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Construction of a Microcontroller Base 60a Electrical Power Distribution Board

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ABSTRACT: This project work presents a microcontroller based electrical power distribution board that overcomes the challenges of conventional distribution boards/circuit breakers such as arcing, contact bounds and slow response. The aim of this project work is to construct a system that ensures reliable and secure power supply to a building. The system is built around pic18f4520 microcontroller, a Hall Effect current sensors and solid state relays (SSRs). When a fault occurs on any line, the current sensor sends data to the microcontroller to issue a command to the switching device (SSR) to switch off the fault line. The system also protects the electronic devices from overvoltage damage. Empirical result shows that the microcontroller based electrical distribution board ensures a reliable and safe power supply to the building by switching off faulty lines when excessive load is sensed.

I. INTRODUCTION

Electric power distribution is the final stage in the delivery of electrical power; it carries electricity from the transmission system to the individual consumers. Distribution sub-station connects to the transmission system and lowers the transmission voltage to medium voltage ranging between 2KVA and 35KVA with the use of transformers. Primary distribution lines carries this medium voltage power to distribution transformer again lower the voltage to utilization voltage used for lighting and individual equipment or household appliances (Anyaka & Olawoore, 2014). Often several customers are supplied from one customer through secondary distribution lines. Commercial and residential customers are connected to the secondary distribution lines through service drop.

Electrical power distribution for both domestic and industrial premises is so important based on its uses. Over the years distribution of electrical power in domestic or industrial premises has been moving from one stage to other for the purpose of safety of the users, the infrastructure, energy saving etc. Since the year 2000, the utility industry has invested over $275 billion (2012 USD) on distribution networks. Going forward, investment in new distribution infrastructure through the year 2030 is expected to reach as high as $582 billion. This investment is driving in parts by the unavoidable need to replace aging equipment and impart by the push for new smart equipment (Thaung, Tun, & Tun, 2016).

Automation has become the most effective way of doing things both in domestic and industrial premises which is also applied in electrical distribution system. This led to the incorporation of a microcontroller based electrical power distribution system into the distribution network (Roy, Newton, & Solomon, 2014).

A microcontroller based electrical power distribution board is an electronic system used in auto-controlling electrical power distribution. It uses a microcontroller (pic18f4520) with a firmware code embedded in the microcontroller which determines the behavior and the action of the system output (Roy, Newton, & Solomon, 2014). It is a system that distributes electrical power to four different final sub-circuits with a current sensor which dictates the output current, measure it and compare with the reference voltage of the sub circuit load. It has a relay which automatically isolates power when the demanded current exceeds the rated value of that sub circuit. And it also displays the load parameters (current and voltage), fault information and status for each of the unit in the distribution system. The system has a HMI (human machine interface) that enables the user to interact with the system thereby having means of effecting changes in case of fault (Bilal, Xiangjun, Robert, & Watermann, 2013).

The project aim in developing an intelligence distribution board that overcomes the failure in miniature circuit breakers. A microcontroller base electrical power distribution board is design in such a way that receives input (single phase) and split it output into four (4) different final sub-circuit and the microcontroller with a firm ware code embedded in it determine the amount of current in each unit output of the distribution board base on the rated current level of such unit. If load on any unit demands much current more than the rated current in that unit, the supply in that unit will be cut off and shows fault detection on the display unit (Neha & Kantilal, 2019).

To correct the fault, the system will be reset through the Human Machine Interface circuit (HMI). The artificial intelligent distribution board is also design to reject over voltage entering into the system, it shows "Over-voltage detection" in all the display when it is powered i.e. during initialization of the circuit.

However, this device "microcontroller base electrical power distribution board" is designed to protect and secure equipment from over-current damage and also protect itself from component damage due to input over-voltage resulting from fluctuation at the generation and transmission level (Hussain, Rahim, & Musirin, 2013).

II. MATERIALS

This project has five (5) distinct units which include the Human Machine Interface unit, the processing unit, the display unit, the relay unit and the sensing unit. The Human Machine Interface unit was implemented with push button switch and resistors, the processing unit was implemented with a microcontroller, the display unit was implemented with a Liquid Crystal Diode (LCDs) and Light Emitting Diode (LEDs), and the relay unit was implemented with electromechanical switches while the sensing unit was implemented with a current sensor (Luo, 2001). The materials used in actualizing this project include Push button switch, Resistors, Capacitor (Electrolytic & Ceramic), Crystal Diode, Microcontroller, Light Emitting Diode (LED), Liquid Crystal Diode (LCD), Diode, Sensors, Potentiometer, Relays, Steps down transformer, Voltage Regulator (Bilal, Xiangjun, Robert, & Watermann, 2013).

III. METHODS

The method used in releasing a workable circuit and construction of the entire project is depicted with the block diagram of figure 1. Each block was designed, constructed and tested separately before interconnecting the units together. Each of these units is explained below.

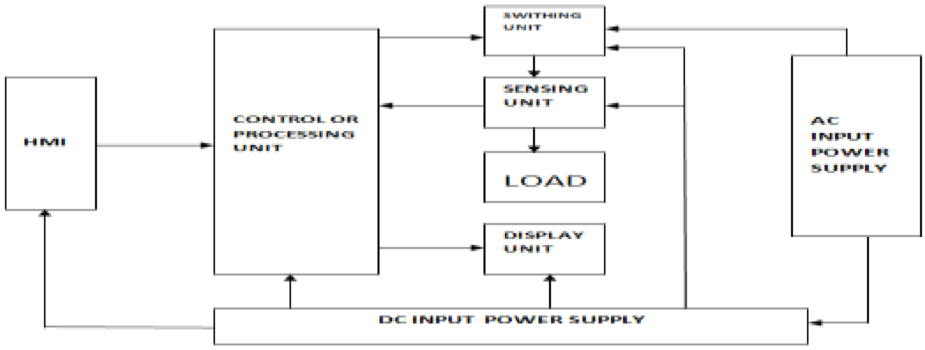

Figure 1: System Block Diagram

1. Power Supply Unit

The power supply unit consists of the transformer (TRI), full wave bridge rectifier (BR1), filters (C7) and voltage regulators (U7). The transformer (TR1) step down the 220V ac input into a 12V AC 50Hz to be rectified (convert from AC to DC) by the bridge rectifier (BR1) by conducting spontaneously at each of the positive and negative half cycles of the incoming AC signal respectively in order to have a pulsating DC signal which after, undergoes filtration by C7 in order to have a smooth dc voltage of 12V DC. The voltage regulator U7 varies the incoming 12V DC to have a specified 5V DC at the output (Vout) and to power the switching unit while 5V DC is used to power the HMI, Display, Microcontroller and sensing unit (Alamgir & Dev, 2015).

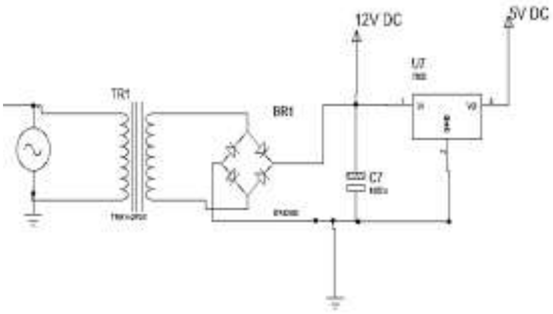

Figure 2: 220v AC, 12v DC and 5v DC power supply unit

2. HMI

The human machine interface (HMI) is made up of push button switch (push-to-make) and Resistors. The push-to-make switch allow current to flow through the microcontroller when it is pressed thereby providing an avenue for adjustment to be made in the microcontroller of which the microcontroller interpret the incoming signal and applies it in controlling the system parameters.

The SET push button just like every other push button switch sends an analog signal through the current limiting resistor R1 to the microcontroller via pin 33 of the microcontroller. The microcontroller has analog to digital converter (ADC) which converts the incoming analog signal to digital signal. Hence, subsequent adjustment can be made. This applies to every other push button switches which include SELECT, INCREMENT, DECREMENT, SAVE AND RESET/EXIT which sends their respective analog signal via R2 and pin 34, R3 and pin 35, R4 and pin 35, R5 and pin 36 and finally R6 and pin 7 of the microcontroller (Luo, 2001).

The current limiting resistors R1 to R6 limits the current flowing into the microcontroller to avoid damage since the microcontroller has a specific current level it can accept. Here, we used 4K7 resistor and input voltage of 5V. Therefore, the current entering the microcontroller is given by:
$I = V/R = 5/4700 = 0.001A$

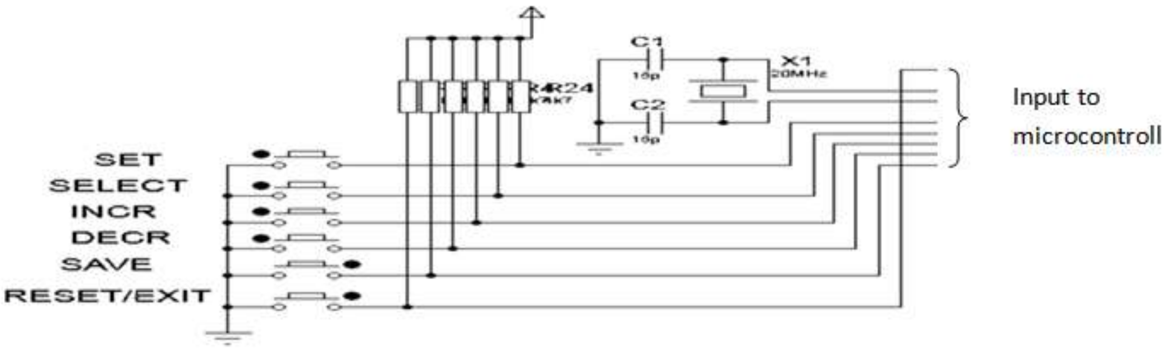

Figure 3: Human Machine Interface

3. Display Unit

The display unit is constructed with liquid crystal display (LCDs) ranging from LCD1 to LCD4 and potentiometer RV1. The LCDs are connected to port C and D of the microcontroller in order to display electrical parameters (voltage and current), it is also constructed in such a way that will display fault message when fault occurs in the system. This project made use of 4(four) LCDs, one for each sub-circuit to display the condition of each sub circuit.

During initialization, the system condition is viewed with the help of the display unit. The sensor detects the current level drawn by the load and sends an equivalent signal to the microcontroller which was programmed in such a way to make comparison between the loads current with reference point. If fault is detected due to overload the microcontroller outputs signal through pin 15, 16, 17 and all eight (8) pins of port D in order for the system condition at this point to be viewed.

The display unit is powered by 5V DC gotten from the 12V DC that was regulated by the regulator U7. The potentiometer RV1 is connected between the display (LCD) and the supply power (5V DC) in order to vary the brightness of the display for clearer view.

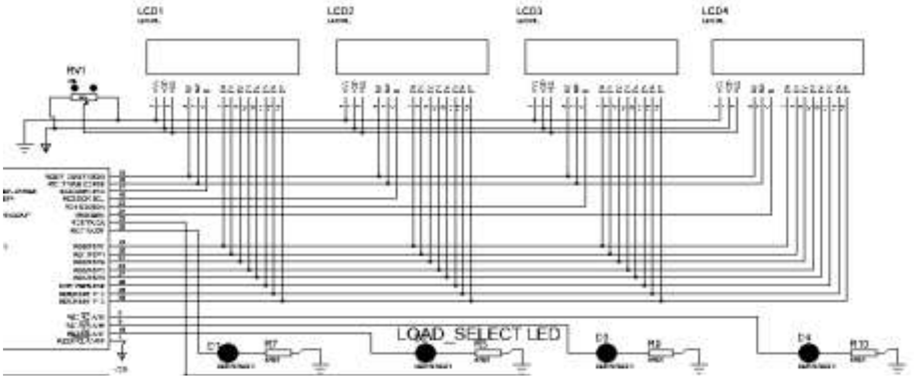

Figure 4: Display Unit

4. Sensing Unit

The sensing unit is made up of the current sensor (ACS 712), potential divider R18 and R20, R17 and R21, R18 and R22, R19 and R23 for each of the four current sensors (ACS 712) circuit which has 2K2 and 10K resistor respectively to provide potential dividing based on the data sheet of the sensor and a half wave rectification circuit which comprises D9 and C3, D10 and C4, D11 and C5, D12 and C6 respectively to provide a half wave rectified DC signal entering the microcontroller via pin 2, 3, 4, 5 respectively. The current sensor operates using the principle of Hall-effect which is the production of a voltage difference across an electrical conductor, transverse to an electric current in the conductor and to applied magnetic field perpendicular to the current.

The sensor is powered by 5V DC and the load is connected between the sensors U2, U3, U4 and U5 and the relays RL1, RL2, RL3 and RL4 respectively. The output of the sensor is connected to a potential divider based on the directive from the sensor data sheet. The signal from the potential divider passes through a half wave rectifier D9 and C3, D10 and C4, D11 and C5, D12 and C6 respectively in order to give a pulsating output signal, which is connected to the microcontroller as input via pin 2, 3, 4, 5 respectively in port A.

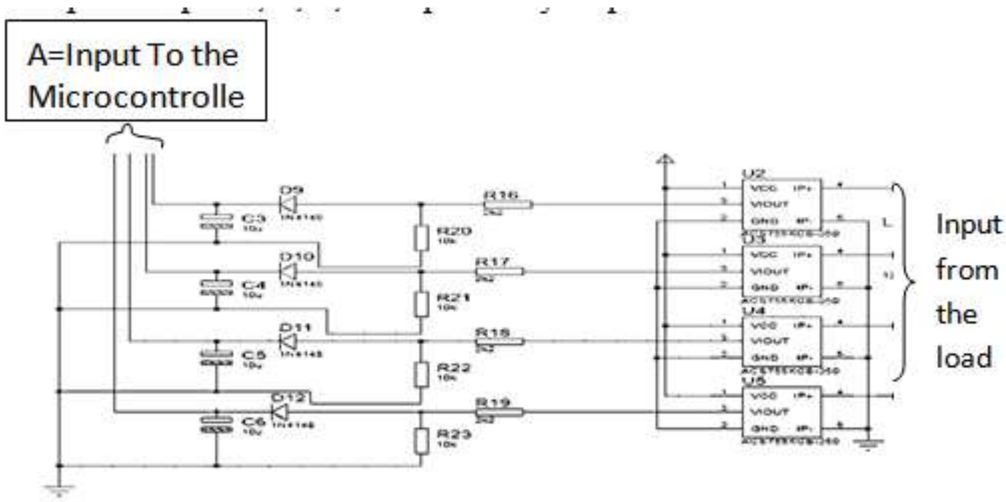

Figure 5: Sensing Unit

5. Control Unit

The control or processing unit consists of the microcontroller (pic18f4520) and an oscillating circuit (X1). A pic18f4520 microcontroller is used in this construction work, embedded with a source code which determines the behavior of the system. A pic18f4520 microcontroller was chosen for this project because of it efficiency and familiarity with the programming code. It receives input signal from the HMI via R2 and pin 34, R3 and pin 35, R4 and pin 35, R5 and pin 36 and finally R6 and pin 7 and sensors through pin 2, 3, 4, 5 respectively in port A. and send out it output signals as 0's and 1's to the display and the relay.

The 1 and 0 representing 5 and 0 volts respectively, it is either used to trigger the relay on

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or off as the case may be depending on the outcome of the initialization.

The oscillatory circuit (X1) which comprises of C1, C2 and crystal diode is to generate a steady frequency of 20MHz to help the microcontroller function effectively. The oscillator used in this construction work is the crystal oscillator.

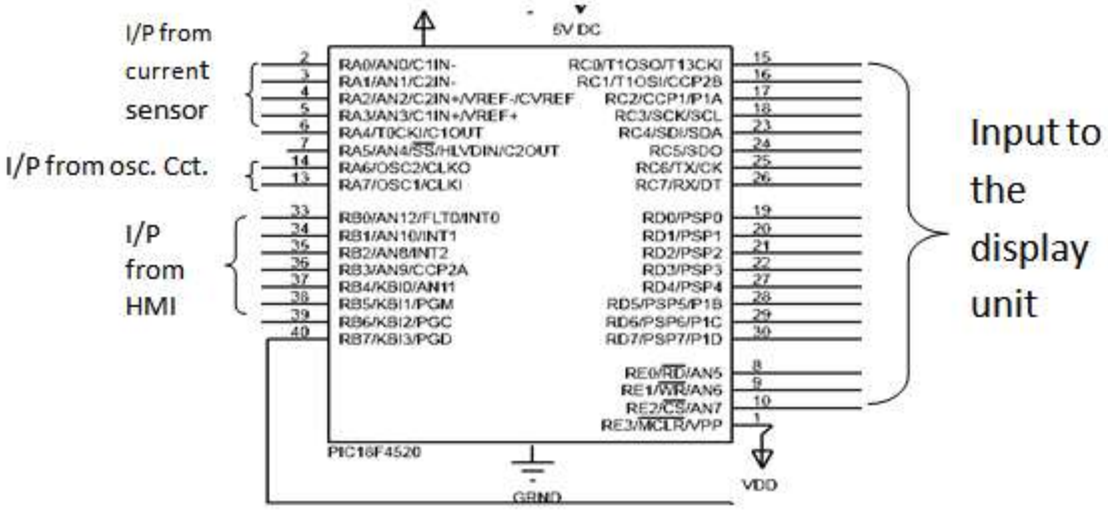

Figure 6: Control and processing Unit

6. Construction of the Switching Unit

The switching unit is constructed with a Darlington pair transistor U6 and four (4) single pole double throw (SPDT) relays RL1, RL2, RL3 and RL4. The four relays are connected to the Darlington pair transistor U6 and also to the loads ranging from L1, L2, L3 and L4 which represents the four sub-units. The Darlington pair transistor (Uln2003Wa IC) receive its input from the microcontroller which is 1s and 0s (0 = 0V, 1 = 5V), the input signal determine the close and open function of the relay.

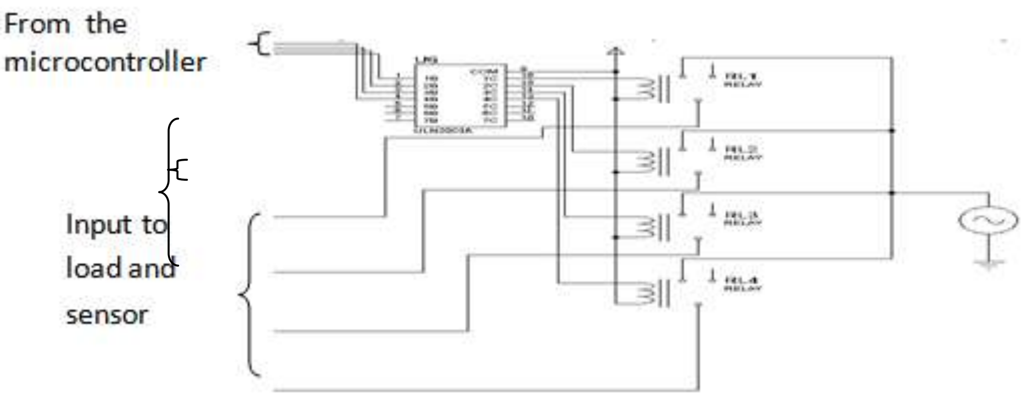

Figure 7: Switching Unit

7. Operational Principle of a Microcontroller Base 60A Electrical distribution board

The system (microcontroller electrical power distribution board) receives an input voltage of 220V AC and the voltage is being tapped and step down to 12V AC using a 220V/12v step down transformer. The 12V is rectified using a full wave bridge rectifier to 12v DC and regulate to 5v DC which is used in powering the relays (12V DC), current sensors, Human Machine Interface, microcontroller and the display system.

The 220V AC live wire is connected to a single pole double throw relay while the neutral wire is connected to the sensor.

Once the circuit is powered, it undergoes initialization process and after which the microcontroller send a digital signal to the relay for a close contact, then voltage flow through the relay to the load which is connected in-between the relay and the sensor. The sensor detects the amount of current drawn by the load and generates equivalent voltage as output; the output voltage passes through a potential divider to a half-wave rectifier circuit for rectification before the signal gets to the microcontroller through an Analog to Digital Converter.

The microcontroller having received the input signal from the sensor compare what the load current with the rated current of that circuit and if the demanded current is higher than the rated current the microcontroller send a digital signal to a switching device to cut-off supply (isolate) and also send a fault message to the display system such as "overload detected".

The HMI is used for SET, SELECT, INCREMENT, DECREMENT, SAVE and RESET/EXIT as input to the microcontroller.

If fault occurs in a particular sub-circuit, the SET button is pressed to provide an avenue of interacting with the system and the SELECT button is pressed to select that particular sub-circuit which fault occurred. The INCREMENT and DECREMENT button is used in increasing or decreasing the systemcurrent rating of that particular sub-circuit of which after the setting is saved through the SAVE button and to quit the window, we use the EXIT/PRESET button.

The oscillatory circuit (X1) generates a steady frequency of 20MHz for the microcontroller to function effectively.

IV. RESULT AND DISCUSSION

1. Power supply unit

The power supply unit was implemented in four stages which include voltage transformation, Rectification, Filtration and regulation stage. The transformer used has a rated input of 220v and an output of 12V ac and this value was obtained from a voltmeter reading connected across the secondary terminals. It was observed that voltage fluctuations at the transformer primarily affected the secondary voltage level at approximately equal rate. Therefore, the input to the regulator was seen to vary within $^{+}$- 5% of the expected value. A dc voltmeter was connected across the output terminals of the regulator, on the other hand, gave 5V dc irrespective of the deviation at the instance of measurement. Hence, the performance of the power supply unit was satisfactory.

2. Display unit

We use a dc voltmeter to test the voltage input terminals of the display unit, and the reading was 5V dc at the instance of measurement which was satisfactory.

3. Switching Unit

The device was powered and after initialization, a dc voltmeter was connected across the input terminals from the microcontroller and the load connected to the final sub-circuit, after the device initialization, the reading for the input to the switching circuit (Darlington pair transistor) was 5V dc which was satisfactory.

4. Sensing Unit.

The load was connected to the final sub-circuit, and the system was powered after initialization, an Ammeter was connected to the output of the current sensor and the current was 2.5v dc which was satisfactory.

5. General Performance Test of the project

The system was tested with appliances having different current ratings. It was set at a given unit rating to see how it will detect over voltage and under voltage. The obtain are as show in table 1 below.

Table 1: Performance test result table

S/N	Device Description	Device Current Rating (A)	MBEPDB Unit Rating (A)	MBEPDB Sub-circuit Performance
1	Soldering iron	0.18	1	ON
2	Soldering Iron	0.18	0.5	ON
3	Soldering Iron	0.18	0.12	OFF
4	Heater	18.18	15	OFF
5	Heater	18.18	20	ON

6	**Laptop**	**0.3**	**0.1**	**OFF**
7	**Laptop**	**0.3**	**0.5**	**ON**
8	**Television**	**0.45**	**O.5**	**ON**
9	**Television**	**O.45**	**0.35**	**OFF**
10	**DVD**	**0.11**	**0.2**	**ON**
11	**DVD**	**0.11**	**0.1**	**OFF**
12	**Electric Iron**	**4.55**	**5**	**ON**
13	**Electric Iron**	**4.55**	**4**	**OFF**
14	**Electric Fan**	**1.09**	**1.2**	**ON**
15	**Electric Fan**	**1.09**	**1.00**	**OFF**
16	**Phone**	**2**	**2.5**	**ON**
17	**Phone**	**2**	**1.5**	**OFF**
18	**Heater**	**18.18**	**17**	**OFF**
19	**Heater**	**18.18**	**18**	**OFF**
20	**Heater**	**18.18**	**18.5**	**ON**

V. CONCLUSION

A microcontroller base electrical power distribution system is interfaced with various sensors and actuators. The system overcomes the challenges of conventional circuit breakers which include slow response, arching and switch bounce. Test result show that the system trip-off once the pre-set or rated current value is exceeded. Besides the system has ability to offer protection against overload. The system has an advantage of testing the load condition before supplying power to the various branch of the circuit thereby preventing any danger of fire accident due to any fault.

VI. RECOMMENDATION

The project has been found viable for domestic and industrial premises, most especially, for those using solar energy in order to save the life of their Battery. This project help in conserving energy and reduce the expenses of electricity bills, it also serves the purpose of safeguarding the electronic appliance from over voltage damage.

In consideration of its usefulness, further development is required to improve its functionality and enhance its reliability. Thus, for further research and development and better applicability of the project, the following are recommended:

1. Increase in the system capability more than 60A and four (4) ways, by the provision of more relay display (LCD), and current sensors.
2. Incorporation of alarm system into the device for notification whenever there is fault for faster rectification and correction of such fault.
3. Incorporation of automatic reset unit which can reset a faulty line after some time without causing damage to the whole system.
4. Incorporation of stabilizer into the system in order to have a stable (fluctuation free) output power supply.

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