Design and Implementation a New Real Time Overcurrent Relay Based on Arduino MEGA

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Abstract. The relay is very important part of a power system to protect the electrical power system from the disturbances. The new proposed relay is overcurrent relay OCR that be used to protect the devices from any increasing of setting current. The new designs of OCR based on embedded system that used to emulate two characteristics: Instantaneous and Definite Time. The Instantaneous work directly without any wait when the current exceed the max current that causes system damage, the other type is working when the passing current exceeded the setting current and at the same time the current continuous in a period of time. The proposed circuit which is used with three-phase power system load depending on the Arduino Mega as a main controller of OCR. The experimental results showed the reliability, sensitivity and flexibility under different operation conditions. This relay was tested on the modern electric system from (Audubon company) to several cases and the results showed the efficiency of the proposed OCR to protect the system.

Keywords: Three-Phase Overcurrent Relay, OCR, Arduino MEGA, Relay, AC80

1. Introduction
A power system ideal must be contain with a good protection system to protect the system from any fault that may be occurring in the system when the power system in the state of operation [1]. The protection unit of any power system consist of a relay and a circuit breaker and a current transformer to tell the relay In quantity the value of the current that input to the relay [2]. The principle of this OCR if the value of the current exceeded the sitting value the microcontroller send the signal to the relay to disconnect the system.

Many studies dealt with the implementation of OCR. In [3] Arduino UNO used to design and implementation a digital inverse Overcurrent. Also In [4] Overcurrent protection (OCR) in the future renewable energy management (FREEDM system) by using Arduino UNO. In [5] the researcher presents a new design for implementation of radial feeder protection by an Arduino. In [6] A GSM module for combination between it and Arduino NANO. In house to protect from OCR that occurred. In [7] the paper present a simulation of overcurrent relay OCR by using Fuzzy logic and based on a neural network. In [8] the researcher present effect of ground fault for to prevent the system from phase to ground fault. In [9] A new design of Overcurrent relay OCR by using FPGA and present the type of IDMT for OCR protection.

Thera are two types of OCR directional and non-directional, In [10], [11] and [12] A new modelling, analysis of performance analysis of the two types of OCR directional and non-directional.
There are some cases will be occurred in Three phase fault: three phase, single phase to ground short circuit, Internal fault, current leakage, over current, etc.... The electric power system required protection system to protect it from these types of fault. In a Power System Protection, the power engineering its necessary to control the current, voltage, frequency. Arduino MEGA used as a microcontroller to protect the system from an increased in current caused by faults.

In this paper, A new implementation was proposed to protect the system from three phase fault by using some tools: current sensor AC80, one channel Relay, Arduino MEGA, switch, LCD. This paper organized as follows: section 2 discusses overcurrent problem, section 3 presents the low cost of overcurrent relay, section 4 discuss practical system description, finally section 5 offers conclusions.

2. Overcurrent Problem
The power system is a very important in electrical engineering because the electrical device and transmission lines are being exposed to any undesirable condition. The aim of the OCR is Reducing the risks resulting from abnormal conditions as a result of high current passing through the power system. This problem can be overcome by isolating all the other components in case this condition occurs. To achieve this, the current and time is set to a value if the current and time exceeds that value the device sent a signal to the CB in order to protect the power system from damage as shown in Figure 1. In this paper, a new design is implemented by using Arduino MEGA. The aim of this is designed to sense the over current that occurred by testing this proposed relay on the three phase transmission line As shown in Figure 2 because different cases of fault like, lime to line fault, line to ground fault, earth fault.

![Figure 1. The principle of an OCR](image1.png)

![Figure 2. The proposed overcurrent protection relay circuit.](image2.png)

3. Overcurrent Relay
The proposed relay is designed by using Arduino MEGA. Overcurrent relay similar to Hidden antagonists in the system. The relay will operate quickly in the event of any error occurs. If the current is exceeded the normal current and how the current increase is serious or not. The program of the circuit was built and written through the C language. To guarantee the quality of the new circuit of overcurrent protection circuit the circuit is tested through Laboratory system from (edibon company),
the program and other associated tools are developed in order to simulate the over current properties. The circuit software and hardware is designed by using Arduino MEGA. All types of fault are tested and checked by using three phase load.

3.1. Instantaneous Overcurrent Relay.
   The instantaneous over current relay defined as the current will be increased sharply and exceed the peak current of the system. This type is very important to protect the outgoing feeder from the fault current that produced because the short circuit and transient and overload condition. The properties of this state, no time delay, and the operation time is less than 0.1 s.
   The condition of this type is:
   If I > Ipeak then CB will operate in 0.1 s.

3.2. Definite Time overcurrent relay
   The second type of Overcurrent Relay is Definite Time Relay. If the current is increased and surpass the sitting value or operation current and at the same time the overcurrent is continuous for a period of time exceed the sitting time of the relay. The relay will send a signal to the CB to turn it on. The value of the peak current and the time delay Depends on what guarantees protecting the system from collapse. The OCR will operated if the condition of peak current and time delay will be achieved. But, If the current exceeds the maximum value and the time condition is not fulfilled, the Relay will not work. The definite time relay is used to support the distance relay and differential relay to protect the transmission lines and transformer respectively, also used to protect the outgoing feeder. This properties showed in figure 3. The condition of this type is:
   If I > I set & T>T set, then CB will operate.

\[ \text{Figure 3. Characteristics of definite time} \]

4. Proposed design
   The steps of the design proposed OCR It is divided into two stages. The first stage is the software part and the other stage is the hardware part. The final proposed design of the Overcurrent Relay and with the characteristics of the OCR is shown in Figure 4. The component of the new proposed OCR consists of some device like an Arduino MEGA and AC80 as current sensor is sensing the current up to 100 Ampere, the circuit Breaker and LCD and switch for setting the time and the current.
4.1. **Software port**
The purpose of the first part of proposal really is the software. The of this part is to connect all part component of the OCR like current sensor AC80 the Arduino MEGA, one channel Relay, LCD and other components produce a distinct type capable of protecting any power system from an increasing in current fault (overcurrent fault). The program of the Arduino MEGA is written in C language by using ARDUINO 1.8.9 program that be demonstrated in flowchart from figure 5.

![Figure 5. The Flowchart of the Arduino MEGA program](image-url)
4.2. Hardware port
The other stage of the proposed relay is assembled and connect all electrical components. The result of the connects the components are produced the proposed Overcurrent Relay. The software is also connected like Hardware To organize the working components of the hardware part.

4.2.1. One Channel Relay
Firstly, The definition of relay is an electrical switch that will be open or close circuit depending on other circuit called control circuit. The properties of this relay is 240V and 10 ampere alternator current. Figure 6 represent the internal circuit of the relay, the circuit of the relay contain a transistor to activate the coil of the relay that feeds from the external source. The properties the relay consumes 80mA at 5V, and contact of 10 A at 250V Alternator current or 30V Direct current also the relay contain a led to indicate the state operation if ON or OFF.

![Figure 6. Relay Circuit diagram of Relay](image)

4.2.2. Sensor Module PZEM-004TAC (AC80)
In this proposed relay the sensor module used is a PZEM-004TAC communication module. This module is a frugal solution specially in the AC multifunction measure, the module is mainly used for measuring AC voltage, current, active power, frequency, power factor. The sender does not contain a display, but the data is read through TTL interface. The measuring range of sensor up to 100A starting measuring current 0.02A, resolution 0.001A, measuring accuracy 0.5%. The sensors read the current from the transmission line and send the reading to the Arduino In order to take the right decision. As shown in Figure 7.

![Figure 7. The practical connection of current sensor AC80](image)

4.2.3. 16x2 LCD
The 16x2 Character LCD has an optional for power supply + 5.0V or 3.0V. The pins connected to the Arduino According to figures 8. The LCD showed the value of time sitting and the reading current and sitting current.

4.2.4. Arduino MEGA
The Arduino will be used in this paper is an Arduino MEGA. It is an open source microcontroller platform. It is considered one of the most wide spread boards and one of the largest sizes available from Arduino types, as it contains the largest number of Analog and digital ports where it works with a microcontroller from type ATMEGA2560. It contains 54 digital ports (input and output), 16 ports can be used as an Analog port. In addition to that It has a USB port that provide source power to the Arduino board also used to programming it by connect the Board to the computer. Also, we can
supply the board with an external power source, either through a 9V battery or through an electric transformer and taking into account the values of 9V 1A By applied to the positive source to the Vin and the negative source to the GND. It also has two values of voltage output one 3.3 V (Pin 3V3) and another 5V (Pin 5V). As well the board also contain on 16 Analog input Pins from (A0 to A15) take values from 0 to 5V , also has a digital input In contrast to the digital signal that you output, either 0 or 1.It also contains Arduino MEGA Board on 15 PWM . And Last but not least the board contains 8 ports send and receive RS/TX .The figure 8 shows the external structure of the Arduino MEGA.

Arduino pins support a maximum of 40mA (plugging in a circuit that lets more current through can burn the pin). Resistors must be calculated to limit current. The entire Arduino provides a maximum of 200mA. But it is possible to control circuits that consume much more current, since the signals sent and received by the pins are intermediated by circuits that reduce currents and voltages to levels supported. This can be done with resistors, capacitors, transistors, relays and other devices.

Care must also be taken not to short the outputs (5V or 3V3 connected directly to GND). Analog and digital pins can be connected directly to 5V or 0V only if used as inputs. These values are treated as information (logical level HIGH and LOW) by Arduino. To use them as outputs, you must configure this functionality in programming, and take the same care as outputs 5V and 3V3 (do not connect directly to GND), and use resistors to keep current flowing within the limit.

![Figure 8. The Arduino MEGA &LCD](image.png)

5. Practical System description
The final form of the practical circuit of The Overcurrent Relay is shown in figure 9 and 10. The circuit consist of six parts: (1) Arduino MEGA work as a microcontroller, (2) current sensor AC80 module to sense the current increase in lines and between lines and earth fault when the fault occurred, (3) Input and output ports to operate the circuit, (4) Relay, (5), 16x2 LCD and finally, (6) switch for settings the time and current. The final circuit of three phases over current relay are tested on the laboratory system Presenter by the (edipon company) , the current sensor real the line current in each phase and compare with the setting value , all the result showed on the LCD screen.

![Figure 9. The practical system libratory from the edibon company](image.png)
According the full circuit designed in the Figure 10, the flowchart in Figure 5 shows the full practical working system. It shows the Arduino MEGA (the microcontroller) senses the single phase current in a transmission line. The first case, If the measuring current greater than the max current sitting value, then the Arduino NANO send signal to turn the Rely ON without any delay or waiting. The second case, If the measuring value exceeds the value of setting value, the microcontroller waiting (TD ms) to check if the measured value is a Fault or just a sudden increase in measuring current. Then, if the measuring vale continued more than (TD ms), the microcontroller sends a signal to the overcurrent circuit relay to turn The relay ON. After 5 minutes the Relay turn OFF and the system returns to measure the line current. These steps are the same in any phase.

6. RESULTS & DISCUSSIONS

6.1. The accurate reading of the current sense AC80 100A.

The result shows the reading of current sensor is less than 0.5% of the trusted meter. The result in table 1 shows the difference between the trusted reading and the current sensor reading. The results demonstrated the accuracy of the current sensor.

| The reading of the trusted meter (A) | The reading of current sensor AC80 (A) | The difference (%) |
|-------------------------------------|--------------------------------------|-------------------|
| 0.58                                | 0.56                                 | 0                 |
| 1.17                                | 1.14                                 | 0.5               |
| 0.69                                | 0.66                                 | 0.33              |

6.2. Instantaneous Overcurrent Relay.

The result shows the accuracy of the OCR and the speed of response to the increase of the current above the max current. The results show in table 2 between the current and the state of the relay if trip or no trip where the reading current exceeds the peak current, and this result can be expressed in Figure 11.

| The peak current (A) | The reading current (A) | State operation |
|----------------------|-------------------------|-----------------|
| 0.9                  | 0.56                    | No Trip         |
| 0.9                  | 1.14                    | Trip            |
| 0.9                  | 0.66                    | No Trip         |
6.3. The Definite Time Overcurrent Relay

This type of fault is used to avoid the transient fault. The principle work of this type if the fault current in the transmission line exceeded the sitting value and in the same time is continuous at a period of time m the Arduino send a signal to the relay and trip at once. Table 3 below show the result between the value of the sitting current and time sitting and compare with sitting value of taking the true decision if the trip or not, and this result can be expressed as shown in Figure 12.

| The reading current (A) | The time (S) | State operation |
|-------------------------|--------------|-----------------|
| 0.56                    |              | No Trip         |
| 1.14                    | 2            | No Trip         |
| 0.66                    | 4            | Trip            |

Figure 11. The relation between The Instantaneous current and the time

Figure 12. The relation between the current and The definite time OCR
7. Conclusions
The overcurrent relay circuit in this paper is designed by using the Arduino MEGA as a microcontroller. And the current transformer CT (AC80) that it used to sense the magnitude value of the current for unidirectional three phase current system in addition to sensitivity the magnitude of earth’s fault resulting from the passage of the current through the neutral part. The software program of the practical system was created through the C language the accuracy of reading is more than 99.95%. The OCR has two types. The first type is instantaneous, it works only if the current input to the microcontroller exceeded the peak value of current that the fault occurred. The other type of OCR is definite time this type will be working only if the current passes exceeded the sitting current and the value of the fault time exceeded the sitting time.

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