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SMART POLE-MOUNTED SUBSTATION

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Abstract: Electricity is very important in today's world and substation monitoring is a key concept in making the system reliable. The proposed work uses a system based on to get the quick, cost-effective, and reliable monitoring, display, storage, and analysis of sensor data. Conventionally, PLCs and SCADA systems are used to monitor substations, but for a small substation, this is prohibitively expensive and not feasible. This project adopts low-cost monitoring solutions based on IoT technology incorporating the microcontroller Arduino for remote monitoring of an 11 kV substation. The project aims to make the pole-mounted substation a smart one by using IoT to monitor the various electrical parameters. It uses IoT technology integrated with the cloud for remote monitoring and alarming for different faults in pole-mounted substations. The quality and continuity of electrical supply are becoming a more and more important issue. The user costs due to a supply interruption are relevant and depend on the duration of the interruption. In the distribution section of the power system, more specifically at the utilization level, when a fault occurs, the supply authority would know only if someone in the locality inform them about the fault. Moreover, occurring of faults or other related issues not only causes economical loss but is also dangerous and causes accidents. This project aims to reduce this long interruption of electrical power. One of the ways that this aim can be achieved is by monitoring different parameters of pole-mounted substations and providing real-time status about the substation to the supply authority. With this, the supply authority will get informed as soon as possible and thereby can take the action against the fault or undesirable conditions. To achieve this goal, the functions of equipment will be provided with sensing devices to measure different parameters. The alarm is sent to both main substation control rooms and displayed in visual signaling in HMI on the web via the wireless communication channel. It uses IoT as a monitor, and communication technology.

Keywords: Monitoring, Cloud, Fuse status, GSM, Alert.

I INTRODUCTION

A major part of our modern industrialized society is powered by electricity. It is an extremely important source of energy. The power systems are nonlinear, massive, and complex networks.[1] With economic benefits, improved reliability, and operational benefits, electric power systems are unified. The failure of these systems has direct and indirect effects on the economic growth and development of countries and is one of the major components of national infrastructure. There are many components of a power system, such as generators, lines, transformers, loads, switches, compensators, etc. Modern power systems, however, usually have widely dispersed sources of energy and loads. Because lack of automation and a lack of real-time analysis, there are still power outages and blackouts in the electricity sector today. The utility can gather information from different subsystems of the power system with IoT and provide the necessary data to provide the needed view.[2] The distribution system especially the secondary distribution network is becoming more and more complex, the automation of substations is necessary to increase reduce downtime, increase continuity of supply and improve the reliability of the power.

The traditional method, of monitoring pole-mounted substations, is considered unnecessary and only done for a few substations.[3] Also, the substations in the rural areas lack monitoring of power outages due to fuse dropout, voltage variations, and power theft are the major concerns. This problem can be dealt with by substation automation. In pole-mounted substation automation, the various parameters like current, and voltage are continuously monitored through different sensors. The output signals from sensors are given to the microcontroller. Microcontrollers are pre-programmed to notify central or intermediate stations if they exceed a predefined threshold value, using wireless communication technologies, like the internet of things. Main advantage of the system is a quick indication of faults or abnormal operations which would occur at the pole-mounted substation. If the faults or any abnormal conditions are informed to the electricity board with lesser delay, they can take the required action as soon as possible. This will ensure continuity of supply and will lower the risk and accidents. The cost-effective solution will ensure the continuity of power with problem indication.

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II METHODOLOGY

Substation tracking is the manner of mechanically sensing the manner parameters withinside the electric substation with the assist of automation gadgets. There isn't any tracking withinside the traditional pole installed substation. There isn't any use of any kind of sensors or instrumentation gadgets CT or PT in current 11kV pole installed substations. Current systems use only transformer fuses and primary protection that do not include any kind of communication between the sensor and the main substation that powers this substation. In the event of a failure, these traditional protective devices will respond (fuse, LA, etc.). When these devices are operational, they need to be replaced or powered back on. This can only be done after notifying and notifying the relevant authorities (Electrical Commission / Substation). This process usually takes a long time and can result in long power interruptions.

III PROPOSED WORK

One solution to all these problems is to monitor the substation parameters and send them over the internet to the major substations and power companies. Various parameters such as current and voltage are continuously recorded using different sensors. The microcontroller is programmed to set thresholds for all these parameters. These thresholds are set by default. Individual sensors detect that the parameter exceeds the limit due to an error or anomaly, and these are handled by the microcontroller. Microcontroller is preprogramed in this kind of manner that if fault detected, it'd tell the intermediate or essential station. For this Internet might be used as verbal exchange media. The gadget will generate indication and alarm on the respective essential substation. In addition to collecting parameters and generating an alarm when the parameters are exceeded, the system identifies any phase out of the three affected phases (RYB). This helps reduce the search scope for clearing errors. For this purpose, each phase is monitored with separate sensors and required circuits.

A SYSTEM DESCRIPTION:

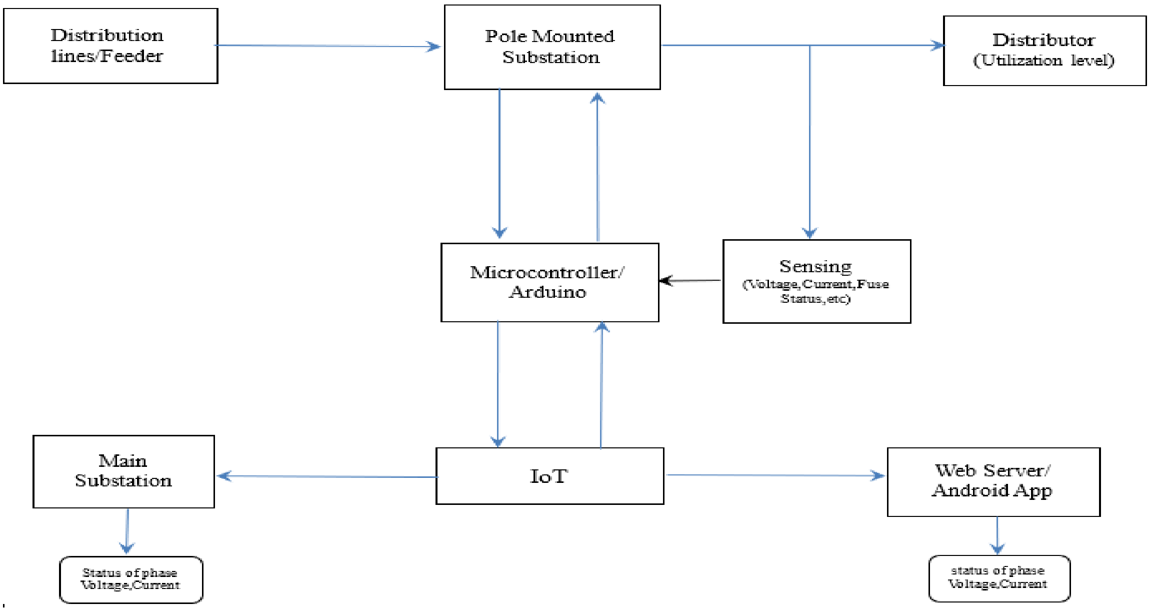

Fig. 1 Block Diagram of Proposed System

1) Distribution lines/ Feeders:

These are generally 11kV overhead transmission lines that supply power to the pole-mounted substations from the main substation which is generally a 110-220/33kV substation. These lines represent input for this application i.e. pole-mounted substation.

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2) Pole mounted substation: This is the part of the system which acts as the application in this case. These are the part of the distribution system where high voltage (11kV/6.6kV) is stepped down to voltage at utilization level with the use of a distribution transformer. By making upgrades proposed in this project, this conventional pole-mounted substation will enhance the reliability of the power supply and will become Smart Pole Mounted Substation.

3) Primary sensing block: This block belongs to the high voltage (11kV) side of the substation It will consist of CT and PT along with the current sensor module and voltage sensor module to get a control level signal to be processed by the microcontroller.

4) Secondary sensing block: Secondary side parameters will be sensed in this block. Similar to the primary side sensing block, it will also contain voltage sensors, Current sensors, etc. for each phase. The voltage level for this block is low, hence sensor modules can be directly used in this block (without CT/PT).

5) Microcontroller (Arduino): The microcontroller will collect data from all sensors, process all signals, and compare it with a set threshold value, it will take the corresponding action. It will also process data so that it will be transferred to the cloud. All sensors and other modules will be connected to the microcontroller.

6) IoT: The output of the microcontroller will be transferred to the cloud via the internet. Pole mounted substation and the main substation will be in contact with each other wirelessly through the internet with the use of this block Internet of things.

*7) Main substation***:** This is the substation from where the pole-mounted substation will get the power. According to the processed data, the microcontroller will send the alarm signal to this substation. Under all conditions, real-time monitored parameters will be shared with this substation.

8) Webserver/Android application: Data will be transferred through the internet to the cloud base and will essentially be available on the webserver of that cloud base and android application. It will show on in graphical widget on this human-machine interface

B ANALYTICAL MODELING:

1) Selection of Voltage limits for indication of Under-voltages, Normal Voltage, and Over-voltage:

As per Indian Electricity Rule No. 54, the distribution company or the supplier should not allow the voltage, at the commencement of supply, to vary from the declared voltage as per the conditions given ahead:
• for low or medium voltage supply not more than 6%;

• for a system of high voltage, on the higher voltage side, not more than 6% and by more than on the lower side not more than 9%; and
• In the case of extra-high voltage, by no more than 10% on the higher side and no more than 12.5 percent on the lower side.[8]

- Specified or Declared Voltage = 230 V ……………………………………… (1)
- Upper Voltage Limit $= 230 + \frac{6}{100} \times 230$ ………………………………….. (2)
  $= 230 + 13 \cdot 8$
  $= 243 \cdot 8$ V
- Lower Voltage Limit $= 230 - \frac{6}{100} \times 230$ ……......……………………………... (3)
  $= 230 - 13 \cdot 8$
  $= 216.2$ V

Table 3**Error! No text of specified style in document.**1 Classification of voltage levels

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Sr. No.	Voltage Classification	Voltage Level (Volts)
1	Normal Voltage	230
2	Under Voltage	216.2
3	Over Voltage	243.8

2) Selection of Current limits for indication of Over-Current:

In the case of current, the limits for over-current will depend on the capacity of the transformer of that particular pole-mounted substation. Depending on what type and how many consumers it feeds electricity to, the transformer's capacity will be determined. One of the ways to decide the overcurrent limit value is by considering the permissible loading of the transformer and current rating. There highest load current value observed for a particular pole-mounted substation can also be considered as an indication of overcurrent or highest current.

Current Upper limit or Overcurrent:	Current rating of transformer or any predefined value by the study of historical values of current

C REALIZATION OF PROTOTYPE HARDWARE MODEL:

In the proposed prototype, we have used the Atmega328p microcontroller chip for standalone Arduino Uno used as the central processing unit, which is the primary processing unit. It will act as the brain of the system and outputs of all other sensors or measuring circuits will be connected to it. We used an ACS712 current sensor, a voltage sensor circuit with a step-down transformer and rectification, a fuse status detection unit, a piezo buzzer, and an indication led in addition to the microcontroller; and to demonstrate the load, we used a 1000W load bank of bulbs of various ratings. Considering the prototype module, we have used a 12V, 1A dc Adapter with a power supply unit, the adapter is used to convert AC mains from a supply of 230V to 12V dc. The supply unit consists of a voltage regulator IC 7805 to get the 5V dc output required for different low voltage circuits. The dc supply is then passed through a capacitor, which acts as a filter, smoothing out the pulsating dc. Because many of our components, such as the microcontroller and current sensors, require 5 Volt regulated DC, the 12 Volt dc from the adapter is given to a 7805 Voltage Regulator, which converts it to 5 Volt regulated dc. We'll need to make some arrangements if the buzzer and relay require a large amount of current to operate. In the case of the relay, we used a BC 547 transistor for amplification. We used two BC 547 transistors for the operation of the red LED, which serves as an indicator and requires a large amount of current. When we turn on the power to our prototype, the display displays the project's name, and the parameters are sensed by all of the sensors, voltage, current, and fuse status, and transfer all of the live values to the cloud base as well as to the LCD. All real-time values are compared to predefined values and if any value is greater than the pre-determined values, it sends alert signals to the blynk dashboard and alarm unit, along with updates it on the display, as shown in the **Table 3.2.** This process continues monitoring the real-time values of the parameters of the smart pole-mounted substation. Logs are generated by the blynk cloud service enabling us to analyze historical values of parameters. Whenever there is a fault in the SPMSS of any type which causes the parameters to exceed its voltage and current predefined limits, the identification number of that SPMSS ID is indicated on the blynk dashboard, to easily locate and identify the pole-mounted substation.

Table 3.2 Working Logic of the system

Sr. No	Condition	Behavior	
1	Fuse operated/blown	Buzzer beep Fuse status indication in Blynk dashboard	
2	Voltage > 243.8 V	High Voltage Led ON Buzzer	Buzzer beep
	< 216.2 V	Low Voltage Indication in Blynk dashboard	
3	Current: Greater than set value- More than Rated-	Buzzer beep High Current Alert on BLYNK board	
4	Faulty Phase	Respective phase indicator	
5	Faulty SPMSS	SPMSS ID on the BLYNK dashboard	

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IV RESULTS

For testing the system, we have used the resistive load bank of 1000W consisting of incandescent bulbs of different ratings and compared the results with the standard voltmeter, ammeter, and wattmeter. The result of each measurement unit is discussed in **Table 4.1**.

Table 4.1 Voltage Measurement Results

Sr. No.	Actual Voltage (Volts)	Measured Voltage (Volts)
1	230	230.5
2	218	218
3	229	228.5
4	224.2	224.5
5	231.2	231
6	234.4	234
7	240	239.95
8	250	250.5

A VOLTAGE MEASUREMENT UNIT RESULTS:

To obtain the different readings and get results for different voltages we have used an autotransformer to vary the supply voltage to the load, which is measured by the system. The table below shows the actual values of voltage measured by multimeter and voltmeter compared with voltages measured by the voltage measurement unit of the project. The deviation of the values from actual values is very small and acceptable. The same readings are observed on the web and mobile dashboards. Here are the photographs of the reading of the specified/Normal/Declared voltage of the secondary side

Fig. 2 Results: Actual voltage and measured voltage

distribution system. The voltages observed on the IoT dashboards for the readings in the above table (table no. 1) are shown below. The readings are the same as that displayed on the LCD.

1) Normal Voltage: Here the voltages are between $\pm 6\%$ of the declared voltage (230V) and therefore under voltage and over indication is off in dashboard

2) Under-Voltage: Here the voltages are less than 6% of the declared voltage (230V) and under voltage indication is off in dashboard. On display U_V_R mean Under-Voltage-R and R stands for phase R. **Fig4.2** Indicators on IoT dashboard and their status during Under-voltage**.**

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3) Over-Voltage: Here the voltages are less than *6%* of the declared voltage (230V) and therefore, under voltage indication is off in dashboard. On display U_V_R mean Under-Voltage-R and R stands for phase R

Fig 3 Normal Voltage Under-Voltage Over-Voltage

B CURRENT MEASUREMENT UNIT RESULTS:

To obtain the different readings and get results for different currents we have used the same load bank and turned on and off bulbs to vary the load and ultimately the load current, which is measured by the system. **Table 4.2** shows the actual values of currents measured by multimeter and voltmeter compared with currents measured by the current measurement unit of the project. The deviation of the values from actual values is quite low and acceptable. The same readings are observed on the web and mobile dashboards. The comparison of actual current measured by a standard ammeter and current measured by our proposed system is given the Table 4.2. **Fig. 4.2** shows the dashboard during the normal loading i.e. when the current is less than the 'High Current' set value, which is 2A for our prototype.

Table 4.2 Current Measurement Results

Sr. No.	Actual Current (A)	Measured Current (A)
1	0.471	0.47
2	1.23	1.21
3	1.96	1.94
4	2.3	2.33

For the prototype, we have set the current for overloading as 2A, when the current is greater than 2A then the dashboard indicates a 'High current', and the buzzer gives a beep. **Fig. 4.3** shows the dashboard during the high current condition.

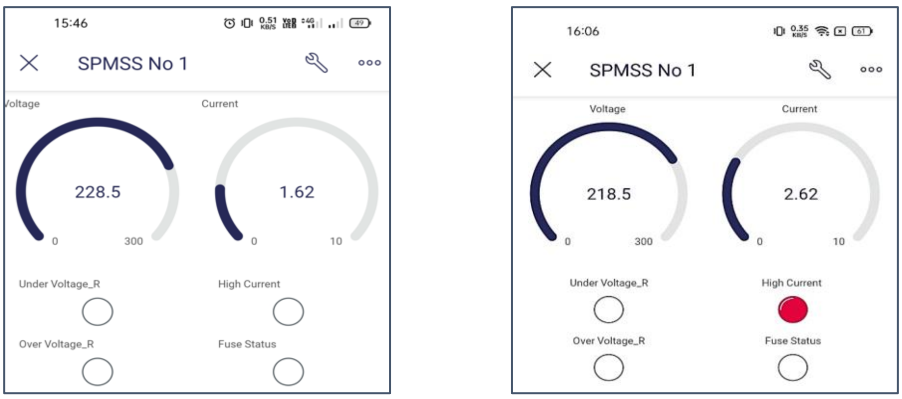

Fig.4 Indication on dashboard (a) During normal load and (b) During over-load

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C FUSE DETECTION UNIT:

This circuit gives a signal HIGH to the microcontroller when the fuse is not available/Operated and the supply is interrupted. To test this condition, we removed the fuse instead of blowing it off and observed the result. The voltage is measured on the input end of the fuse, and the voltage recorded can be used for the analysis.**Fig 4.6** shows the status of indicators on the IoT dashboard when the fuse is operated.

The overall results and operation of the prototype of the proposed system can be summarised in **Table 4.3**. Parameter 'Faulty SPMSS' represents that there is some fault in that substation and it may of any kind. 'SPMSS ID' is the identification number given to each smart pole-mounted substation to easily identify and locate the substation uniquely.

Table 4.3 Monitoring Parameters and their indication results

Sr. no.	**Monitoring**	**Indications**
1	Fuse operated	Buzzer
2	Voltage: 243.5 > Rated Voltage- 2 I 6.2 < Rated Voltage-	High Voltage Buzzer Low Voltage Buzzer
3	Current: Greater than max set-	High Current Alert
4	Faulty Phase	Respective phase indicator
5	Faulty PMSS	PMSS ID

D Components:

1) ACS712 Current Sensor: For cost-effective and precise ac or DC, current measurement ACS712 is used in industrial, commercial, and communications systems. It is simple to use as it comes in a single device package makes it useful for use in current measurement. Controls of motor, management of load, switched-mode power supplies, and overcurrent fault protection are examples of common uses. The ACS712 Module measures current utilizing the Hall Effect concept and the well-known ACS712 IC Two terminal connectors are included with the ACS712 module.

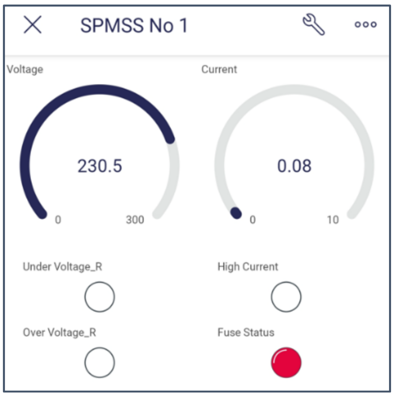

Fig. 5 Dashboard: When fuse is operated

*2) Display Unit (16 *2 Display):* A liquid crystal display (LCD) is an electrical display module that produces a visible image using liquid crystal. The 162 corresponds to a two-line display with 16 characters per line. Each character is presented in a 5x7-pixel matrix on this LCD.

3) Voltage Regulator: The voltage regulator is used to get a constant voltage. The 78xx series of voltage regulator ICs includes the IC 7805. It's a voltage regulator with a fixed linear output. The value of the fixed output voltage provided by the IC is represented by the xx in 78xx. IC 7805 gives a +5V dc regulated voltage supply. This voltage regulator can accept an input voltage of up to 35V, and it can output a constant 5V for any input voltage less than or equal to 35V, which is the threshold limit.

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4) Piezo Buzzer: The piezo buzzer working is based on the piezoelectric effect. When an electric potential is applied across the piezoelectric material it generates pressure variation or strain and produces sound. It can be used in an alert system, alarming in response to various actions, counting signals, or any input.

5) GPRS Module: SIM 800C: SIM800C is a quad-band GSM/GPRS module that works on frequencies GSM850MHz, EGSM900MHz, DCS1800MHz and PCS1900MHz. SIM800C features GPRS multi-slot class10/class12 (optional) and supports the GPRS coding schemes CS1, CS-2, CS-3 and CS-4. With a tiny configuration of 17.6*15.7*2.3mm, SIM800C can meet almost all the space requirements in customers' applications, such as smart phone, PDA and other mobile devices. SIM800C is a SMT package with 42 pads, and provides all hardware interfaces between the module and customers' boards.

6) Blynk: Blynk was created with the Internet of Things in mind. It can remotely access hardware, display sensor data, store/log data, visualize it, and do a lot more

7) Web Dashboard: The template of the web dashboard is shown below. On the first page, smart pole-mounted substations under the main substation are shown. For the prototype, we have only added two SPMSSs.

8) Mobile dashboard: Mobile Dashboard is built from Widgets - modular UI elements which can be positioned on the canvas. Every Widget serves a special function (a button, a slider, a chart, etc.). Every Widget has its settings based on its functionality. app for the single-phase system of SPMSS No 1. With this pole-mounted substation, parameters can be monitored from anywhere at any time.

V CONCLUSION

Monitoring entails obtaining significant parameters from the system of interest. The acquired data can be used to analyze and diagnose the condition of assets, which is useful for maintaining system health, managing faults, and requiring control of the system. As it is known, most of the faults in the secondary distribution system are persists for a longer time because of the lack of indication or alert of faults or abnormal conditions. The proposed system is specially designed to monitor the status of pole-mounted substations situated in many different places, a long way apart from each location. By appointing a person to monitor the parameters at all the locations, it would be incredibly costly and difficult, in addition to the fact that manual monitoring is more error-prone. The problems described above can be significantly reduced through our proposed system. We have proposed the solution for a three-phase system and verified and implemented it for a single-phase system successfully.

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