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DESIGN AND IMPLEMENTATION OF INTELLIGENT CIRCUIT BREAKER FOR ELECTRICAL CURRENT SENSING AND MONITORING

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Abstract

The sudden increase in electrical current due to increased load or electric short circuit lead to the control panel damage in homes and companies or other institutions, and may also cause damage in the electric wires which carries the electric current, which may cause to electrical seam and then lead to the connected appliances damage to the same system as well as lead to the fire. In this, paper will build intelligent circuit breaker based on Arduino and necessary sensors such that current and voltage sensor and with help of LCD can print the result of voltage and current, the intelligent circuit breaker will monitor and control the consumption current due to various domestic loads or short circuit. In short, circuit condition the current is very large and the voltage approximately equal to zero, the Arduino receive these values from sensors then compare it with the threshold values to make the proper decision to protect system from damage and the same principle with increasing the load limit.

Keyword: Arduino, Circuit breaker, Current sensor, Voltage sensor, Electrical seam, LCD

I. INTRODUCTION

Because the increase the problems of electrical currents such as burning of buildings or exposure to direct shock due to electric short circuit or over loading and thus damaged the control panel ,so must take more sophisticated and intelligent measures to limit those risks such the smart and fast response circuit breaker. Through this paper, we are going to protect the system from overload conditions and short circuit.

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A fault will cause currents of large value (short circuit current) to flow through the network to the faulted point whether in an electric current transmission line or a control panel, This short-circuit current rating is normally expressed in R.M.S symmetrical amperes and is specified by current magnitude only[1]. The voltage variation and increasing in absorbing current have always a trouble and liable for most of the breakdown in Alternating current appliances usual house appliances such TV, toaster or high performance artificial apparatus like the induction motors, CNC or everything has a rated voltage which with it run smoothly without any problems at its maximum efficiency[2].

1. ARDUINO

Arduino is a microcontroller for making computers that can sense and control more of the physical world than desktop computer, Arduino is an open-source electronics platform based on easy-to-use hardware and software, Arduino can used for developing interactive objects, able to read/write digital or analog signals from a finger on a button , sensors, keyboards, or touch screens and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can communicate with software running on the computer [3]. The open-source Arduino environment makes it easy to write code and upload it to the I/O board it works on Windows, Mac OS X, and Linux, the environment it written in Java and it based on Processing language, and other open source software, the Arduino IDE contain a text editor for writing code, error and other message area, text console, and toolbar with buttons for common functions such verify button, code upload button, Arduino programs are written in C or C++[4]. The figure (1) shown below illustrate some of Arduino families.

Figure (1) Arduino families

1.1 HARDWARE DESIGING OF INTELLIGENT CIRCUIT BREAKER

Arduino UNO

The Uno is one type of Arduino families, a microcontroller board based on the ATmega328P. It has 14 digital pins can used for digital input or digital output specify that through programming (6 pins of which can using for analog output by PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, as ICSP header and a reset button. It contains everything needed to support the microcontroller, simply connect it to a computer

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with a USB cable or power it with an DC adapter or battery to get start [5],the figure(2) below shows the Arduino UNO kit.

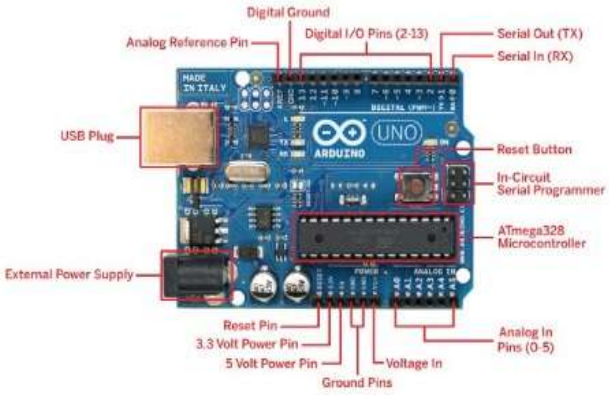

Figure (2) Arduino UNO kit

Arduino Uno Specifications and description of memory are list in table (1) below [6]:

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Table (1) Arduino UNO specifications

VOLTAGE SENSOR

The module shown in figure (3) it based on resistance point's (voltage divider) pressure principle and it can make the input voltage of red terminal reduce five times of original voltage. The max analog input voltage can Arduino read it up to 5 V, so the input voltage of this module

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should be not more than 5 V * 5 = 25 V. Because the Arduino chip have 10 bit ADC, so this module simulation resolution is 0.00489 V (5 V / 1023), and the input voltage of this module should be more than 0.00489 V x 5 = 0.02445 V. The working principle of this sensor based on divider the input voltage upon two series resistors, and then compute the output voltage and read it by the Arduino; the Special Parameters of the voltage sensor are listed below [7]:

1. The range of the input voltage are from 0Vto 25 V (DC).
2. The range of voltage detection are from 0.02445 V to 25 V (DC).
3. The resolution of analog voltage is0.00489 V.
4. DC input interface: red terminal positive with VCC, negative with GND

Figure (3) Arduino Voltage Sensor Module

This module consist of two series resistors 30KΩ and 7.5KΩ as shown in figure (4), to determine the output voltage use the voltage divider rule. The goal to evaluate the value of output (i.e. voltage across 7.5KΩ) by using the voltage divider rule, as the following equations [8]:

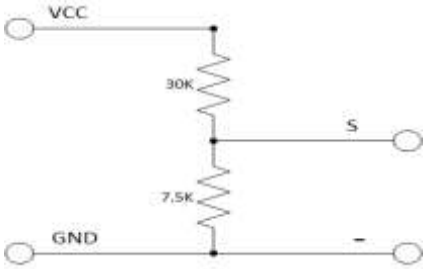

Figure (4) internal resistors of the sensor

The total resistance in series circuit equal to summation of the resistors in the circuit:

R=$R_1 + R_2$ ..... (1)

The total current according to ohm's laws is:

$I_= \frac{V_{total}}{R_{total}}$ ..... (2)

Now, the total voltage equal to (V) and total resistance equal to(R):

I=$\frac{V}{R}$

The voltage across 7.5KΩ resistance:

$V2 = I * R_2$ ..... (3)

From substituting Eq. (2) in Eq. (3) get the voltage on 7.5KΩ:

$V_2 = R_2 * \frac{V}{R}$ ..... (4)

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CURRENT SENSOR

The current sensor it is based on the precept of Hall Effect, According to this precept, when a current carrying conductor is placed into a magnetic field, a voltage is generated across its edges verticalness to the directions of both the current and the magnetic field. It is explicated in the figure (5) shown below. A thin sheet of semiconductor material is carrying a current (I) and is placed into a magnetic field (B) which is verticalness to the direction of current flow. Due to the presence of Lorentz force, the distribution of current is no more uniform across the Hall element and therefore a potential difference is created across its edges perpendicular to the directions of both the current and the field. This voltage is known Hall voltage and its typical value is in the order of few microvolts. The Hall voltage is directly proportional to the magnitudes of I and B. So if one of them (I & B) is known, then the observed Hall voltage can be used to estimate the other [9].

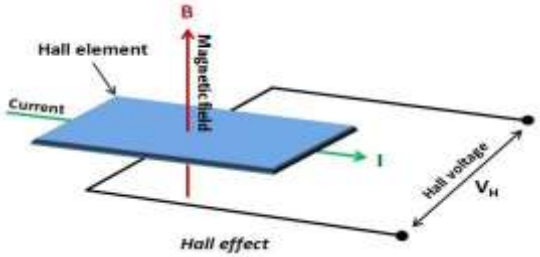

Figure (5) Principle of Half-Effect

the ACS712 sensor shown in figure (6), works according to the hall effect principle this sensor can deal with both of alternating current (AC) or directed current(DC) to determine the current. The ACS712 is designed to three ranges of current 5A,20A and 30A, the sensor consist of integrated circuit that works according to Hall-Effect principle it generates voltage proportion with the flowing current in the electric device[10]. The figure (7) illustrates the variation of the output voltage with the current flowing in any connected device.

Figure (6) ACS712 current sensor

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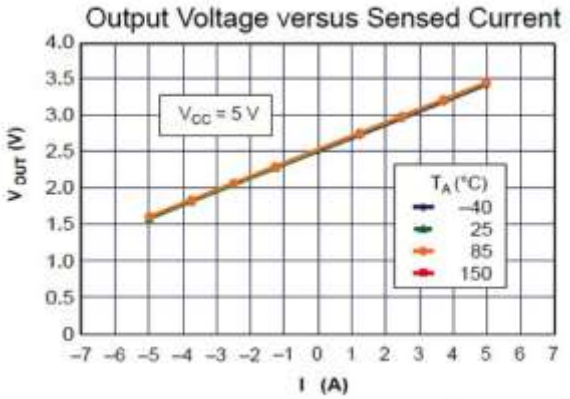

Figure (7) variation of the output voltage with the current

Usually the expression of AC current will be in RMS value. When need to use the ACS712 current sensor to measure AC current, it is important to calculate an RMS current value from the device readings, With an ACS712, current measured are converted with a voltage output the, figure (8) illustrate the waveform of alternating current[11].

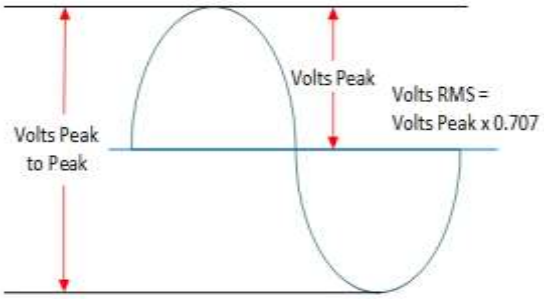

Figure (8) waveform of alternating current

To calculate the RMS value of the output waveform should performed as the following steps:

1. Obtain the peak-to-peak voltage (Volts Peak to Peak)

2. Divide the peak-to-peak voltage by two to get the voltage per one peak.

3. Divided the peak voltage by $\sqrt{2}$ to obtain the root mean square value (Volts RMS).

To obtain the RMS value used the following equations:

$$u_{RMS} = \sqrt{\frac{1}{T}\int_0^T u(t)^2 \cdot dt} \quad \text{..... (5)}$$

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The sinusoidal waveform time dependency can be, describe by the function below:

$$u(t) = a_1 \sin(\omega t), \text{ where } \omega = \frac{2\pi}{T} \quad \text{..... (6)}$$

Where:

T=the periodic of signal

a1=the amplitude of signal (Vpeak)

Now sub Eq. (6) in Eq. (5) and take the square to both side get:

$$u_{RMS}^2 = \frac{1}{T}\int_0^T u(t)^2 \cdot dt = \frac{a_1^2}{T}\int_0^T [\sin(\omega t)]^2 \cdot dt \quad \text{..... (7)}$$

Use the trigonometric identity below to evaluate the integral:

$$[\sin(\omega t)]^2 = \frac{1}{2} - \frac{\cos(2\omega t)}{2} \quad \text{..... (8)}$$

So, RMS becomes:

$$u_{RMS}^2 = \frac{a_1^2}{T}\int_0^T \left(\frac{1}{2} - \frac{\cos(2\omega t)}{2}\right) \cdot dt = \frac{a_1^2}{2}\left(1 - \frac{1}{2T}\sin(2\omega t)\Big|_0^T\right) = \frac{a_1^2}{2} \quad \text{..... (9)}$$

Now, get the final equation:

$$u_{RMS} = \frac{a_1}{\sqrt{2}} = 0.707\, a_1 \quad \text{..... (10)}$$

The equation of RMS can be write as:

$$V_{rms} = \left(\frac{V_{p\text{-}p}}{2}\right) * 0.707 \text{..... (11)}$$

The output value of the ACS712 sensor are constantly changing when deal with measuring alternating current, in order to ensure that must have taken very close to finding the peaks, its need to sample very fast enough and long enough. Because mains or line power is at a frequency of 50 to 60 HZ, the Arduino will be fast enough provided it take consecutive samples with little or no interruption [12]. The ACS712 connect in series with load to maintain the current flow to the electric device flow through it as shown in figure (9).

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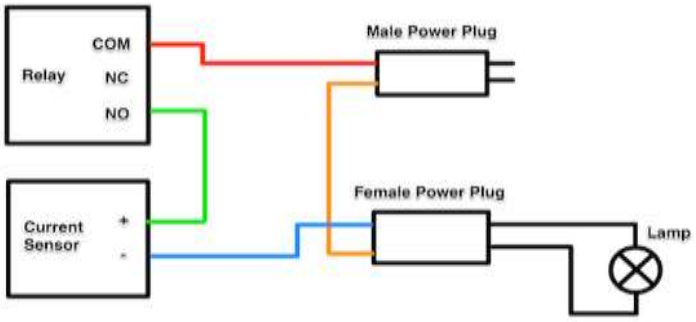

Figure (9) connection of ACS712 with load

II. SYSTEM IMPLEMENTATION AND WORKING PRINCIPLE

A Smart Electrical Circuit Monitoring system is built on a Vero-board to monitor the voltage and current values and make a decision to switch off automatically the heavy load using a relays, in this work used the 4-channel relay to connect or disconnect part of connected appliances or whole system. After decision making inside the Arduino with respect to the values taken from current and voltage sensors, a control signal it sent to the relays to switch off the loads that are connected to the relays. In this work when the current reaches to (10A), two relays switches OFF (i.e. there is main load must working usually), then re-switch them ON again if current not exceed 10A. The secondary loads are suppose that the one of the secondary load as fan work with two speeds automatically, the first speed take 2A and the second speed take 4A so, when the current and exceed 10A the relays of secondary loads will be turned off and after few seconds of time will be ON to restart the system and the secondary load work with low vale of current. When the current reaches to (12A), all relays switch OFF the loads for a while then re-switch them ON again after few interval of time to inform the house owner there is over loading. If the current large and voltage approximately equal to zero this meaning, the short circuit is detected so the system will completely shut down. Figure (10) shown below illustrate the intelligent circuit breaker.

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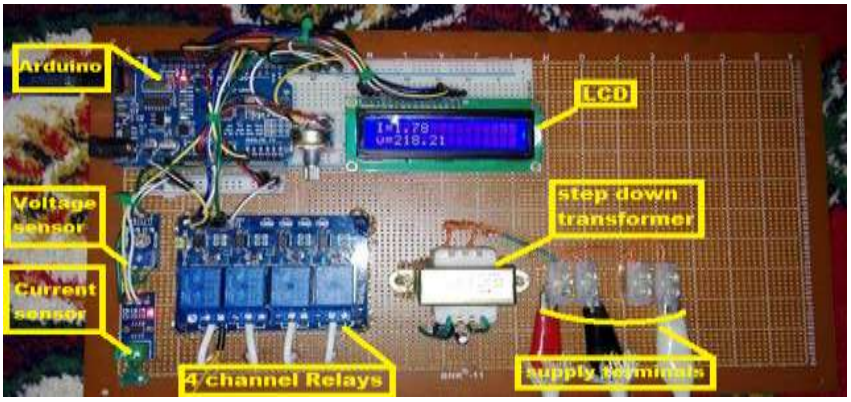

Figure (10) the intelligent circuit breaker

The figure (11) shown below illustrate the block diagram of the intelligent circuit breaker

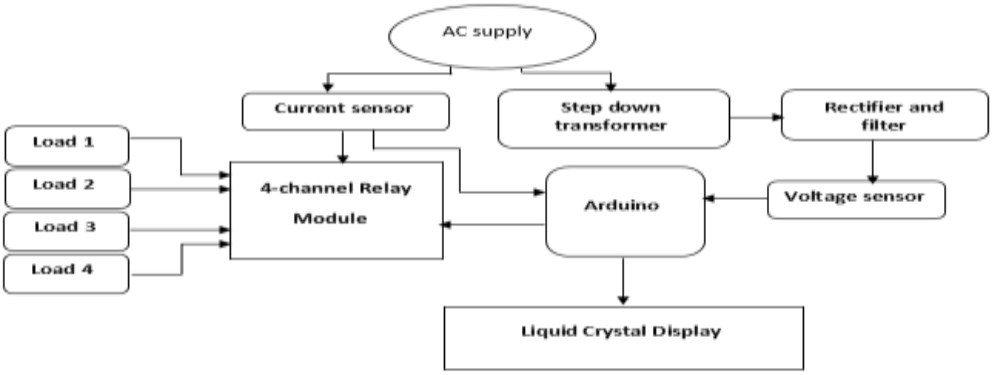

Figure (11) block diagram of the intelligent circuit breaker

A step down transformer is used in the system to decrease the voltage from AC (220V) to AC (7V), the AC voltage is converted to DC Voltage using Rectifier Bridge, then a capacitor is used to filter the DC signal, Figure (12) shows this section.

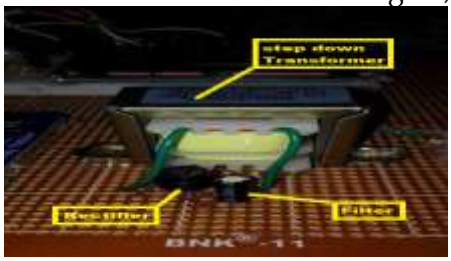

Figure (12) step-down transformer

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The voltage sensor readings are multiplied by a factor from the analog readings of the sensor, which is of the range (0 to 1023), to get the rate from the 220 V AC. The current sensor reads the current value and convert it into a relevant voltage value. Then the values of the voltage and the current are printed on the LCD screen as shown in Figure (13).

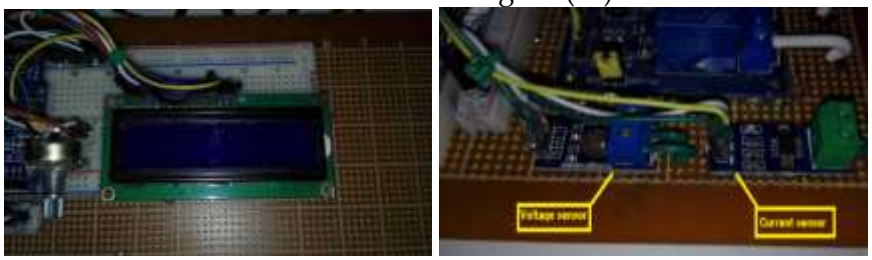

Figure (13) Sensors and the LCD

III. RESULT

There are more ways for controlling and monitoring the alternating current depending on the controller type or the used sensor or the type of display the results of the voltage and current. In this paper used the Arduino for controlling unit and the necessary sensors such that voltage and current sensors to help the control unit to take the suitable decision during the short circuit condition or over loading automatically instead of the traditional way such manual circuit breaker. In this work, there is two major parts, which are the controlling, and the monitoring parts, the controlling part it responsible to make the whole system shutdown during short circuit. The monitoring part responsible on make the main load usually "ON" by make the secondary "OFF" and after few time make it "ON" to make the system stable and in range with the threshold vales of current and responsible on print the result on the LCD. The figure (14) shows the practical reading of current and voltage for a small load.

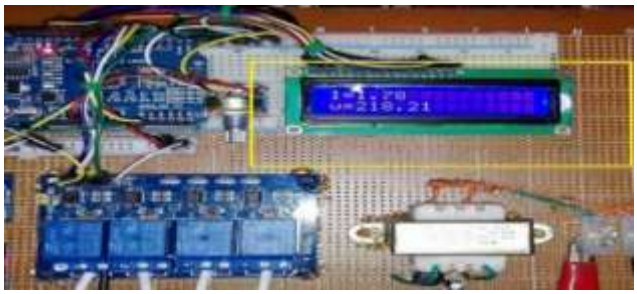

Figure (14) practical reading of current and voltage

IV. CONCLUSION

The low power equipment's take vital role in markets and demand is increasing in homes or elsewhere, to avoid the dangers of electrical power and to obtain the adequate safety must use the fast response circuit breaker. The system design to protect the owners of houses or the other institutions from dangers of electric current it is designed to instantaneous breaking if fault or over loading has been occurs due to short circuit or over loading.

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