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Hybrid Off Grid Solar UPS

Using Arduino UNO and Proteus Simulator

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The main objective of this thesis report was to study the basic working principle of Hybrid off grid solar powered UPS and create a simulation model on Proteus 7.10.

In this project, solar panel and AC mains were used to charge the battery and AC mains, inverter and diesel generator were used to provide supply voltage for operating loads by switching relays with the help of Darlington pair ULN 2003A.

The study of this project was carried out by implementing the theoretical concept, theorem and principles into concrete model. The simulation of the circuit was carried out by using Proteus simulation software.

The final result of the project was carried out in simulation where it shows that the charging of the battery was carried out by supply from mains or solar energy whereas the load was operated by using supply from mains, inverter or diesel generator.

Keywords	AC mains, Solar, Battery, Inverter, Microcontroller, Arduino, Simulation

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APPENDIX 1 Enlarged image of ATMEGA 328P pin configuration

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Acronyms

AC	Alternating Current
DC	Direct Current
EMF	Electromotive Force
UPS	Uninterruptible Power Supply
LCD	Liquid Crystal Display
LED	Light Emitting Diode
RAM	Random Access Memory
ADC	Analog to Digital Converter
USART	Universal Synchronous and Asynchronous Receiver-Transmitter
SPI	Serial Peripheral Interface
GND	Ground
AREF	Analog Reference
LDR	Light Dependent Resistor
DG	Diesel Generator
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
IDE	Integrated Development Environment

1 Introduction

Hybrid Off Grid Solar UPS utilizes two inputs AC mains and solar energy to charge battery. The DC current generated from solar panels is used to charge the battery and if solar panels stops generating current then battery is charged by AC mains. Usually, the load operates on main supply but if there is no presence of AC mains then Inverter uses the power from battery to operate the loads.

This project utilizes the idea of Hybrid Off Grid Solar UPS design where the load is supplied with power supply from different sources like AC mains, inverter and generator by prioritizing the supply by using switching mechanism to trigger different relays. On the other hand, the battery is charged through the main power supply or through the solar power.

The daily uses of electricity is increasing rapidly which results in frequents power cut-offs. The disruption in supply of power may cause great problems in important places like hospital, industries, etc. This system can play a vital role in solving those problems. Also, solar energy is abundantly available in earth's surface which makes the availability of energy source easy.

This project was carried out by collecting different documents for circuits, microcontroller, rectifier circuit, relay driver, control circuit, etc. Also, a representation of concept on a simple block diagram is given in the report. The algorithm and flowchart shows the charging of battery as well as whether the output for load is supplied from either AC mains, inverter or generator by comparing the availability of AC mains and charge in the battery. Arduino UNO board and C language is used in programming for the interfacing of the ULN 2003A and input source. After this, the testing of the code is done by loading into microcontroller on simulation circuit where Proteus simulator is used for simulating the circuit. At last, the final circuit is achieved by analysing the output of simulation with desired output and modifying the circuit until the required output is obtained.

2 Solar Powered UPS

Solar UPS stands for Solar Uninterruptible Power Supply. Solar UPS is an electrical and electronic component combined backup power system which can store and supply electricity with the help of sunlight energy to run electrical devices that can either be small home appliances or larger scale devices during the power cut-offs. The DC current generated from solar panels is regulated using charge controller for charging battery then converts that DC current in form of AC to run the loads connected.
Solar UPS consists of converter, inverter and charge controller in its combined power unit system.

2.1 Charge Controller

Charge controller can determine whether the power in backup unit is of low, normal or high level. When the power in the battery bank is low, the charge controller stops the battery bank from supplying the energy to the load and also the charge controller provides arrangement for alternative power source for the load using Grid supply.

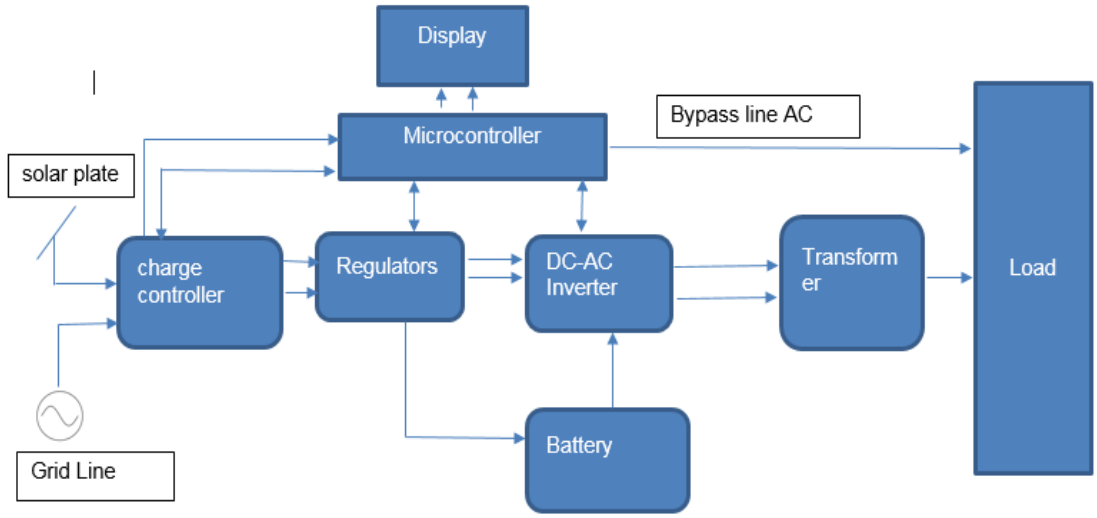

Figure 1: Solar UPS flow diagram [1]

In Figure 1 when charge controller collects current from solar panels, it is regulated for charging battery bank using DC regulators. DC regulators can also convert AC current to DC current which can be used for charging purpose when there is no power generated from solar panel. Here, charge controller also has another source of supply as AC source. The battery charger unit or regulator converts the AC line provided sinusoidal

current into non-sinusoidal current format, i.e., DC current. The generated DC signal is stabilized by using high frequency filter and low frequency filter circuit because if there is changes in voltage produced then the battery bank will be damaged earlier. So, regulator system is an integral part of the UPS. When the battery is fully charged, the charge controller tells regulator system to stop the supply of energy through microcontroller. After this, the rest of converted current is supplied to the inverter from where it is supplied to the load after DC to AC conversion.

2.2 Inverter

As we know, solar energy is produced in DC form which cannot be used by AC appliances or devices. In UPS design, regulators are specially designed with diodes to rectify AC to DC while inverter system is designed to convert DC to AC. The inverter consists of silicon control rectifiers which can change direct current half cycles in different phase angles which is 0 degree to 90-degree, 90 degrees to 180-degree, 180 degrees to 270 degrees and 270 degrees to 360 degrees. Here, we can get two sinusoidal waveforms by inverting 4 DC half cycle. This way we can convert 12V DC to 12V AC which is then directed to step up transformer which boosts the voltage and current for appliances that consumes high voltages. [1].

2.3 Transformer

Here, step up transformer converts 12V AC from inverter to 230V AC current with 50Hz frequency range. However, most of solar ups used for home purposes comes without the transformer since, the household appliances usually don't need high power to run the devices. However, there will be no change if you supply DC current to the transformer because DC current gives uniform output thus, there will be no electromagnetic changes.

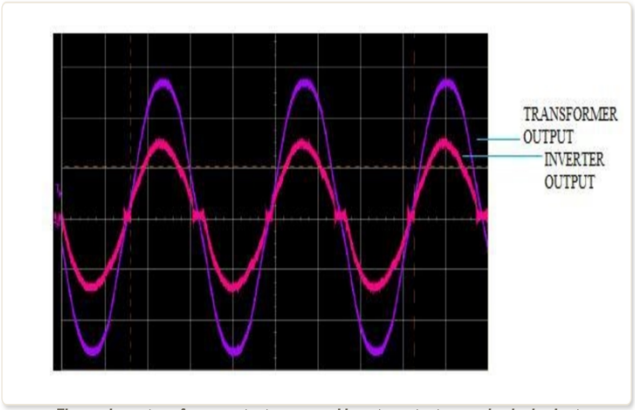

Figure 2: Transformer output wave and inverter output wave [1]

Therefore, we need to convert the DC to AC for simulating the magnitude in the transformer system.

The sine wave variation induces the magnetic strength in electric field thus creating the electromagnetic force. This force will be stored in E-core coil of the transformer coil. If given 180V AC to transformer, it will be increased to 230V AC depending on the number of coil turns in primary and secondary winding. Figure 2 shows the output signal in wave form of both Transformer and Inverter respectively.

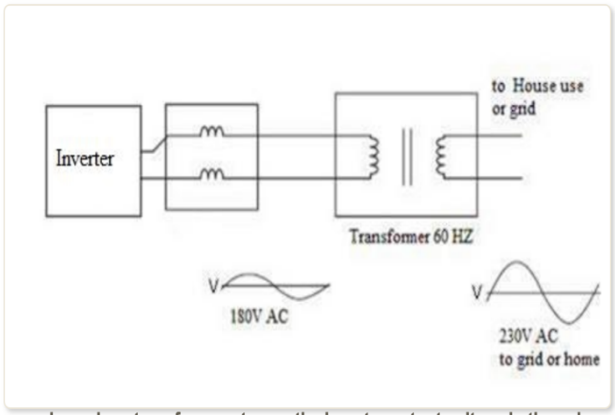

Figure 3: Transformer step up the output voltage in the solar UPS [1]

If we need to step down the voltage then we can increase the number of turns in primary coil and you will get a step down transformer. If you need to step up the voltage then we can increase the number of turns in secondary coil thus giving us a step up transformer. It is not possible to provide high voltage without the help of transformer. Figure 3**Error! Reference source not found.** shows the output voltage from a step up transformer.

LCD or LED displays UPS status such as battery level, power source status for operating load . All this information is fed to the LCD through the microcontroller as shown in Figure 1. This will help the user to figure out the problems like low battery level, circuit disconnection, battery overload. [1]

3 Hardware components

3.1 Bridge Rectifier

In Figure 4 and Figure 5, circuit converts the AC voltage to DC according to conduction of opposite diodes in positive and negative half cycles. A 34v 3300uF capacitor is used to filter out the ripples so that we can obtain a constant DC output.

Diodes D1 and D3 are forward biased in the positive half cycle whereas D2 and D4 are reversed biased. In Figure 4 the direction at which current flow in positive half cycle is shown.

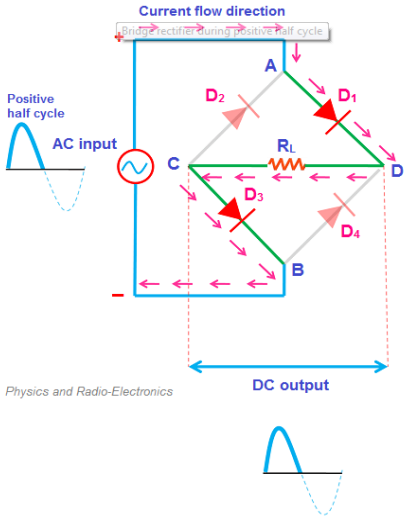

Figure 4: Bridge rectifier during positive half cycle [2]

Diodes D2 and D4 are forward biased whereas D1 and D3 are reversed biased in negative half cycle. In Figure 5 the direction at which current flow in negative half cycle is shown.

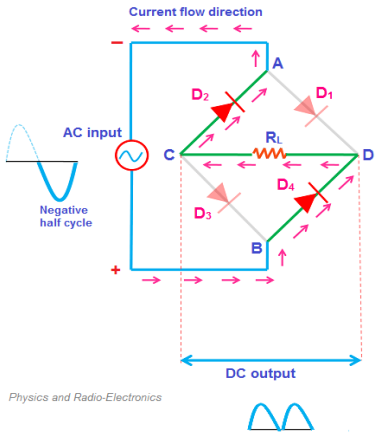

Figure 5: Bridge rectifier during negative half cycle [2]

Figure 6 represents AC input fed into bridge rectifier which is then converted into pulsating DC by bridge rectifier. [2]

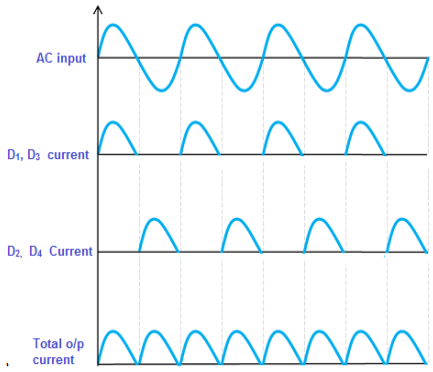

Figure 6: Output waveform of bridge rectifier [2]

3.2 Capacitor

A capacitor consists of two conduction plates which are separated by a dielectric material. A capacitor helps in storing electric charges. When connected to a supply, the two plates accumulate positive and negative charges respectively.

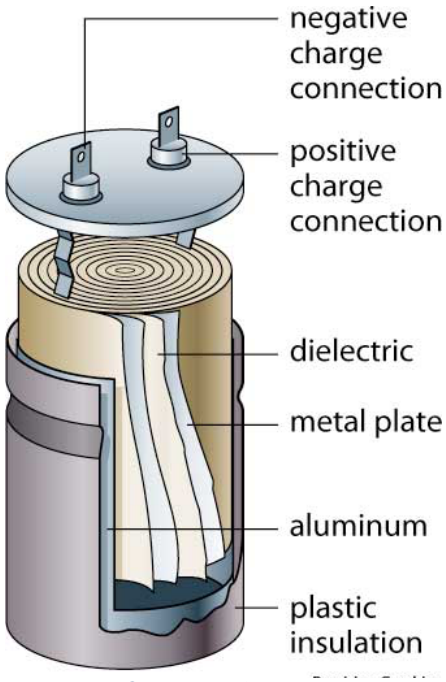

Figure 7: Capacitor [3]

One common capacitor as shown in Figure 7 is made up of metal foils which is separated by thin layer of insulating film. Many common electrical devices uses capacitors as a part of electrical circuits. [3]

3.3 Voltage Regulator

A constant level of voltage is provided by using voltage regulator. It may depend on some parameters like temperature coefficient, thermal noise, transient response, etc. As per the requirement the following two types of voltage regulators are used in this project:

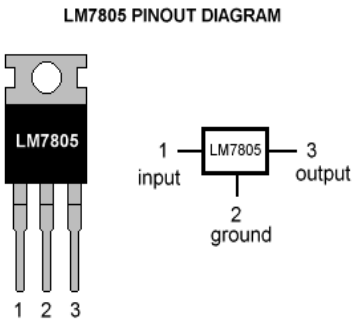

Figure 9: LM7805 [4]

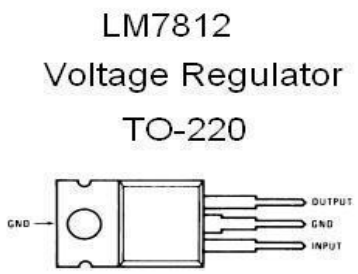

Figure 8: LM7812 [5]

In Figure 8 , voltage regulator gives a constant output of 5v [4]. In Figure 9, LM7812 gives the constant output of 12v [5].

3.4 Arduino

Arduino nowadays are widely used for constructing electronic projects. Arduino has a physical board which consist of a microcontroller embedded in the board and it uses a software program known as Arduino IDE (Integrated Development Environment) where the programming codes are written and uploaded to the Arduino board. One of the most commonly used Arduino board is Arduino Uno board. The programming language used for Arduino is C++ programming language.

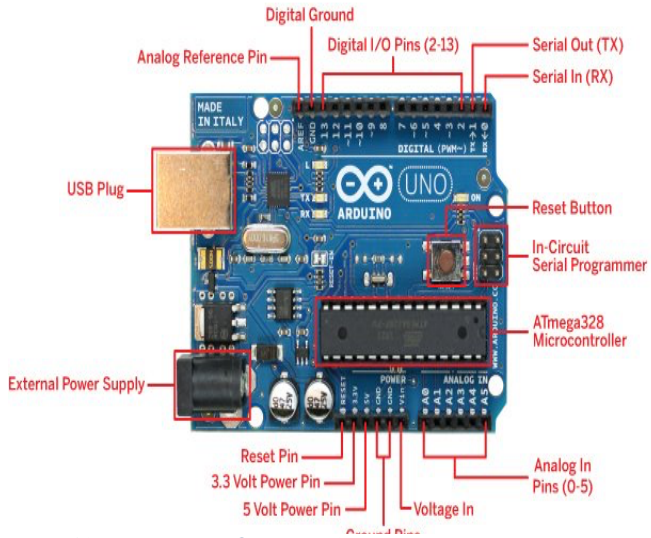

Figure 10: Arduino UNO board [6]

All the hardware components of the board is shown in Figure 10. [6]

3.5 ATMEGA 328P

Arduino UNO is embedded with ATMEGA 328P microprocessor. It operates from 3.3 V to 5 V and its low power output feature makes it ideal for operating darlington pair ULN 2003A in low current mode for switching relays.

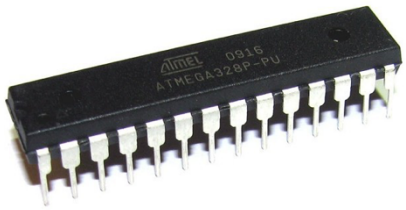

Figure 11: ATMEGA 328P [9]

The ATMEGA 328P as shown in Figure 11 consist of 28 pins in total. The three ports found in ATMEGA 328P are Port B, Port C and Port D where Port C is an analog port and has 6 analog pins. It has 14 digital pins which are found in Port B and Port D each consisting of 7 digital pins thus, Port B and Port D are digital port [7]. A crystal oscillator ranging from 4 MHz to 40 MHz can be used for generating the frequency [8]. A 16MHZ crystal oscillator is used by Arduino uno board. It has advanced RISC architecture.
The pin configuration for ATMEGA 328P is as shown in Figure 29. [9]

3.6 ULN 2003A

ULN 2003A is a relay driver IC which consist of a Darlington array. It consist of seven open collector darlington pairs with common emmiter. It can operate seven different relays at the same time. Its operating current is in the range of 500 mA to 600 mA and consist of two bipolar transistors.

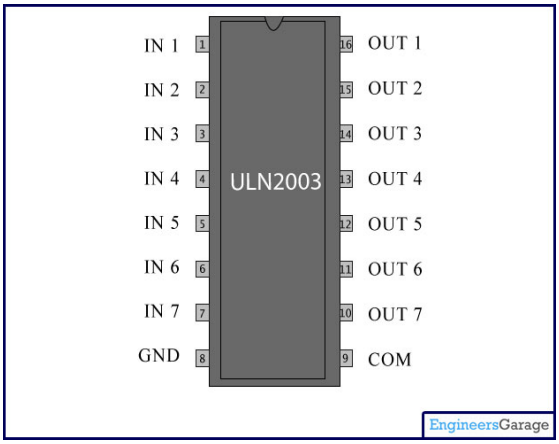

Figure 12: ULN 2003A [10]

It has a total of 16 pins of which seven are input pins (from pin1 to pin7) , seven output pins (from pin 10 to pin 16), one ground pin (pin8) and one common pin (pin9) as shown in Figure 12.

These transistors have high current gain,therefore, in this project it uses small amount of current from microcontroller which is amplified for switching relays. [10]

3.7 Relay

A relay is an electro-mechanical switch which is used to switch loads that uses larger voltages or currents by electro-magnetism generated from small voltage or current. These relay protects the circuit from overload and faults. There are different design and types of relays switching circuit but most commonly used are MOSFETS and transistors. In Figure 13, the minimum switching voltage is 5 V and relay's coil is rated up to 12V

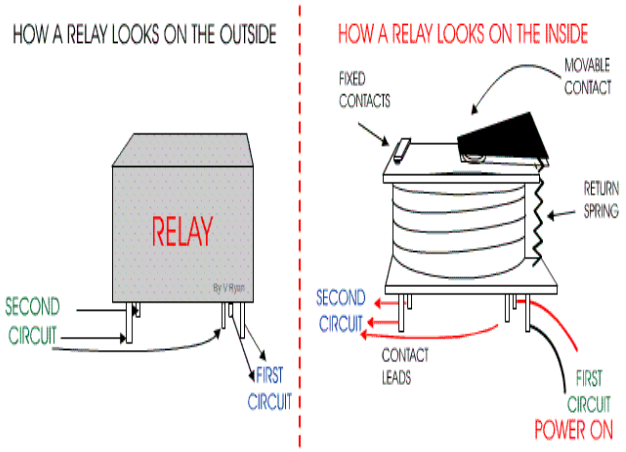

Figure 13: Relay [11]

with a minimum switching voltage of 5V. [11]

3.8 Resistor

The ratio of the potential difference measured across a resistor's terminal to the current flowing through the circuit is its resistance [12]. The current through a resistor in Figure 14 is in direct proportion to the voltage across the resistor's terminals. This relationship is represented by Ohm's law:

$R=V/I$

Where, R is the resistance of the conductor in the units of Ohm.
I is current through the conductor in units of Amperes.
V is the potential difference measured across the conductor in the units of volts.

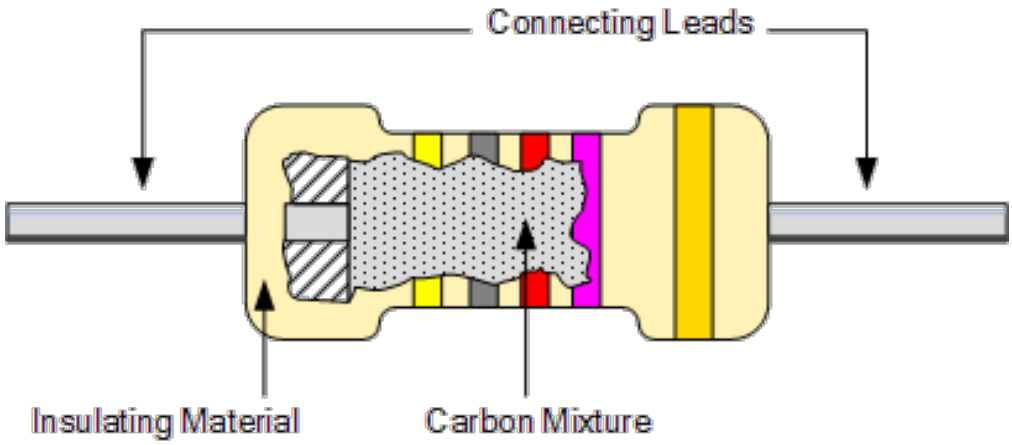

Figure 14: Resistor [12]

3.9 LCD

A light modulating properties of liquid crystals are used in LCD (Liquid Crystal Display) for the display purposes. Lights are not emitted directly by liquid crystals.

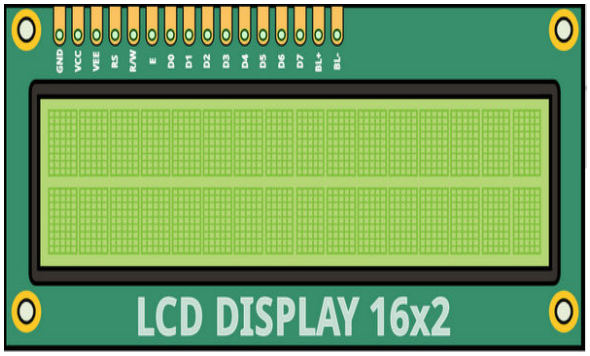

Figure 15: Liquid Crystal Display (LCD) [13]

Figure 15 shows 16*2 LCD display which is used in this project to shows whether the battery charge is ok or not. It is a very common LCD screen which is used in many electronic circuits. The low level instructions to processing data is simplified by Liquid-Crystal Library so, it makes the use of LCD more easier for user. [13]

3.10 LDR

LDR has a special character, i.e., when the intensity of the incident light increases, the resistance of LDR decreases meaning that it is a light dependent resistor. It is mostly used in circuit that is sensitive to light and switching circuit that is activated by light and darkness. LDR as shown in Figure 16 can have high resistance in the dark sometimes even a few mega ohms (MΩ) but it can also have a very low resistance in the presence of light (around hundred ohms). [14]

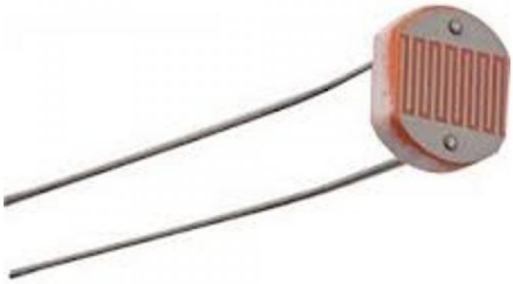

Figure 16: Light Detecting Resistor [14]

In this project, LDR is used in simulation as a reference to solar panels. Here, when the intensity of the incident light increases then the resistance of LDR decreases and vice-versa. LDR gives analog output value which is connected to the analog pin on the arduino. The output from LDR is used to control the output to the load. The analog value from LDR is converted into digital value with the help of an inbuit ADC (analog to digital converter) in Arduino UNO board.

4 Software Aspects

Software is an important part of the project. Hardware cannot alone exist in a project. So, software development process is an important aspect of running a project successfully. Software is the collection of the related programs and related data that provide the instructions to the computers to perform a particular function. There are various types of programming languages available. In this project, high level programming language i.e., C programming language has been used. Also, ATMEGA 328P microcontroller is used as a programmable device. The flow of the project depends upon the software written in the microcontroller. Different available software such as Arduino compiler and Proteus simulator have been used in this project. The following software are used in the project:

4.1 Arduino Compiler

Arduino IDE (Integrated Development Environment) is a software that is used to interact with the Arduino UNO board. The programming can be carried out in this software by using C/C++ language programming. It basically consist of an editor and complier where editor part can be used for writing codes and complier can be used to run the code. It also has debugging features which helps sometimes in finding the mistakes in coding. At last when all the coding is done and complied then a hex file is generated which is later then uploaded to the Arduino Uno board.

4.2 Proteus Simulator

Proteus is a software which is used for designing printed circuit board (PCB), simulation of microprocessor and capturing schematic. The developer of this simulation software is Labcenter Electronics Ltd. The Proteus is simulation software that can simulate the electronic as well as the electrical in real time.

A hex file which is generated from Arduino IDE software is uploaded to the microcontroller in Proteus for simulation purposes. It also supports the animated simulation and got large IC packages and different electronic and electrical components. It has got over a dozen virtual instruments for live and interactive measurement and analysis during simulation.

5 Methodology

5.1 Basic Description

This project is about the selection of different sources AC-mains and solar for charging battery and AC source, inverter and diesel generator to run the AC load. As it is not feasible to provide all different sources of supply, different switches and LDR are used to get the same function. LDR circuit output is fed to the analog pin of an Arduino, whereas the output of two switches indicating presence of AC-mains and status of battery (battery ok) is fed to digital pins of Arduino. A LCD is also provided to view output from different sources effectively.

The AC-mains (220 V) is converted into 5 V and 12 V using two rectifier circuits in this project. The charging of the battery is done by the converted 12 V whereas the presence/absence of AC-mains is known by feeding 5 V supply to the digital pin of the Arduino.
The status of the battery is known by feeding another 5 V to another digital pin of the Arduino through switch by charge controller. Arduino provides with the output data and these outputs helps in triggering five different relays using Darlington pair ULN 2003A.

Here, output of microcontroller is mainly executed for two operations namely charging of the battery and operating the load. The five relays are used for switching purposes depending upon the output of our algorithm. Relays 1 and 2 are used for charging of the battery which is used as an inverter in the absence of AC mains power cut-off as shown in **Error! Reference source not found.**. Relay 3, relay 4 and relay 5 are used for supplying output to the load as per the availability of different power sources. Relay 3 is triggered when there is availability of AC mains and the load is powered on resulting into the effective operation. Similarly, the triggering of relay 4 occurs when there is no power

in the AC-mains looking for the power through inverter. If the inverter has enough energy to power the load, the circuit is closed using the inverter. However, when both the AC mains and inverter are unavailable to power the circuit the energy is generated with the help of generator which runs through the non-renewable energy namely diesel used as a reference in the experiment.

System consists of

- AC and DC sources
- Load
- Relays
- Microcontroller
- Bridge Rectifier
- Relay Driver (ULN 2003A)
- Liquid Crystal Display (LCD)
- Voltage Regulator
- LDR (Light Dependent Resistor)

- Transformer

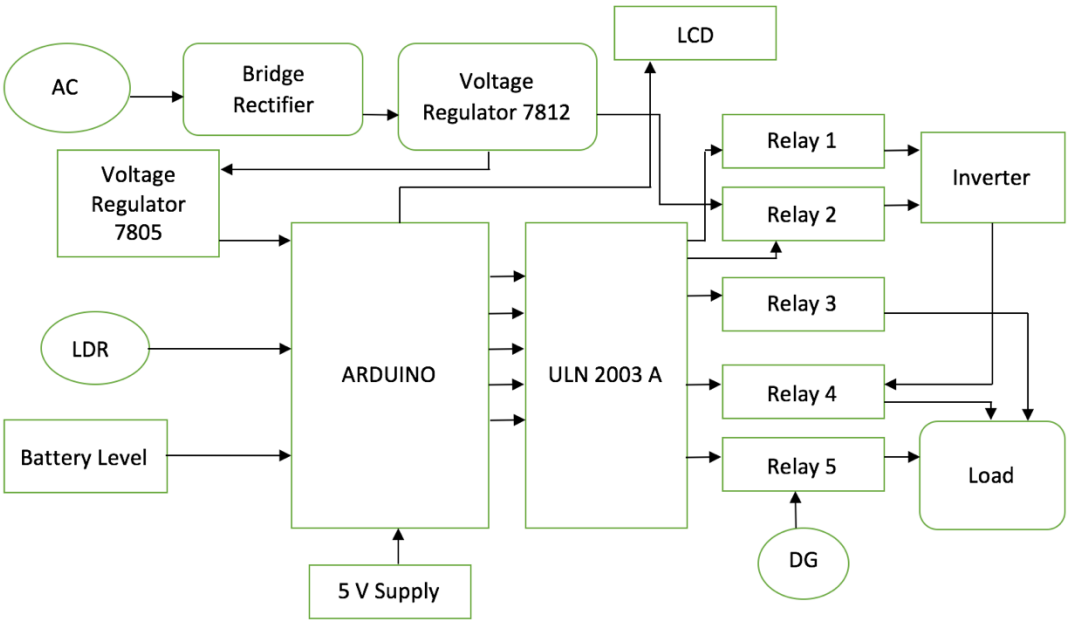

Figure 17: Block diagram of Solar powered UPS

5.2 Algorithm and Flowchart

An algorithm is a series of process that converts the input of a data, processes it through decision making and as a result an output is obtained. In other words, algorithm is a series of instructions which helps in carrying out operations to solve problems.
While writing a program the computer needs to know step by step what you want it to do. While doing this you can tell the computer how its done also. Here is where computer algorithm comes handy. Basically, the algorithm is a set of instructions to get a work done.

In flowchart, the operations are carried out by using suitable symbols to represent the starting and ending of a program, a decision or an input-output process. All the symbols used in flowcharts are connected by using arrows hence showing the flow of a program.

5.2.1 Algorithm and Flowchart for charging the battery

- Start.

- AC mains or Solar.
- If all sources are present, then priority goes to solar.
- Compare AC mains with solar.
- Check if solar source is present or not.
    - Check if solar source=1; AC source=0; do nothing.
    - Display solar.
- If solar source=0; check AC mains.
    - if AC mains=1;
    - Display AC-DC
    - If AC mains=0;
    - Display NO source.
- Finished.

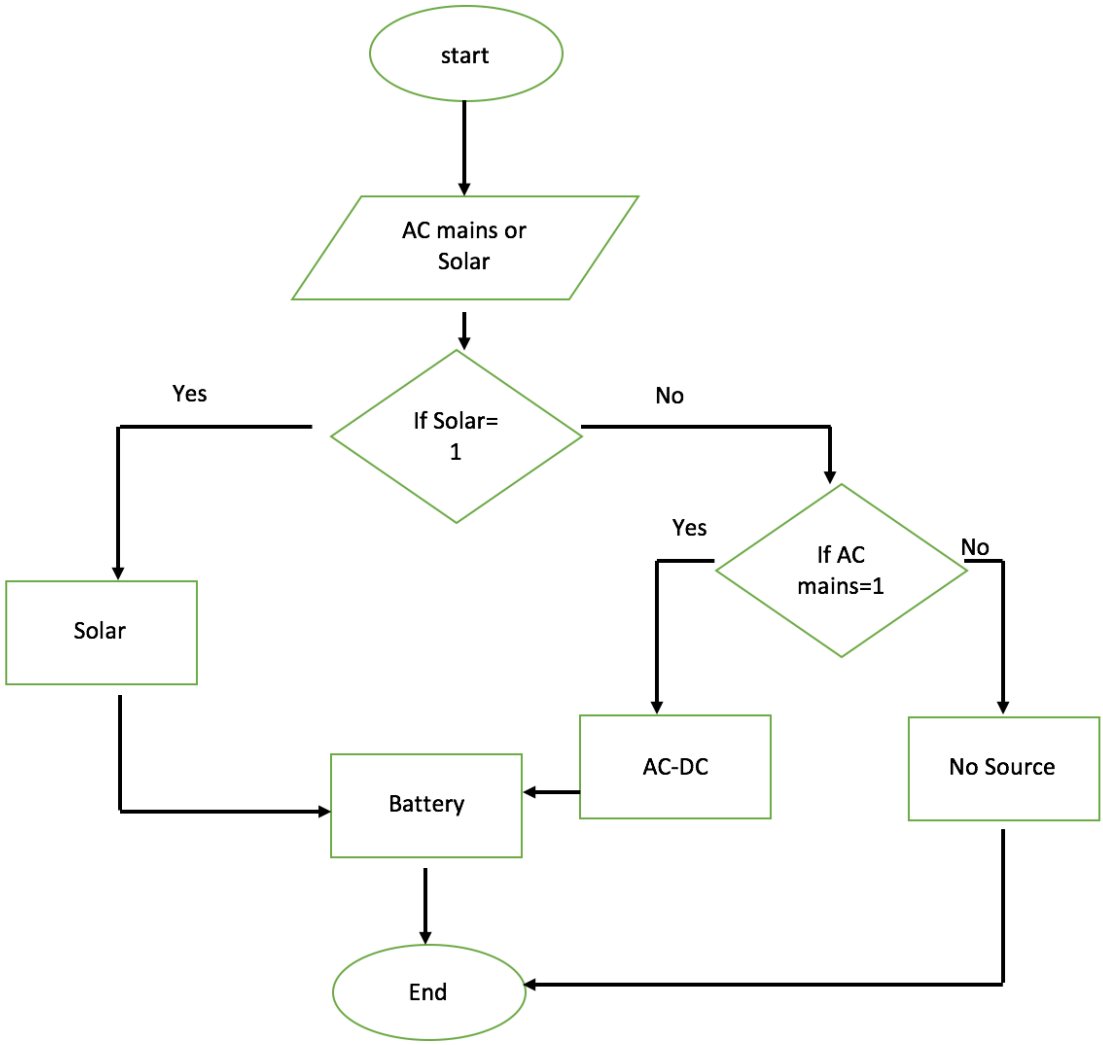

Figure 18: Flowchart for charging battery

As shown in Figure 18, when the AC mains and solar both are present then priority goes to solar. Then, we compare AC mains with solar. And if solar is present and AC source is absent then nothing is done and the display shows solar. If solar source is absent, check AC mains and if AC mains is present then display shows AC-DC. If AC mains and solar both are absent then display shows no source.

- **Priority switching to charge the battery**

Microcontroller gets the input from the input section i.e. microcontroller gets the signal about availability of the sources. Then the microcontroller reads the input signals and output from the Arduino is fed to the ULN 2003A for driving different relays.

Truth Table

Table 1: Priority switching method to charge battery

LDR (Intensity)	AC mains	Output
1	1	solar
0	1	AC-DC
1	0	Solar
0	0	No source

In

Table 1, if solar and AC mains both source are present then the battery is charged through solar. But if solar is absent and AC mains is present then the battery is charged through AC-DC converter.

However, if solar is present and AC mains is absent then battery is charged through solar. But, if there is no solar neither AC mains then there is no source to charge the battery.

5.2.2 Algorithm and flowchart for output to load

Here, this algorithm and flowchart shows whether the output for load is supplied from either AC mains, inverter or the generator by comparing the availability of ac mains and the charge in the battery.

- START.
- AC mains or battery ok.
- Check the sources.

If all sources are present, then priority goes to ac mains.

- Compare ac mains with battery ok.
  - If ac mains=1; battery ok=1/0; do nothing.
  - Continue with ac mains.
  - Display AC MAINS.
  - If ac mains=0; check if battery ok=1;
  - if battery ok=1;
  - Display INVERTER
  - If battery ok=0.
  - Display DG.
- FINISHED

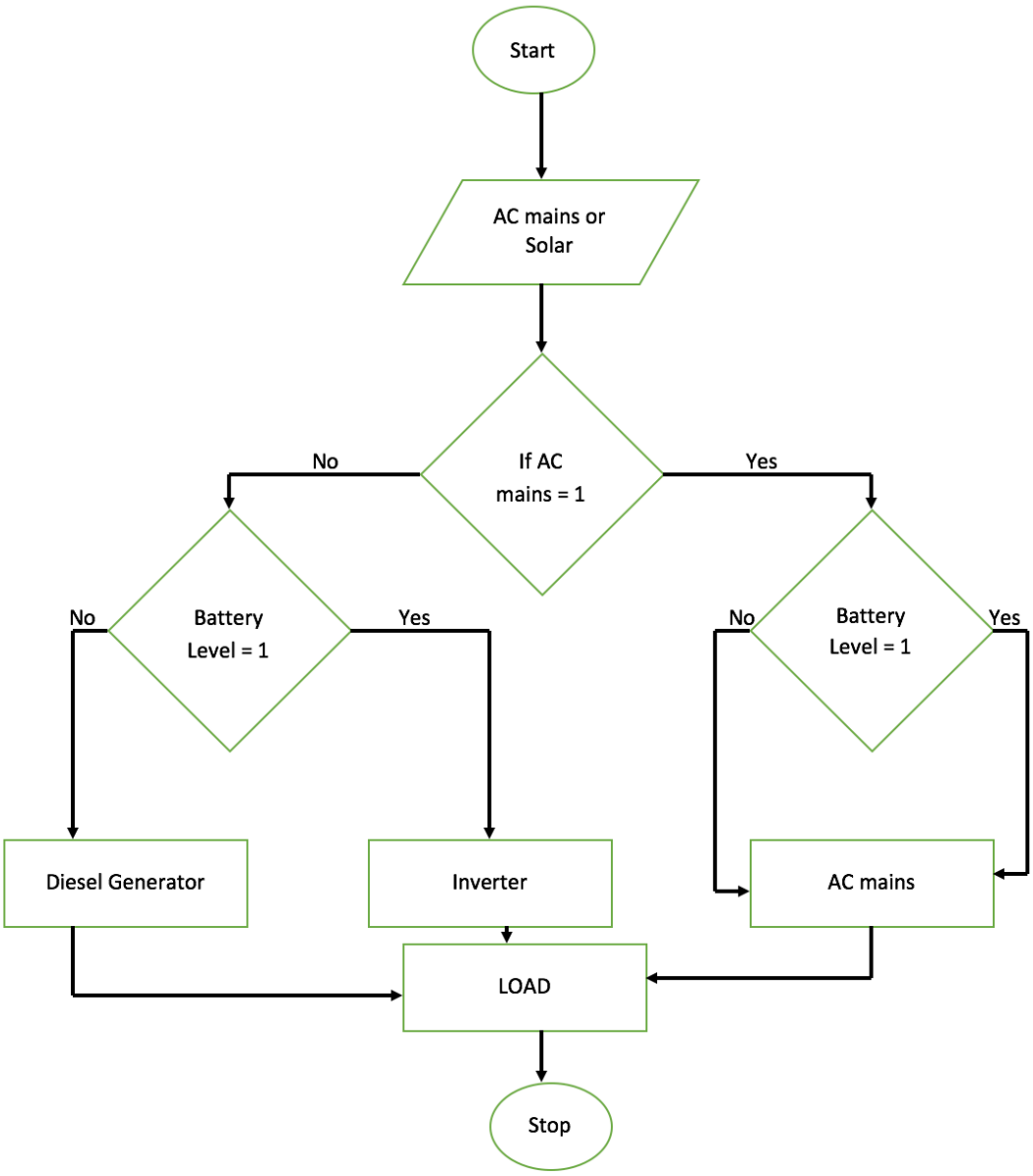

Figure 19: Flowchart for output to load

In above flowchart Figure 19, when AC mains is present and battery charge is full then the priority goes to ac mains. Then we compare AC mains with the battery and if ac mains are present and battery is not charged, nothing is done, and display shows AC mains as the output is supplied from AC mains. If AC mains is absent and battery is charged, then the display shows inverter as output to load is given from battery charge. If both AC mains and battery charge is absent then display shows generator as the output to load is obtained from the generator.

- **Priority Switching for Output to The Load**

Truth Table

Table 2: Priority switching method for output to load

AC mains	Battery Ok	Output
1	1	AC mains
0	1	Inverter
1	0	AC mains
0	0	Diesel Generator

In

Table 2, prioritization is done to provide the uninterrupted supply to the load. If AC mains is present, then the microcontroller sends the signal to activate the relay for supplying power to the load through it. In absence of AC mains, microcontroller reads the signal from battery ok and if the battery is ok then load is supplied with inverter. Finally, if microcontroller reads the low signals from both AC mains and Battery Ok then it sends a signal to actuate a relay to run the Diesel generator.

6 System Overview

This system describes the simulation part of this project where working system is simulated using Proteus 7.10. Detailed description of the simulation can be found on the following sub-heading.

6.1 Working diagram and Simulation in Proteus

Figure 20 shows the overall simulation circuit in Proteus. Here, the AC-mains (220 V) is converted into 5 V and 12 V using two rectifier circuits in this project. The charging of the battery is done by the converted 12 V whereas the presence/absence of AC-mains is known by feeding 5 V supply to the digital pin of the Arduino. The status of the battery is known by feeding another 5 V to another digital pin of the Arduino through switch by charge controller. Arduino provides with the output data and these outputs helps in triggering five different relays using Darlington pair ULN 2003A.

Charging of the battery is done with the switching of relays 1 and 2 when there is absence of AC mains power. The supply for the load is provided by switching of relay 3, relay 4 and relay 5.

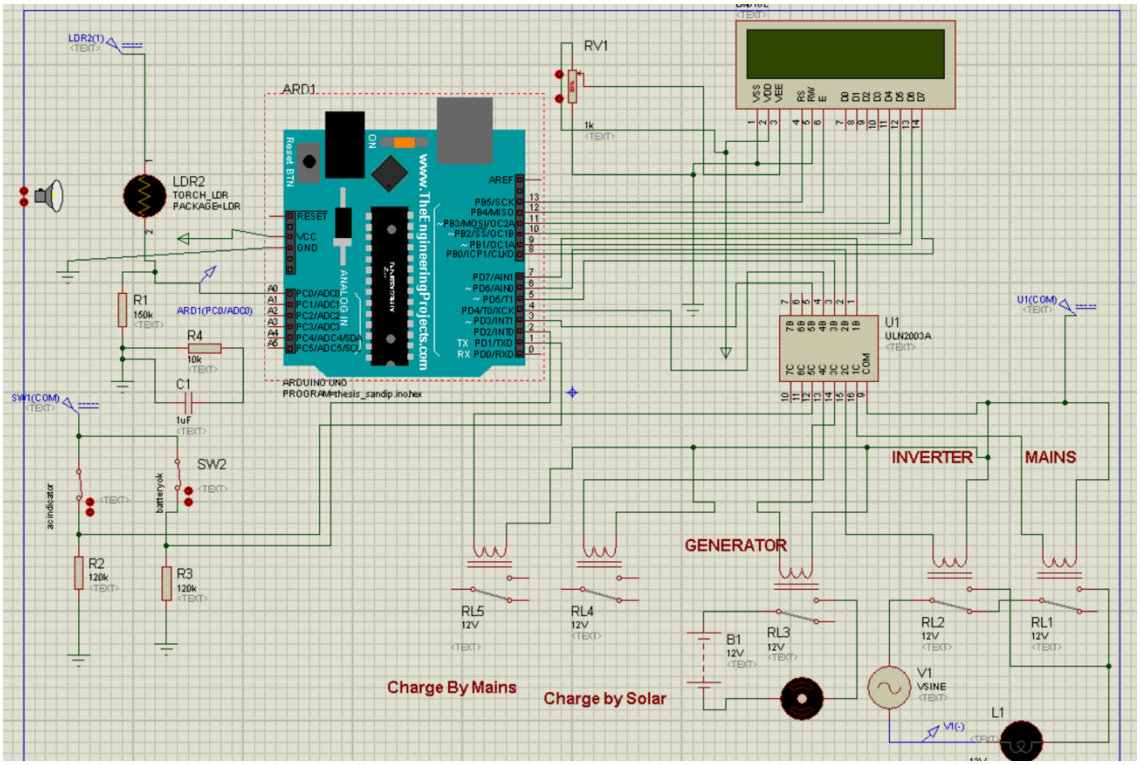

Figure 20: Proteus Simulation

If AC supply is available, then it triggers relay 3 and the output is supplied to the load for proper operations. When AC mains is not available then relay 4 is triggered resulting the supply for load through the inverter. If inverter has enough power to run the load, then the output to load is provided through inverter and the circuit is closed but if both AC and inverter are not available then relay 5 is triggered through the diesel generator and the power to operate the load is provided through the generator which runs on diesel power.

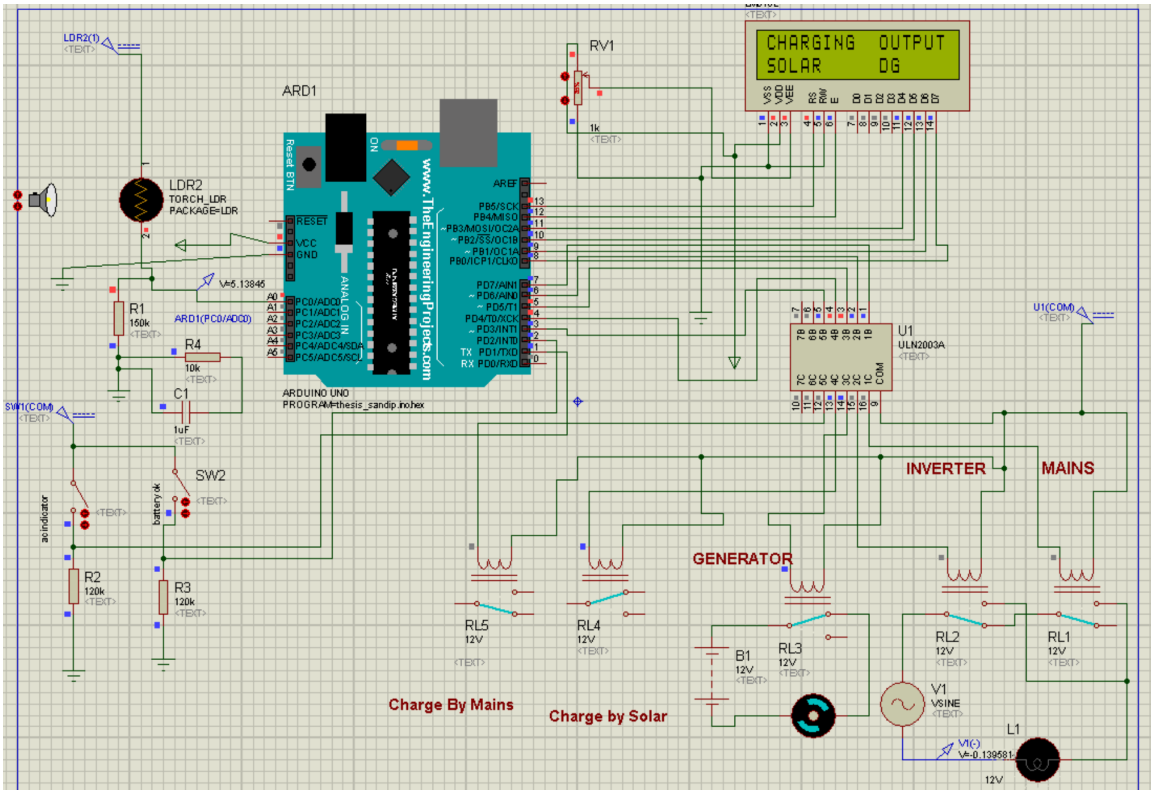

Figure 21: Simulation 1

Here in Figure 21, the battery is charged through the solar as there is presence of solar power source while the output to the load is provided through Diesel Generator (DG) since all other sources of supply AC mains and inverter both are absent (switched off).

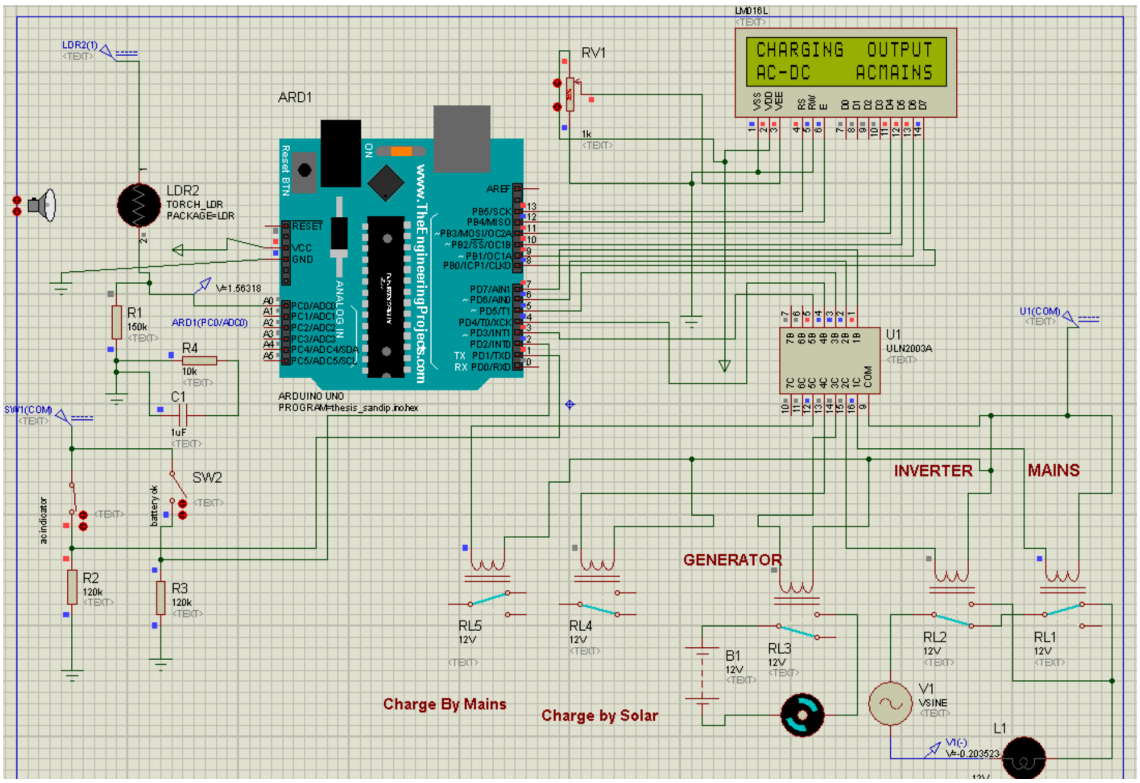

Figure 22: Simulation 2

The supply for charging the battery comes from main supply which is then converted into DC for charging battery by using bridge rectifier while the output for load is provided from AC mains in Figure 22 since AC mains power source is turned on.

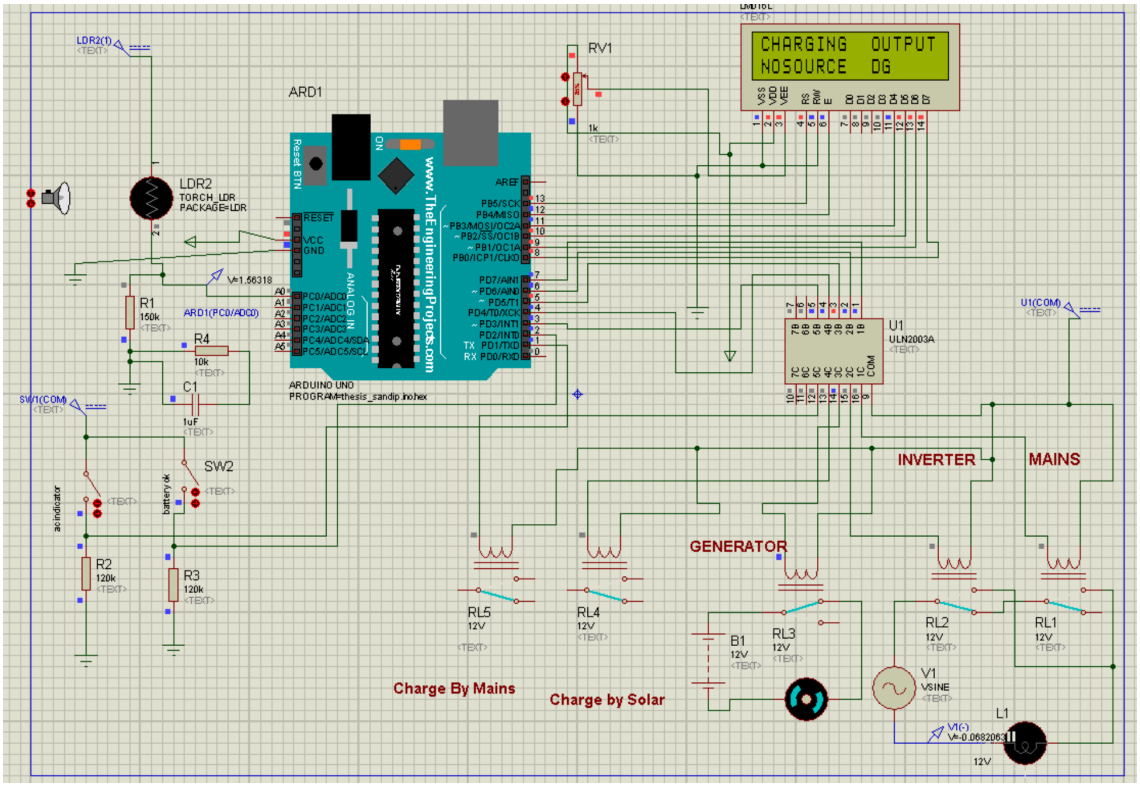

Figure 23: Simulation 3

In the above Figure 23, there are no source of power i.e., neither AC mains is on nor the LDR is detecting any lights so the charging in LCD screen shows no source. On the other hand, both AC mains and inverter are absent so the output to load is provided through the DG (Diesel Generator).

However, the idea of diesel generator is simply used as a backup plan to operate the load if there is absent of both solar energy and AC source.

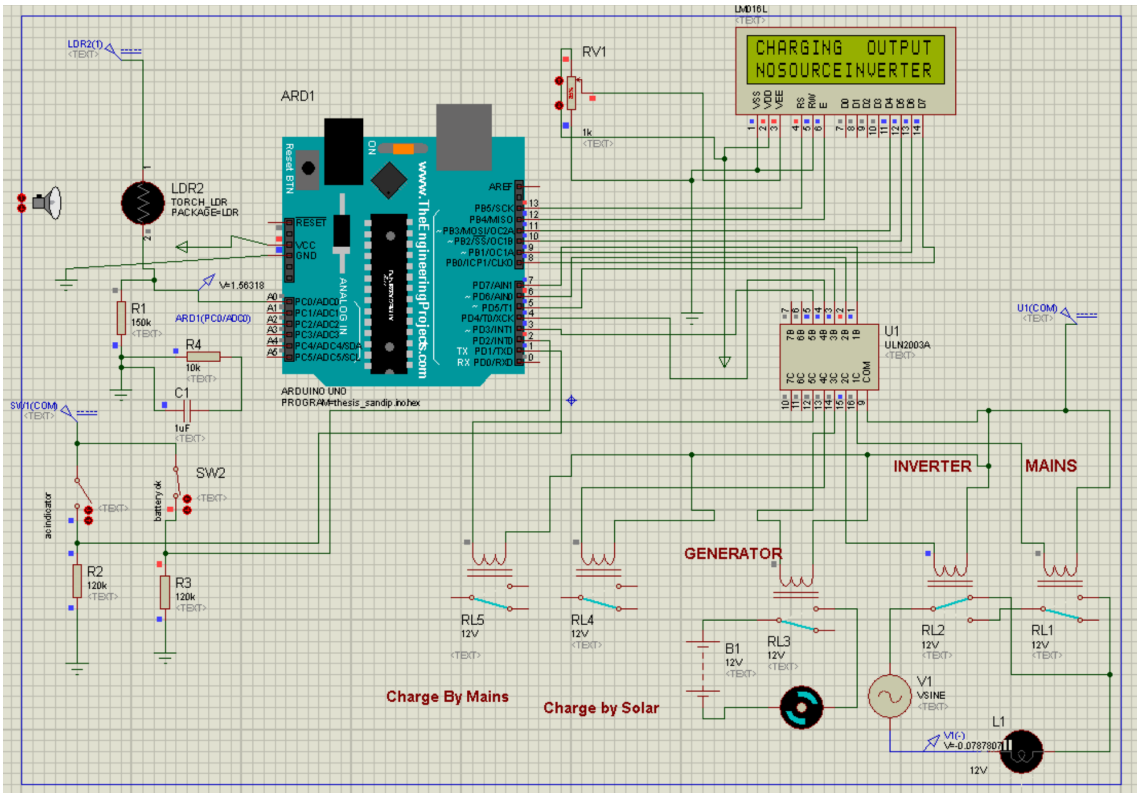

Figure 24: Simulation 4

Since all the source of power for charging the battery is absent, the LCD screen displays no source in above Figure 24. The load on the other hand runs through the inverter since AC mains is absent. Inverter is prioritized before DG (Diesel Generator) so, the power to the load is provided from inverter rather than generator.

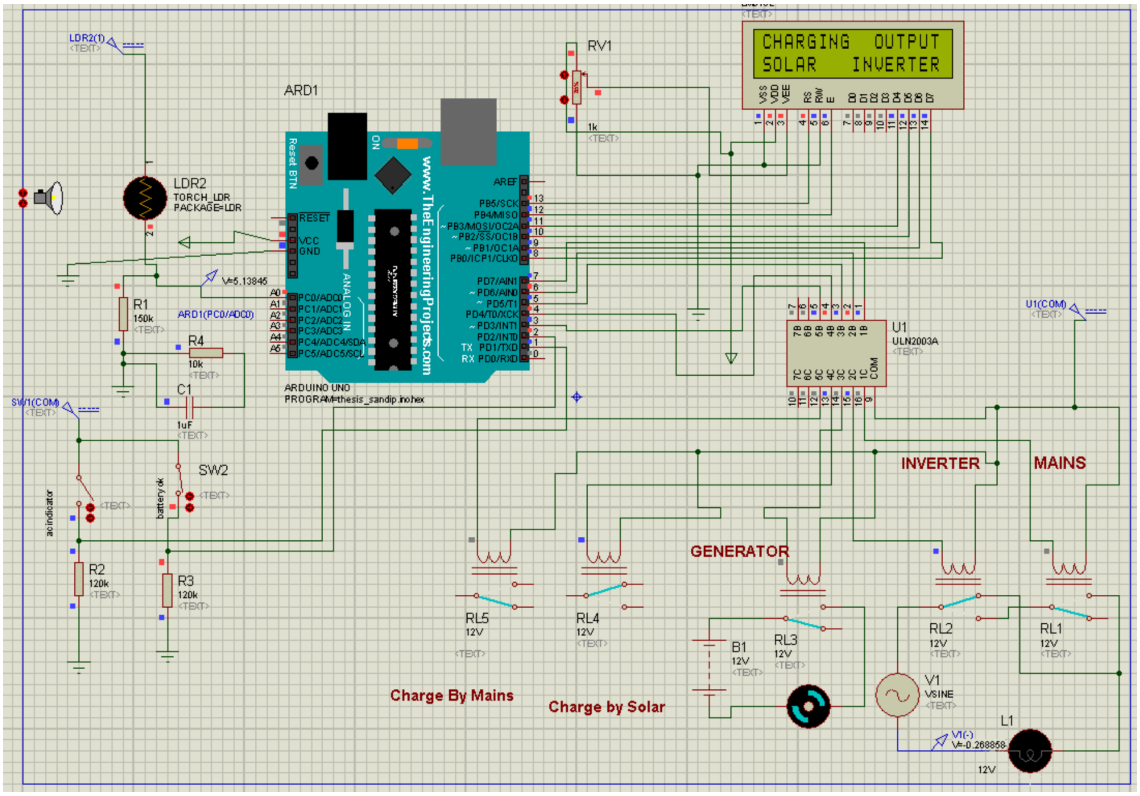

Figure 25: Simulation 5

Here, in Figure 25 the power for charging the battery comes through the solar power as shown in the LCD screen while the output to load is provided by the inverter since AC mains is not available as shown in the above figure.

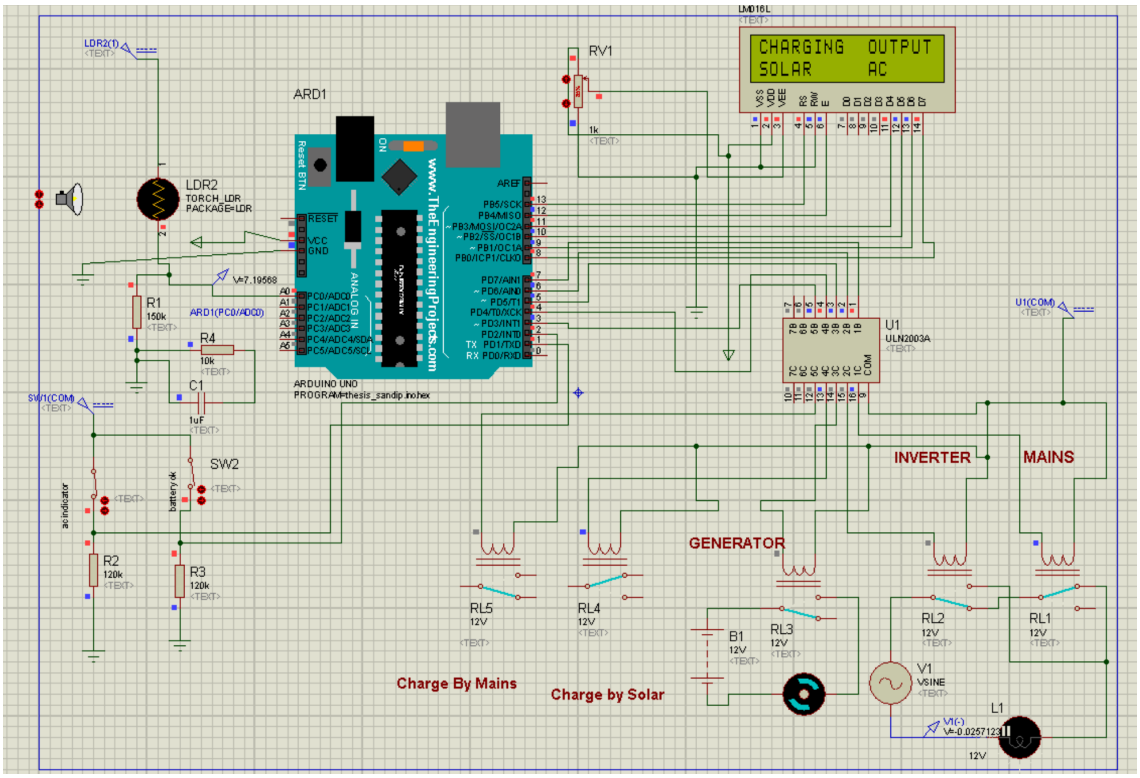

Figure 26: Simulation 6

The solar power is used to charge the battery in above Figure 26 although there is present of AC mains also because it is more economical to use solar power than AC mains. The supply for load is provided through the AC mains even though inverter also have charge but AC is prioritized over inverter.

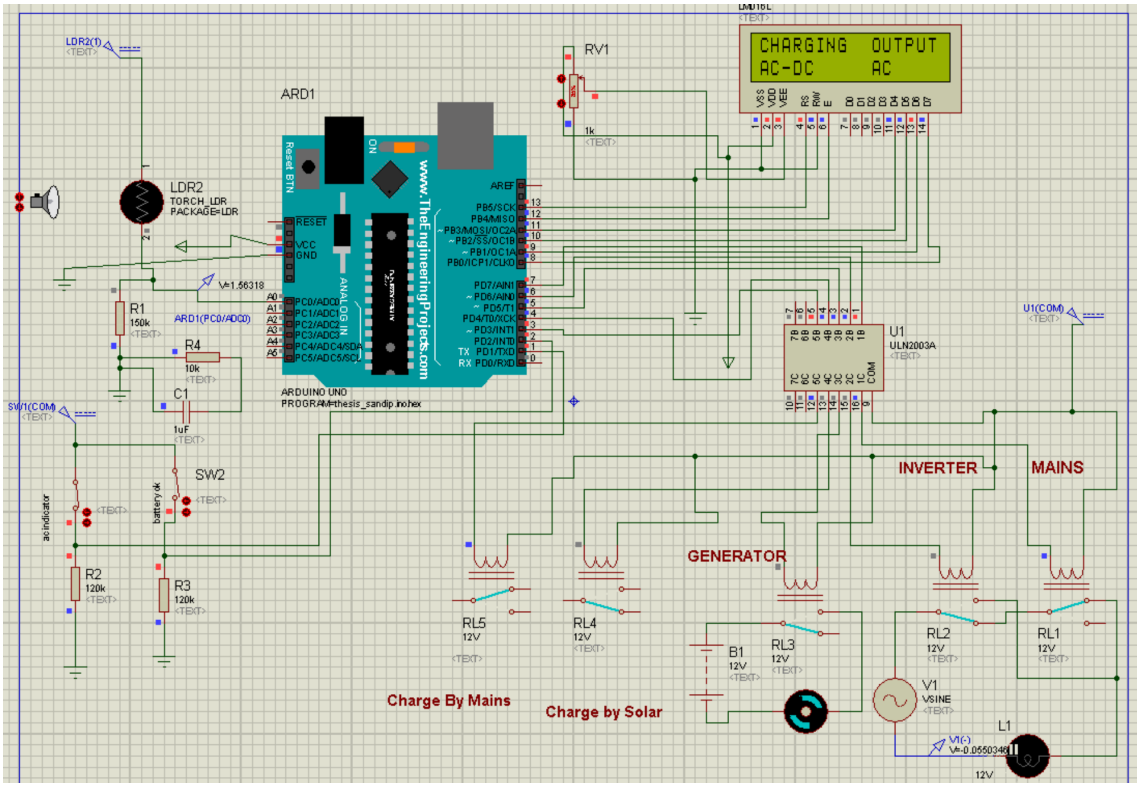

Figure 27: Simulation 7

The supply for charging the battery is AC-DC in Figure 27 because there is no presence of light so LDR cannot detect any intensity of light to provide power. The load runs through the AC mains supply as shown in the LCD screen in above Figure 27.

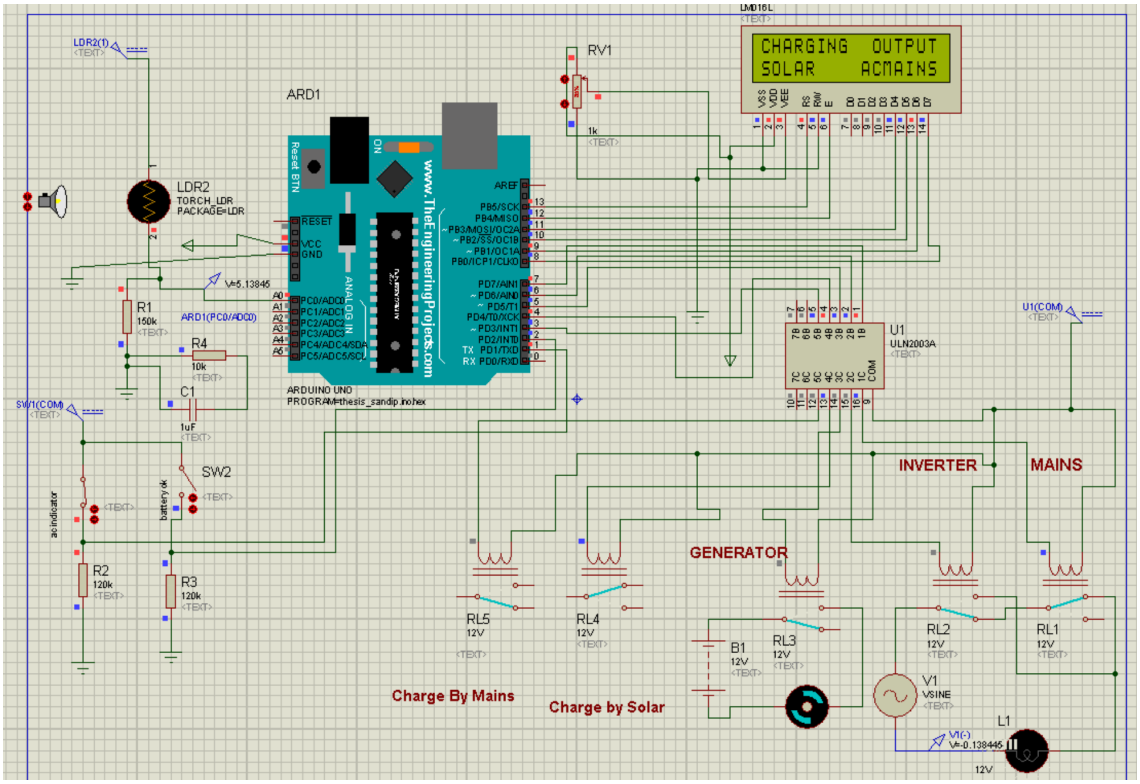

Figure 28: Simulation 8

However, solar and AC mains both are present here in Figure 28, battery is charged through the solar power while the output to load is provided from AC mains.

7 Result Analysis and Recommendation

7.1 Project Output

The charging of the battery was done by using solar as well as regulated DC in this project and also the load is operated using different supply in priority mode. The priority switching remains with AC mains if it is present. The priority goes to inverter if in case AC mains is absent thus triggering the relay by switching mechanism. When battery status is low then switching mechanism triggers the corresponding relay of diesel generator source.

7.2 Recommendation

Proper voltage divider can be used to attain the required voltage. All components should be tested properly before assembling because it is necessary to use components with right value to get the best output. Proper converter can be used to avoid charging effect of capacitors.

7.3 Future Enhancement

Power utility can adopt this scheme in larger areas for improved reliability of supply interfacing different power supply sources. Hardware components like transformer, relay and voltage divider can be changed to expand this project in future for larger size and for three phase supply.

8 Conclusion

The final result of the project was carried out in simulation where it shows that the charging of the battery was carried out by supply from mains or solar energy whereas the load was operated by using supply from mains, inverter or diesel generator. It is not sure that all the power sources are not identical in terms of cost and availability. This scheme ensures the efficient utilization of resources. There has been a tremendous success in the improvement in solar powered technology in past few years. The reason for such an improvement has to be the system being more efficient and reliable in harnessing solar energy as well as the availability of the system at lower and cheaper prices. Also, the future of the solar powered systems seems brighter as there is unlimited source of solar energy available to carry out projects in larger scale. Therefore, Solar UPS is the best when it comes to backup power consumption and emergency supply of power rather than power generator which uses gas or diesel generators. Solar ups can also be used to control the home appliances and other devices from the over voltage problems and short circuit problem thus, it can also act as voltage defender.

In this project, Diesel Generator is not preffered to charge batteries as it uses diesel to run which makes it costly in comparison to solar energy. So, Diesel generator is only used as a backup power to run load in emergency situations.

Applications and Limitations

This type of system is used in most sensitive industries and hospitals where continuity of supply is of great importance. This is applicable where there is excess of different source, but these sources should be used in priority based. The places where there is more often disconnection of power supply and uses alternative sources can get benefit from this system. Also, this system is of great importance where solar power, generator, inverter in addition of ac power is to be interfaced as per need and availability.

Power loss is one of the limiting factor of this project reducing the devices efficiency. Compared to the normal UPS systems hybrid off grid systems are bit expensive and its installation charge is much higher.

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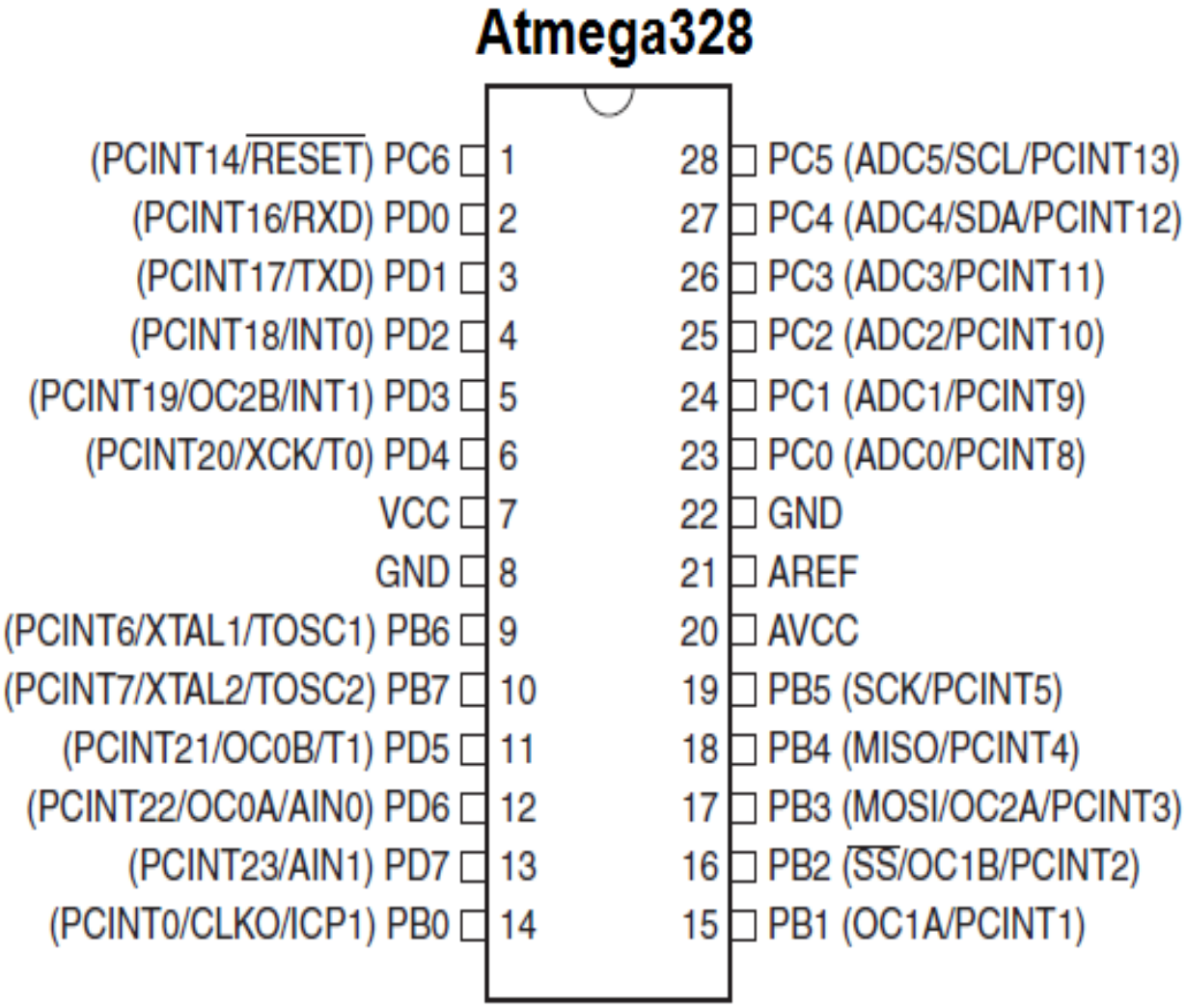

Figure 29: ATMEGA 328P pin configuration [7]