IoT BASED PILOT WIRELESS DIFFERENTIAL RELAY

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Abstract

Differential relays are simple, reliable and widely used type of protection scheme that are very much suitable for electrical system or equipment protection. The relays use pilot wires to find the 'difference' but the pilot wire itself creates so many problems. To eliminate the problems, in this paper an IoT based wireless current differential protection system is proposed based on Wi-Fi communication and is implemented as a small project work and has also been tested for the protection of a pseudo power system network. Pilot wire differential relay is one of the most common methods for protecting short transmission lines. The conventional protection scheme has drawbacks, such as malfunction due to line disconnection and limited line length. The protection algorithm is based on current signals measured at both ends of the transmission line. The data is exchanged through the wireless communication network. The relay decision is based on data sharing obtained through wireless communication network. Current differential protection using is applied widely on transmission line as the main operation. Vector difference between the measured currents at the two ends of the transmission line protected by the pilot wire differential protection is limited by the effect of resistance and capacitance of the pilot wire. The status of both the end is transferred with the help of a wireless communication through Adafruit IO server.
Keywords: Differential relay, compact module, IoT, Wi-Fi, pilot wires, Adafruit IO.

Introduction

Nowadays there are several problems associated with electricity. The flashover of lightning and other faults in the transmission line leads to shortage of electricity. There are so many methods to overcome this problem and one such method is implemented in this paper. Differential protection can be done through pilot wires and also through wireless communication Pilot wire differential protection is one of the most common methods for protecting short transmission lines[2]. The main requirements of line protection is that in the case of a short circuit, the circuit breaker nearest to the fault should open, all other circuits remaining in a closed position. The conventional protection scheme has several drawbacks.

The differential protection is applied only with the help of pilot wires. These methods are already used in transformers, generators and bus bars since small lengths of pilot wires are required. The pilot wires are made up of aluminium and copper wires, but the cost is very high. The transmission line requires lengthy wires to follow the procedure so it is not economical. The resistance and capacitance effect may change the value of current and cause the continuous tripping of the relay without any fault. These problems are eliminated by the arrival of a wireless media so we are not using any of the wired equipment [4].

The impedance of the pilot wire is a problem. This impedance even in 'no fault' condition can cause a difference. So a sensitive relay may operate even in no fault condition. Pilot wires need a proper amount of insulation considering the amount of voltage it would have to handle. The pilot wire length is limited by the acceptable amount of loop resistance as well as shunt capacitance [5]. This capacitance causes incorrect operation as large current flows through it. Moreover, the relay operation may be lost because of line disconnection of the pilot wires. So in this case we need additional protection for the pilot wire itself [6].

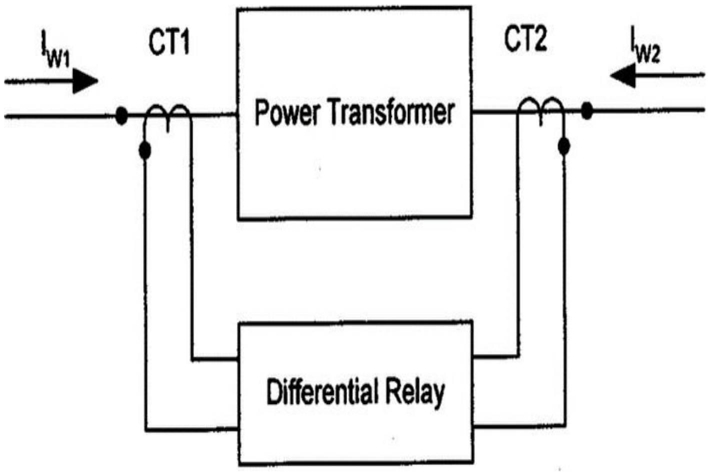


Figure-1: A Simple arrangement of current differential relay

In our research work a current differential relay based protection system replacing the pilot wire by wireless communication using Wi-Fi protocol is proposed. The authors have proposed a concept of wireless differential relay and in our work this concept has been 'implemented' as a practical project or prototype using Current sensor, Relay board and NodeMcu Wi-Fi module. This paper eliminates the above problem and also the problems associated with pilot wire disconnection.

Statement of the Problem

- The concept of wireless differential relay, a system model and current measuring devices was designed which are able to measure currents on the both sides of the protected zone and send the measured values over the internet to a web server and display the results in a web page.
- By observing the values of the currents, fault and no-fault condition can be determined and with this determination necessary command can be given like isolation and connection of the protected zone to the system.
- As IoT and Wi-Fi based internet connectivity was used, the system can be observed and controlled by an authentic user (by providing user password) from anywhere in the world.
- This wireless differential relaying system do not require any pilot wire, so all the problems associated with pilot wires are solved.

Objectives of the study

- To overcome the problems faced by the usage of pilot wires.
- No length or distance limitations for protected zone as pilot wireless and Wi-Fi internet connected.
- Remote monitoring and controlling.
- Digital type of protection.
- Better and more reliable type of protection.
- Can be controlled from anywhere in the world.
- Pilot wireless. So all problems related to pilot wires are removed.
- Can be implemented in real life power system operation with a small update like:
- Fully automation in fault detection and isolation.
- The free server used here should be replaced with a dedicated and faster one.
- The whole system should be protected against any cyber-attack.

Review of Literature

A wireless communication network supported with Wi-Fi protocol for data handling by K. M. Abdel-Latif suggested that Pilot wire differential protection is one of the most common methods for protecting short transmission lines. The wireless communication network offers advantages over conventional techniques such as no pilot wire that can break, faster response, lower cost compared to leased lines. The protection algorithm is based on current signals measured at both ends of the transmission line. The data is exchanged through the wireless communication network and the relay decision is based on data sharing obtained through it.

A new protection technique for short length transmission lines by M. Elissa using IEEE 802.11 protocol introduced that When relays communicate with each other, they can exchange information which helps the relay to make an accurate decision. The suggested protection system collects current data from both ends of the transmission line through Intelligent Electronic Device (IED) and communicates with each other to share the data.

A system protection scheme to augment traditional backup relay methods in the transmission system by X. R. suggested that Agents are used to give each protection component its own thread of control as well as the ability to communicate with others. This leads to greater capabilities to self-check and self– correct. This method naturally points towards a new philosophy for backup protection. Simulations are used to illustrate the concepts, using a simulation engine that combines the EMTDC/PSCAD power simulator with the NS2 network communications simulator.

The problems and practical solutions for applying digital line current differential protection over copper wires by I. Voloh states that Digital current differential protection has the advantages of application simplicity, operation speed, and high sensitivity. Pilot wire analog differential relays are commonly used for protection of short lines.

Research Methodology

The circuit diagram consists of two compact modules consists of Arduino, Current Sensor, NodeMcu and Relay module. The current sensor is connected in series with the line. This sensor senses the amount of current under the command of Arduino. To send the value of measured current to web server we have used Wireless Wi-Fi protocol using NodeMcu Wi-Fi Module. The NodeMcu is configured to communicate with the specified server of Adafruit IO that we desire via internet. Thus we are able to monitor the values on the dashboard provided by Adafruit IO from anywhere in the world by providing verified password to the server.

In normal operating condition, the currents shown in the system in Figure-2 should be close or equal. But in case of fault, the currents should differ from each other and the difference should be very large. So by 'observation' it is possible for a human operator to read the currents and determine the fault as stated in the flowchart in Figure-4, step 6, 'Read the values of currents I1 and I2 manually. In fault condition we need to isolate the faulty section and then clear the fault and after clearing we can resume the system operation again. To isolate the faulty section, we need to press the 'TRIP' button on the control system as mentioned in step 9, Figure-3.

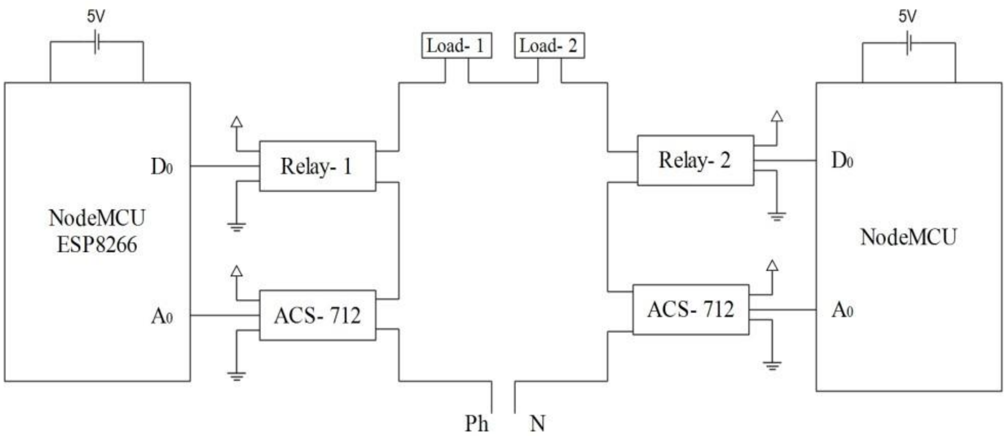


Figure-2: Proposed Pilot Wireless Differential Relay System

This will cause the relay to operate and isolate the protected zone from the rest of the system via wireless internet from anywhere in the world. After the fault is cleared we should press the 'RESUME' button to resume the system. This will cause the relay to connect the protected zone to the rest of the system as it was in the normal condition.

This 'observation' of currents and controlling of the system by 'Tripping' and 'Resuming' operations all are done remotely via IoT but till now in this work but manually.

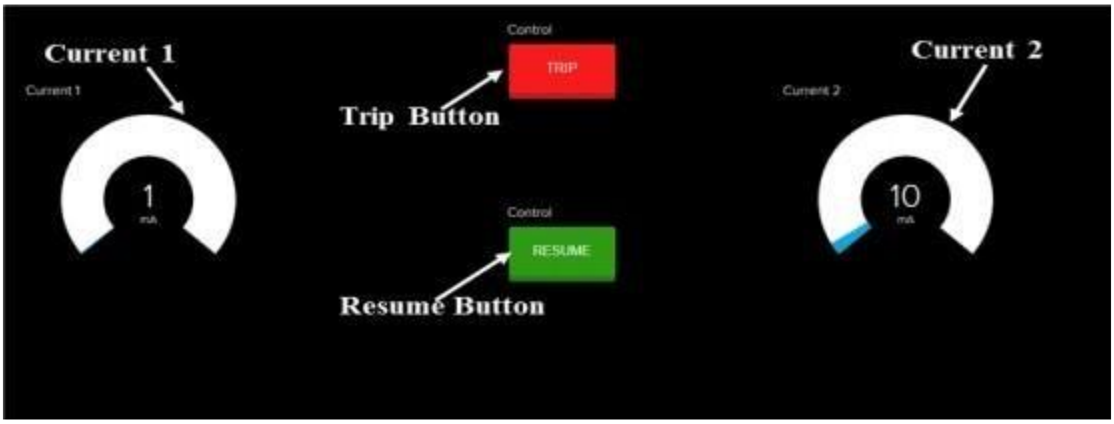


Figure- 3: Control System (Adafruit IO Dashboard) for this project.

A control system is designed using Adafruit IO web server [8]. Fig. 3 shows the control system. Here two gauges are used to show the measured values of currents labelled as 'Current 1' and 'Current 2'. Two buttons named 'TRIP' and 'RESUME' are used to operate the circuit breakers to isolate the protective Server is a place where we can store data and use the stored data whenever needed. Web server is an internet connected server that can be accessed through internet. The client can request for access and the server serves the request. Adafruit IO is a free internet based server that follows MQTT (Message Queuing Telemetry Transport) Protocol [8]. In Fig.3 the control board designed in Adafruit for the control and monitoring of current for our work is shown. The components required for the proposed system is as mentioned below in the tabular column.

Requirments	**Quantity**
Current sensor ACS712(30A)	2
ESP8266 NodeMcu Lua Wi-Fi modules	2
Relay module (5V)	2
Fault switch (240V)	1
Bulb (60W)	2
Connecting wires	Required number

Table- 1: components required

Results and Discussion

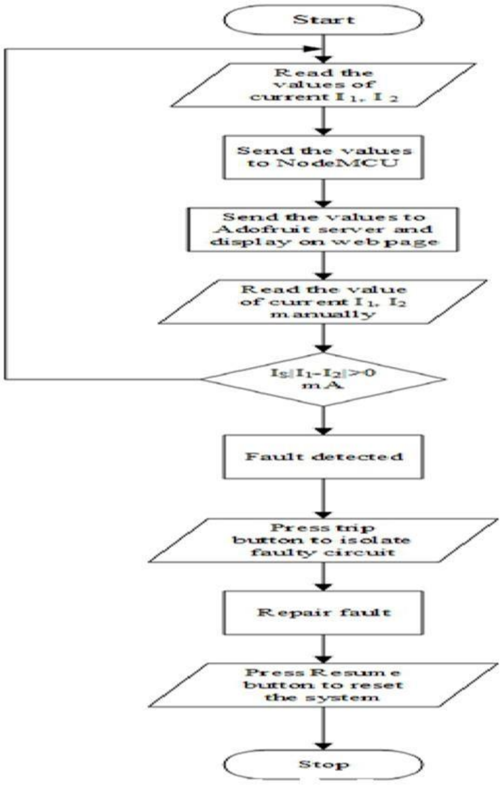
To verify the effectiveness of the proposed system, here the currents are measured in normal and fault condition. The experimental results are shown in table 2 and the set up for this conditions (normal and fault) is shown in Figure-5 and Figure-6 respectively.

In the proposed system two conditions of operation exists i.e.,

1. Normal condition
2. Fault condition

1.Determine normal condition:

In the normal operating condition, the currents on the two sides of the protected zone should be equal or at most a difference of 10 mA may occur. So from the Adafruit:



In control system if the gauges labelled as Current 1 and Current 2 show

i) The same current, or

ii) ii) |Current 1 – Current 2| < =10 mA,

Then it is considered as a normal or 'no fault' condition.

Figure-5: At normal condition

2.Determine fault condition:

At fault condition, on the display, the difference between current 1 and current 2 should be very large. So we consider if,

|Current 1 – Current 2| >

10 mA Then it is a 'fault' condition.

In Figure-4, the flowchart of the proposed system is provided for the better understanding of the system.

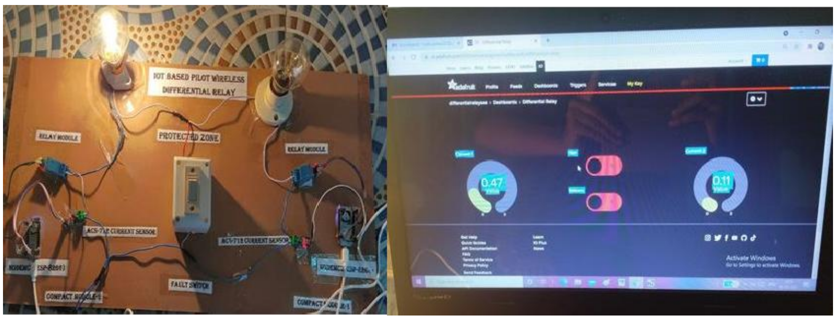


Figure-6: At fault condition

The following are the experimental results obtained on performing the two condition of operations Table.2 Experimental Result Table

S.NO	CONDITION	CURRENT MEASURED BY SENSOR 1, mA	CURRENT MEASURED BY SENSOR 2, mA
1	NORMAL	0.36	0.34
	FAULT	0.47	0.11
2	NORMAL	0.32	0.30
	FAULT	0.38	0.8

Conclusion

Here in this project, based on the concept of wireless differential relay, a system model and current measuring devices was designed which are able to measure currents on the both sides of the protected zone and send the measured values over the internet to a web server and display the results in a web page. By observing the values of the currents, fault and no-fault conditions can be determined and with this determination necessary commands can be given like isolation and connection of the protected zone to the system. As IoT and Wi-Fi based internet connectivity was used, the system can be observed and controlled by an authentic user from anywhere in the world. This wireless differential relaying system does not require any pilot wire, so all the problems associated with pilot wires are solved here. An improved version of this project can be implemented for practical application. With necessary updates this project can be made capable of giving protection to the real life power system and equipment successfully.

Benefits of the proposed model:

- Pilot wireless. So all the problems related to pilot wires are removed.
- No extra cost for pilot wire.
- Digital type of protection.
- Better and more reliable type of protection.
- Can be controlled from anywhere in the world.
- Remote monitoring and controlling.

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