Indian Journal of Science and Technology, *Vol 12(28), DOI: 10.17485/ijst/2019/v12i28/146229, July 2019*

ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

An Effort towards Zero Percent Load Shedding utilizing Four Different Sources

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Abstract

Background/Objectives: With the swift increasing electricity demands, Pakistan is a densely populated nation that commonly encountered the problem of low energy sources. To tackle the energy crises, four different means of low-cost energy sources mainly Solar, Inverter, Generator, and Water and Power Development Authority (WAPDA) are employed. **Methods/Statistical Analysis:** The current work will give ceaseless power supply to a load, naturally from one of the above four sources which is more cost-productive. **Findings:** Cost of every source is found out and it has been observed that the price of photovoltaic cells is the minimum one for the next ten years. **Applications/Improvements:** The proposed system can be best implemented in hospitals or remote areas where the electricity is not present and real-time companies which manipulates the data at every movements. Also the home users can be benefited from this system but the initial cost would be high and for once only. Moreover, the improvements can be done by adding the GSM module which can be used to regularize the load according to user convenience.

Keywords: Generator, Inverter, Solar, Water and Power Development Authority (WAPDA)

1. Introduction

Nowadays, Pakistan is encountering the most dreadful energy crises and it really hampering the pace of monetary activity. In addition, it leads to public unrest with prolonged breakdowns of electricity. This dilemma could become even more serious if no proper understanding or correct implementations have been contemplated over. Currently, Pakistan is making use of natural resources that include coal and water to yield electricity. These assets are depleting with every tick of the clock, thereby, plummeting the potential for transforming the natural assets into electrical energy[1-3]. With higher energy demands, Pakistan is facing power outages and interrupts in offices, industries, hospitals, and homes, etc.

To meet the present-day demands, the auto power supply is a potential solution that delivers an automatic means of distribution of electrical power from different sources. The auto power supply provides reliable nonstop energy to the load in an event when one energy source is rotten while utilizing the other sources present and ready to take load depending upon the cost per unit of utilizing the source. This will not only ensure continuous supply to the load but also reduce the expenses for utilizing the sources.

Whilst a power supply, say Water and Power Development Authority (WAPDA – a Pakistan's government body that maintains power) falls flat. Thus, there is a need for considering the other means of electrical sources, which rely on least on cost. In this connection, renewable sources such as wind, solar, tidal, geothermal, etc. are inexhaustible for nature and can supply constant energy to the load[4,5]. If one source is unavailable or delivers less voltage in comparison to the desired level, the other sources can be used that compensate the load, depending upon the requirement and environment conditions.

The existing work targets the current energy crises of Pakistan by exploiting the four different

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energy sources. These energy sources include WAPDA, solar, inverter, and generator. To avoid load shedding, a complete state-of-the-art prototype is developed using the Arduino module that handles the automatic switching of power supplies based on low cost. Moreover, the work also delivers the numerical computations for the cost calculations of four sources. The full paper is apportioned into the succeeding sections. Section 2 portrays the system model of the prototype. This section also delivers the necessary knowledge required for the circuit elements. While section 3 exhibits knowledge of boost converter in the next section mathematical computations is done which is obligatory for the cost analysis. Section 5 discusses the hardware setup and presents the results of experimentation. The last section gives the concluding remarks about the complete work.

2. System Model

The suggested system is designed and implemented in such a way that the power delivery to the load must be uninterrupted and in case of any failure, the load is automatically shifted to the next available source which most cost-efficient among the available one. The block diagram of the system is depicted in Figure 1 where in the supply of four sources is given to four different relays respectively. These relays are attached with Arduino that provides input signals to it and Arduino will decide which source is the most cost-efficient among the available sources and it will transfer the load to that source which has least per unit cost. Relay driver that receives the output of the controller and depending upon that output the load is shifted by operating that particular relay. Lamp use as a load and suppose it is running on WAPDA and due to some reason WAPDA is failing than the controller shifted the load by operating relays automatically to that source which has least per unit cost, say the load is shifted to an inverter which is less the third priority of controller depending upon the per-unit cost and the load is still running uninterruptedly on the source of third priority in the absence of first priority source and the priority is depend upon per unit cost. The source which has least per unit cost has first priority. An liquid crystal display (LCD) is used to display, which source is delivering power to the load and it also displays the sources which are available.

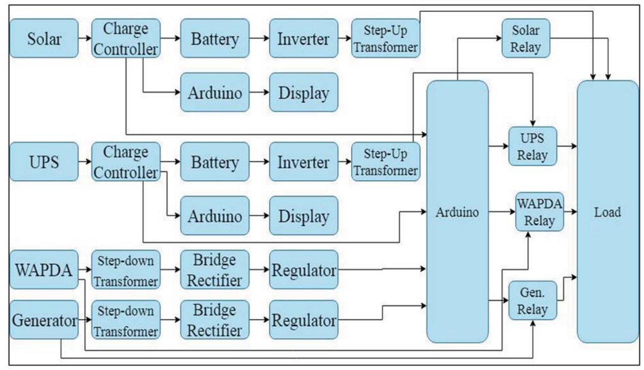

Figure 1. Block diagram of auto power supply control system.

2.1 Solar Distribution

The first source is solar.100W and 12V solar panel plate is used in it. Sometimes solar plate voltages exceed 12V to 18V in that way it can damage the battery. So that solar is connecting charge controller. It is a device which controls the voltages. Input voltages can be high or low; it will maintain the voltages about how much voltages are required by the battery. A charge controller is connected to the heart of the system. Arduino displays the input voltages of the solar and also display the output voltages given to the battery. The rating of the battery is 12v and 7A. A charge controller is also connected to the master Arduino. Three controllers are used in the system. This will decide which source has to switch on depending on the price calculated earlier in algorithm. It will check which source has minimum cost and then it connects to load. Arduino is used to control the four sources and takes the decision which source has efficient cost. Master plays a major role in the system because it controls the whole circuit and shifts the available cheap source to the load. Master checks which sources are present and which one is the minimum per-unit cost. The battery is also connected to the push-pull inverter. This inverter will change the supply from 12V DC to 12V AC. The inverter is also connected to the transformer. The transformer converts from 12V to 220V. It is connected to the relay. The Relay operates when we give a signal to it and it will drive the load.

2.2 WAPDA Distribution

The second source is WAPDA. This is the main source which is directly connected tothe relay through to. WAPDA is also connected to the transformer. This wills step-down the voltages 220V to 12V. It is connected to the bridge rectifier circuit. A rectifier changes the AC (Alternative Current) into Direct Current (DC). The bridge circuit is used in four diodes 1N4007. It converts 12v AC to 12v DC. It is connected to the voltage regulator. The voltage regulator provides 5V fixed to the master Arduino which gives signal to the relay and switch on the 100w load.

2.3 Push-PullInverter Distribution

The third source is Push-Pullinverter, WAPDA is connected to the transformer which change the voltages from 220V AC to 12V AC. The output is connected to the rectifier which change the voltage from AC to DC. Charge controller controls the voltages. Input voltages are high or low it maintains the voltages about how much voltages are required by the battery. Which is further connected to controller. Arduino displays the input voltages of the WAPDA and the output voltages of the battery and tell how much battery is charged. It is also connected to the master Arduino which is used to control the circuit and selects the sources which source is athigh priority. Battery supply is used by the inverter. An inverter changes the voltage 12V DC to 12V AC. The inverter is connected to the transformer. The Transformer is stepped up the voltages 12V to 220V. The Relay is connected to the load which switches on it.

2.4 Generator Distribution

The fourth source is a generator. A generator is a source that is directly connected to the load through relay. It is also connected to the step-down transformer220v to 12v. Which is further contected to bridge rectifier which converts 12V AC to 12V DC. A bridge rectifier is connected to the voltage regulator. The voltage regulator provides 5V fixed to the master controller, which gives signal to the relay and connect the load.

3. Boost Converter

The solar PV module generates low voltages, so it is need here to boost the voltages to meet the requirement of battery[5]. So boost converter is used to maintain the voltage and provides a fixed voltage. In order to maintain the voltages of the battery, it connects the boost converter circuit at the output of the solar panel plate to ensure that the voltages of the battery is equal to 12V. The circuit diagram of boost converter is shown in Figure 2. Voltages of solar plates depend upon the intensity of light so when the solar plate produces lower voltages then the boost converter boosts the voltages for a battery. DC to DC voltage converter is used to set up the voltages[6].

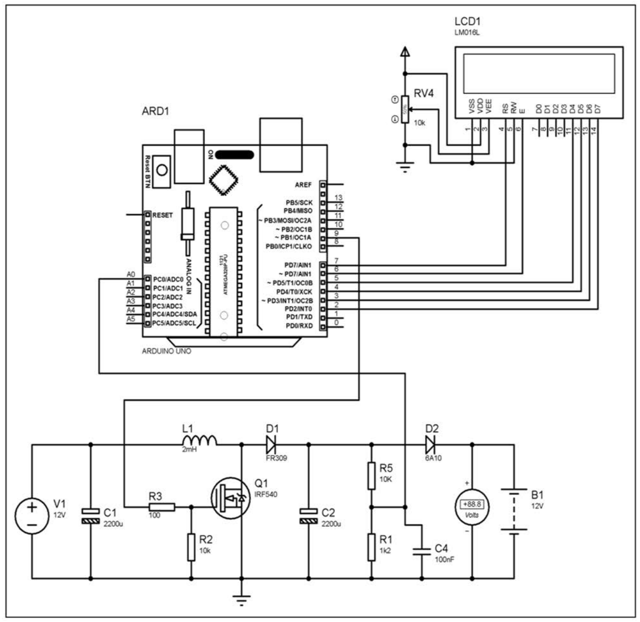

Figure 2. Circuit diagram of boost converter.

4. Experimentation and Cost Analysis

Power is generated using solar, Generator, WAPDA and back-up for an inverter combination of both in power generation stage[7]. The cost of each source is calculated hereunder.

4.1 Solar Cost Analysis

The device that converts sunlight into electrical light is called solar energy. Solar energy is a clean available source. In Pakistan, main renewable sources are biogas, solar, solar thermal, wind and hydropower. These cannot produce toxic gases such as CO_2 gas. Solar is environment-friendly. It cannot affect the environment and can be easily installed in Pakistan, but one major problem is that its installation cost is very high and it requires a storage device such as battery[8]. Due to environmental situation the output of the solar is not certain, day time gives more power or might be less power but at nighttime gives no power so backup battery is required to maintain the power solar system can work individually or simultaneously too[9].

The earth receives a huge amount of strength without delay from the sun each day. Even as passing through the ecosystem, the entire energy is reduced due to the reflection, scattering, and absorption by means of dust debris, water vapors' and some gases. On a clear day at midday, the depth of the solar energy reaches the earth's floor is set 1kwm-2. The direct conversion of daylight into energy thru the use of semiconductor device known as sun cellular also referred to as photovoltaic cells. The circuit diagram of solar is shown in Figure 3. Solar cells are thin wafers made from silicon. Electrons in the silicon gain energy from sunlight to create a voltage. Energy can be stored during the sunlight in batteries by connecting them with solar panels. The battery can then provide power to electrical appliances at night or cloudy days. Solar energy gives DC voltage at the output. Solar power supply DC is converted into AC by using an inverter which converts 12v DC to AC and stepped up transformer is also used to setup the voltage 220v[10]. 100W solar panel plate is used in the system whose complete specification is given in Table 1.

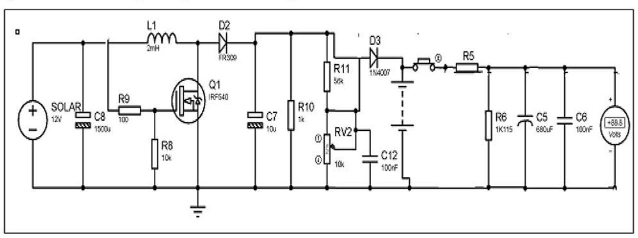

Figure 3. Circuit diagram of solar.

Table 1. Solar panel specification

Solar panel type	AKT-100-ML Solar panel
Maximum power (Pmax)	100 watt
Optimum operating voltages (VMP)	18.9 V
Optimum operating current (IMP)	5.29 A
Open circuit voltage (VOC)	22.5 V
Short circuit current (ISC)	5.75 A
Dimension	550*1380*35 mm
Weight	10.5 kg

4.1.1 Calculation of Solar Panel per Unit Cost

Per unit cost of the solar panel system:

Formula: 1000w solar panel plate generates 1 unit in 1 hour

1000w solar = 1 unit generate1 hours (1)

$$\frac{1\,hour}{1000w} \times 100w = 0.1\ unit \quad (2)$$

The 100w solar plate generates 0.1 units in 1 hour.

Day: Sunshine for summer in 10 hours for 1 day.

Eq. (2) Multiply 10 hours.

1 day = 0.1unit × 10hoursday = 1 unit generate (3)

Month: 100w solar plate generates in 1month.

Eq. (3) Multiply with 30 days.

1 month = 1unit per day×30 day (4)

So 100w solar plate generates in 6 months.

Eq. (4) multiplies with 6 months.

6 month = 6month(summer) × 30units = 180 units genetors in 6 month (5)

Winter:

Day: Sunshine for winter in 5 hours for 1 day.

100W solar plate generates 0.1 units in 1 hour.

Eq. (2) multiplies with 5 hours.

1 day = 0.1 unit × 5 hours

1 day = 0.5 unit generate (6)

Month: 100w solar plate generates in 1month.

Eq. (6) multiplies with 30 days.

1 month = 0.5unit per day × 30 day (7)

So 100w solar plate generates in 6 months.

Eq. (7) multiplies with 6 months.

6 month = 6 month(winter) × 15 units = 90 units genetors in 6 month (8)

The total unit generates in 1 year:

Sum of Eq. (5) and Eq. (8)

sum = 6 month (winter) + 6month (summer)

Units = 270 units generates in 1year (9)

10 year: 100w solar plate generates 270 units in 1 year.

Eq. (9) multiplies with 10 years.

10 years = 270 units × 10 years = 2700 units generate in 10 years

= 2700 units generate in 10 years (10)

5% losses:

5% losses of 2700 units = 135 (11)

Eq. (10) subtract with Eq. (11)

sum = total units-losses

Units -135 units = 2565 units

The total unit generates in 10 years = 2565 units generates in10years (12)

Maintenance cost:

6.27$ cost in 1 year.

10 year = 6.27$ × 10 = 62.7 $ maintenance cost (13)

$$\frac{\text{Total investment cost} + \text{ maintenance cost}}{\text{The number of actual units generates}}$$

$$\frac{31.36\$\text{ cost} + 62.7\$\text{ cost}}{2565\text{ units}} = 0.036\$\text{ per unit cost for 10 years}$$

Per unit cost of solar for 10 years = 0.036$ per unit cost.

4.2 WAPDA Cost Analysis

Water and Power Development Authority (WAPDA) is one of the main sources in the system because after the solar panel it provides cheap electricity. The circuit diagram of WAPDA is shown in Figure 4 per unit of WAPDA is 0.063$ per unit.

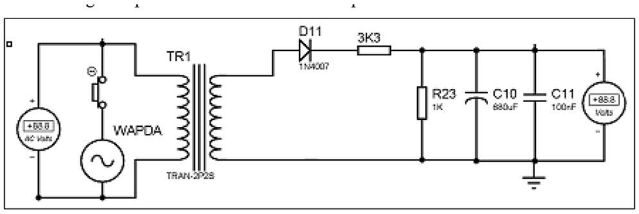

Figure 4. Circuit diagram of WAPDA.

4.3 Push-Pull Inverter Cost Analysis

The inverter is converting from Direct current (DC) to Alternative current (AC). The direct source may be battery or solar it connects into an inverter and then AC output comes from the inverter[11]. The schematic diagram of push-pull Inverter is shown in Figure 5. It takes the input of 12V DC from a battery and converts it into 12V AC. Per unit cost of an inverter is 0.13$ per unit.

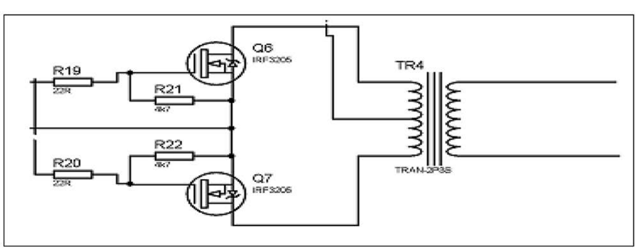

Figure 5. Circuit diagram of push pull inverter.

4.4 Generator Cost Analysis

The generator is also one of the sources in the system. This system is a major aim to make cost-efficient electrical supply system, thus when all the other sources are unavailable then the generator is ON and supply electricity to load uninterruptedly. The schematic diagram of the generator is shown in Figure 6. The electricity produces by the generator is costly, but the second motive of our system is the continuous supply to the load is fulfilled.

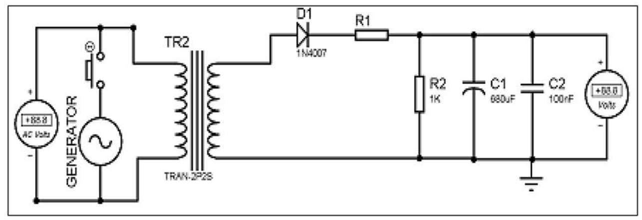

Figure 6. Circuit diagram of generator.

4.4.1 *Generator Unit Cost Calculation Method*

Generator unit cost calculation method:

1. Total Diesel consumption
2. Total generator kWh
3. Diesel rate per litter

Total Diesel consumption

Total diesel consumption = previous diesel level – current diesel level

Total diesel consumption=3liter-1.5 liter

Total diesel consumption=1.5 liter (14)

Total generator kWh

= current diesel level – previous diesel level

Total generator kWh = 6 - 3

Total generator kWh = 3 (15)

Eq. (14) divides by Eq. (15).

$$\text{Per liter generator unit} = \frac{\text{total generator kWh}}{\text{Total consume diesel}}$$

$$\text{Per liter generator unit} = \frac{3}{1.5}$$

per liter generator unit = 2 (16)

Diesel rate per litter = 0.74$ (17)

Eq. (17) divides by Eq. (16)

Per litter generator unit = 2

$$\text{Per unit cost} = \frac{0.74\$}{2}$$

Per unit cost of generator = 0.37$

5. Simulation and Hardware Implementation

The simulation of the system is shown in Figure 7. Here can be seen that there four sources used. The first one is solar which is shown by a 12V input. For hardware purpose a 100W solar panel plate is used for this purpose. Solar is not directly connected to the load because the solar plate provides DC voltages. The Solar panel is connected to the charge controller because the charge controller maintains the voltage and provides fix voltages. If the battery is fully charged, then the controller stops the battery charging. The battery is connected to the inverter that converts DC into AC. The simulation of solar is shown in Figure 8. A transformer is used to step-up the voltages. The Relay is also used which is connected to the controller. Arduino gives a signal to the relay then it operates and connects to the load.

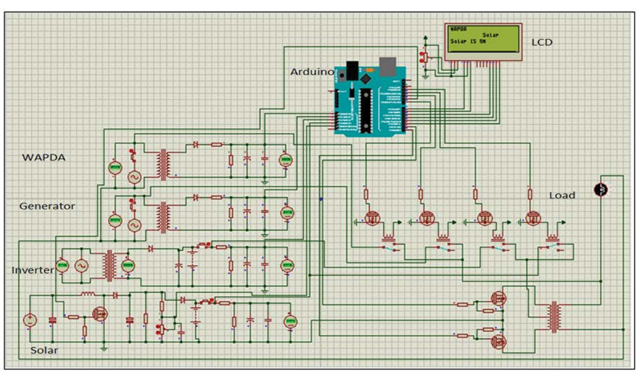

Figure 7. Simulation of four sources.

The second source is an inverter. WAPDA charges the inverter battery. 220V step-down the voltages, then it Converts into AC to DC and charge controller is used to charge the battery. H Bridge Inverter is used to convert DC into AC and transformer is used to step-up the voltages. The Source is connected to the controller. Arduino gives

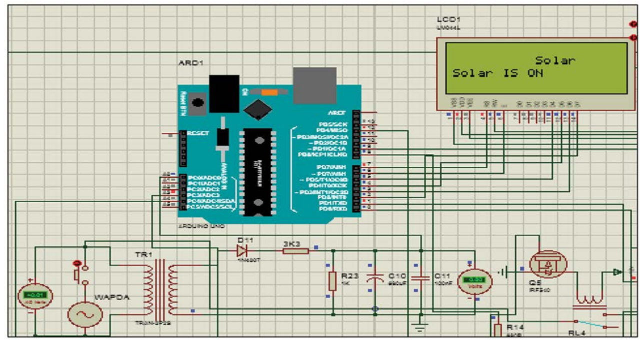

Figure 8. Solar simulation.

a signal to relay whether it operates or not. The Relay is connected to the load.

The third source is the WAPDA which is the main source which directly connected to load. Simulation is shown in Figure 9. The Hardware result of solar is shown in Figure 10.

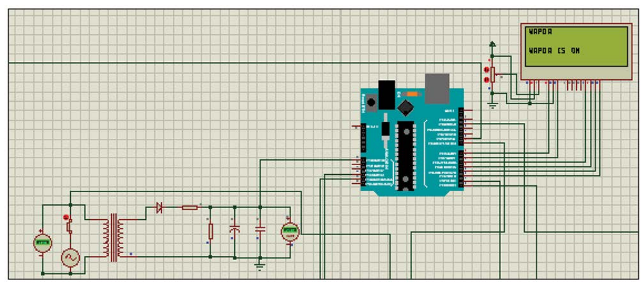

Figure 9. WAPDA simulation.

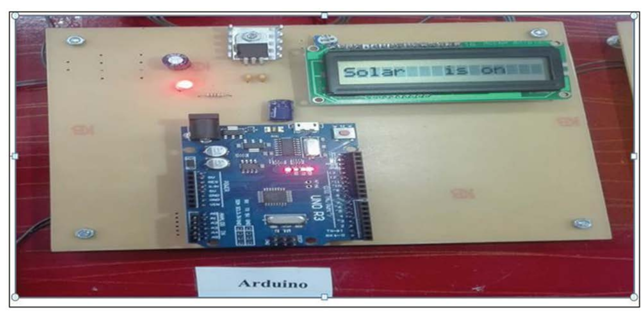

Figure 10. Hardware result of solar.

Arduino decides which relay is operating. In-circuit simulation two sources WAPDA and solar are ON. LCD has shown sources; WAPDA and Solar. The Hardware result of WAPDA is shown in Figure 11.

A generator is the fourth source that connects relay to load. The output of the generator is shown in Figure 12. These Four sources are connected to the master Arduino. The hardware result of an inverter is shown in Figure 13 where the ac output can be seen on the oscilloscope. The complete hardware implementation result of four sources is shown in Figure 14.

Figure 11. Hardware result of WAPDA.

Figure 12. Hardware result of generator.

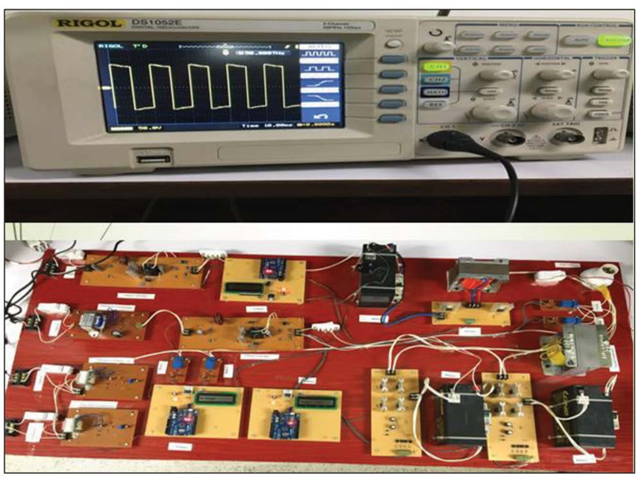

Figure 13. Hardware result of push pull inverter.

6. Conclusion

In this study, auto power supply from four different sources Solar, Inverter, WAPDA and Generator has been explained with all its information and facts which concludes solar is the best for the next ten years and then WAPDA and inverter is on the third one and lastly the

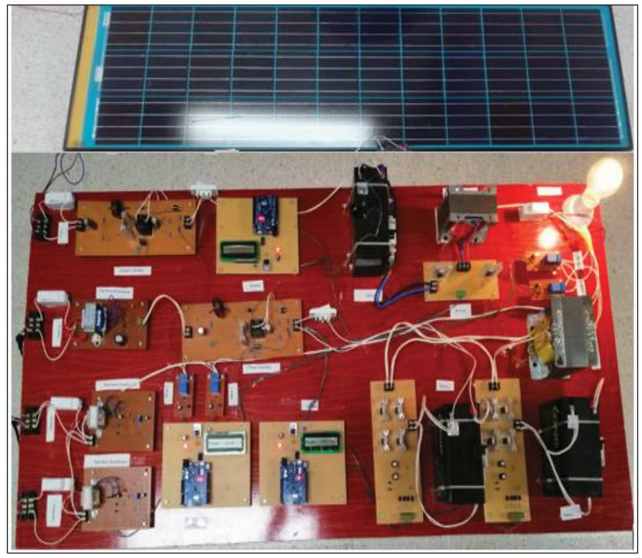

Figure 14. Hardware implementation of auto power supply control system.

generator depending on the cost shown in Table 2. Wind part can be added for future work. GSM module can also be interfaced with the system to control the sources like which source want to switch on for our own convenience due to not the presence of any source and also switch on the devices through GSM module.

Table 2. Table per unit cost

Sources	Present Sources	Cost Per Unit	Load W
Solar	ON	0.036$	100
WAPDA	ON	0.063$	100
Inverter	ON	0.13$	100
Generator	ON	0.37$	100

7. Acknowledgment

Authors would like to acknowledge The University of Lahore for providing us the physical resources to perform this experiment.

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