An IoT based Strategy to Predict Weather-related Power Outages and Electric System Resilience

Bhuvaneswari A[1], Narmadhadevi R[1], NeethuSasi S[1], Poorani M[1]

[1] *UG Student, Department of Electrical and Electronics Engineering, Government College of Engineering, Thanjavur-613402, Tamil Nadu, India*

Dr. C. Mahalakshmi[2]

[2]*Associate professor, Department of Electrical and Electronics Engineering, Government College of Engineering, Thanjavur-613402, Tamil Nadu, India*

Abstract

Power outage means an interruption in the supply of electricity. It may occur for many reasons and can exist from a few seconds to hours or days. The high winds, lightning, freezing rain and snow, rain or flooding are the causes for power outages. The heavy wind or rainy seasons causes the power line failure that leads to the voltage or current to be too high rather than normal voltage and also there is a change of getting power line cable hanging in air or connected with ground. These conditions lead to the problem of power failure or even tripping of the substation. In order to avoid these circumstances, proper corrective measures have to be implemented. In this work, a strategy has been developed such that any disturbance in the power transmission system can be sensed in advance and preventive measures can be employed. The proposed system is designed based upon online monitoring of key operational parameters of distribution transformers. It gives the information regarding the working of healthy transformers and maintains the benefits in operation for a longer duration. The speed of the rain and the wind are measured with help of rain sensor and the wind sensor. Besides, the current and voltage are sensed by current and potential transformer respectively. The power line failure information is sent to EB office through Internet of Things (IoT module) and power line will be tripped by relay circuits.

Keywords: Weather outage, resilience, IoT, wind sensor, rain sensor

I. Introduction

Electricity plays an important role in day-to-day life. The energy industries always look forward to improve the performance of the power system. The traditional power system comprises of generation, transmission and distribution which is unidirectional in nature. This power system is required to be monitored and controlled in real time [1].

The high speed wind and heavy rain cause damages to electricity utility system, resulting in service interruptions to a large number of electricity customers. Most of the power outages are caused by the heavy wind and rain on local electricity distribution lines, which carry bulk power to long distances [2]. The resulting impairment, power outages can last a few hours or extend to period of several days.

In power grid network distribution, a transformer distributes power to the low-voltage users directly and its operating condition is a vital part of the operation of distribution network. The operation of distribution transformer under rated condition assurances their long life. However, their life is significantly reduced if they are subject to overloading condition, resulting in sudden failures and loss of supply to a large number of customers thus affecting system reliability [3]. The overloading and rise in oil and winding temperature of transformer are the major causes of failure in distribution transformer.

By using modern technology, the Smart Grid can be built on the existing power system. In this concept, things are being monitored for the better performance of the substation and the grid. This word presents an idea on real time monitoring of the distribution transformer in order to make the system more reliable [4]. The different parameters of the distribution transformer are monitored and demonstrated through Internet of Things platform. The system data has been screened and analyzed. The IOT based monitoring of distribution transformer is rather useful as compared to the manual operating system.

II. RELATED WORK

The high speed winds or fallen trees due to tornadoes or hurricanes may cause transmission lines to touch and short circuit, causing the circuit breaker to trip and produce an outage. Flooding as a result of heavy rains can cause damage to both above ground and underground lines and the equipments. The snow and ice buildup during a storm can increase the weight of ice on a tree and its branches, causing it to fall onto power lines. The more complex large power outages are the result of a small and single event that gradually leads to cascading outages and eventually collapsing the entire system. The average 43% of length of weather related power outages over 5 minutes are caused by heavy rainfall, high wind, hurricane, tornado, etc.

The Predictive Risk Analytics for Weather-Resilient Operation of Electric Power Systems have been suggested. They proposed a metric that considers the weather conditions vulnerability, grid susceptibility and monetary costs in the changing weather prototype and related meteorological forecasts over time. Moreover, the new improved formulations for power system network control through transmission line switching for quick and appropriate revival of the weather-caused electricity outages is recommended [5].

An approach using the fuzzy model for weather related outages of overhead lines has been defined. The mean values of reliability indices and membership functions are evaluated using simulation which offer a deep understanding into the fuzziness of weather conditions [6]. An outage-forecasting model which uses lesser variables to predict outages with high accuracy has been developed. The obtained results depict that wind speed based system reliability are not enough and a multivariate methodology can result in more precise power outage predictions [7].

The progress on various research filed related to the methods and tools of predicting disaster based power system disturbances and restoration models have been reviewed. The causes of blackouts, rectification methods to improve the resilience of the power grid during abnormal conditions have been studied [8]. Models to estimate wind and lightning related power outages have been investigated. A learning approach based on a boosting algorithm has been proposed to predict weather related outages. The acquired results are compared with the previous models suggested for the outages and it is proved that the proposed methodology predicts outages with high precise than the other models [9].

Two methodologies have been projected to model overhead distribution line failure rates in the power system. One method is based on the Poisson regression model which accounts for the failure occasions while the other method works on the Bayesian network model that makes use of conditional probabilities of collected from various climatic conditions. The resultant of both the methods are used to predict the annual weather related failure actions on overhead lines [10]. The effect of weather and climate changes on the power system reliability has been analyzed. The various measures for increasing power system resilience to extreme worst weather conditions have been outlined. The general outline regarding the resilience has been discussed [11].

Even though the concepts of weather related power outages and electric system resilience have been deliberated and implemented in the past years, the practical measures to be followed in overcoming the associated failure events that occur in the power system transmission line are not discussed adequately.

III. PROPOSED SCHEME

During power outage conditions, the closing of electrical equipments result in disturbance in the adjacent section of the system leading to a consequential breakdown of the major sections of the network. Modern power systems are designed to be resident to this sort of cascading failure, but it may be unavoidable. Moreover, since there are no short-term economic benefits in preventing rare large-scale failures, the researchers have expressed concern that there is a good tendency to erode the resilience of the network over time, which can be recovered after a major collapse had been taken place.

The main objective is to design a monitoring system for distribution transformer and to control it when it goes to abnormal condition. It uses IoT based technology that allows resourceful two way communications between the utility and the customers. It will monitor the critical parameters such as current, voltage, power and temperature continuously and preventive measures will be initiated if any disturbances have been observed and thereby resulting in improving reliability, security and efficiency of the electric system.

In a distribution network system, there are many distribution transformers and connecting each transformer with such a system can easily figure out faulty transformer from the message sent to mobile, thereby no need of checking all transformers phase current and voltage and thus it can improve the efficiency of the system in less time. The block diagram of the proposed methodology is shown figure 1.

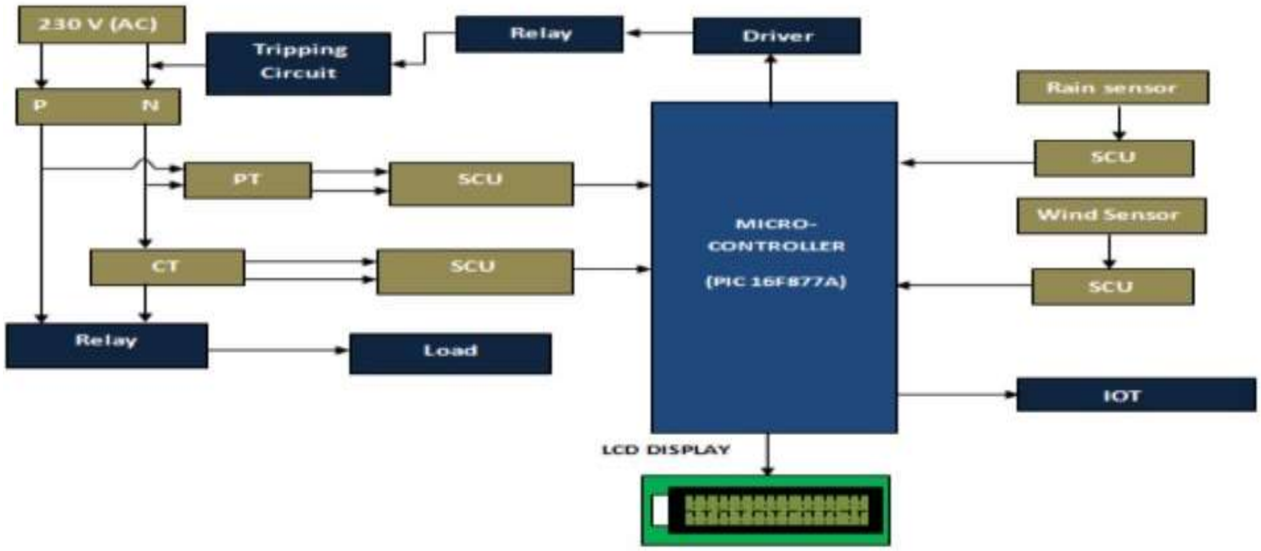

Fig. 1. Block diagram of the proposed strategy

Power supply is reference to a source of electrical power. The required input voltage for the circuit is given from the regulated power supply. An AC input of 230V from the main supply is stepped down by the transformer to 12V and is fed to a rectifier. The output obtained from the rectifier is a pulsating DC voltage. So in order to get a pure DC voltage, the output voltage from the rectifier is fed to a filter to remove ripples present even after rectification. The operation of the current transformer is similar to that of the conventional power transformer. The current transformer is used to measure the range of current flowing towards the load. The voltage transformer converts the supply voltage to a voltage level suitable for a meter. It has error that has been measured and can be applied to calibrate the meter. The transformers are used in electrical circuits to change the voltage of electricity flowing in the circuit.

Programmable Interface Controller **(**PIC) microcontroller is used as the heart of the proposed methodology. The entire functioning of the system depends on this board. PIC reacts to the 5V supply and keeps on counting the supply and then calculates the power consumed and the cost. It continuously stores this data on the webpage, so that users can visit any time and check their consumption. It even reacts accordingly as per programed, to the situations like messages sending during threshold value etc.

The relay is an electrically operated switch. The current flowing through the relay creates a magnetic field which attracts a level and changes the switch contacts. The rain sensor is a one kind of switching device which is used to detect the rainfall. It works like a switch and the working principle of this sensor is such that, whenever there is rain, the switch will be normally closed.

The wind sensor is a device used to determine the speed of wind. It detects and senses the wind direction information of the wind by the rotation of the wind direction arrow, and transmits it to the coaxial code wheel, and simultaneously gives the result to the connected device corresponding to the flow of wind.

The Liquid Crystal Display (LCD) is used to monitor the level of voltage and the current value and it also detects the transformer condition state. When the transformer goes to abnormal condition or the value of current and voltage increases above the limited value, then the relay changes the switch contacts i.e. it can switch off the power supply through the tripping circuit or the drivers that are used to trip the power supply. The power lines failure information is conveyed to the substation through Internet of Things (IoT) module.

IV.RESULTS AND DISCUSSION

In the power transmission system, the various electrical parameters are measured and monitored continuously and communicated to the corresponding stations for taking necessary actions under normal running conditions. In case of any contingency, there is a possibility that the system is not able to recognize the sudden changes in the transmission lines which results in the power outage or even block out of the substation itself.

In order to overcome this problem, a scheme on real time monitoring of the distribution transformer in order to make the system more reliable has been proposed. A mechanism has been developed that senses the disturbance produced in the transmission system well in advance so that suitable precautionary actions can be employed. To facilitate this, the proposed strategy makes use of a rain sensor, wind sensor, current transformer, potential transformer, LCD monitor and Internet of Things (IoT) module. Figure 2 shows the various components used and the experimental setup of the proposed work.

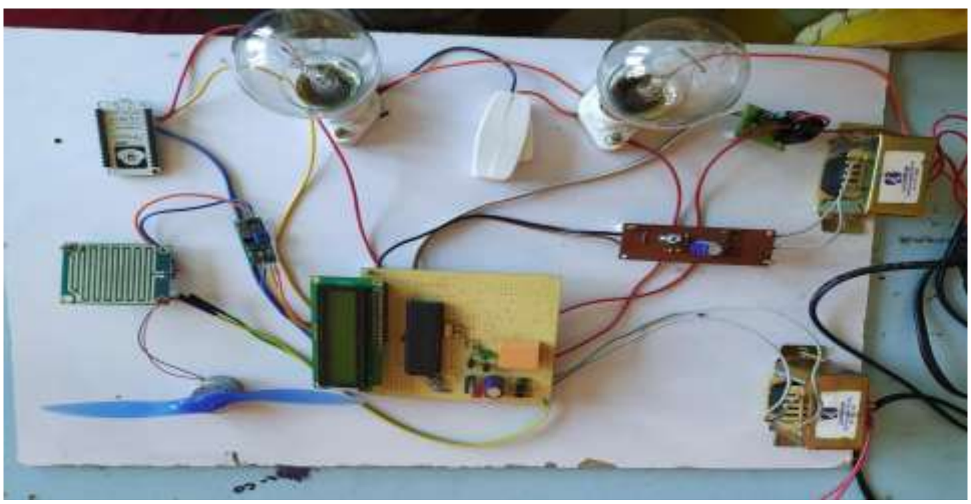

Fig. 2. Experimental Setup

Figure 3 illustrates the condition where a single load is turned on along the transmission line. The system will work in a normal manner and supply the electricity to the consumers as long as the values of the defined parameters are within the specifications.

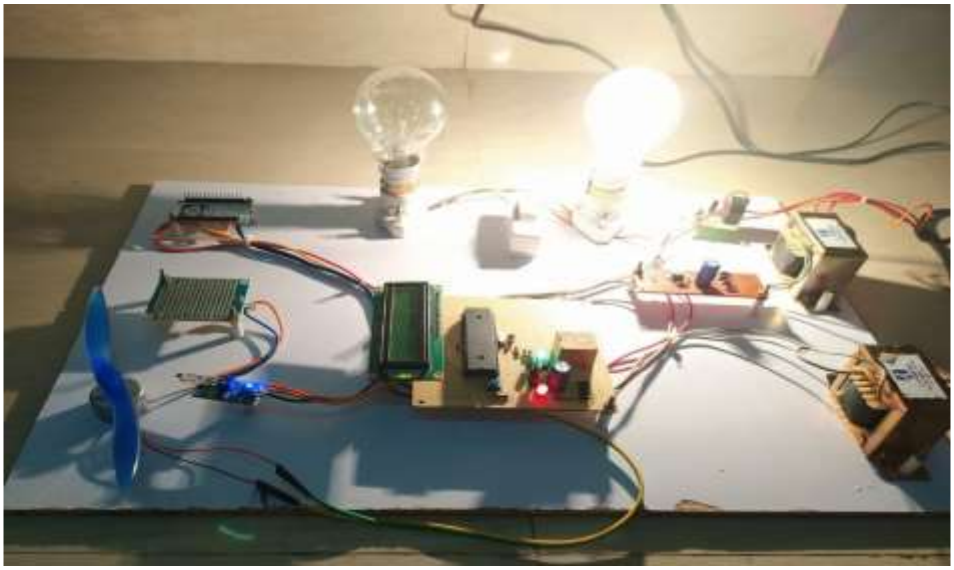

Fig. 3. Single Load-On condition

Figure 4 depicts the overload condition which arises if any disturbance occurs in the distribution system.

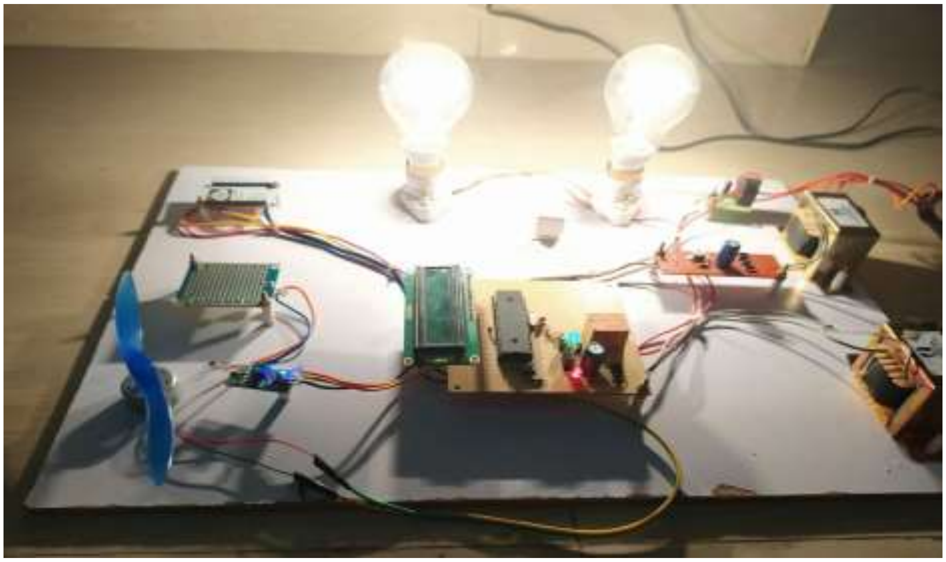

Fig. 4. Snapshot showing overload condition

For example, if rainfall occurs or the speed of the wind exceeds the standard values given in the specifications, these are sensed by the rain and the wind sensor respectively. From the figure, it is clear that both the lamps start glowing indicating that there is some problem in the transmission system. This power line collapse information will be conveyed to the corresponding office through IoT module and the proposed methodology immediately trips the power line circuit by the relay circuits and thus evades the consequent damages that may occur due to the overload condition.

IV.CONCLUSION

The establishment of the resilient power system and the improvement of resilience have become inevitable requirements for the power system. In the face of extreme events, resilience is recognized as an essential characteristic of the critical infrastructures as well as the whole society. Despite the large body of research, resilience is still a new topic in the power system. The proposed system is very useful in monitoring the current and voltage that flow through the lines continuously and it also updated in the IoT server. The system automatically gives alert to the EB station and it is also helpful in avoiding death during the unconditional weather conditions. The significant features of the designed strategy make it suitable to find applications in the electric power transmission and distribution systems.

Future work may include the co-simulation of transmission and distribution networks that would help to get a better understanding of a wider range of aspects that can affect the resilience performance of a power system as a whole, e.g. the duration of load reconnection following such extreme events.

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