Real Time Monitoring and Supervisory Control of Distribution Load Based on Generic Load Allocation: A Smart Grid Solution

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ABSTRACT

Our work is the small part of the smart grid system. This is regarding the check and balance of power consumption at the consumer level. It is a well known fact that the consumers are allocated a fixed load according to their requirement at the time of application for the electricity connection. When the consumer increases its load and does not inform the power company, the result is the overloading of the system. This paper presents a solution regarding distribution and load allocation to each customer. If the customer uses power greater than the load allocated, further power is not provided and consequently that appliance is not turned on unless the total load must not be decreased than the allocated load. This is achieved by designing a processor controlled system that measures the power on main line and also the power taken by each device. Now when a device is turned on, its power is measured by the controller and compares it with the main line power, and when the device consumes some power consequently main line power will also be increased thus this main line power is monitored and if it exceeds particular limit that device is turned off through its relay.

Key Words: Load Forecasting, Load Monitoring, Smart Grid Solution.

1. INTRODUCTION

The electrical power system in Pakistan is unpredictable, the power that is generated at the Power Stations does not meet the power requirement for the consumers, and mostly power shortage occurs whether it is winter or summer. We can't forecast how much power the consumer will use per day due to lack of power monitoring and mismanagement. Let us suppose the Power Company allocates a particular amount of power to each user and therefore generates the power as required by the particular area, but there is no any limit for any consumer how much that consumer uses the power per day. There is no any check and balance for power usage in any area. And almost all the consumers use power more than they are allocated, resulting power shortage, load shedding and overloading of distribution transformers. This causes failure of distribution transformers which becomes very costly. Hence the power generation company cannot generate the required amount of power for the consumers [1]. Hence firstly we need to monitor and forecast the power so as we come to know

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the power usage limit for any area. This is a kind of Demand side load management [1-2]. Demand side load management is a set of methods that coordinate the activities of energy consumers and energy providers in order to realize the best adaption of energy production capabilities for consumer needs [3-4]. Therefore, here we provide one solution regarding power use limitation at consumer side. We have designed a controller that will limit the consumer not to use the power more than the allocated.

The system consists of Current and Voltage transformers used to measure the AC current and voltage and then the microcontroller calculates the power from the analog measured voltages and currents. If any of the device is switched on, its power is measured by the microcontroller, and then adds that power to the main line power (already measured through ADC (Analog to Digital Converter)) to see whether it exceeds the power or not, if it exceeds the allocated power, then the relay for that device disconnects the device from the power line and thus the device fails to turn on, this way the main line does not exceeds the allocated power [5].

The electric power transmission grid has been progressively developed for over a century, from the initial design of local dc networks in low voltage levels to three phase high voltage ac networks, and finally to modern bulk interconnected networks with various voltage levels and multiple complex electrical components [6-7]. The development of human society and economic needs was the catalyst that drove the revolution of transmission grid stage by stage with the aid of innovative technologies [8]. Here our system is a smart grid solution in the sense that the load is monitored and maintained at consumer side. A smart grid is a modern electricity system. It uses sensors, monitoring, communications, automation and computers to improve the flexibility, security, reliability, efficiency, and safety of the electricity system [9-11].

2. BLOCK DIAGRAM

The block diagram (Fig. 1) contains VT (Voltage Transformers) and CT (Current Transformers) of main line and devices along with Microcontroller i.e. Atmega 328.

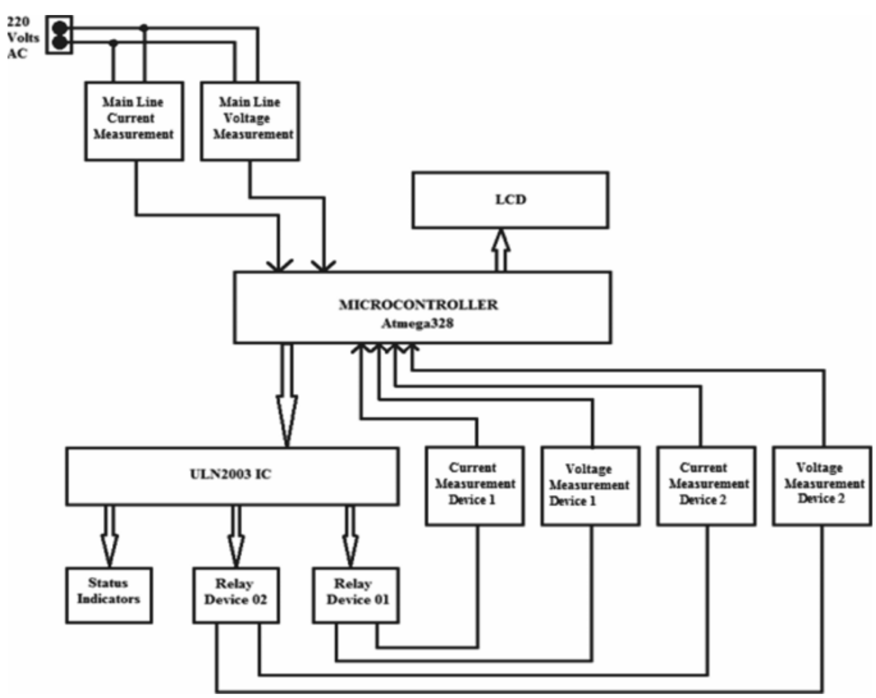

FIG. 1. BLOCK DIAGRAM

The CT and VT are used to measure the main line currents and voltages respectively. The measured data is fed to the ADC of microcontroller. Microcontroller is further connected to the ULN2003 IC. ULN2003 IC is a current driver, used to drive the relay devices. Each device has its separate CT and VT for measuring the current and voltage for the device.

The system operation is done by the microcontroller (Atmega 328 embedded on Arduino board) [3] through a dynamic programming. Programming is done in such a way that if a load exceeds by a particular mentioned load then relay of particular device may turn off the device immediately otherwise load will remain turned on. LCD (Liquid Crystal Display) is also connected to the microcontroller which shows the current, voltage and power measured by transformers.

3. FLOW CHART

The flow chart of the system is shown in Fig. 2.

4. SIMULATION

For the system, microcontroller is programmed and then test circuit is simulated by placing the potentiometers in place of current and voltage measurement transformers to see how the circuit works. The circuit schematic of the microcontroller with LCD and potentiometers is shown in Fig. 3.

For simulation, there are potentiometers connected at each analog input of the microcontroller to provide the power measured from the devices and from the main line. The main line power and the device power are compared and if, by turning on any one device, the power exceeds the load limit then its associated relay will turn off. The LCD shows the main line power and the measured power of both devices as shown in Fig. 3.

Now for relay operating through microcontroller, a separate circuit is made that is connected with the outputs of the microcontroller, it uses ULN2003 IC. Schematic for the interfacing the circuit is shown in Fig. 4.

5. CURRENT AND VOLTAGE MEASURING CIRCUIT

The CT and VT are used that scale down the actual values and then they are rectified so as to measure those values on the ADC. The schematic is given in Fig. 5.

5.1 Oscilloscope Reading

The output DC voltage waveform is shown in Fig. 6 and Table 1. It is 4.2V DC when the input to the measurement circuit is 220V.

6. IMPLEMENTATION

Before making a model of this system, firstly the microcontroller was programmed and tested on the

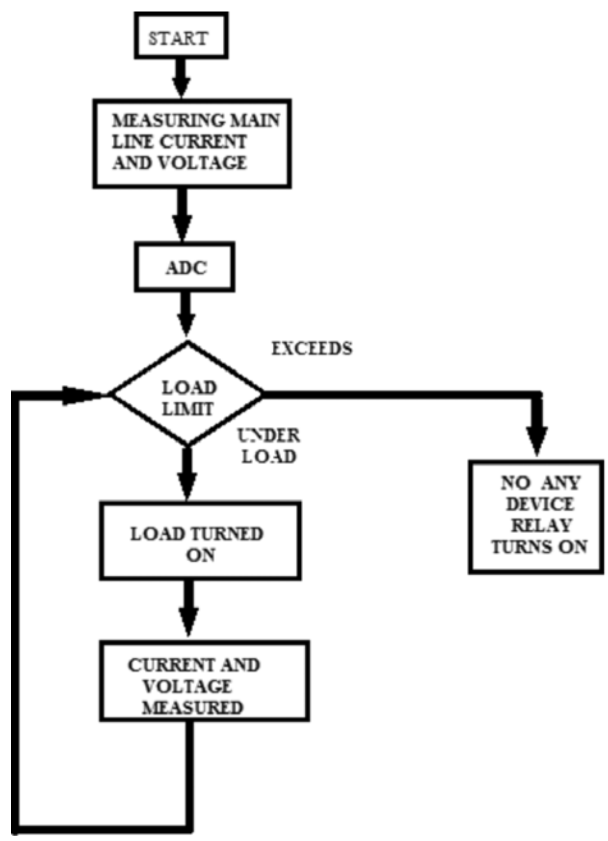

FIG. 2. FLOW CHART OF SYSTEM

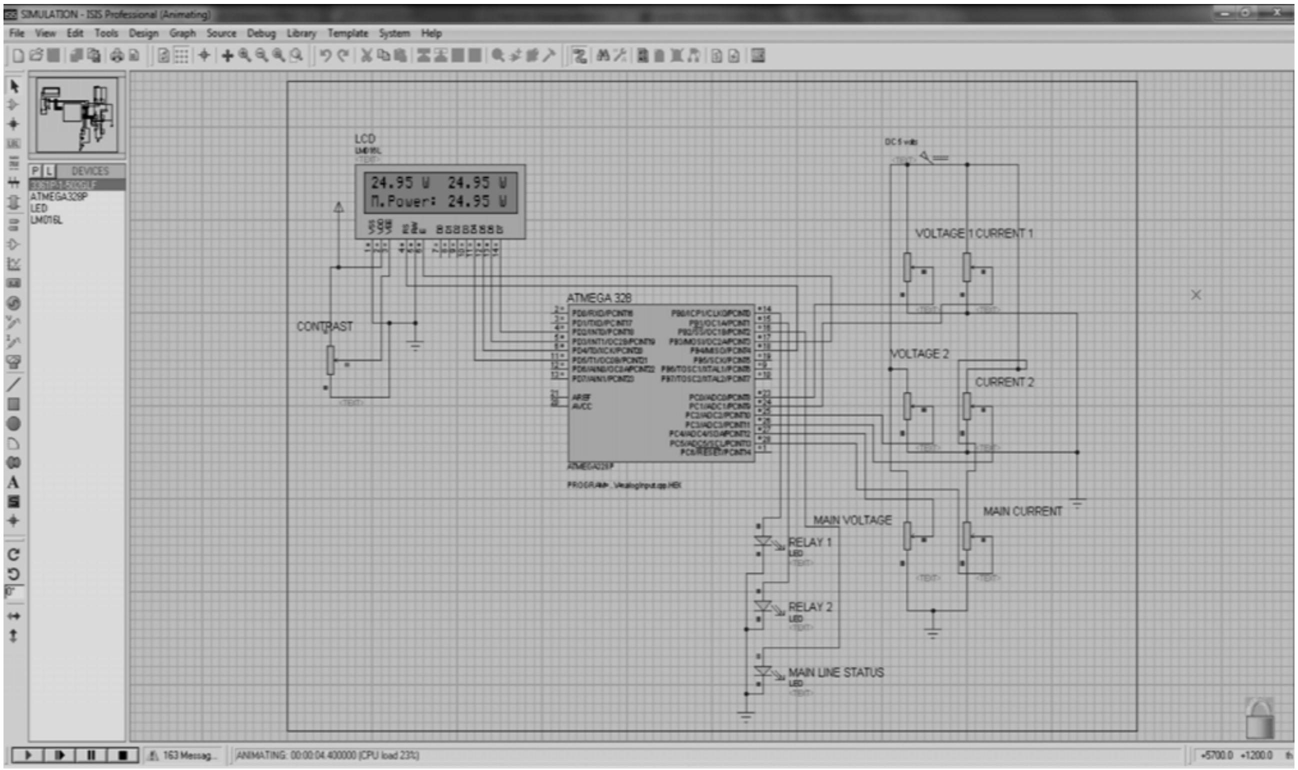

FIG. 3. SCHEMATIC OF THE MICROCONTROLLER CIRCUIT

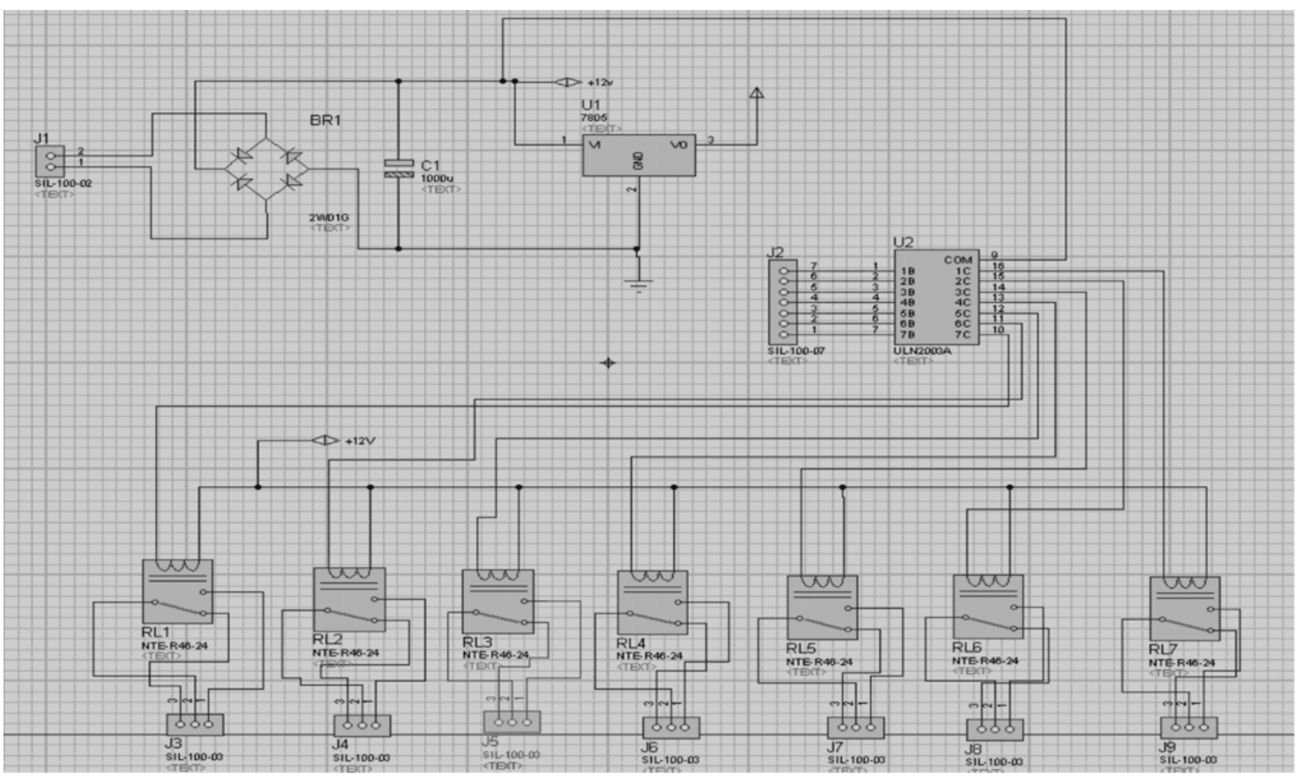

FIG. 4. SCHEMATIC OF THE RELAY INTERFACING CIRCUIT

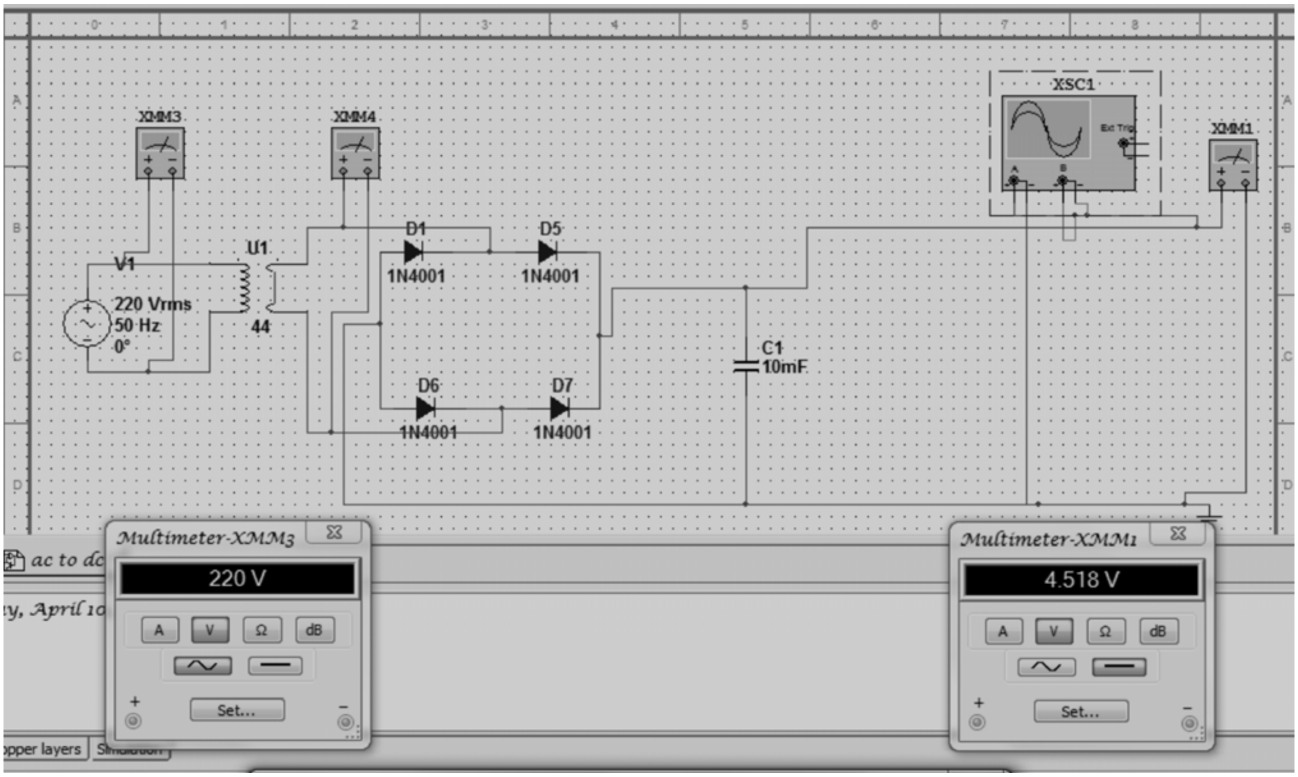

FIG. 5. CURRENT AND VOLTAGE MEASURING CIRCUIT

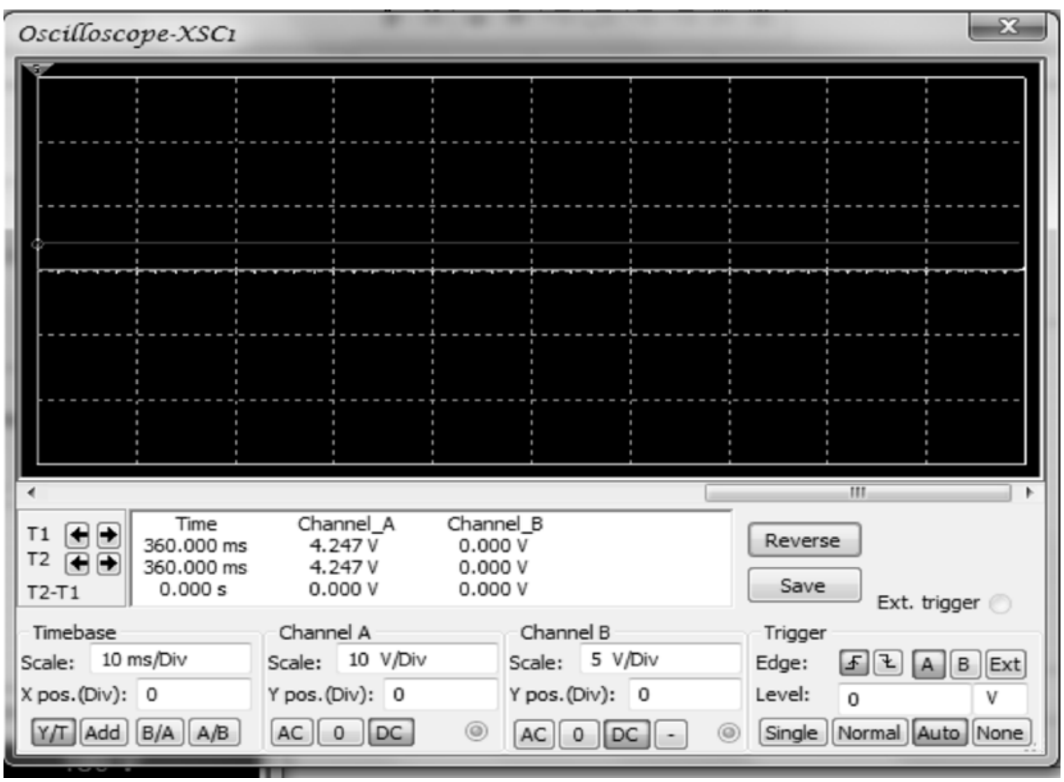

FIG. 6. OUTPUT DC VOLTAGE WAVEFORM

breadboard to see the main working of the controller. And the errors and problems were solved. The system test hardware on breadboard is shown in Fig. 7.

For all the hardware components, a panel is made where all the components are assembled and connected together, as shown in Fig. 8.

There are two power sockets given for the load where any device can be connected to make it operate. There are total of 7 transformers connected, of which one VT is for power supply, 3 VT for voltage measurement and 3 CT for current measurement. After each transformer there is Diode Bridge that converts AC voltage to DC. The current is also measured in terms of voltage. The measured voltages and currents are in the range of 0-5V DC. These measured voltages and currents are given to the analog inputs (ADC inputs) of the microcontroller. The microcontroller takes the product of voltage and current to calculate the power in the line. If the main line is running on full load (threshold), then the RED indicator glows showing that the main line is already on full load and no device can be turned on, if the main line is under load, green indicator glows showing that further devices can be turned on. Now When any device is connected on the power socket, and switched on, initially its relay is on, the current and voltage is measured through microcontroller and added to the main line. If the main line exceeds the threshold, the relay for that device is energized and the contact is open and thus the device does not operate irrespective of its power switch. If the main line does not exceed the threshold the relay is left uncharged and the device operates. This way the main line in any way does not exceed the power limit (here we have power limit of 2 kW).

TABLE 1. VOLTAGE MEASUREMENT RESULTS

Input (AC Voltage)	Output (DC Voltage)
220V	4.518V
110V	2.18V
180V	3.8V

7. ADC READING

The transformers measure the current and transformer scaled up to 0-5V DC, when this signal is applied to ADC

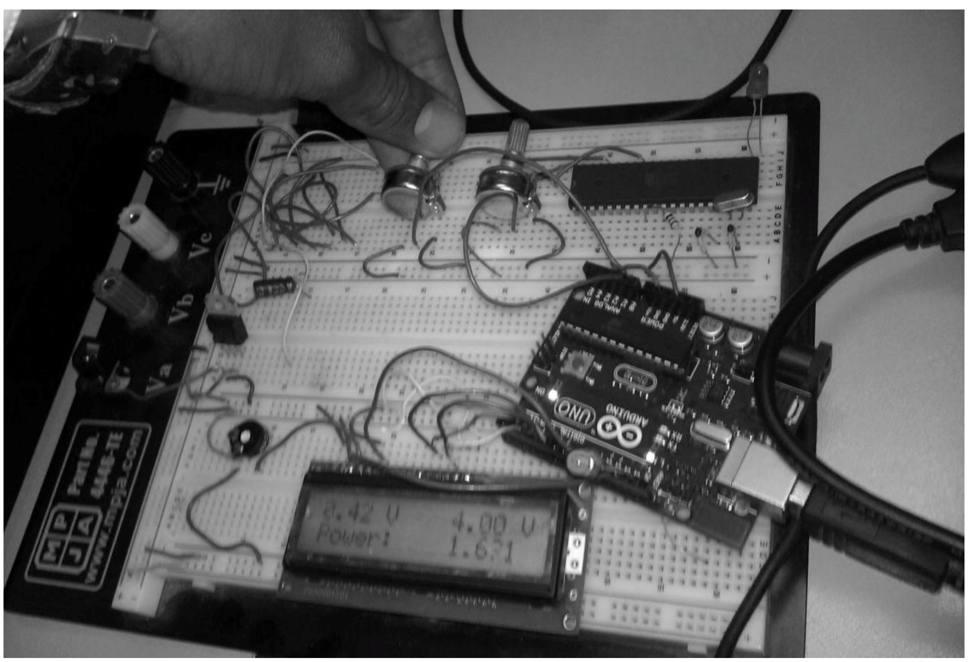

FIG. 7. PROJECT TEST HARDWARE IN BREADBOARD

of the microcontroller, the ADC output value is in binary value, so in order to calculate the original analog signal, we apply the following formula:

$$\text{Analog Value} = \left(\frac{(\text{V Reference} \times \text{ADC Value})}{\text{Resolution (Maximum ADC Value}} \right)$$

And here we have 5V reference value and resolution is 10 bit, so maximum ADC value is 1024. So the formula we used to calculate analog input value from transformers is:

$$\text{Analog Input Voltage} = 48 \times \left(\frac{(5 * \text{ADC Value})}{1024} \right)$$

$$\text{Analog Input Voltage} = 2 \times \left(\frac{(5 \times \text{ADC Value})}{1024} \right)$$

8. CONCLUSIONS

When the main line is running on 1kW load Green indicator glows which shows the main line is under load and further load can be derived. Now suppose we turn on a device of 100W, it is turned on because the main line does not exceed the load limit. But if we try to turn on a load of 1kW when main line is already on 1.1kW, microcontroller measures its power and since turning this load on will make the main line 2.1kW which is more than the allocated load (i.e. 2kW), hence the microcontroller energizes the relay for that device and the load is disconnected from the phase. This way the devices that derive the load making main line greater than load limit, are not switched on and this way the main line in any way does not exceed the allocated load.

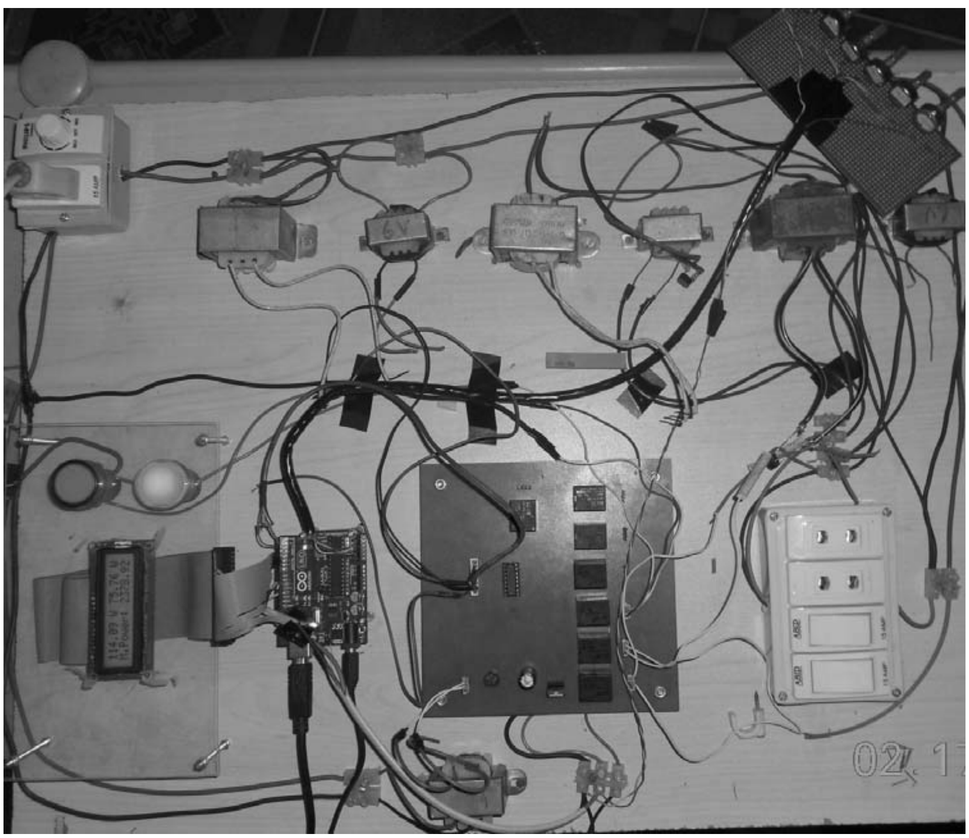

FIG. 8. REAL IMPLEMENTED SYSTEM

Through this work, distribution load is monitored and the consumer is limited to use allocated power. Load forecasting can be achieved through this system implementation of this system and thus generation and demand are balanced. Main line load is monitored and both voltage and current are monitored.

This system can be implemented with smart meter and thus all the parameters can be monitored and managed.

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