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**Research Article**

# A Novel Method of Remote Battery Back-up for A DMS Sub-station

Suba Srinivasan, Subhronil Dey and Sarat Kumar Sahoo
School of Electrical Engineering, VIT University, Vellore-632014, Tamilnadu, India

**Abstract:** This study presents a remote battery backup for Distribution Management System substation. It elucidates the importance of the battery at the substation and the necessity of the automation at the substation. By achieving this we can remotely check the health of the battery from Back Control Center. It also enlightens the affects of the unavailability of power supply and how the charger gets activated and gives supply to the motors connected to the isolators and also acts as auxiliary supply to the Field Remote Terminal Unit until the station comes online.

**Keywords:** BCC, DMS, FRTU, RMU, RTU, SCADA

## INTRODUCTION

A Distribution Management System (DMS) is a collection of applications designed to monitor and control the entire distribution network efficiently and reliably. In the system operation architecture, DMS includes four layers, a hardware layer, operation system layer, support platform and application layer (Fan, 2009). It acts as a decision support system to assist the control room and field operating personnel with the monitoring and control of the electric distribution system. Improving the reliability and quality of service in terms of reducing outages, minimizing outage time, maintaining acceptable frequency and voltage levels are the key deliverables of a DMS (See *et al*., 2009).

A Remote Terminal Unit (RTU) is a microprocessor-controlled electronic device that interfaces objects in the physical world to a distributed control system or SCADA (Supervisory Control and Data Acquisition) system by transmitting telemetry data to a master system and by using messages from the master supervisory system to control connected objects (Ahmed and Soo, 2008). Another term that may be used for RTU is remote telemetry unit, the common usage term varies with the application area generally.

An RTU monitors the field digital and analog parameters and transmits data to the Central Monitoring Station. It contains setup software to connect data input streams to data output streams, define communication protocols and troubleshoot installation problems (Kudtongngam *et al*., 2009).

Modern RTUs are usually capable of executing simple programs autonomously without involving the host computers of the DCS or SCADA system to simplify deployment and to provide redundancy for safety reasons. An RTU in a modern water management system will typically have code to modify its behavior when physical override switches on the RTU are toggled during maintenance by maintenance personnel.

The RTU connected to the feeder is called Field Remote Terminal Unit. FRTU are comparatively smaller in size. The basic structure of a feeder automation system in a substation is it contains a Feeder Dispatch Control System (FDCS), a Feeder Remote Terminal Unit (FRTU) inside the substation and a Remote Terminal Unit (RTU) in the feeder (Shi-Bing, 2009).

If any permanent fault occurs in the feeder, the distribution automation system, after the protective device has been opened in lock-out status, identifies the fault zone based on the fault information which is collected sequentially from the switch Feeder Remote Terminal Units (FRTU) on the fault feeder. Then, after entirely separating the fault zone, it closes the protective device and transfers the fault-free outage zone to other feeders according to the network configuration strategy (Liu *et al*., 1988; Aoki *et al*., 1989; Taylor and Lubkeman, 1990; Civanlar *et al*., 1988; Jung *et al*., 1993).

In the recent scenario there is an uncertainty in the drainage of the battery present in the FRTU. To overcome this, an additional under-voltage cut-off card is implemented in the FRTU. In this case the UV card monitors the voltage level of the battery. Whenever the battery voltage drops below 21.6 V then it triggers the relay and connects the charger to the battery and also sends a pulse to Back office (BCC) informing them about the status of the battery. Now in case of any failure in connection between the charger and battery the voltage level will continue to remain below the cut-off voltage and a continuous pulse will be send to the BCC thereby indicating some technical failure in connection between the charger and the battery. Since the RTU/FRTU can work at a voltage as low as 12 V

**Corresponding Author:** Suba Srinivasan, School of Electrical Engineering, VIT University, Vellore-632014, Tamilnadu, India

therefore it will take minimum 8-10 h for the battery to drain to 12 V thereby giving enough time to the crew member to come to the site, fix the issue and avoid the station to go completely offline.

The objective is to automate the BCC command and develop a under voltage cut-off card which will automatically sense the voltage of the battery and check the health of the battery as well as the charger. If there is an under-voltage scenario the battery will be automatically connected to the charger. The whole system will operate only if the charger is online. The role of the battery is very important as it provide auxiliary supply to the FRTU and to the motors of the isolators in the RMU. The control over the substation is remotely possible only if the battery is healthy. The goal of the project is to place the under voltage cut-off card between the charger and the battery in the RMU at a substation and implement it successfully. The BCC command that is the push to ON switch in the schematic diagram would be automated using a LM555 timer circuit. The basic approach towards the design of the under-voltage cut-off card is to compare the voltage levels with the reference voltages using opamps and for the relay operations. Reference voltages are created with the help of potential divider circuits. TPs (Test Points) are provided at every stage in the under-voltage cut-off to check the voltage levels. Two relays have been used in the UV card to provide NO and NC contacts which are UV relay and resetting relay. The healthiness of the battery and the charger is made sure using AND IC. TRIAC is used to energies the UV relay and inter-lock the situation.

## MATERIALS AND METHODS

**Current state of art:** As per the Fig. 1 in the present scenario the 230 V AC supply is converted into 24 V DC supply which acts as an auxiliary supply for the RTU/FRTU. Now in the case of any power cut-off the supply from the charger is replaced by the 24 V DC supply from battery. At present there is no monitoring over the battery status and the complete RTU/FRTU system will be off-line once the battery drains completely.

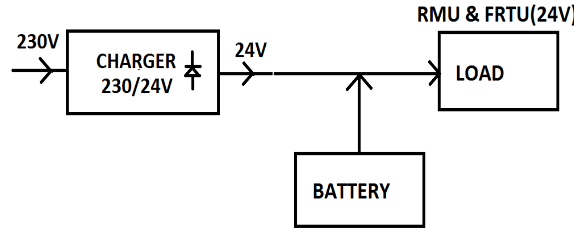


Fig. 1: Block diagram representing the connection between charger, battery and load

**Complete system:** Here an additional contact circuit containing Under Voltage cut-off (UV) card is added as shown in Fig. 2. Upon adding this UV card the problem regarding the uncertainty of drainage of battery is overcome. In this case the UV card monitors the voltage level of the battery. Whenever the battery voltage drops below 21.6 V then it triggers the relay and connects the charger to the battery and also sends a pulse to Back office (BCC) informing them about the status of the battery. In case of any failure in connection between the charger and battery the voltage level will continue to remain below the cut-off voltage and a continuous pulse will be send to the BCC thereby indicating some technical failure in connection between the charger and the battery.

Since the RTU/FRTU can work at a voltage as low as 12 V therefore it will take minimum 8-10 h for the battery to drain to 12 V thereby giving enough time to the crew member to come to the site, fix the issue and avoid the station to go completely offline.

**The overall schematics:** In order to determine the health of the battery the current should flow from the battery to the load which is in this case is RTU. The whole schematic is given in the Fig. 3.

It is done by giving a 1 sec pulse acting as the bcc command. Once the 1 sec pulse is given the k1 relay gets energized and the NC (Normally Closed) switch gets open and the NO (Normally Open) switch gets closed. Once the relay is energized and the NC is open the charger gets disconnected from the battery. Thus the

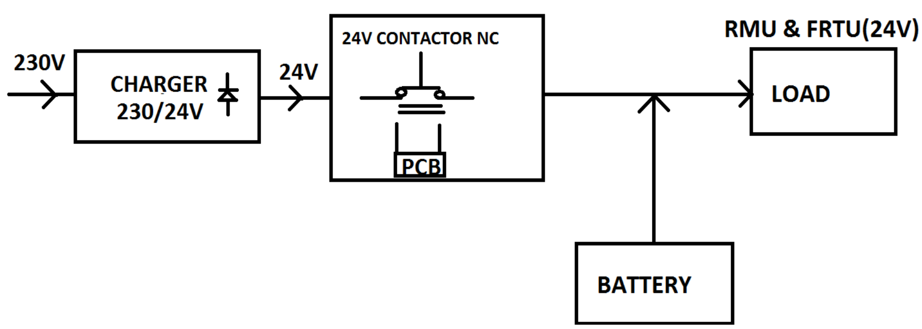


Fig. 2: Block diagram with contact circuit between the charger and the battery

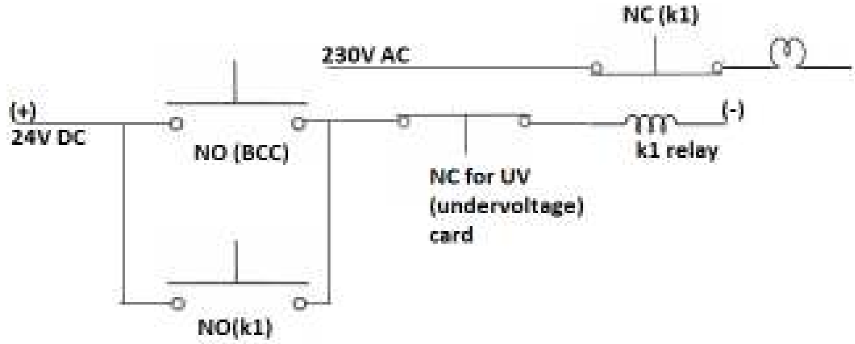


Fig. 3: Overall schematics of contact circuit


Fig. 4: Prototype for the overall schematics

supply flows from the battery to the RTU. And it will keep discharging until the relay is discharged and the charger is again connected to the battery. In order to achieve that there is a Under-Voltage (UV) cut-off card which senses the health of the battery and once the battery voltage reaches the cut-off point the NC of the UV relay gets open thus discharging the relay which in turn connects the battery to the charger.

**Description of the prototype model:** As per the Fig. 4 the connection between the charger and the battery is represented by the bulb. The push to on switch (green switch) acts as the 1 sec command pulse from BCC (back office) the push to off switch (red switch) acts as the UV (Under Voltage cut-off) card. K1 coil-relay (24 volt DC) is used for providing NO and NC contacts. Pin configuration of relay K1 (relay base connections) K1→2 and 10; NO→9 and 11; NC→1 and 4.

**Various steps of operation:**

**Step 1:** By default when the board is connected, the light glows, which indicates that the charger and the battery are connected during normally operating conditions.

**Step 2:** When the green button is pushed, i.e., the command from BCC is received, (1 sec pulse) the light goes off, which indicates the charger is disconnected from the battery, as the Person at the BCC wants to know about the health of the battery.

**Step 3:** When the red button is pushed, the light glows again, which indicates the charger is connected

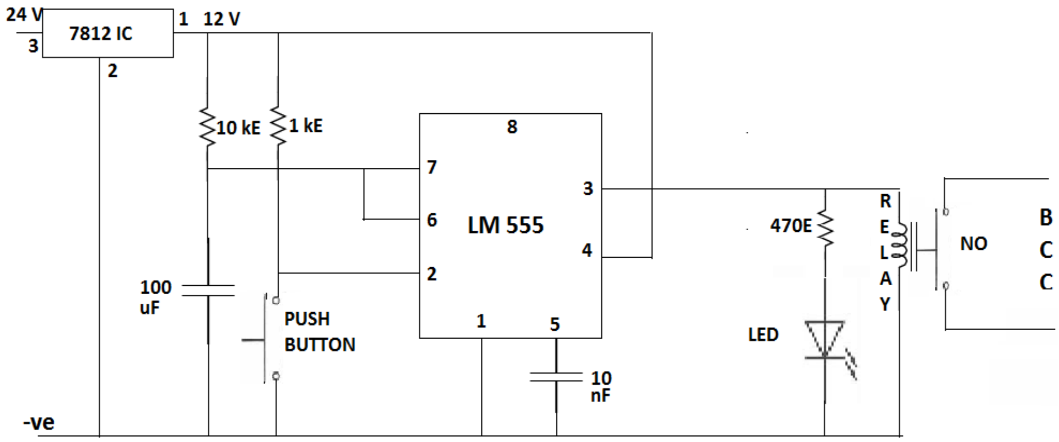


Fig. 5: Circuit diagram for LM555 timer

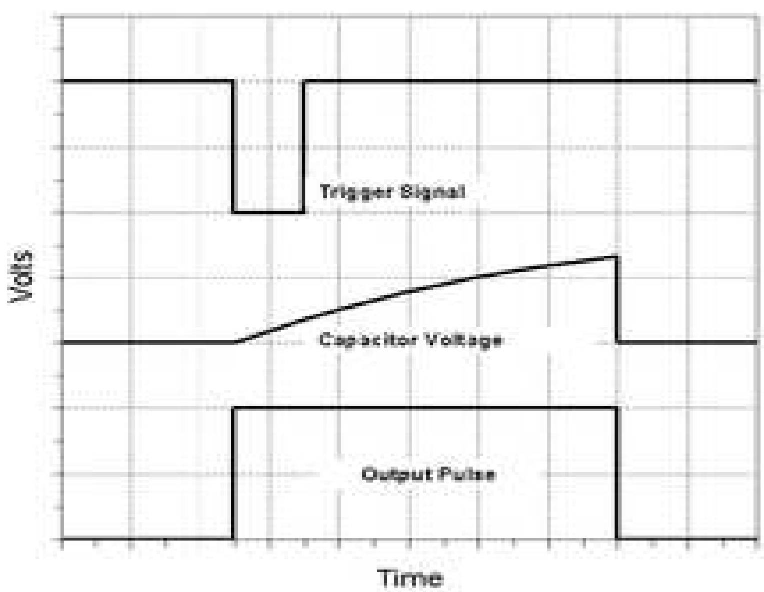


Fig. 6: Output waveform at pin No. 3 of LM555

back to the battery because the UV card will detect the voltage of the battery, as it reaches to 12.6 volt, it automatically connects the battery back to the charger.

**Step 4:** The step b can also be performed using PCB, with the help of the push to on switch on the PCB.

**Design description of BCC command:** BCC command is given as one second pulse or a 500 msec pulse. Thus the same has been achieved by using LM555 timer in mono-stable mode. In the Mono-stable mode, 555 timer acts as one shot pulse generator (David, Year). The pulse begins when the timer receives a signal below 1/3$^{rd}$ of the voltage supply. The width of the output pulse is determined by the time constant of the RC network which consists of the resistor and the capacitor as shown in Fig. 5 to 7. The output pulse ends when the voltage on the capacitor equals to the 2/3$^{rd}$ of the supply voltage. The output pulse width can be lengthened or shortened to the need of the specific application by adjusting the values of R and C. The output pulse width as in Fig. 6 has a time period of t, which is the time it takes to charge C to 2/3 of the supply voltage, is given by Eq. (1):

$$t = RC \ln(3) \approx 1.1RC \quad (1)$$

Fig. 7: RC network which consists of the resistor and the capacitor

where,
t = In seconds
R = In ohms
C = In farads

While using the timer IC in monostable mode, the main disadvantage is that the time span between any two triggering pulses must be greater than the RC time constant. The description of the LM555 timer circuit is given as follows:

- 7812 IC (1amps) is used here, as a voltage regulator, which will convert 24 volt DC supply to 12 volt DC supply
  - **Pin No. 1:** Input (24 volt DC)
  - **Pin No. 2:** Ground (-ve)
  - **Pin N0. 3:** Output (12 volt DC)
  - Heat sink is used with the IC 7812, for the heat dissipation. As the IC gets continuous power supply, there would be more heat generated due to the increase in internal IR drop (E = V-IR).

Fig. 8: Under-voltage cut-off card

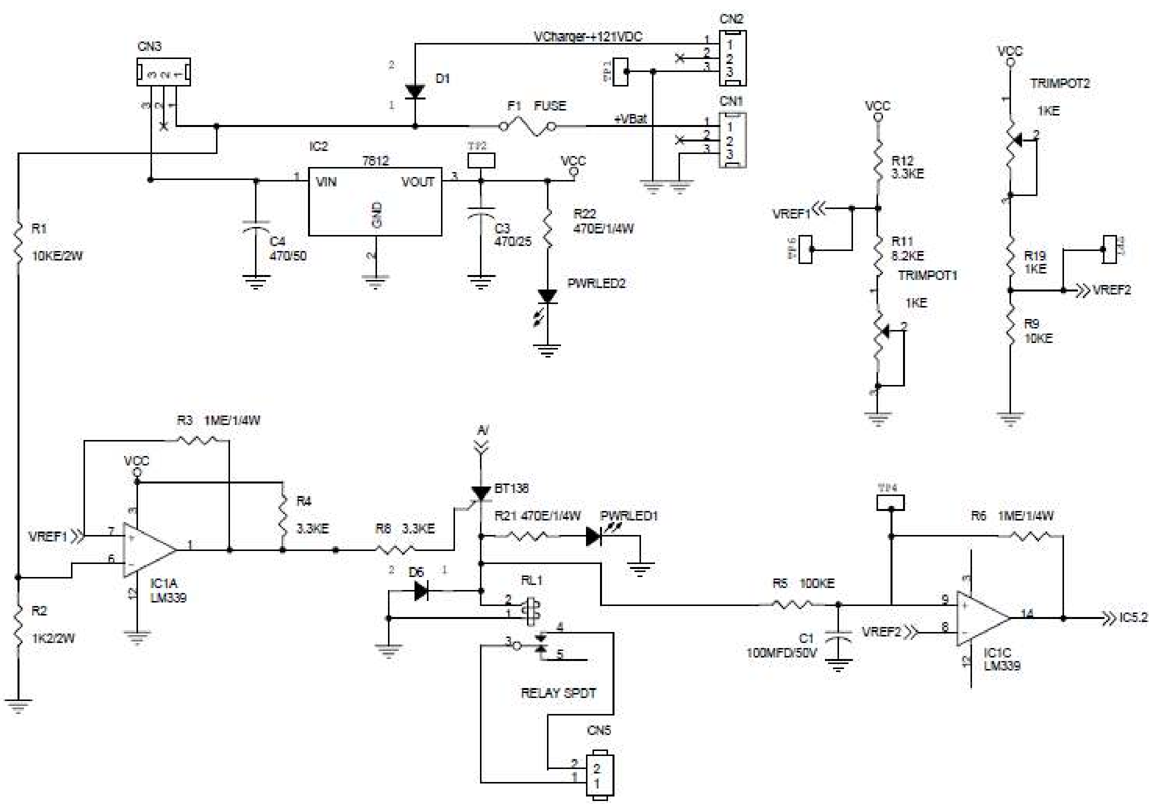


Fig. 9: Circuit diagram of the UV card part-A

Though the metallic contact the heat is dissipated

- A 12 volt DC relay is used for coil and NO (normally open contacts). The LM555 is connected to the coil of the relay and grounded. The alternate connection for the green switch in the board is taken from the relay for this circuit
- Two connectors are used, one for the input (24 volt DC supply) and the other for the NO Contacts acting as BCC command
- LED, is used to indicate the time period of the output pulse is one sec at pin No. 3. The same can be verified by connecting the CRO probes across pin No. 3 and ground
- The 10 nF capacitor is used to reduce the noise created at the output

**UV card design methodology:** Figure 8 shows the fabricated under-voltage cut-off card on printed circuit-board. The related circuit diagram is shown in the Fig. 9 and 10.

As shown in the Fig. 11 the input to CN1 comes from the battery output terminal. The input to CN2 comes from the charger output terminal. The input to CN3 comes from the battery-charger junction. The output of the CN3 is given to the input of the 7812 IC which convert 24 to 12 V DC supply which will act as auxiliary supply in form of Vcc for all the components in the circuit. The green LED is connected to the 7812 IC to indicate that the auxiliary supply is active.

The 1/3 of the battery voltage is given to the inverting terminal of the 1st comparator as shown in the Fig. 12. The reference voltage $V_{ref1}$ which can be measured from TP6 is given to the non-inverting terminal of the comparator. Generally the voltage at the inverting terminal is higher than the non-inverting terminal which is the comparison between the battery voltage and the cut-off voltage. Once the battery voltage reaches the cut-off voltage the comparator gives a positive pulse to the gate of the TRIAC.

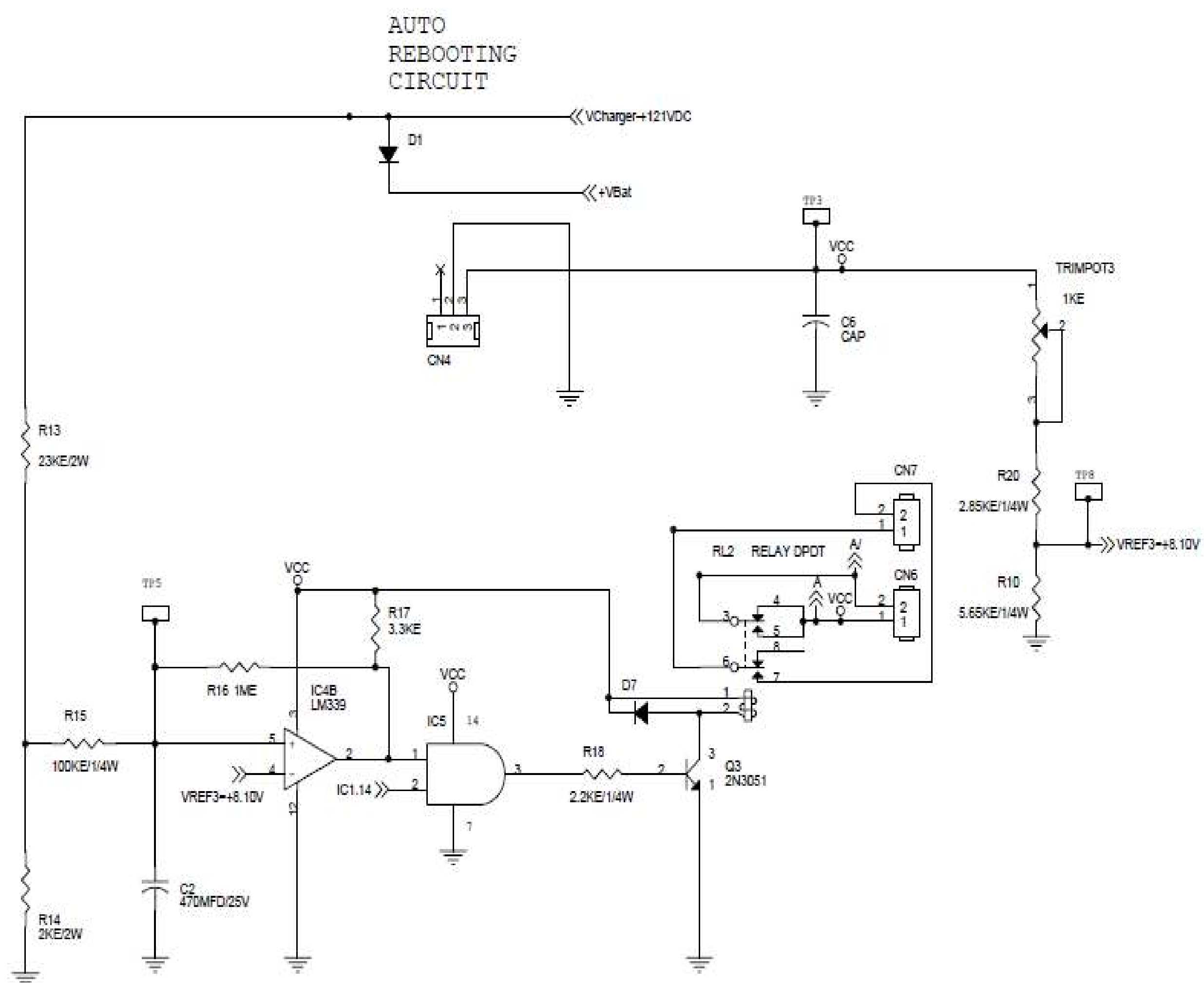


Fig. 10: Circuit diagram for the UV card part-B

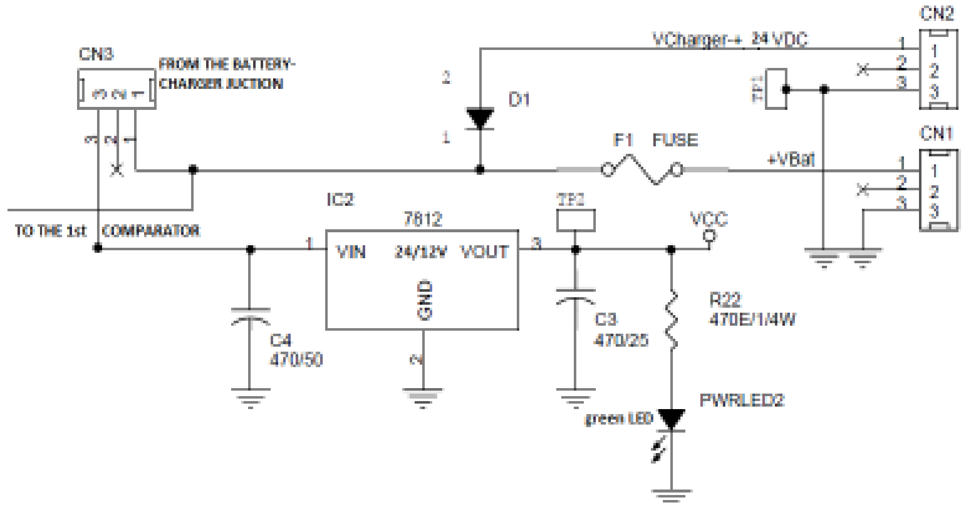


Fig. 11: Connection taken from the charger and battery

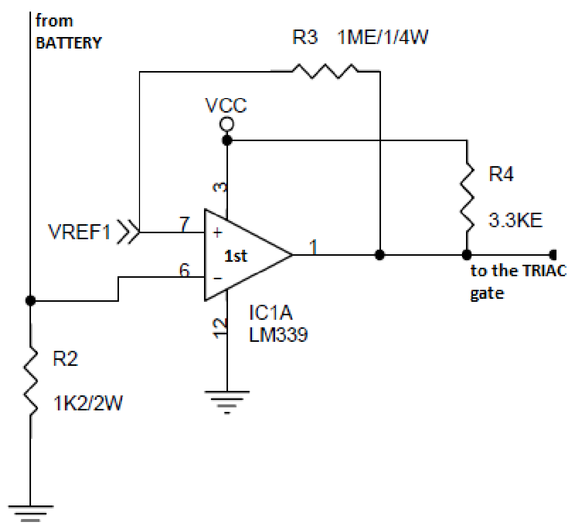


Fig. 12: Circuit diagram for 1st comparator

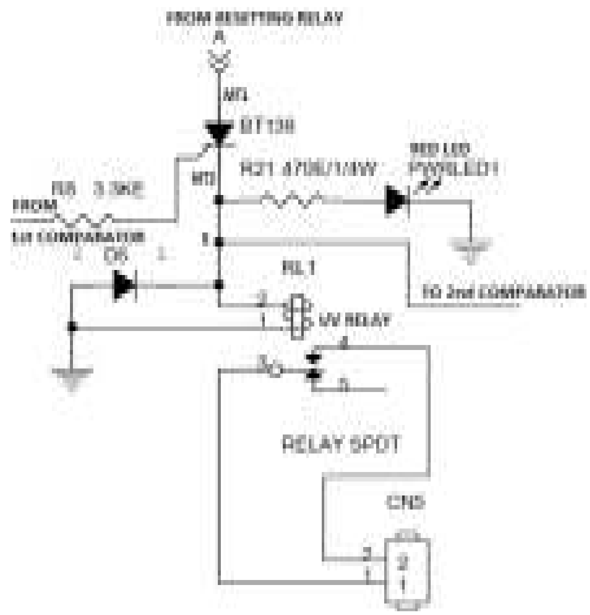


Fig. 13: Circuit diagram for the TRIAC

Once the battery voltage reaches the cut-off voltage the comparator gives a positive pulse to the gate of the TRIAC as shown in the Fig. 13. This will in turn makes the red LED glow and energizes the ‘UV’ relay and the NC contact of the ‘UV’ relay gets open and the k1 relay discharges thus connecting the charger to the battery. In order to give the next command from the bcc the ‘UV’ relay must be de-energized and the NC contact of the ‘UV’ relay must be closed again. In order to de-energize the ‘UV’ relay voltage across the TRIAC must be made zero.

The 2nd IC confirms if the TRIAC is activated as shown in the Fig. 14.

It uses a delay circuit by using a capacitor and a resistor. The voltage across the capacitor increases slowly and is compared with the $V_{ref2}$. Once the voltage across the capacitor reaches the $V_{ref2}$ the op-amp sends forward a positive pulse to the AND gate. The delay time period is determined by the resistor and the capacitor value. The delay circuit is used to avoid instantaneous high voltage which can be created by various reasons.

The whole system will work if and only if the health of the charger if good. The 3rd comparator IC will send a positive pulse only if the charger voltage i.e., TP5 is greater than the Vref3 i.e., TP8 voltage as shown in Fig. 15. The AND gate ensures that if the TRIAC is activated and the health of the charger is good i.e., if the charger is online because the AND gate will trigger only if the 2nd and the 3rd comparator together send a positive to the both input terminal of the AND gate. When both the conditions are satisfied then the AND gate will generate a high pulse at the output.

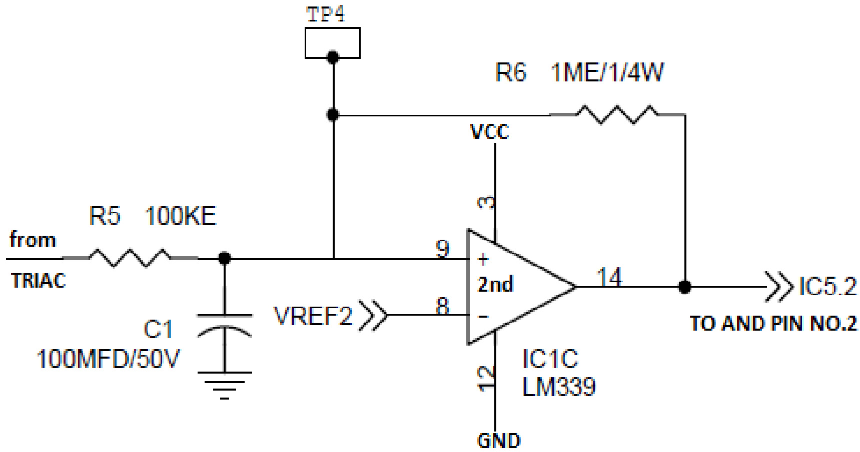


Fig. 14: Circuit diagram for the 2nd comparator

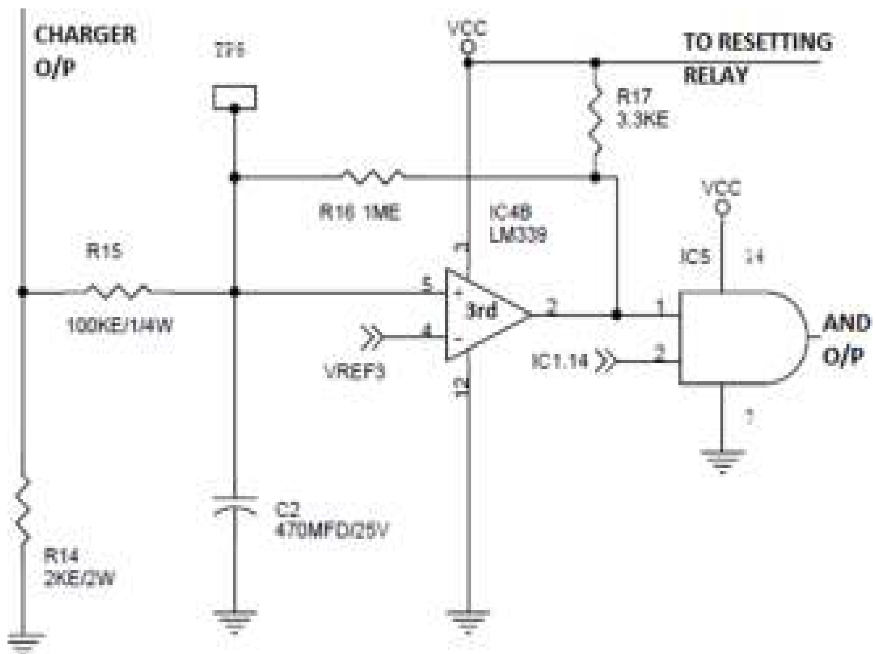


Fig. 15: Circuit diagram for the 3rd comparator

Once the AND gate triggers the thyristor gets short circuited. Once the transistor gets short circuited it will energize the ‘reset’ relay as shown in Fig. 16. Once the resetting relay gets energized it will operate its NC an NO contacts. At normal condition there is always a Vcc = 12 V to the MT1 of the TRIAC since both the NC and NO contacts are connected to the MT1 of the TRIAC. So even after the ‘reset’ relay gets energized the MT1 terminal of the TRIAC will continue getting Vcc. Whenever the ‘reset’ relay gets energized the NC will get open and the NO will get closed. In this process there will be a momentarily zero voltage applied across the TRIAC which is achieved by the overlapping time period in the closing and the opening of the NO and NC contacts respectively. Thus making both the upper and the lower terminal of the TRIAC zero will reset the TRIAC. This momentarily OFF state caused by the relay will act as a reset for the TRIAC. Once it gets reset the UV relay will get de-energized. Once the UV relay gets de-energized its NC contact will get closed again thus making it ready for the next BCC command. Once the TRIAC has been operated there will be zero potential at ‘x’ point. Thus it will make one of the terminal of the AND gate at zero potential. Therefore there will be zero potential at the output of the AND gate. So there won’t be any potential at the gate of the transistor which in turn will make it off thus de-energizing the resetting ‘reset’ relay.

The reference voltages can be varied using the POT provided in the respective circuits as shown in the Fig. 17. The reference voltages can be measured at the TPs (Testing Points).

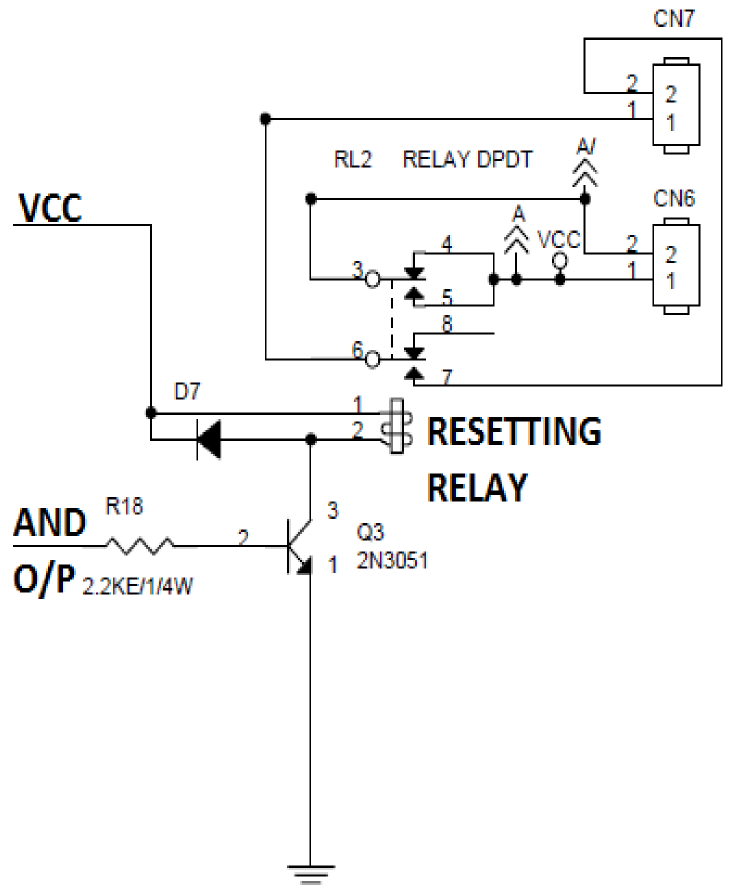


Fig. 16: Circuit diagram for the resetting relay

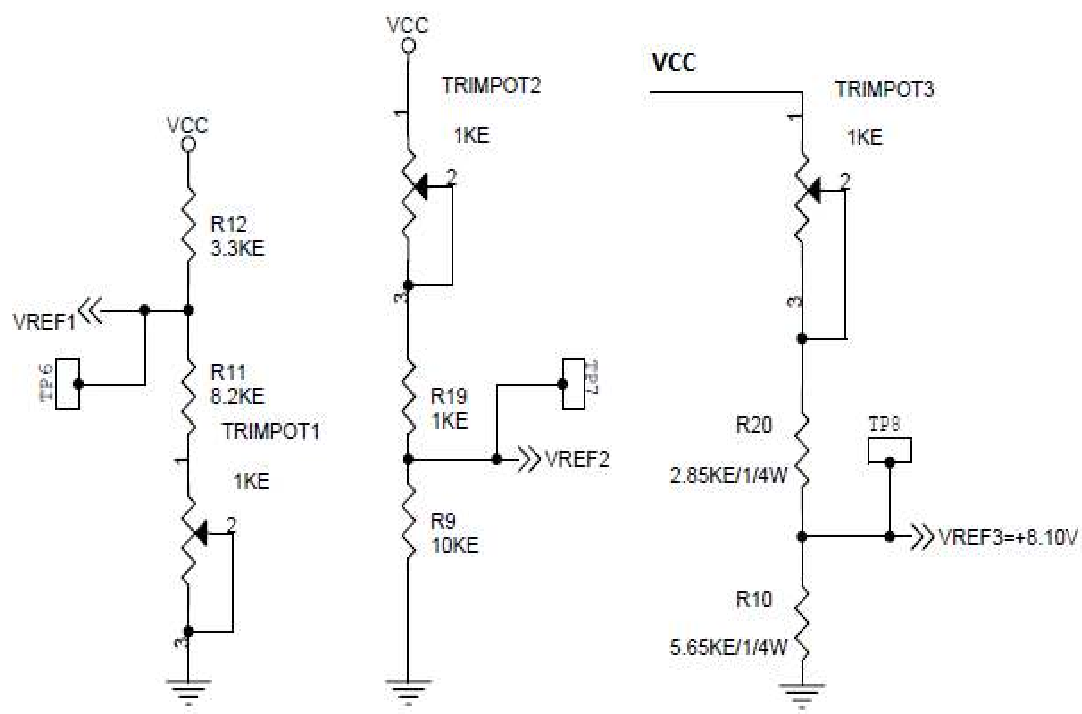


Fig. 17: Reference voltages

## RESULTS AND DISCUSSION

The two chargers as shown in Fig. 18 are in the hot stand-by position and the output of the charger is given to the internal relay. The output of the internal relay is connected to the external relay. The output of the NC contact of the external relay is connected to the battery as well as the load which is FRTU. In order to give command to the external relay, in form of the BCC command the signal is given from the 25 and 26 terminus of the DO command. Now when the command is given through the address of this signal, the command reaches the terminus 25 and 26 wherein 24 V waiting supply is given and through which it gets connected to the external relay coil i.e., k1 coil. Now the relay coil gets energized and it dissociates the charger and battery as well as the load. Thus the load is taken the battery. During that time there is also a digital signal at pin no 5 in the digital input which is going towards BCC which is indicating that the load is on battery also called as acknowledgement signal. Afterward the battery is in service and whenever 21.6 V or anything less than 21.6 V reaches on the battery voltage then the under voltage cut-off card immediately detects it and it again reconnects the charger back to the battery.

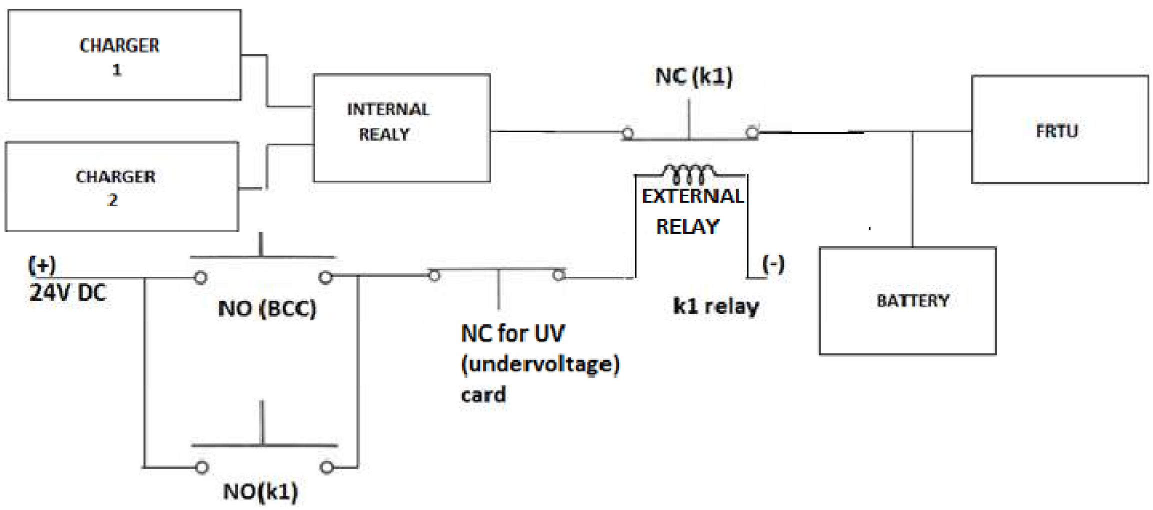


Fig. 18: Block diagram of the implemented system

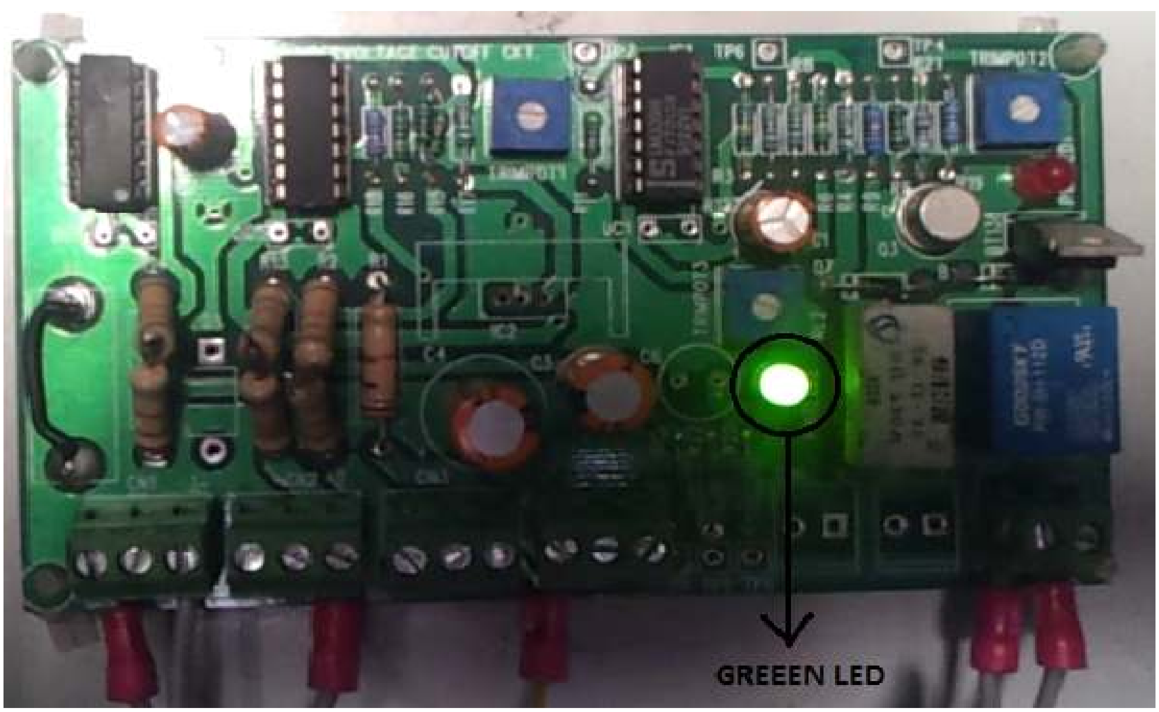


Fig. 19: Picture showing the green LED in switched ON state

**Parameters to be noted before testing:**

- Testing Point (TP) 1 = ground point of the charger
- TP2 = Output voltage of the 7812 IC
- TP3 = Direct 12V from the auxiliary supply
- TP4 = Voltage across the UV relay
- TP5 = Charger voltage
- TP6 = Reference voltage for the 1st comparator
- TP7 = Reference voltage for the 2nd comparator
- TP8 = Reference voltage for the 3rd comparator

**Consumption by the UV card:**

- Consumption at 24 V DC supply from the junction between the battery and the charger when neither the battery nor the charger is connected = 82 mA.
- When the battery is connected to the UV card, current consumed = 89 mA.

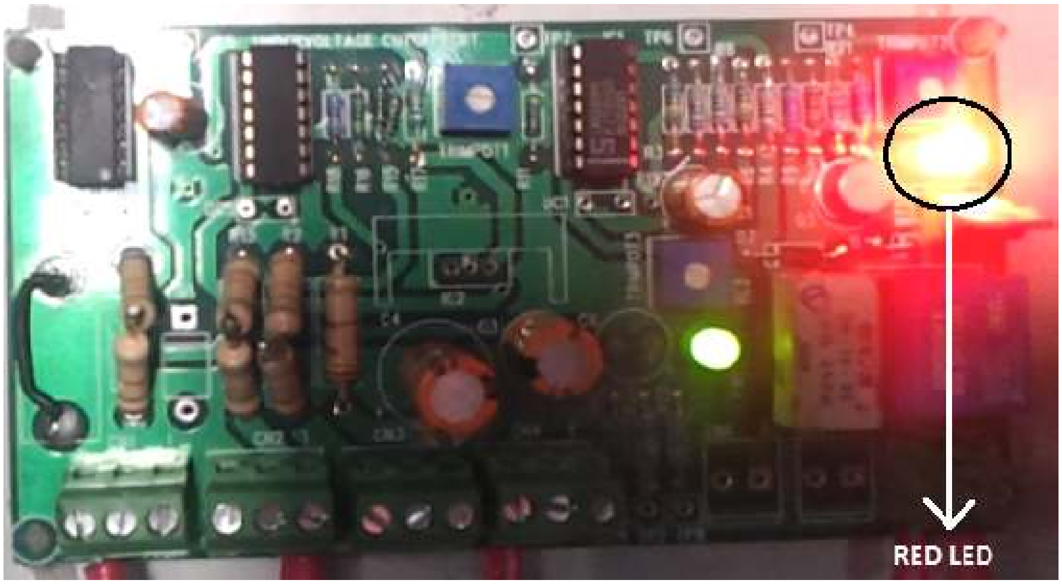


Fig. 20: Picture showing the red LED switched ON


Fig. 21: Picture showing the red LED is resetted

- When both the battery as well as charger is connected, the current consumed = 35 mA.

**At normal working condition:** Figure 19 represents the normal working condition when the supply is available to the UV card and the green LED is ON.

**At under-voltage condition:** Figure 20 represents the under-voltage condition which is represented by the RED LED. Here the under voltage has occurred and the charger is connected back to the battery.

After the battery is fully charged the under-voltage signal will terminate and the RED LED will be reset. Thus it will be ready for the next cycle of command as shown in Fig. 21.

## CONCLUSION

In this study we have tried to explain the importance of the battery in a RMU and the automation done to connect the charger to battery in an under voltage scenario. This study also describes the configuration of the under voltage cut-off card.

We have automated the BCC command as well using a LM555 timer circuit and the under voltage cut-off card which will automatically sense the voltage of the battery and check the health of the battery as well as the charger. If there is an under voltage scenario the battery will be automatically connected to the charger. The whole system will operate only if the charger is online. The role of the battery is very important as it provides auxiliary supply to the FRTU and to the motors of the isolators in the RMU. The control over the substation is remotely possible only if the battery is healthy. This under voltage cut-off card has to be placed between the charger and the battery in the RMU at the substation for its successful operation.

The hardware which was developed in order to realize these advanced applications were shown above. There is abundant information from a power system stored in the protection and control equipment. It is necessary to be able to carry out cooperation among many protection and control devices through a network, for utilizing this information effectively. For which monitoring the battery and the health of the battery are vital. Under voltage technology is an effective means for satisfying these requirements.

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