

Modelling and Analysis of a Multifunctional Microcontroller based Relay for Protection of Solid State Transformer

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Abstract—In Modern power systems the Solid State Transformer (SSTs) is an emerging technology, where it acts as the interface between MV AC and the LV AC/DC micro grid. Due to the faults that occur in the system, the SSTs are subjected to different electrical stresses. Therefore a suitable protective scheme has to be developed. This paper is aimed at proposing a suitable protective scheme has to be developed. This paper is aimed at proposing a multifunctional protective schemes to protect the Solid State Transformers against Over Voltage, Under Voltage and the Over Load by using Arduino Uno Microcontroller. The protective schemes are modeled and analyzed by using Proteus software and a software program has been developed using Proteus package C-language. The microcontroller monitors the network voltage and current, therefore it energizes the relay in case that system voltage, and current exceeds the preset value. The performance of OV/UV relay is investigated by performing different conditions at Instantaneous, Momentary and Temporary categories according to IEEE 1159 standards. The Over Load relay operates whenever the current in the system exceeds the pickup value and it is compared with theoretical calculations, therefore the performance of the relay is investigated.

Index Terms— Solid State Transformer, Over Voltage, Under Voltage, Over Load Medium Voltage, Low Voltage, Arduino Uno Microcontroller.

I. INTRODUCTION

The Power Systems is a network and is categorized into Generation, Transmission, and Distribution. Transformers and Generators are the two major equipments in power system [1]. The Low frequency acts as the interface between different voltage levels which are bulky in size, heavy and operates with low frequency. Whereas with increase advancement in semiconductor devices has led to the idea of Solid State Transformer (SSTs) which operates at high frequency. The Low Voltage grid is powered by the Medium Voltage grid by using the SSTs, as it establish the interface between MV AC grid and LV AC/DC grid [2]. As it acts as the interface between grids subjected to stresses caused due to faults that occurs in the system. The Over Voltage,

Under Voltage and Over Load are identified as the most common stresses that affect the Solid State Transformers. The Over Voltages are caused due to Insulation failure, lightning, connecting large capacitor banks, disconnecting large loads [3]. If the Over Voltage exists for a long time leads to a damage of power electronic devices in the SSTs. The Under Voltage is caused due to the reverse actions of Over Voltages. The Over Load is nothing but whenever the current in the circuit circulates more than the rated capacity of the components is known as Over Load. Due to this the components gets overheated and leads to the damage of the components [4]. Thereby the protective schemes are mandatory. The main objective is to protect the Solid State Transformers against these abnormal conditions.

The Over Voltage and Under Voltage are categorized as per duration i.e., short and long according to IEEE standard 1159. For short duration it is categorized as Instantaneous (0.5-30cycles), Momentary (30cycles-3secs), and Temporary (3secs-1 min). According to the magnitude, the OV is classified sequentially as (1.1-1.8 pu), (1.1-1.4 pu), (1.1-1.2 pu) and under voltage (0.1-0.9 pu). Various applications in system are failed due to various applications; among them over load is the main cause [5]. This paper is aimed at proposing multi functional protective schemes for protection against Over Voltage, Under Voltage and Over Load by using Arduino Uno microcontroller. The schemes are simulated using proteus software. The simulation results from protective scheme reflect reliability, flexibility, accuracy and security.

II. PROBLEM STATEMENT

The components in Power systems such as Generators, Transformers, Solid State Transformers, loads, are subjected to many operational conditions due to faults (OV, UV, OL) where they can damage the electronic equipments in the SSTs. Reliable, Secure, and accurate over voltage, under voltage and over load protective schemes are proposed.

III. PROPOSED TECHNIQUES

A. The Over / Under Voltage Protective Scheme

The monitoring and protecting of SSTs against are done by using the Arduino Uno Microcontroller. The Block diagram of the proposed technique is shown in figure 1.

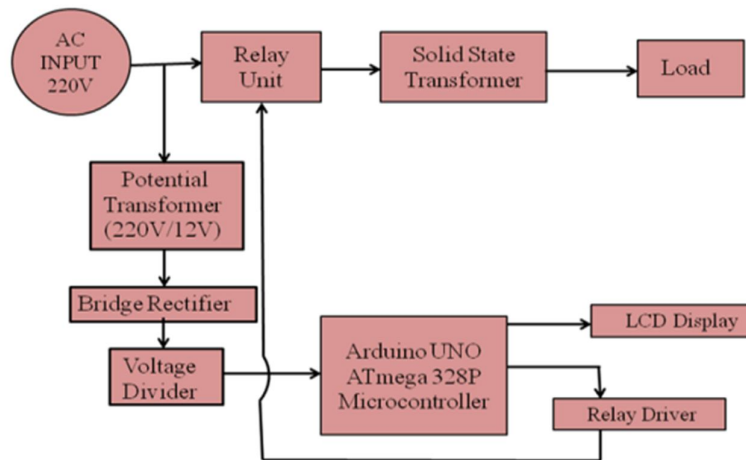


Figure 1. Block diagram of OV/UV protective Scheme

The arduino uno microcontroller operates as per the program C code that has embedded into it. The OV/UV protective schemes are simulated according to flowcharts shown in figure 2, 3.

B. Methodology for Over Load Protective Scheme

The block diagram of over load protective scheme is shown in figure 4 below. The current supply from load is sensed by ACS712 Hall Effect current sensor. The current sensed by sensor is converted to voltage as Arduino microcontroller. Therefore whenever the current in the circuit is more than its set value display then it sets a tripping signal to relay unit through microcontroller and driver circuit. The status is shown on LCD.

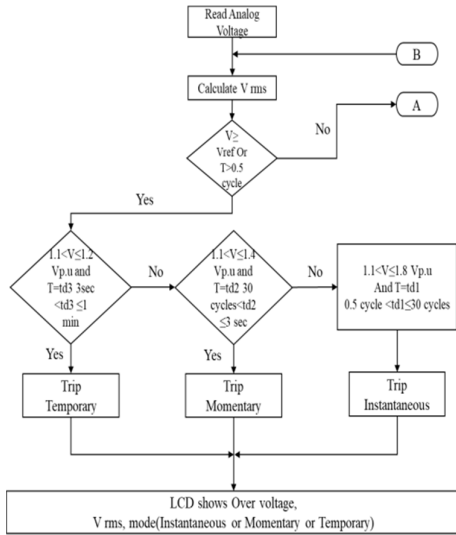


Figure 2. Flow chart OV simulator relay based on Arduino Uno controller

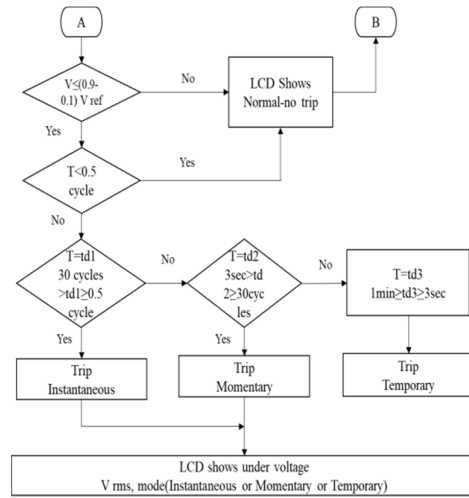


Figure 3. Flowchart for UV simulator relay based on Arduino Uno Controller

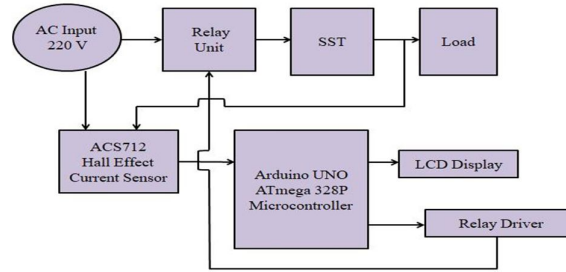


Figure 4. Block Diagram of over Load protection Scheme

IV. SIMULATION CIRCUIT AND RESULTS

A. Over Voltage and Under Voltage Schemes

The components and the specifications of the prototype circuit are indicated in Table I:

TABLE I. SPECIFICATIONS OF MODEL CIRCUIT

S.No	Components	Range
1.	Supply Voltage	220V
2.	Arduino Uno Microcontroller ATmega 328P	5V
3.	LCD (Liquid Crystal Display)	20(Columns)X4(Rows)
4.	Relay	12V
5.	Potential Transformer	220V/12V
6.	Resistors	33k,47k,1k
7.	Frequency	50Hz

The main model circuit contains ac supply, potential transformer, relay unit, relay driver circuit, potentiometer, Arduino microcontroller, relay unit, and LCD display.

- The supply Voltage is varied by using Potentiometer in order to create the abnormal conditions i.e., over voltage/ under voltage.
- The varied supply voltage is given to the Bridge Rectifier where it steps down the 220V AC supply to 12V DC supply.

- c) The 12V DC supply is sent to capacitor to remove the pulses as the DC voltage from rectifier circuit is pulsating.
- d) Arduino microcontroller: The controller which is easy to use and an open source is known as arduino control. Its programming language is very easy, which compares the signal voltage from supply is compared to the set value fed to the software program. If the values of voltage magnitude and times are exceeds the limits as per standards the tripping signal is sent to the relay unit. The proposed is simulated under two scenarios, one for OV and another for UV relays when they are at Instantaneous, Momentary and Temporary categories.

A1.Over Voltage Relay Simulation- Instantaneous Relay Simulation

The Potentiometer is varied for a particular percentage as per standards for Instantaneous, Momentary and temporary are shown in figures (5-7) and the results are tabulated in Table II.

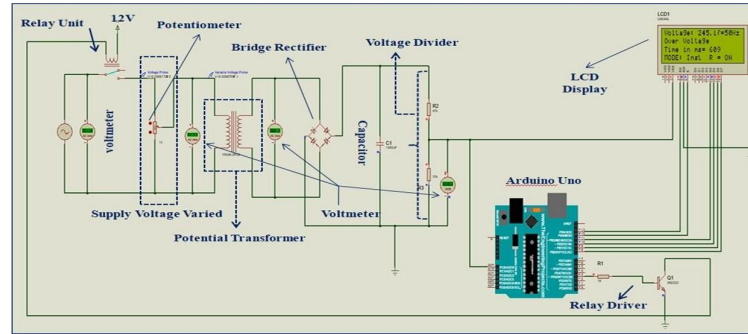


Figure 5 (a). Instantaneous Over Voltage Relay Scheme for 245.5V

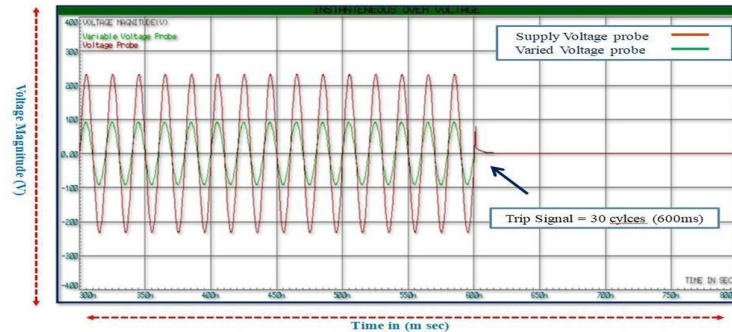


Figure 5 (b). Waveform for Instantaneous over Voltage for 245.5V

A2. Over Voltage Relay Simulation- Momentary Relay Simulation

The figure 6 shows the momentary condition, where the relay trips at 3sec whenever the Voltage magnitude is between (1.1-1.4) pu of rated voltage.

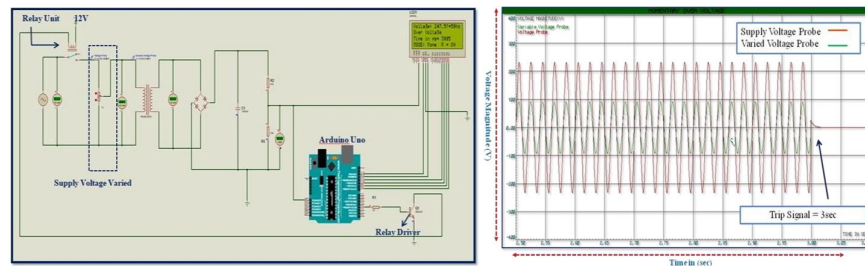


Figure 6. Momentary over Voltage for 247.5V & Waveform

A3. Over Voltage Relay Simulation- Temporary Relay Simulation

Whenever there is increase of voltage magnitude in between (1.1-1.4) pu for duration of 3sec -1min, then this condition is categorized as Temporary. The simulation circuit results and its corresponding waveform

is shown in figure 7, where the relay trips at 1min.

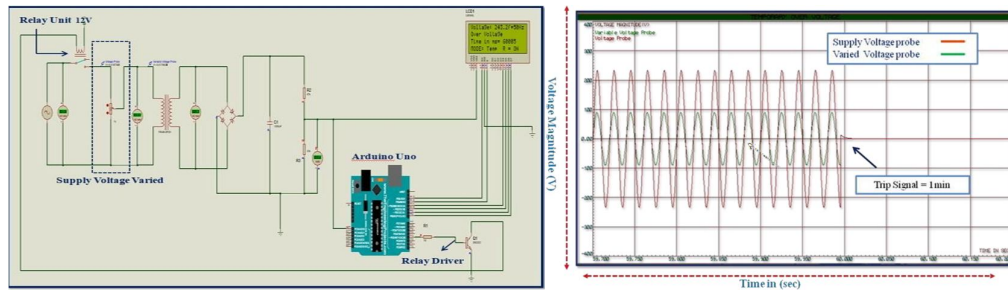


Figure 7. Temporary over Voltage relay scheme for 243.2V & Waveform

The simulation results of Over Voltage for various voltage magnitudes are performed for all categories are tabulated in Table II.

TABLE II. OVER VOLTAGE RELAY CHARACTERISTIC RESULTS FOR 220V SUPPLY

Type of Over Voltage (P.U)	Measured Voltage(V)	Voltage Increment (%)	Time in ms	Duration
Instantaneous 1.1-1.9	245.5	110.40	609	5cycles-30 cycles
	326.3	148.3	602	
	296.6	134.8	604	
Momentary 1.1-1.4	247.5	112.5	3005	30cycles-3secs
	261.8	119	3006	
	280.7	127.5	3002	
Temporary 1.1-1.2	243.2	110.54	60005	3secs-1min
	256.0	116.36	60009	
	263.7	119.86	60005	

A4. Under Voltage Relay Simulation- Instantaneous Relay Simulation.

The decrease in voltage from (0.1-0.9) pu of rated voltage is known as under voltage. The Potentiometer is varied to a specific percentage as per IEEE 1159 for Instantaneous, Momentary and Temporary conditions till the relay operates and isolates. The simulation results are shown in Figures (8-10).

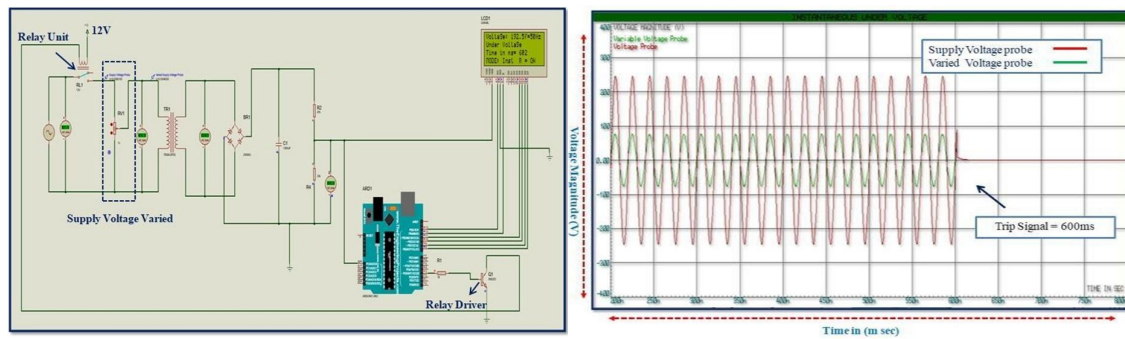


Figure 8. Instantaneous under Voltage relay scheme for 192.5V & Waveform

A5. Under Voltage Relay Simulation- Momentary Relay Simulation

The figure 9 shows the momentary under voltage condition where the relay trips at 3sec. The simulation result and their corresponding waveform are shown below.

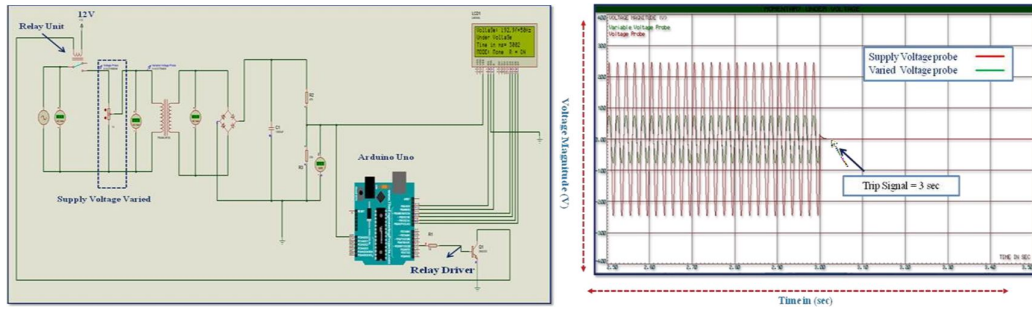


Figure 9. Momentary under Voltage relay scheme for 192.9V & Waveform

A6. Under Voltage Relay Simulation - Temporary Relay Simulation

The relay simulation for temporary under voltage with corresponding waveform is shown in figure 10.

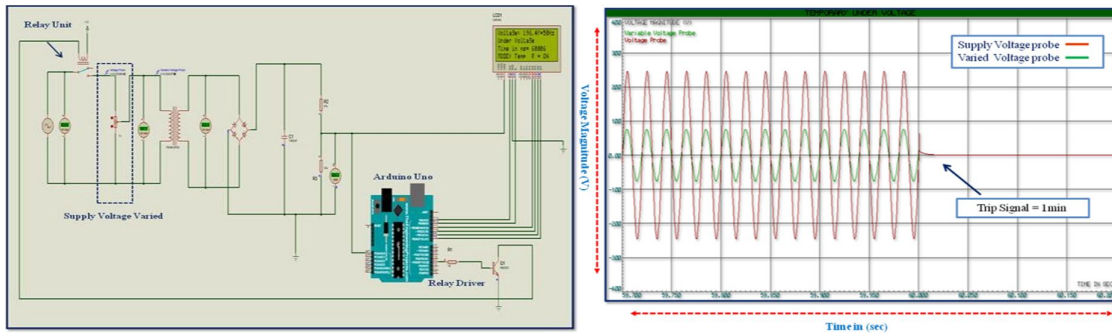


Figure 10. Temporary under Voltage relay scheme for 196.4V & Waveform

The simulation results of Under Voltage for various voltage magnitudes are performed for all categories are tabulated in Table III.

TABLE III. UNDER VOLTAGE RELAY CHARACTERISTIC FOR 220V SUPPLY

Type of Over Voltage (P.U)	Measured Voltage(V)	Voltage Increment (%)	Time in ms	IEEE standard duration
Instantaneous 0.1-0.9	192.5	87.5	602	0.5cycles-30 cycles
	175.9	79.9	602	
	120.6	54.8	602	
Momentary 0.1-0.9	192.9	87.68	3002	30cycles-3secs
	176.3	80.13	3002	
	120.2	54.81	3005	
Temporary 0.1-0.9	196.4	89.27	60006	3secs-1min
	147.3	66.95	60003	
	116.7	53.04	60006	

B. Over Load Protective Scheme

The components and their specifications required to model over load scheme are tabulated in Table IV.

Simulation Of Over Load Protective Scheme

The simulation circuit of over load protective Scheme is shown in Figure 11 with original load of 100W. Different loads are considered in order to check the performance of the schemes.

TABLE IV. SPECIFICATIONS OF MODELED CIRCUIT

S.No	Components	Range
1.	Supply Voltage	220V
2.	Relay	12V
3.	ACS712-Current Sensor	20A module –Sensitivity(100mV/A)
4.	Arduino Uno-ATmega 328P microcontroller	5V
5.	Lamp Load	100W
6.	Current	0.45A
7.	Pick –up current	$0.45 \times 150 = 0.67\text{A}$
8.	Frequency	50Hz
9.	LCD display	20(Columns)X 4(Rows)

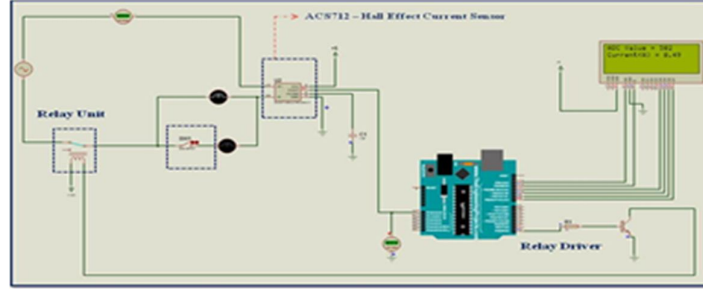


Figure 11. Over Load Protective Scheme for the load of 100W

The protection scheme of over load uses the ACS712 current sensor of 20A module having sensitivity of 100 mV/A, means the sensor can measure the current 20A. The sensor can continuously monitor the current of 100W load. Whenever the current exceeds the pickup value, the relay senses the abnormal condition and sends the tripping signal to the circuit breaker. In the below figure 12 the load of 30W is added to the circuit and the sensed current is less than the pickup value, the Relay unit will not be operated. In the figure 13, the load of 100W is added to the circuit it becomes the 200W, and it becomes the over loaded. Hence the relay unit will be tripped. The results for various loads are tabulated in Table – IV.

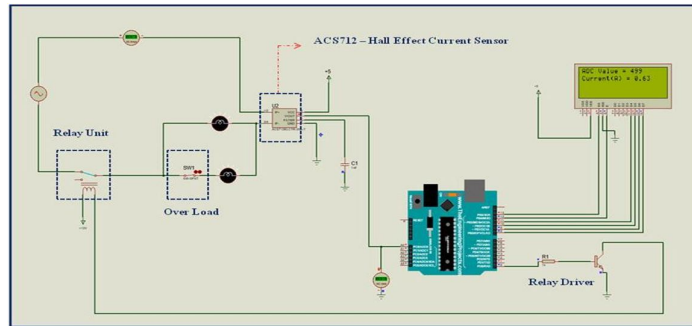


Figure 12. Over Load protective scheme for load of 30W, Load current 0.63A

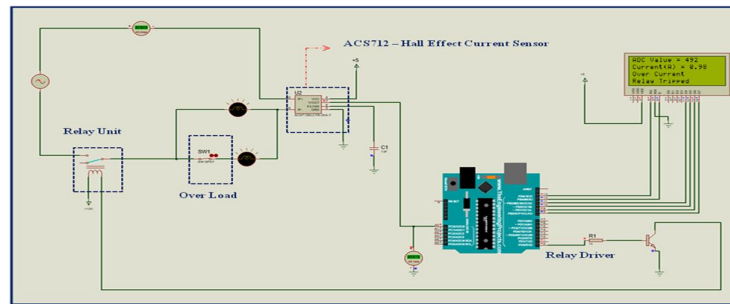


Figure 13. Over Load Protective Scheme for the load of 100W, load current 0.98A

V. CONCLUSION

Protecting the solid state transformer against Over Voltage, Under Voltage and Over Load by using Arduino Uno microcontroller is the main objective of this work. An Over Voltage, Under Voltage relay and Over Load protecting schemes are modeled by using Arduino UNO microcontroller. The software program has been developed through Proteus package using C language. This simulation software simulates the Over voltage, Under Voltage protecting schemes are modeled and they are compared with IEEE standards 1159. The over load protective scheme is modeled by the load of 100W which is resistive load relay is able to operate and isolate the load in the case of over load conditions. The software program is developed and it embedded in the Arduino Uno microcontroller to operate and isolate the load.

From this it is observed that numerical relays are more effective that their settings can be changed according to our requirements. It is observed that the relay will operate and isolate the load in case of any abnormal conditions, thereby protects the Solid State Transformer. The number of functions can be increased with the use of high speed processors. It can be implemented on a Digital Signal Processors (DSP), as Digital Signal processor has MAC (Multiply and Accumulate in single instruction) and the total system can be directly integrated to the SCADA. The relay can be modified to act as a Multi - Function and the number of input sensors and output ports can be increased to sense current as well as voltage signals and the operation will be fast and accurate.

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