, a real-time notification alert is sent for management action and decision.

With so many factors that affects the performance of a photovoltaic system, such as dust particles buildup on the surface of solar panels [36] and solar irradiance intensity being not constant always [37], the need to monitor the energy output of a solar photovoltaic system is essential. Data received from the node sensors can be sent to cloud servers for storage and analysis. Warning alert system are used to notify if parameters are outside predetermined values. With informed decisions, the performance of the system is optimized and management of the system is improved.

An improved intelligent monitoring system integrated into existing solar photovoltaic setup that uses fault detection and power prediction in the system is an enhancement to the contemporary solar photovoltaic system. A long short-term memory (LSTM) can predict the generated output power of the photovoltaic system under different environmental conditions while machine learning based model is used for fault detection [38] with energy saving functionality [39]. With the integration of these technologies, on time and informed decision-making strategy is enhanced and reliability of the system is improved.

Multiple fault algorithms had been developed [40], [41], [42] for fault detection on photovoltaic systems, helping achieve accurate and early failure detection in photovoltaic systems.

5 Alert Systems Implementation: Concerns and Challenges

As the complexity of systems increases, challenges on the management and control of such systems are inevitable. Such issues and concerns are related to data security, efficiency, data handling, data transmission range, panel degradation, accuracy of sensors, large data processing and storage [43]. Adding these functionality of notification systems, increases the complexity of the system and application for both hardware and software implementation. Newly developed technological enhancement should be utilized to mitigate these challenges.

With the evolution of threats and attacks to network devices and nodes, a robust defense should be strictly implemented. Using the latest encryption such as Advanced Encryption Standard (AES) and Rivest Cipher 4 (RC4) enhances security of data being exchanged between nodes [44]. Hybrid encryption improves transmission success by limiting malicious data to be inserted making data transmission more secure and preventing intrusion of hackers. It is only by the application of artificial intelligence techniques that certain cybersecurity issues could only be effectively solved [45]. By utilizing the power of artificial intelligence techniques such as, machine learning, data mining, in-depth learning and complex algorithms, cybersecurity capabilities of any system are significantly enhanced as traditional security systems are inadequate in countering these challenges [46].

Another concern regarding transmission of data is synchronization between physical assets and virtual space, optimization and coordination on connected networks, connectivity and privacy challenges, high cost of deployment, increased demand for power and storage, integration challenges and development of computationally efficient algorithms for real-time response [47], [48]. These can be mitigated by using latest technology of cloud computing architecture so as to be resilient to such challenges.

Sometimes, node sensors are deployed in rough environment and conditions that it is inevitable to receive unusual and erroneous data from these installed sensors. Likewise, these sensors are prone to failure, malfunction, rapid attrition, malicious attacks, theft and tampering [49], [50]. Identifying sensor faults becomes a challenge which is crucial in detecting high probability of data corruption where quality of data being processed is inaccurate.

6 Alert Systems: The Future

Big data has also seen new trend in the environment of networked devices and cloud computing processes. With multiple sensor nodes sending information to the cloud, the amount of data being processed by cloud servers becomes massive. The outbreak of IoT and Big Data caused a large amount of information that needs to be organized and processed properly to exploit its potential in digital transformation of information [41]. One of the current trends being used to fortify and advance data security is machine learning [52]. It can identify anomalies, forecast potential threats by employing intricate algorithms in understanding gathered data. In this process, it has the capability of preemptive response to vulnerabilities and intrusions.

Blockchain technology integrated with fault detection algorithm can enhance the monitoring and notification functionality by strengthening the security of the system through data integrity and accuracy. Integrating the benefits of blockchain, machine learning and artificial intelligence enhances the data trustworthiness, security and reliability [53].

Wireless Sensor Network (WSN) is getting traction as an essential part in a networked smart system as a sensing technology for smart surveillance and monitoring application [54]. An access control mechanism can be strictly enforced for an effective and secure node deployment. This prevents newly deployed nodes from malicious users designed to disrupt and compromise data collected from the smart application.

7 Conclusion

There has been plenty of studies regarding the use of system fault identification and notification as a requirement for monitoring renewable energy systems for improved operation and performance. Integrating this functionality has also lowered the operational and maintenance cost of such systems. Enhancing safety and reliability of the system has also been observed once system optimization and predictive maintenance has been utilized as part of the overall set up.

Although renewable energy systems had grown exponentially in last few years, there is still so much room for its growth regarding its improvement of the overall systems' management, control and optimization. With the inclusion of predictive maintenance, the system has not only increased in complexity regarding its design and implementation but also in the management, operation and troubleshooting of existing systems.

Real-time monitoring these systems demands careful consideration for its remote management and control mechanisms. Notification systems play a very important role in the fault detection, diagnosis and mitigation of these systems for its predictive maintenance operation. With the current trend in artificial intelligence and machine learning, these innovations need to be addressed also for the system to be more resilient to emerging challenges and issues.

8 Recommendations

Sensors for monitoring important parameters in our daily lives such as environmental, weather, health, transportation are already being utilized in growing trend. These sensors need energy supply for them to operate continuously and these small-scale set-up needs these monitoring systems for its fault detection and identification requirements. It is recommended that further study be performed in considering and implementing system optimization and predictive maintenance techniques for the operation of these small-scale sensor systems.

System algorithm for fault detection and identification should also be enhanced. To improve fault diagnosis and mitigation, using the latest trend in artificial intelligence and machine learning is also recommended. Preventing different types of network attacks can also enhance the system with regards to its continuous operation and availability. Alternative network infrastructure needs to be developed because of intermittent downtime and unavailability of existing networks.

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10 References

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