Hardware Implementation Of Non Directional Over Current Relay on Arduino®

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Abstract: This paper presents the design and hardware implementation of non- directional Over-Current Relay (OCR) on Arduino®. The Standard Inverse (SI), Very Inverse (VI) and Extremely Inverse (EI) characteristic of OCR have also been incorporated in the designed relay. The performance of the designed relay was tested on different load scenarios and it was observed that the relay was well observing the desired inverse time characteristics including SI, VI and EI curves.

Keywords: Over-Current Relay (OCR), protective relays, IEC 60255.

I. INTRODUCTION

A power system is exposed to a different fault either due to inevitable accident or by the mal-operation of the system. This can result in permanent damage to power system components leading to considerable costs for their replacement and in longer disconnections of power supply to customers, which is highly undesirable. This needs some requirements for power system to sustain faults. A protection system is designed to minimize the damage in important components of power system and effects of faults as much as possible. This is achieved by power system protection relays [1]. Here it should be remembered that protective relays could not prevent the occurrence of fault, it could only limit the cascading effect of fault.

Protection relays are tested using different relay tests to confirm their reliability and safe operation before select them in a substation. Based on this analysis, protection system and power system controllers can be developed for more efficient, reliable and safe operation of power systems. This paper has presented the hardware implementation of OCR relay. The detailed modeling and simulation of digital non-directional OCR is presented in [2].

II. OVER-CURRENT RELAY (OCR)

Overcurrent relay (OCR) provides protection against over currents. This relay uses current inputs from a current transformer (CT) and compares the measured values with preset values. If the value of input current exceeds the predetermined value, the relay detects an overcurrent and issues a trip signal to the breaker which opens its contact to disconnect the protected equipment. When the relay detects a fault, the condition is called fault pickup. The relay can send a trip signal instantaneously after picking up the fault (in the case of instantaneous over current relays) or it can wait for a specific time before sending a trip signal (in the case of time overcurrent relays). This time delay is also known as the operation time of the relay, and is computed by the relay on the basis of the protection algorithm incorporated in the microprocessor. The application of OCR includes transmission line and feeder protection Transformer Protection, generator Protection, Motor Protection and Bus bar Protection.

OCR has a single input in the form of ac current, as shown in Fig. 1. The output of the relay is a normally-open contact, which changes over to closed state when the relay trips. The relay has two settings. These are the time setting and the plug setting. The time setting decides the operating time of the relay while the plug setting decides the current required for the relay to pick up.

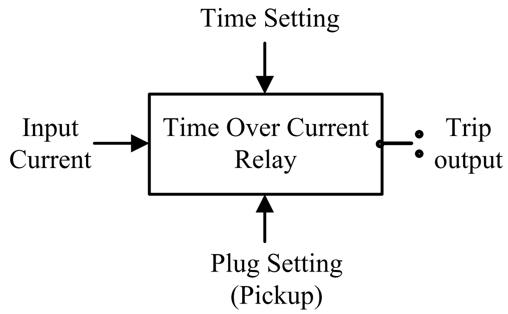


Figure 1: Block Diagram of OCR

The characteristic curve of OCR is shown in Fig. 2 below. Characteristics curve shows the fault current and operation time of the relay. The characteristic curve of OCR follows inverse and instantaneous characteristic. Inverse characteristic is achieved by using the thermal (bimetallic strip) tripping and instantaneous characteristic is achieved by magnetic tripping [2].

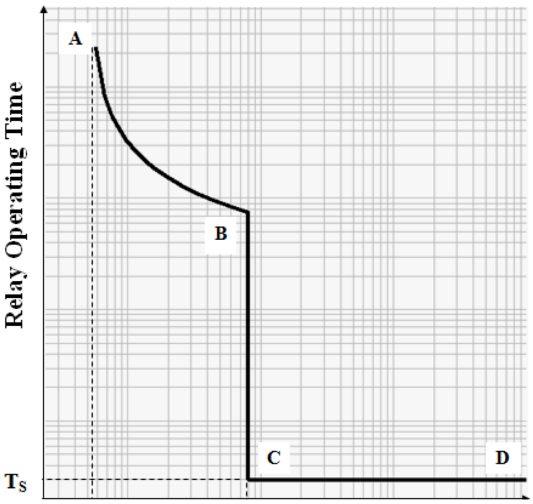


Figure 2: Characteristic curve of OCR [2]

In Fig. 2, the curve A-B is the inverse time characteristics curve of the relay and it is used to protect the system from excessive currents but less than short circuit current but they are large enough if they are allowed to sustain they damage the system. Also the curve B-C-D are known as instantaneous curves they are allowed to protect the system against large amount of current such as short circuit current and reducing the time of relay to only Ts (instantaneous time setting). Inverse Definite Minimum Time is the relay with an inverse current or time characteristic. The time delays are reduced for higher currents and time delay are long for low currents flow. These relay are known as IDMT re1ays. A minimum time of operation is incorporated to ensure coordination between the relays when the fault level does not vary along the feeder. IEC 60255 defines following standard IDMT OCR depending upon the operation time (top) of relay [3].

Standard Inverse (SI) relay:

$$top = \frac{0.14 \times (TMS)}{(PSM)^{0.02} - 1} \tag{1}$$

Very Inverse (VI) relay:

$$top = \frac{13.5 \times (TMS)}{PSM - 1} \tag{2}$$

Extremely Inverse (EI) relay:

$$top = \frac{80.0 \times (TMS)}{(PSM)^{2} - 1} \tag{3}$$

Here TMS stands for Time Multiplier Setting and it is used for proper grading between the two relays, connected in back-back manner. PSM stands for Plug Setting Multiplier and it shows the severity of the fault current. For example, if the pickup current is set 5A and the relay is observing 15A of fault current, the pickup current will be equal to 3. PSM or PMS are used interchangeably and both represent the same thing.

$$PSM = \frac{\text{Fault current in relay coil}}{\text{Pickup Current}} \tag{4}$$

The performances of such relays are observed for different values of TMS and PMS and the results are presented in Table 1.

Table 1: IDMT relays characteristics for different TMS and PMS values

a. SI Curve

PMS	TMS									
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
10	0.29706	0.59412	0.89118	1.188239	1.485299	1.782359	2.079419	2.376479	2.673539	2.970599
20	0.226736	0.453471	0.680207	0.906943	1.133678	1.360414	1.587149	1.813885	2.040621	2.267356
30	0.198889	0.397778	0.596668	0.795557	0.994446	1.193335	1.392225	1.591114	1.790003	1.988892
40	0.182846	0.365691	0.548537	0.731382	0.914228	1.097074	1.279919	1.462765	1.64561	1.828456
50	0.172027	0.344054	0.51608	0.688107	0.860134	1.032161	1.204188	1.376215	1.548241	1.720268
60	0.164063	0.328126	0.492189	0.656252	0.820315	0.984378	1.148441	1.312504	1.476568	1.640631
70	0.157863	0.315727	0.47359	0.631453	0.789317	0.94718	1.105043	1.262907	1.42077	1.578633
80	0.152846	0.305691	0.458537	0.611383	0.764228	0.917074	1.06992	1.222765	1.375611	1.528457
90	0.148667	0.297334	0.446001	0.594668	0.743336	0.892003	1.04067	1.189337	1.338004	1.486671
100	0.145111	0.290221	0.435332	0.580442	0.725553	0.870663	1.015774	1.160884	1.305995	1.451105

b. VI Curve

PMS	TMS									
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
10	0.15	0.3	0.45	0.6	0.75	0.9	1.05	1.2	1.35	1.5
20	0.071053	0.142105	0.213158	0.284211	0.355263	0.426316	0.497368	0.568421	0.639474	0.710526
30	0.046552	0.093103	0.139655	0.186207	0.232759	0.27931	0.325862	0.372414	0.418966	0.465517
40	0.034615	0.069231	0.103846	0.138462	0.173077	0.207692	0.242308	0.276923	0.311538	0.346154
50	0.027551	0.055102	0.082653	0.110204	0.137755	0.165306	0.192857	0.220408	0.247959	0.27551
60	0.022881	0.045763	0.068644	0.091525	0.114407	0.137288	0.160169	0.183051	0.205932	0.228814
70	0.019565	0.03913	0.058696	0.078261	0.097826	0.117391	0.136957	0.156522	0.176087	0.195652
80	0.017089	0.034177	0.051266	0.068354	0.085443	0.102532	0.11962	0.136709	0.153797	0.170886
90	0.015169	0.030337	0.045506	0.060674	0.075843	0.091011	0.10618	0.121348	0.136517	0.151685
100	0.013636	0.027273	0.040909	0.054545	0.068182	0.081818	0.095455	0.109091	0.122727	0.136364

c. EI Curve

PMS	TMS									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
10	0.080808	0.161616	0.242424	0.323232	0.40404	0.484848	0.565657	0.646465	0.727273	0.808081
20	0.02005	0.0401	0.06015	0.080201	0.100251	0.120301	0.140351	0.160401	0.180451	0.200501
30	0.008899	0.017798	0.026696	0.035595	0.044494	0.053393	0.062291	0.07119	0.080089	0.088988
40	0.005003	0.010006	0.015009	0.020013	0.025016	0.030019	0.035022	0.040025	0.045028	0.050031
50	0.003201	0.006403	0.009604	0.012805	0.016006	0.019208	0.022409	0.02561	0.028812	0.032013
60	0.002223	0.004446	0.006669	0.008891	0.011114	0.013337	0.01556	0.017783	0.020006	0.022228
70	0.001633	0.003266	0.004899	0.006532	0.008165	0.009798	0.011431	0.013064	0.014697	0.01633
80	0.00125	0.0025	0.003751	0.005001	0.006251	0.007501	0.008751	0.010002	0.011252	0.012502
90	0.000988	0.001976	0.002963	0.003951	0.004939	0.005927	0.006914	0.007902	0.00889	0.009878
100	0.0008	0.0016	0.0024	0.0032	0.004	0.0048	0.005601	0.006401	0.007201	0.008001

The comparison of SI, VI and EI characteristics of OCR are presented in Table 2 and Fig. 3.

Table 2: Comparison of SI, VI and EI Curve for TMS=1.0

PSM	SI	VI	EI
10	2.970599	1.5	0.808081
20	2.267356	0.710526	0.200501
30	1.988892	0.465517	0.088988
40	1.828456	0.346154	0.050031
50	1.720268	0.27551	0.032013
60	1.640631	0.228814	0.022228
70	1.578633	0.195652	0.01633
80	1.528457	0.170886	0.012502
90	1.486671	0.151685	0.009878
100	1.451105	0.136364	0.008001

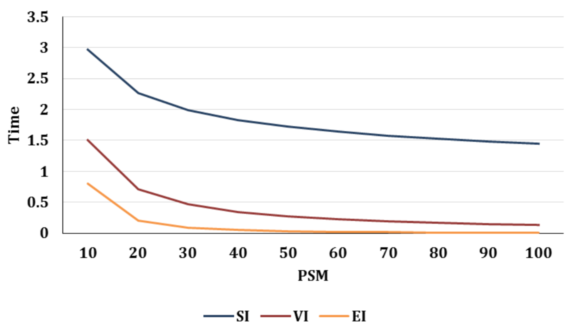


Figure 3: Comparison of SI, VI and EI relays (for TMS =1.0)

III. PROJECT HARDWARE

A. Hardware Components Used

Following are the main hardware components that are used in the project are listed be.

1. Arduino Mega 2560
2. ACS712 Current Sensing Module
3. Vero board
4. Load bank/Switch Boards/Bulbs
5. 4-Channel Relay Module Srd-5dc-Sl-C
6. Connecting Wire.

1. Arduino Microcontroller:

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. Arduino Mega 2560 is the most recent addition to the Arduino lineup is the Arduino MEGA. This board is physically larger than all the other boards and offers significantly more digital and analog pins. The MEGA uses a different processor allowing greater program size and more [4].

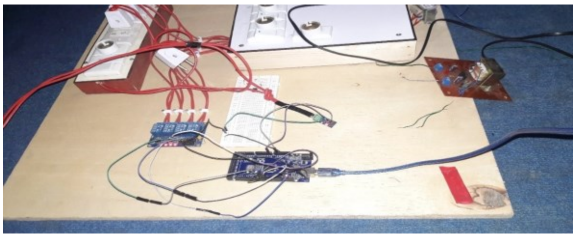
2. ACS712 Current Sensor

Measurement of current flow is a fundamental requirement in this project. ACS712 module is used in this project. ACS712 module is a current sensor module that read current value and converts into relevant voltage value. The value that links the two measurements is sensitivity which for 5A to typical value of 185Mv/A.

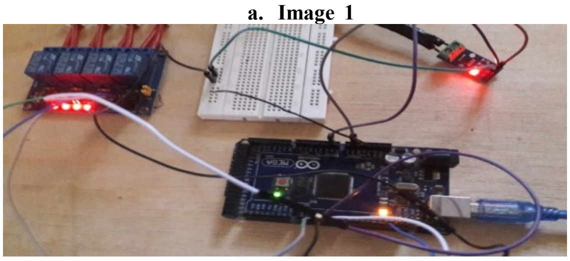
3. Four Channels Relay Module

The four channels relay interface board operates by 5V constant supply and each channel needs a 15 – 25m A driver current. It can be for switching of various electrical appliances & equipment's with large current. It is equipped with high current relays that work under both AC & DC i.e. under AC 250V 10A or DC 30V 10A. It can be controlled through different microcontrollers & Arduino as well.

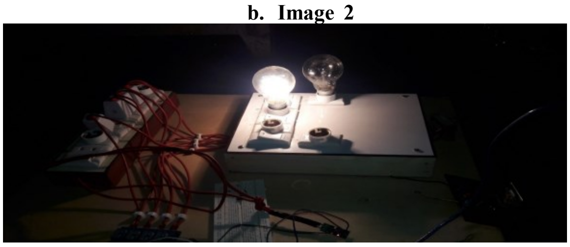
The hardware images of the project are shown in Fig. 4.



a. Image 1



b. Image 2



c. Image 3

Figure 4: Hardware Images

IV. OBSERVATIONS AND RESULTS

The designed relays are tested under different load scenarios and their time of tripping are observed and summarized in following sections. The pickup current is set 1A for all cases.

A. Standard Inverse OCR:

Table 3 shows the SI characteristic of the designed relay.

Table 3: SI characteristic of designed relay under different load scenario

Case	Load	Irms (A)	Tripping operation	Tripping Time (Sec)
1	No Load	0.0	No Tripping	--
2	One Bulb is ON	0.453	No Tripping	--
3	Two Bulbs are ON	0.886	No Tripping	--
4	Three Bulbs are ON	1.138	Tripping	0.561
5	Two Bulbs and One Tube light is ON	1.092	Tripping	0.548

B. Very Inverse OCR:

Table 4 shows the VI characteristic of the designed relay. The inverness of this characteristic is higher than that of the standard IDMT characteristic.

Table 4: VI characteristic of designed relay under different load scenario

Case	Load	Irms (A)	Tripping operation	Tripping Time (Sec)
1	No Load	0.0	No Tripping	N/A
2	One Bulb is ON	0.453	No Tripping	N/A
3	Two Bulbs are ON	0.886	No Tripping	N/A
4	Three Bulbs are ON	1.138	Tripping	0.270
5	Two Bulbs and One Tube light is ON	1.092	Tripping	0.279

C. Extremely Inverse OCR:

Table 5 shows the VI characteristic of the designed relay. The inverness of this characteristic is higher than that of the very inverse characteristic.

Table 5: VI characteristic of designed relay under different load scenario

Case	Load	Irms (A)	Tripping operation	Tripping Time (Sec)
1	No Load	0.0	No Tripping	N/A
2	One Bulb is ON	0.453	No Tripping	N/A
3	Two Bulbs are ON	0.886	No Tripping	N/A
4	Three Bulbs are ON	1.138	Tripping	0.133
5	Two Bulbs and One Tube light is ON	1.092	Tripping	0.121

From the above Tables (Table 3 to Table 5), we can conclude that:

1. No tripping was observed when the load was less than 1 Amp (case 1 to case 3).
2. When the load amperage becomes greater than the 1 Amp, tripping was observed (case 4 and case 5).
3. Further it can also be observed that the tripping time follows the inverse pattern with the increase in load current.
4. The operating time of EI relay is lesser than the SI and VI relays. Therefore the designed relay work satisfactorily and observing the SI, VI and EI inverse relay characteristics.

V. CONCLUSION

This paper has well presented the design and operation of over-current relay. The standard inverse (SI), very inverse (VI) and extremely inverse (EI) characteristic of OCR have also been incorporated in the designed relay. The proposed relay was designed using Arduino. The performance of the designed relay was observed on different load scenarios and it was observed that the relay was well observing the desired inverse time characteristics including SI, VI and EI curves.

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