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Adoption of Internet of Things (IOT) in Renewable Energy

Madhu Kumari
National Institute of Advanced Manufacturing Technology, Hatia, Ranchi, Jharkhand

Pankhuri Solanki
Kalinga Institute of Industrial Technology, Bhubaneswar, Odisha

ABSTRACT
The world requires more energy for day-to-day activities due to rapid globalization, development and industrialization. There has been an increased stress on the usage of fossil fuels, in order to minimize this stress and dependency on fossil fuel, the most sustainable course of action is to exploit the renewable resources found on Earth. By adopting Internet of Things (IoT) in renewable energy systems, we can integrate clean energy sources and optimize energy use for maximum output. Renewable energy sources such as solar energy and wind energy can be digitized by the usage of IoT-enabled grids. IoT is commonly utilized in the measurement of energy for efficiency, as well as in determining the renewable energy plant's health, helping in minimizing cost of conversion, and maximizing output. In this study, an effort has been made to identify the implementation as well as critical challenges when it comes to adopting Internet of Things (IoT) in a growing economy, primarily in solar energy and wind energy harvesting systems.

***Keywords*:**
Energy, Internet of things, renewable energy, solar energy, sustainable, wind energy

1. INTRODUCTION

Electricity has become one of most demanded resources for survival, in order to curb the daily rise in the use of energy, alternative energy sources are being utilized to meet these requirements. Due to an increase in energy demand, there is also a requirement for a solid action that can help in diminishing negative consequences of environmental change following the usage of conventional energy sources such as coal, natural gas and fossil fuels. Furthermore, there has been an increase in the utilization of renewable energy sources led by the current environmental crisis.

Most renewable sources are nature-driven, the most significant obstacle is that of unexpected changes in the climate conditions, leading to irregular usage. A major and widely used example for the same is, the use of solar energy is limited to sunny days, whereas on cloudy days, the system fails to generate electricity, on multiple days with no sunlight, there will be almost negligible to no electricity generation. This failure leads to loss of energy, and economic loss for the user. Independent renewable energy plants often require high storage capacities, and are often distributed, leading to little to no connection. This leads to the problem of monitoring the systems, and transmission of data. Thus the usage of renewable sources in generation of electricity require stable, secure and efficient systems which provides resistance from the issues, as well as puts forward an affordable and smart solution.

In order to digitize renewable energy, there's a need to introduce technological advancements in the systems. A primary technology for the same is Internet of Things (IoT). The Internet of Things (IoT) is a system of related computing devices, mechanical and digital machines, objects, people or animals that are provided with unique identifiers and also the potential to transfer data over a network without requiring human-to-human or human-to-computer interaction. (Patil et al., 2017). Internet of Things (IoT) is a significant technology that lets machines connect to the cloud, this connection allows the use to gather information and interact with the machines that are connected via the internet or via an already existing network infrastructure. This opens up possibilities for the seamless integration of the real world with computer-based systems, improving efficiency, accuracy, and financial gain while also lowering the need for human intervention. Numerous uses of this technology exist, including micro grids, solar street lighting, smart villages, solar cities, wind turbine grids and so more. Devices such as computer devices, software, sensors and actuators are connected over the internet or the network, enabling data collection and transmission.

Internet of things enabled technologies put forward a bigger picture on the further advancement of various fields, such as in engineering, agriculture, or medicine, and in other fields that have not been explored yet (Nižetić et al., 2020) due to lack of proper information, showcasing the importance and power of this technology.

In a developing economy like India, the problem of frequent power cuts can be solved by the utilization of renewable energy sources such as solar energy and wind energy. IoT-enabled monitoring systems may be further incorporated to monitor the energy consumption in a household, or a society. The data can be applied in the generation of electricity on sunny days for a solar energy conversion system, or windy days for a wind farm, while saving the leftover energy to be used on days without satisfactory climate conditions, thus real-time monitoring of the renewable energy systems ensure increased efficiency by consistent monitoring of demand and supply.

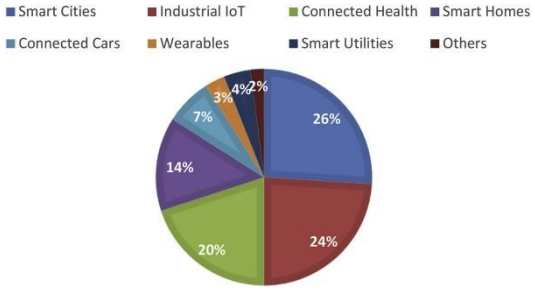

Fig. 1. General market structure of IoT technologies.

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It should be noted that Internet of Things (IoT) can combine various renewable energy sources, such as solar energy, wind energy, geothermal energy, to ensure a stable and steady power supply. By integrating sensors with a wireless communication module,Internet of Things (IoT) based on fog and smart gateways can be used for real-time monitoring of the energy generation stage. Through the wireless connection module, the smart gateway gets sensory data from each plant and forecasts the amount, cost, and demand for electricity.

In this paper, an effort has been made to discuss about IoT-enabled monitoring systems, developed and researched as of now, in renewable energy sources, primarily solar and wind energy.

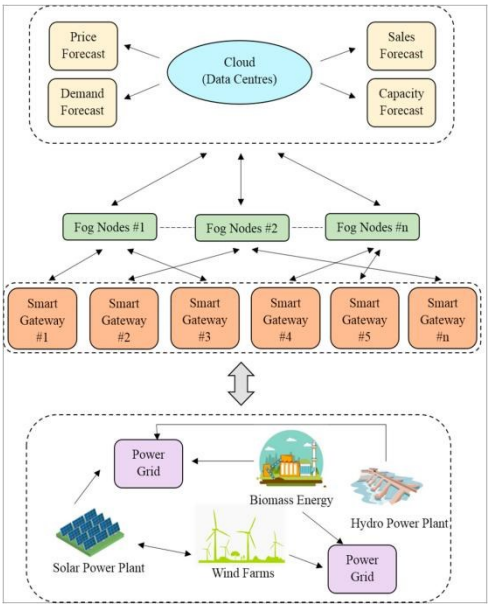

Fig. 2. Example of a real-time monitoring system for renewable energy generation using fog nodes and smart gateways.

2. IOT-ENABLED SOLAR ENERGY MONITORING SYSTEM

The conversion of sunlight (light energy) to electricity by the use of photovoltaic (PV) panels is known as solar energy. Solar electricity is abundant, as well as the cost of conversion is lower than other renewable energy sources. Since solar electricity is derived from a renewable energy source, it helps in controlling pollution, PV systems do not emit greenhouse gas, whereas conventional sources like coal, natural gas and fossil fuels not only increase pollution when used, but also take a long time to regenerate in comparison to solar energy which is readily available. These reasons make solar energy an extremely popular option as an energy source.

In order to maximize output generated by a solar energy plant, an IoT-enabled monitoring system can be implemented. An IoT-enabled monitoring system helps to restore economic power production from power plants by replacing defective star panels, looking for contacts and alternating those issues with sludge accumulated on output reducing panels and shaking wire (Prasanna Rani et al., 2023). Author Kabalci, Ersan, Gorgun and Yasin Kabalci, introduced an instant monitoring infrastructure of a renewable energy generation system that constituted a wind turbine and solar panel arrays. The basis for the monitoring system were current and voltage measurements of each renewable source.

The system monitors the photovoltaic panels and transmits the data obtained via the internet using an Internet of Things (IoT) network, it's primary objective is to maintain the optimum output received. Analysis of the outputs received can help in detection of system failures such faulty connections, solar panels, and dust particles or pollutants accumulated on the surface of the panels. The aforementioned contaminants have an impact on the performance of the photovoltaic panels, which result in differing outputs. Since monitoring by the help of human efforts is a tedious task which involves more time and manpower, the Internet of Things monitoring system can simplify the same by the use of sensors and peripheral units (Kalaiarasi et al., 2024).

Photovoltaic panels may also consist of their own IoT devices for data gathering. This includes of parameters such as voltage, temperature, energy generation, and so on. An in-depth analysis can be provided, and maintenance for a sole PV panel can be scheduled, the efficiency of the panel can be studied and performance can be improved.

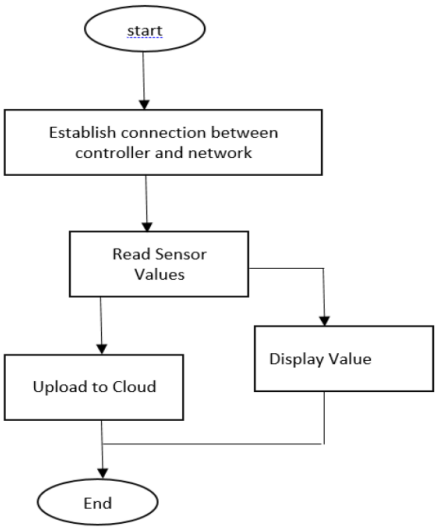

Fig. 3. Working of an IoT-enabled solar energy monitoring system.

On rainy and foggy days, the temperature sensor is used for the temperature measurement so that on rainy and foggy days the outcomes of the maximum output of the system are measured (Zohora Saima et al., 2022). The purpose of solar energy monitoring systems is to offer continuously a clear information about various parameters, namely the energy potential, extracted energy, fault detection, historical analysis of the plant, and associated energy loss. Furthermore, the monitored data can be used for preventive maintenance, early detection of warning and evaluating the weather variations and so on (Cheddadi et al., 2020).

An IoT-enabled monitoring system provides enhanced security by real-time monitoring against issues like vandalism of the conversion system, theft of PV panels, and unauthorized access.

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3. IOT IN WIND FARMS

Wind energy is crucial for meeting climate and energy sustainability targets. Human civilization has advanced significantly thanks to wind energy, which is produced by the difference in air pressure caused by the Earth's rotation and unequal heating of its surface (Wang et all., 2023).

With the intelligent revolution and introduction of Internet of Things (IoT), big data and Artificial Intelligence (AI), wind energy harvesting technology can be further transformed to yield better output. The implemention will allow the system to "self" analyse, and detect faults in order to perform in a better and more efficient manner. Often times, wind farms are created in locations which are highly exposed, thus, in order to fix an error, be it big or small, in the system, one has to travel to that specific spot. This is time-consuming as well as requires more effort. These constraints may lead to fluctuating output, and do not allow the wind farms to operate at the highest capacity.

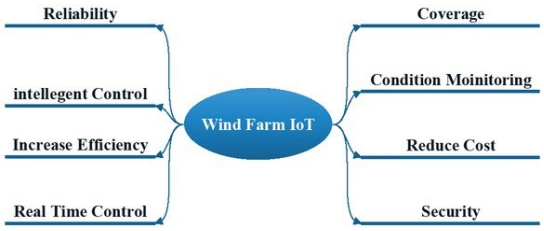

Fig. 4. IoT in wind farm.

IoT-enabled monitoring can provide a solution for the same by continuously monitoring conditions, offering meteorological data, and simplifying the planning and carrying out of maintenance, reducing the need for human intervention by real-time monitoring of the wind turbines.

Author Alhmoud, Lina proposed a model to utilize IoT in wind energy generation for reliability enhancement. The proposed model is shown in Figure. Each wind turbine present in the wind farm is equipped with it's own IoT platform, that can be directly connected to a network. The wind data is saved and processed on the cloud using ThingSpeak, and the wind data can be accessed from any part of the world via any system, such as a regular computer or a smart mobile phone where commands can be directed to the wind farm.

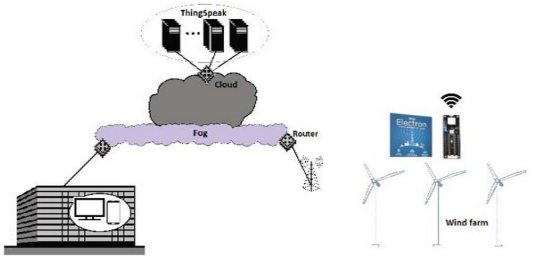

Fig. 5. Proposed model for IoT in wind energy conversion system.

4. CHALLENGES TO IMPLEMENTATION OF IOT IN RENEWABLE ENERGY

Implementation of IoT technologies in renewable energy can make energy conversion systems smarter, more efficient and effective. However, the process of digitization is a complicated process and requires various challenges to be overcome.

1. Promotion of IoT in a developing economy like India is a difficult task, as the market still is not reformed for these technological advancements. Consumers who are unfamiliar to the technology and its uses may not want to invest and would prefer to invest in a simple renewable energy system instead.

2. The rapid development of IoT technologies causes fast consumption of raw materials to produce different electronic devices where unfortunately some of raw materials are already rare or becoming (Nižetić et al., 2020).

3. There are challenges in the implementation of an IoT system, which consists of durability as well as practicality. While there have been developments on these systems, the durability of these systems have been brought up. The components of an IoT system need to be of proper and durable material in order to serve their purpose in the long run. This poses to be a difficult task, as it required proper investment. There is also lack of evidence regarding the practical applications of an IoT-enabled system.

4. Increased electronic waste due to IoT-enabled systems pose a threat to the environment. While the renewable energy systems are made more sustainable, and pollution-free, e-waste generated from the IoT systems may not be disposed off properly. Developing economies are not capable enough to recycle such waste, this may lead to further environment damage.

5. The components of an IoT-enabled system have to fulfil the target of reduced energy supply (Nižetić et al., 2020). The primary motive for using an IoT-enabled system is to yield maximum output from a renewable energy system, while using minimum energy. This required further research and development in sensors and actuators, which are used in IoT technologies.

6. There is a lack of ability to manage Internet of Things (IoT) technologies due to lack of information in the field. Additionally, it is difficult to find new employees and re-skill the previous employees.

7. Inadequate digital infrastructure and insufficient digitization experience may also negatively affect the business while integrating IoT technologies.

8. To provide the required energy supply for IoT production lines, a greater use of fossil technologies would result from the rising use of IoT technologies. In the long run, the production of electronic equipment may lead to an imbalanced waste of scarce metals and resources in general, which could be a serious problem. Unfortunately, only 20% of electronic waste is now recycled, which raises concerns about the ability of available resources to create Internet of Things products—especially in light of growing consumer demand (Nižetić et al., 2020).

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The primary goal of this study was to evaluate the role of implementation of Internet of Things (IoT) in renewable energy. Within this context, we discussed how IoT has been changing the renewable energy conversion systems by providing real-time monitoring, thus, encouraging maximum output and better power supply. It helped in improving security of the conversion systems, predicting maintenance required, and in making the system more efficient by the prediction of demand and supply of power consumption by the use of data obtained in cloud.

On the other hand, we also discussed the major issues related to digitization of renewable energy conversion systems, typically related to e-waste management and lack of information related of Internet of Things (IoT).

To conclude, it is quite clear that the adoption of Internet of Things (IoT) is a much-needed step to create sustainable systems for electricity generation in the long-run, but the problems related to the same must be taken in account and should be tackled properly.

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Madhu Kumari received her B.Tech degree in electronics and telecommunication engineering from BIT, Sindri, Jharkhand and MTech degree in Digital Image Processing. She is currently an associate professor and HOD at ECE department in NIAMT, Hatia, Ranchi, Jharkhand. Her areas of interest are renewable energy, Internet of Thigns and digital image processing.