Electronic Overcurrent Protection Relay Design and Application

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***Abstract*— In this study, it is aimed to control the AC circuits of ACS 714 sensor up to 30 A with over current, time and external signal parameters. The user can determine which current range the system should operate on. The phase control is intended not only to overcurrent protection relay, but also to manually control the relay on / off by intervention from the outside and automatic control with software defined time. This is done by measuring the phase current with the ADC sensor of the ACS 714 to perform protection and control operations. In the experimental study, it was seen that the error rate in overcurrent after calibration was more successful than the previous observations.**

***Keywords*— Overcurrent, Relay, ACS 714, Protection, Arduino**

I. INTRODUCTION

Throughout history, humanity has been found in great search for energy needs. There is no doubt that the greatest invention of this quest is electricity. From the needs that make human life easier to health, life, economy, technology, development and living standards, all the living things have changed positively in this life. It is also a fact that electricity is a very useful need and that it will lead to great disasters if it is not used properly and if necessary, precautions are not taken. Protection and control equipments are used in all stages from generation to transmission and distribution in order to avoid damage. One of the most important of this equipment is the fuse and over-current relays designed to protect people and all electrical-electronic appliances in overcurrent conditions on adverse conditions. With these devices, the risk is reduced and the security needs are met.

If mechanical or analogue-digital phase currents are measured at a higher level than allowed by the device, the circuit is switched off after the necessary operations and electricity is cut off. By removing the risks that may arise in this way, human health and material losses are under great control. In the overcurrent relays used in transformer substations, large currents are controlled away from the energy field under high voltage with the current ratios of 1-5 A level. The relay connected to the secondary terminals of the current transformers protects the circuit by sending a signal to the circuit breakers when the current value is exceeded. These relays can send not only the current value but also the signals connected to the coil ends, or activate the necessary warning outputs. Another circuit element that has a similar operating principle to current transformers is the ACS 714 sensor. Thanks to this sensor, the current passing through the input terminals is magnetically measured by the sensor and reduced to very low voltage levels and then the necessary current measurement is performed. This voltage at the mV levels at the output of the ACS 714 allows measurement to be made with increasing or decreasing input current. On this count, the high power AC line can be protected by low DC voltages which are reliable and not harmful.

When the studies are examined, there are various applications where microcontroller-based overcurrent protection relays are used. In these applications, the microprocessor is used to make the system more precise and more protected so that the system with the overcurrent protection relay is made more reliable [1, 9, 10, 12]. The overcurrent relay coordination ensures that in an integrated system, the nearest energy source is cut off where the fault is. Thus, the electricity in the whole system cannot be cut off, only the electricity is cut off in the area where the fault is. This ensures that electrical continuity and unnecessary power interruptions are avoided. Therefore, various studies have been carried out on overcurrent relay coordination [5, 7, 8, 15]. Any nonlinear elements or non-sinusoidal sources produce different amplitude and frequency signals. These signals, other than the pure sinusoidal signal, are defined as harmonic and the presence of these signals in the system is dangerous. Several studies have been made in the literature on reducing these hazards with the overcurrent protection relay [2, 3, 13, 14]. Various studies have been made in the literature with overcurrent protection relays in order to prevent damages that may occur in asynchronous motors or generators [4, 6, 11].

In this study, it is aimed to control AC circuits up to 30 A with ACS 714 sensor with over current, time and external signal parameters. With the Arduino development card, the user has tried to provide an optional advantage. In this case, the current limit can be set at the desired levels, not at a constant value. Thanks to the 2 external signal inputs, it is possible to open the relay not only from over current but also from outside. At the same time, 1 relay input signal is provided to turn off the relay from a remote point while the relay is open. There are 3 NO, 1 NC and 2 change contacts on it. With these contacts it is possible to obtain information from outside by looking at whether the relay is open or closed.

A. *Solid State Relay (SSR)*

The SSR used as a breaker in practice is a switching element which made entirely of electronic components. SSR that do the same work as classical relays and contactors also have control and power circuits. The SSR used in switching power circuits can control large currents such as 1000-2000A with small voltages like 4-32V. The internal structure of the SSR is shown in Figure 1.

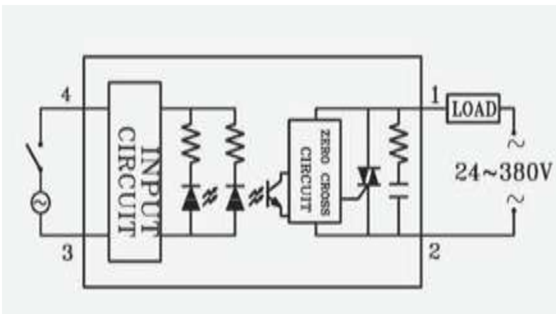

Figure 1. The internal structure of the SSR

B. *ACS 714 ± 30 A Current Sensor*

The ACS 714 is a current sensor with 5, 20, 30 and 50 Amperes versions, with linear variation depending on the magnetic field. Thanks to the Hall Effect feature, the current line is isolated from the electronic circuit of the sensor up to 2.1 kV. Due to the very low internal resistance and very low power dissipation due to the fact that the PCB is 2-oz copper, it offers a high sensitivity of 1.5%.

As shown in Figure 2, the phase current through the AC inputs of ACS 714 gives a voltage value from the output VIOUT. This value gives a 2.5 V output voltage when the passing current is 0 A, which changes linearly in the 0.5 - 4.5 V band.

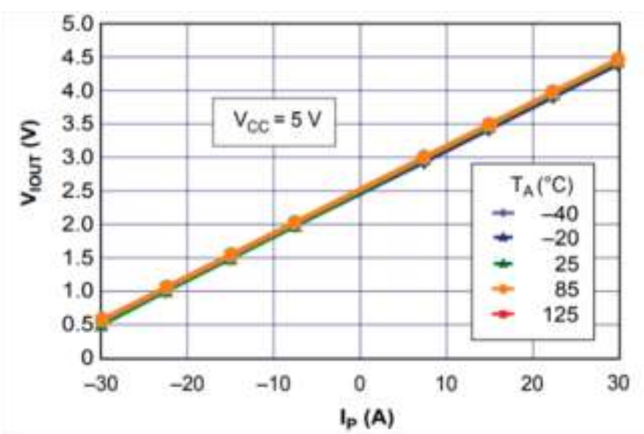

Fig. 2. Current coefficient graph of ACS 714.

C. *Arduino MEGA 2560 R3*

The controller card used in this study is the Arduino MEGA 2560 R3 series. Arduino contains Atmel AVR microcontroller. Having a 5V regulated system in itself, it obtains the voltage to be used as stability. With Arduino, you can get physical information from various sensors, this information can be processed and used in different combinations. Arduino has multiple fuses that can be reset to protect your computer's USB port from overcurrent and short circuit. Although most computers have their own protection for ports, this fuse provides an extra layer of protection. If the USB port is loaded with a load of more than 500mA, the fuse automatically disconnects.

D. *Introducing Control System Software*

In the over current protection system, the relay first sends the voltage in formation from the ACS714 sensor to the analog input of the Arduino and the voltage values in Arduino are processed between 3.1V and 3.3V If this value is greater than the current limit then the circuit is opened by SSR. The block diagram of the applied system is given in Figure 3.

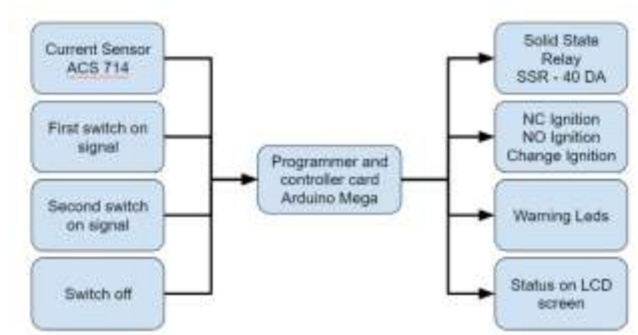

Fig. 3. The block diagram of the applied system

E. *Communication Calculations of Sensor and Microcontroller*

Arduino operates on binary systems just like computers. Arduino has a 10-bit ADC. Analogue data read from the outside is converted to digital data by ADC. An analog data converted into a binary system is converted to logic 0 and 1 on the ADC side by 210, that is, 1024. Arduino operates between 0-5 V. In other words, there are 1024 data in total between 0-5 V. Therefore, the value read from the analog input is calculated as in Equation 1.

$$V_{pp} = V_s \times \frac{5}{1024} \quad (1)$$

Since the value read from Arduino is the maximum value, the effective value of this voltage is calculated as in Equation 2.

$$V_{rms} = V_{pp} \text{ x } 0.707 \quad (2)$$

The relationship between the voltage level and the phase current is given in equation (3).

$$I_{rms} = V_{rms} \text{ x } \frac{1020}{66} \quad (3)$$

F. Relay Program Flow Chart

The flow diagram of the application to be performed in this study is as shown in Figure 4. After the relay has energized here, the SSR closes the pole. With the current read from the relay, time and externa lparameters, the relay opens the SSR. In this view control is provided depending on all parameters.

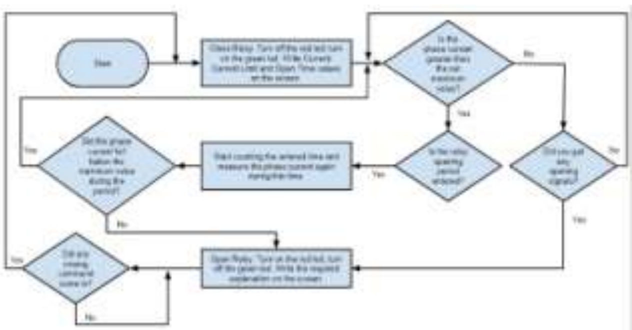

Fig. 4. Relay Flow Chart

According to the given flow diagram, the working relay first performs the current measurement. If the current value is greater than the desired value, the line opens at the end of the entered time. If the current value is less than the desired value and the external signal is received, therelay is opened. If the current measured by the relay falls below the desired level again with in the specified time, the relay can not be opened. In this way, it is prevented to open and close the system continuously in sudden current increases.

G. Experimental Study Results And Discussion

Experiments we performed on different load types and grades were software corrected for the required calibration procedures based on the resulting data and the received data. As an experiment, first of all, a working test was carried out without load. Without the load test prior to calibration, the relay showing 0.18 A current and showed 0 A after calibration. The error, which was 6-7% before calibration, fell below 1% after calibration. The test environment is given in Figure 5. The values obtained before calibration during the test are given in Table 1 and the values taken after calibration are given in Table 2.

Fig. 5. Test Environment

Table1. The values obtained before calibration during the test

Value read from the Ammeter (A)	Value read from the relay (A)	% Error
0.00	0.18	---
0.32	0.57	78,125
0.59	0.64	8,474
0.86	0.91	5,813
1.18	1.32	11,864
1.49	1.53	2,684
1.82	1.91	4,945
2.04	2.21	8,333
2.36	2.42	2,542
2.54	2.7	6,299
3.1	3.21	3,548
3.67	3.8	3,542
3.9	4.1	5,128
4.26	4.34	1,877
4.66	4.72	1,287
5.08	5.14	1,181
5.46	5.56	1,831

Table 2. The values obtained after calibration during the test.

Value read from the Ammeter (A)	Value read from the relay (A)	% Error
0.00	0.00	0
0.18	0.18	0
0.43	0.44	2,325
1.24	1.22	1,612
1.80	1.81	0,555
2.35	2.33	0,851
2.82	2.83	0,354
3.76	3.74	0,531
4.10	4.12	0,487
5.10	5.10	0
0.00	0.00	0
0.18	0.18	0
0.43	0.44	2,325
1.24	1.22	1,612
1.80	1.81	0,555
2.35	2.33	0,851
2.82	2.83	0,354

Tables 1 and 2 give the data from the experiments performed before and after the calibration and the calculated error rates. The% Fault-Current graphs prepared using these values are also given in Figures 6 and 7.

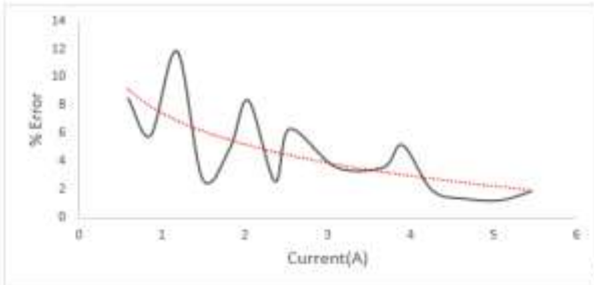

Fig. 6. %Error – Current chart before the calibration

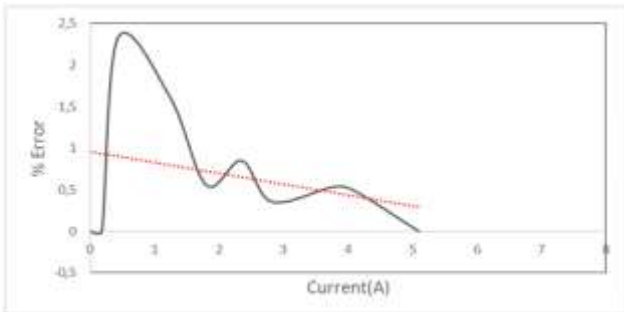

Fig. 7. %Error – Current chart after the calibration

Designed with an ACS 714 ± 30 A current sensor, the current is controlled in this operation. If the circuit current rises excessively, the current is cut off according to the operation of the program. The parameters that can be set in the program are the maximum circuit current and the circuit break period. This value is 0 seconds when the program is opened for the first time. Since there is no moving part in the Solid State Relay (SSR), which we use as a circuit breaker, the reaction time is kept low and the possibility of arc is removed.

Different values of omics, inductive loads have been studied. In these experiments, it is observed that there is an error margin of up to 20% between the current values taken from the ammeter and the relay. The biggest effect of this error margin is the sensitivity of the selected sensor of ± 30 A in low currents. This margin of error is less than 1.5% when it comes to around 30AFor more precise results, the ACS 714 current sensor should be selected to best suit the system requirements from the ± 5, ± 20, ± 30, ± 50, ± 75 A versions.

Software locking is done to prevent someone from intervening in the system. No parameters can be changed without opening this lock. At the same time, it can be remotely controlled by 2 external opening signals and 1 external closing signal, and it can output signal information with 8 outputs on the relay.

II. CONCLUSIONS

With the Arduino Mega processor and ACS 714 ± 30A Current sensor, the software and hardware of the overcurrent protection relay system have been implemented and the system is compactly designed. Based on the results obtained from experimental studies (Tables 1 and 2), it was tried to reduce the error rate to about minimum level of 9,137%, to be about 0,671%. As a matter of fact, as seen on chart 2, the results are close to real values. In the subsequent studies, it is thought that materials that will be able to obtain more stable and quick results in the experience light obtained in this process will be selected and the relay designed with fixed time can be developed and turned into a reverse time relay with the help of faster processors.

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