Advancement of Current Differential Relay using Arduino

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Abstract-With the rapid industrialization and modernization of power sector and increase in demand requires electrical supply without failure. In this regard, it is essential to have adance protection schemes for complete power system. It incorporates frequent swiching losses and has high response time against the faults. In this work, an advance current differential relay for better safety of equipment is presented in which Arduino is programmed like that it takes instantaneous value of current through which reliability, accuracy and efficiency of this protection scheme is increased and also it is more flexible for various applications by providing repogramming feature of Arduino.

Keywords–Arduino, differential relay, power system

1. INTRODUCTION

In modern electrical power systems, confirming the safety and reliability of transmission and distribution networks is of paramount importance.One main aspect of maintaining system integrity is the timely detection and isolation of faults, which can lead to catastrophic failures if left unchecked.Current differential relays have long served as a cornerstone in protective relay systems, offering efficient fault detection capabilities by comparing currents at different points in the power system network.However, traditional current differential relays hold inherent restrictions that obstruct their performance in rapidly evolving power system environments [1].

Due to the emergence of microcontroller technology, epitomized by platforms like Arduino, has reformed the landscape of embedded systems and automation. These versatile and cost-effective microcontrollers provide a flexible platform for the implementation of sophisticated control and monitoring systems. With the advancement in microcontrollers technology brings an opportunity to enhance the functionality and performance of current differential relays, thereby improves the protection system of power system [1, 2].

This paper presents an advance current differential relay with proper integration of microcontroller technology on Arduino platform. With the utilization of computational power and versatility of Arduino UNO platform for current sensing and signal processing in relay operation brings improvements in accuracy, efficiency, reliability, responsiveness and adaptability. Through a systematic investigation of design principles, implementation methodologies, and experimental validation, this study seeks to demonstrate the feasibility and efficacy of employing Arduino-based solutions in enhancing the capabilities of current differential relays.

2. LITERATURE REVIEW

Current differential relays have been comprehensively studied and utilized in electrical power systems for its ability to detect faults by comparing the currents entering and leaving the protected zones. This section provides an overview of literature review on current differential relays and explores preceding research on the integration of microcontrollers in relay systems.

2.1 Current Differential Relays

Current differential relays are widely used relay since a long back in the area of protective relaying of electrical power system. These relays operate based on the principle of Kirchhoff's current law, which states that the sum of currents entering a node in a circuit must equal to the sum of currents leaving the node.By comparing the currents at different points in the power system network, current differential relays can detect abnormal conditions such as short circuits and line faults. Based on the literature, it is revealed that various aspects of current differential relays have been investigated considering their design, operation principles, and applications in electrical power system protection [3, 4].

2.2 Integration of Microcontroller

The integration of microcontrollers in relay systems has brought significant attention during recent years, driven by advancements in embedded systems and automation technology. Microcontrollers basically based on Arduino platform offers a cost-effective, flexible and robust solution for implementing advanced control and monitoring functionalities in protective relays of an electrical power system. Based on the past recent research, it is explored that the use of microcontrollers in the field of protection system has been utilized on the large scale for signal processing, data acquisition and communication systems [11,12]. The recent studies shows that the utilization of microcontrollers has enhanced the performance and intelligence of protective relays by enabling the features like selectivity, discrimination, operating time, fault location identification, and remote monitoring [1].

2.3 Gaps in Literature

Though there exist an extensive literature on current differential relays and the integration of microcontrollers in relay systems, certain gaps need to be addressed as yet..Foregoing studies have mostly focused on theoretical aspects and proof-of-concept implementations, with limited emphasis on practical aspects and real-world applications of current differential relay based on microcontroller technology. Moreover, there is a lack of comprehensive research that thoroughly investigates the design, implementation, and performance evaluation of current differential relay integrating microcontroller technology.

This paper focused on bridging these gaps by providing a detailed analysis of an advancecurrent differential relay using microcontroller technology, with anemphasis on practical implementation and experimental validation.

3. METHODOLOGY

In this work, the proposed methodology is described as follows:

3.1 Hardware and Software Selection

The selection of harware components depends on the type of project such as this project is a protype which can lead to industrial uses also.Arduino is the main key component of the system.Aproximately, every electronic equipmentis working on below 5V voltage and the supply is provided from Arduinoand Arduino is taking supply from a 12V DC voltage adapter.Here we are using components that are listed in Table 1.

3.2 Circuit DesignConcept

The concept behind the circuit design of this project is based on the principle of current differential relay that is the comparison of difference between input current and output current with a preset value [5,6]. The preset value of current for the project is = 0.1A

There are two cases as follows:

Case1: Normal condition

Difference of input and output should be less then the pre-set value, in this case supply will be continuous and relay doesn't operate.

$I_1 = 0.39A$, $I_2 = 0.38A$

I_1-I_2 =0.01A that is less than 0.1

Case2: Fault

Difference of input and output current will be greater then the pre-set value, in this case supply will be cut-off and relay operates and the equipment will be isolated from the fault.

$I_1 = 0.39A$, $I_2 = 0.01A$

I_1-I_2=0.38A that is greater than 0.1

Table 1: List of components

Hardware	Arduino- UNO
	16*2 LCD Display
	I2C module for LCD
	Current Sensor -ACS712(30Amp)
	5V Active Low Relay module
	220V AC to 12V DC Adopter
	Load- Bulb(100W)
	Buzzer
	Switch
Software	Arduino-IDE

3.3 Programming

The Arduino microcontroller is programmed to perform various tasks, including reading current sensor outputs, implementing differential relay algorithms, and controlling relay operation [7]. Programming logic is developed to detect fault conditions, trigger relay tripping, and provide status indicators for system monitoring.Programing of Arduino is centeredon the logic that is:

$$I_1 - I_2 >= \text{Pre-set value}$$

where I_1 and I_2 are input and output currents throught the element in ampere respectively.

- Upon the fulfillment of the given logic condition, a trip signal is dispatched to the linked mechanical relay, prompting it to interrupt the power supply.
- If the condition ceases to hold true, no trip signal is dispatched to the relay, allowing the power supply to persist, thereby enabling the system to operate under normal conditions.

The following steps of the proposed algorithm are followed to for functioning of relay:
Step 1- Provide supply to the circuit at relay end.
Step 2- Connect supply to the active load.
Step 3- Current sensor 1 measures the incoming current on active load.
Step 4- Give supply to passive load.
Step 5- Current sensor 2 measures the incoming current on passive load.
Step 6- Arduino compare the current sensors 1 and 2 and compare it with preset value 0.1A.
Step 7- If the value is less than 0.1 then the trip signal is sent to the relay.

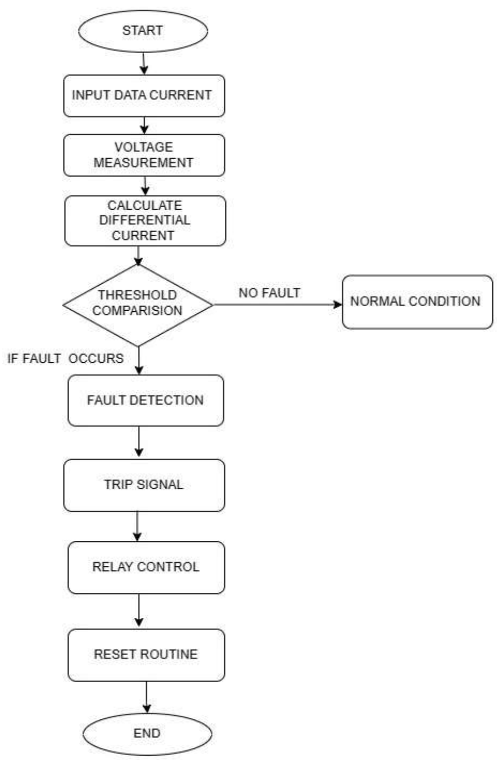

Figure 1: Flowchart for differential relay

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4. DESIGN AND IMPLIMENTATION

4.1 System Architecture

There is a simulated circuit of differential relay as shown in Figure 2.

4.2 Hardware Implementation

Initially a 230V, 50Hz supply is given to the load (100W bulb). Here two current sensors are utilized to collect the sample and measure the input current and the output current across the load and these samples are stored into the Arduino [8, 9].

For the occurance of fault, a separate load (100W bulb) is utilized that can be turned ON and OFF using switch.

Due to the fault there is a signal sent to the mechanical relay by which the supply will be cut-off and due to the Arduino programming the system will not be turned ON until the removal of fault and then reset the Arduino.

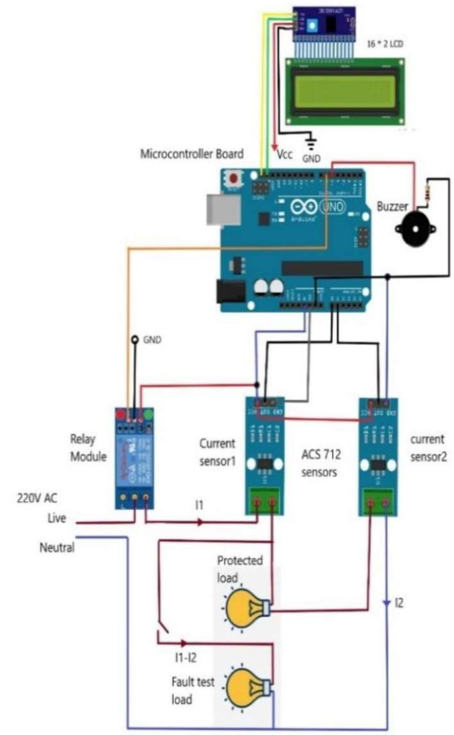


Figure 2: Simulated circuit of differential relay

In this work, in order to identify the fault a current differential relay principle is utilized that is the comparison of difference of inputand output current with a preset value of 0.1A. Thus, the logic for the operation of differential relay is

$$I_1 - I_2 >= 0.1$$

During Normal Condition:

Input and output current measeured by the current sensor 1 and 2 are respectively approximate 0.39A and 0.38A.
$I_1 = 0.39A$, $I_2 = 0.38A$
$I_1 - I_2 = 0.01A$ that is less than 0.1

During Fault Condition:

Input current is 0.39A but for the fault second load is ON due to which output current is 0.01Amp.
$I_1 = 0.39A$, $I_2 = 0.01A$
$I_1 - I_2 = 0.38A$ that is greater than 0.1

In this work, there are two ways to show the occurrence offault:

a) LCD displays "**Fault Occuured**"
b) Buzzer starts beeping

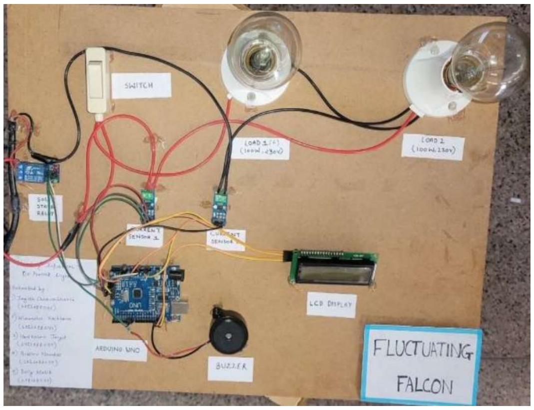


Figure 3: Hardware circuit of differentialrelay

4.3 Implementation of Current Differential Relay Program using ARDUINO Software

Theprogramme is implemented through the Software Arduino IDE on Arduino UNO [10].

Procedural Steps:

- We are including Liquid crystal library.
- Output of current sensors are stored in Arduino at analog pins.
- Lcd pins are connected at digital pins of Arduino.
- Solid state relay (Mechanical switch) connected at digital pin of Arduino
- Buzzer is connected at digital pin of Arduino for the alert during fault.

The programming logic developed for the Arduino microcontroller. Code snippets and algorithms are provided to elucidate the implementation of differential relay functions, fault detection algorithms, and relay control routines.

4.4 Effect of Integration during Testing

The integration of hardware and software components is performed, followed by rigorous testing to validate the functionality and performance of the relay system.

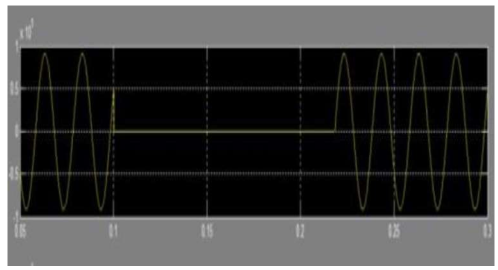
During the tests some key points comes into picture are as follows:

- This protection system is highly sensitive.
- Response time of relay during fault is decreased, and thereby,relay becomes fasterso thatfaulty equipment is isolated fastly.
- Due to the fast isolation overall life of equipment increases.
- Cost of this protection scheme is less than convention scheme
- Due to the reprogramming feature, device is flexible for the use in various applications.

The simulation results of the prosped differential relay is presented in Table 2 that whenever the difference of the two

Table 2: Simulation results

Time (s)	Condition	Input Current (I1)	Output Current (I2)	Difference	Relay	LCD Message	Buzzer
0	Normal	0.39	0.38	0.01	Off	Normal	Off
1	Normal	0.4	0.39	0.01	Off	Normal	Off
2	Normal	0.41	0.4	0.01	Off	Normal	Off
3	Fault	0.39	0.01	0.38	On	Fault Occurred	On
4	Fault	0.39	0.02	0.37	On	Fault Occurred	On
5	Fault	0.4	0	0.4	On	Fault Occurred	On
6	Recovery	0.4	0.4	0	Off	Normal	Off
7	Normal	0.41	0.41	0	Off	Normal	Off
8	Normal	0.42	0.42	0	Off	Normal	Off
9	Normal	0.43	0.43	0	Off	Normal	Off



Normal Fault Normal

Figure 4: Simulation waveform

5. CONCLUSION

The key findings of this work is that with the integration of microcontroller devices such as Arduino in the current differential protection system, the overall efficiency of the differential relay is increased, and thus making it more efficient, reliable, accurate and faster for various applications of power system protection system. In near future, this advance protection relay could be utilized for more applications into the power system for higher ratings with some more inclusion in design and technology.

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