

Improving the performance of the hybrid power system consisting of a photovoltaic system and diesel

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Abstract:

Generators are mostly employed in isolated locations that are not wired into the energy grid. Generators are regarded as non-renewable resources because of the harm they do to the environment and the potential risk they pose to human health. In order to lessen the impacts of the diesel generator and solve the issue of voltage fluctuation for the photovoltaic system, it was decided to integrate the diesel generator with the solar system. When a voltage fluctuation occurs, an electronic circuit is built to connect the generator and solar system in a hybrid system (PvDHS occurred). On the basis of climate data, the system was examined and enhanced. The hybrid optimization model for renewable energy programmes employed local insolation measurements and meteorological data in collaboration with various system components and configurations to optimise the design that results in the lowest energy cost. system with a 3 kW power output In addition to lowering carbon dioxide emissions, the solar system and a 2 kW diesel generator were chosen to solve the voltage fluctuation issue.

Keywords: *hybrid systems. voltage fluctuation; diesel generator; automatic conversion; greenhouse gas emissions.*

I. INTRODUCTION

The Earth's population has grown over time, and this rise is inversely correlated with the amount of energy consumed.

Scientists claim that one of the energy technologies with the quickest growth is renewable energy. Because it offers several options for producing clean, affordable energy with outemitting carbon emissions, solar energy is a significant choice. However, transmitting uninterrupted electricity into the network is challenging due to the intermittent nature of solar energy [1, 2]. Energy is a necessity since it fuels everything in our environment, just like food and water do. In integrated networks, power outages or blackouts are eventually brought on by frequency variations, voltage challenges, and high peak loads [3–4] In order to send solar PV to the network in a regulated way, it must first be smoothed.

A circuit that has been ergonomically built to regulate, manage, and optimise the energy supply process connects the energy storage system with the diesel generator [5, 6]. Fig. 1 shows a typical micro-grid system with power. It is known that electrical networks are very essential to human life. The European Directive on Renewable Energy Sources is only one of several organisations and groups that have devised procedures to reduce the consequences of increased energy demand on the environment. The rising interest in renewable energy sources (RE), which are the least destructive to the environment, throughout the world is justified by this fact. [8] The quantity of power produced by clean and renewable energy sources has been discussed by several researchers in various proposed solutions, and associated technologies are being studied, developed, and used globally. Wind, sun, geothermal, biofuels, tides, and waves are some of these alternative energy sources. There are downsides to using renewable energy sources. For instance, solar panels are inefficient and their electricity output is influenced by the weather. Compared to single-system systems, hybrid power systems provide improved generating dependability. Energy produced by renewable sources differs from that produced by conventional power plants. sustainable power Sources like wind and photovoltaic have erratic characteristics that change based on the [7] season, location, and weather. When PV output is high or low with a high penetration level, power grid problems like voltage fluctuation and frequency deviation might happen. Therefore, the hybrid system is the most widely used kind of renewable energy. A PV primary system and a diesel generator subsystem make into a hybrid PV system/diesel generator [8]. was developed, where the electronic circuit is built for monitoring and switching, locating the failure, since it is affordable and needs less maintenance. The recommended hybrid PV power generating system makes use of an electronic circuit to keep track of things and limit disruptions while the solar panels are running at their maximum capacity. Either the diesel generator or the solar panels supply the required load power to the proposed controllers. Within the nominal radiation range, normal and connected loads are powered by photovoltaic in the case of intense radiation. When the insulation is broken, an electronic circuit is created (shading)level is insufficient to power the load. It does away with the need for human contact to start a PV system and switch the power source. The circuit detects a PV power failure and, if necessary, initiates a backup source (a generator). if the utility remains unavailable. [9] The conversion procedure begins when there is a complete loss of energy.



Fig. 1. A typical micro grid system model.

II. VOLTAGE FLUCTUATION

Voltage fluctuation is a change or swing in voltage, and can be problematic if it moves outside specified values.

It affects the performance of many household appliances. Effects on loads are usually noticed when the voltage fluctuates more than 10% above or below the nominal voltage, and the severity of the effects depends upon the duration of the change [10] Extended under voltage causes “brownouts” characterized by dimming of lights and inability to power some equipments. Extended overvoltage decreases the life

III. METHODOLOGY

Solar PV plants produce intermittent power due to differences in sunlight caused by moving clouds. The resulting oscillating force can cause various problems in the network, such as frequency deviations, power system failures, and power outages. To mitigate large-scale grid hacking of solar energy [11], the PV output must be refined before it can be injected into the main grid.

The objective of this study is to design and develop solar energy by linking solar energy with a diesel generator through an electronic circuit that has been practically designed.

Fig. 2's hybrid system is mostly powered by solar energy. The solar panels feed the load under standard connection conditions. Additionally, the diesel generator is linked directly in case the solar panels malfunction; it shuts off automatically once the main power supply is restored. The system's capacity to identify problems and switch between power sources is its key benefit. When compared to previous published designs, this one offers a number of benefits, including lower costs, a simpler design, more readily available materials, and—most significantly—the ability to run on a single-phase power supply.

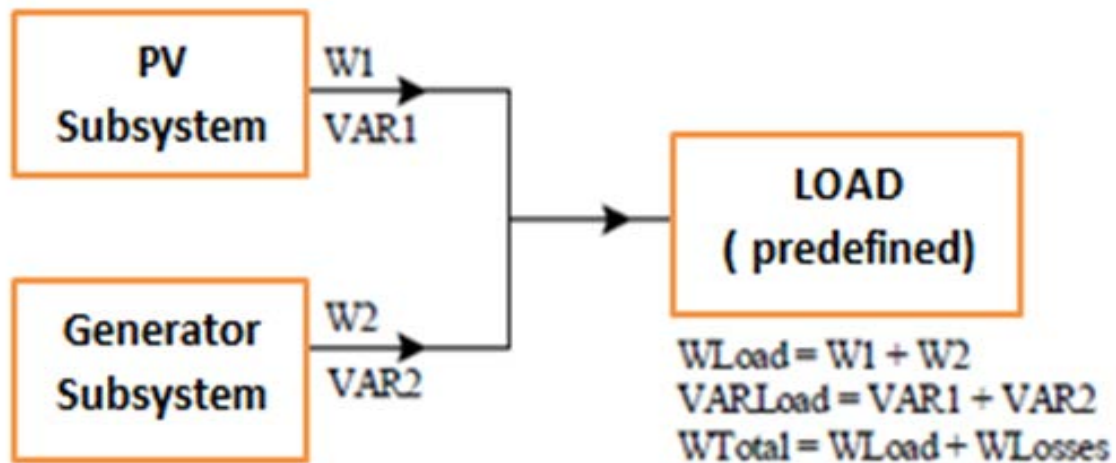


Fig.2. PV-DIESEL Hybrid System

IV. EXPERIMENTAL ANALYSIS OF THE DYNAMIC BEHAVIOR OF THE “FLEX ENERGY” PROTOTYPE

Experimental set up

The experimental setup is a solar PV/diesel hybrid system without Storage in batteries. It consists of a PV array of 2.85 kW, a 3.3 kW single phase inverter and diesel generator rated at 5 kW (see Figures 3 and 4).

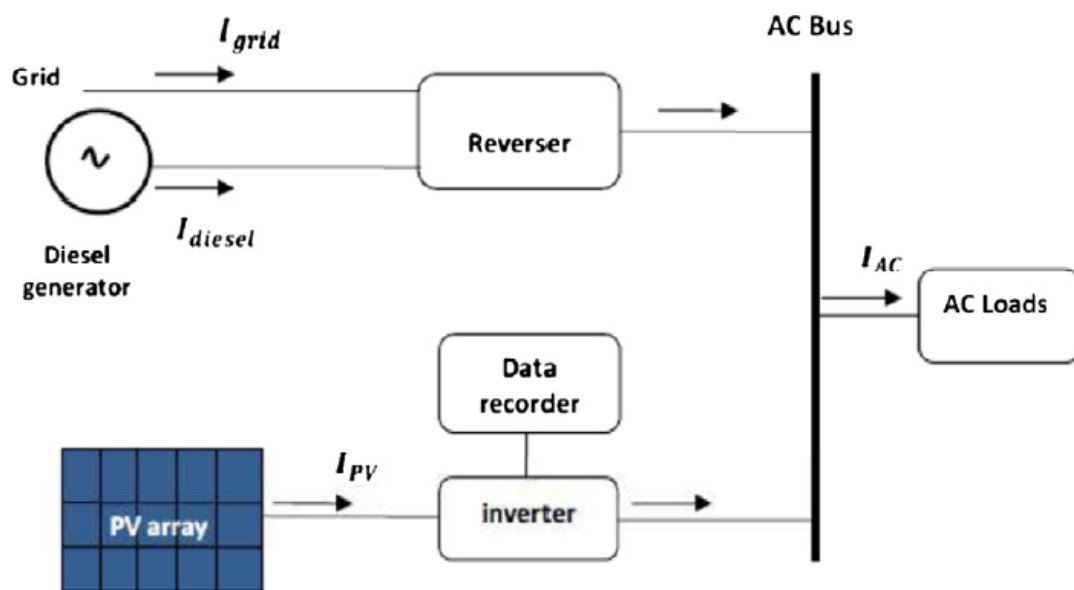


Fig. 3. Schematic diagram of the experimental set up.

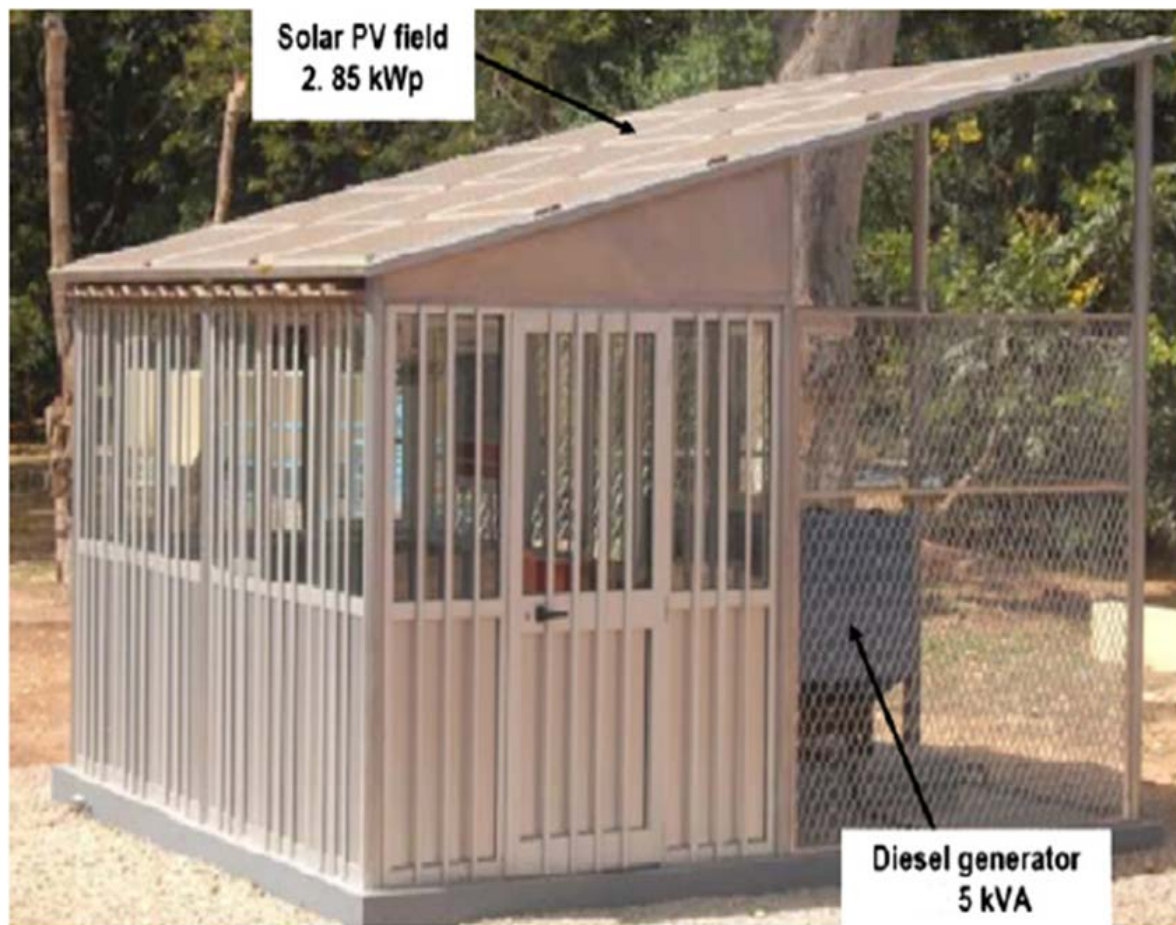


Fig. 4. Prototype of “flexy-energy” concept at 2iE-Kamboinse.

Hybrid system components description and operation

ENERGY FLOW OF THE PROPOSED HYBRID PV-DIESEL THE SYSTEM IS SHOWN IN FIGURE 3. THE LOAD DEMAND IS MAINLY SATISFIED BY PV. WHEN THERE IS A FLUCTUATION IN THE VOLTAGE OR AN INCREASE IN THE LOAD, THE GENERATOR IS INSERTED AS A BACKUP SOURCE. IF THE SUM OF PV AND WT OUTPUT POWER IS HIGHER THAN THE LOAD REQUEST, EXCESS POWER IS USED TO RECHARGE THE BATTERY. A GENERATOR IS USED WHEN PV AND BATTERIES CANNOT MEET LOAD REQUIREMENTS. DEPENDING ON THE ELECTRONIC CIRCUIT THAT WAS DESIGNED TO CONNECT THE TWO SOURCES AND OVERCOME THE PROBLEM OF OSCILLATION AND THE LACK OF ENERGY NEEDED BY PREGNANCY AND THE VARIOUS SYSTEM COMPONENTS (ENERGY SOURCES) ARE SHOWN IN THE SECTION BELOW.

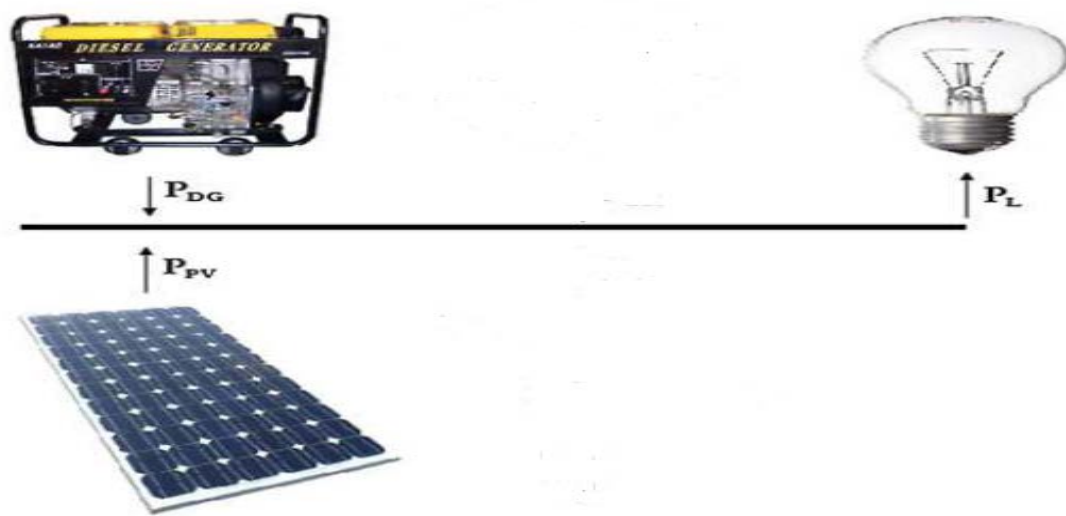


Fig. 5. Proposed hybrid system layout and power flow

PV system

When light strikes a silicon, gallium arsenide, or cadmium sulphide An electric current is generated through the PV effect [12]. The power rating of a PV panel is expressed in peak watts (W_p).indicated at "standard test conditions" conducted at a cell of 25 °C and an irradiance of 1000 W/m². The output The power of the solar PV system can be expressed as follows [13].

$$PPV = APV \times \eta_{PV} \times \int_{t_0}^t I(t) \times f(t) \times dt \quad (1)$$

where: APV is the total area of the PV generator (m²); η_{PV} is the system's efficiency; I is the hourly irradiation (kWh/m²) and $f(t)$ is the radiance density.

Diesel generator

DG is a normal diesel generator coupled to an alternator. DGs are typically designed to operate in close proximity to the PV system in the event of a voltage or cloud problem, resulting in voltage fluctuation and insufficient load feeding. And while reducing the use of the generator will lead to a decrease in fuel consumption and the carbon footprint, it will also increase the lifespan of the DG [14]. FC for one day is calculated by the following equation:

$$C_f \sum_{j=1}^n (aP_{DG(j)} + bPDG(j) + c) \quad (2)$$

Where: a, b and c are the fuel-related parameters of any DG fuel consumption curve (available from the manufacturer); C_f is price for one liter of diesel fuel; PDG(j) is the output power or Control variable from the DG at any sampling period.

electronic circuit (ATS)

The circuit design is based on a microcontroller representing the brain of the device and all other functional or peripheral elements are connected to the microcontroller for instant interpretation. The microcontroller requires a power supply (5V DC) to operate; This power

source is derived from a 12V regulated battery[15]. The microcontroller when turned on performs the sensing function, it senses a signal and sends an appropriate signal in return. The microcontroller senses the main AC supply voltage with the help of optocoupler and gives an output load (220V at 30A at full load) through a relay. An interruption of the mains supply requires the start-up of a secondary source of supply.

The generator acts as a secondary source of supply; The microcontroller sends a signal to the operating and starting relay which normally opens and closes respectively to turn on the generator, and when the generator is turned on, a 220V voltage feedback is sent to the microcontroller through the optocoupler to turn off the relay. This process continues in the same manner until the mains supply is back on and the load is automatically switched to mains while the generator is turned off through a starting relay which is disconnected from power and becomes normally open. This process repeats itself when the power is cut off or is turned on in series as often as the microcontroller is turned on. Fig. 6. shows the complete circuit diagram.

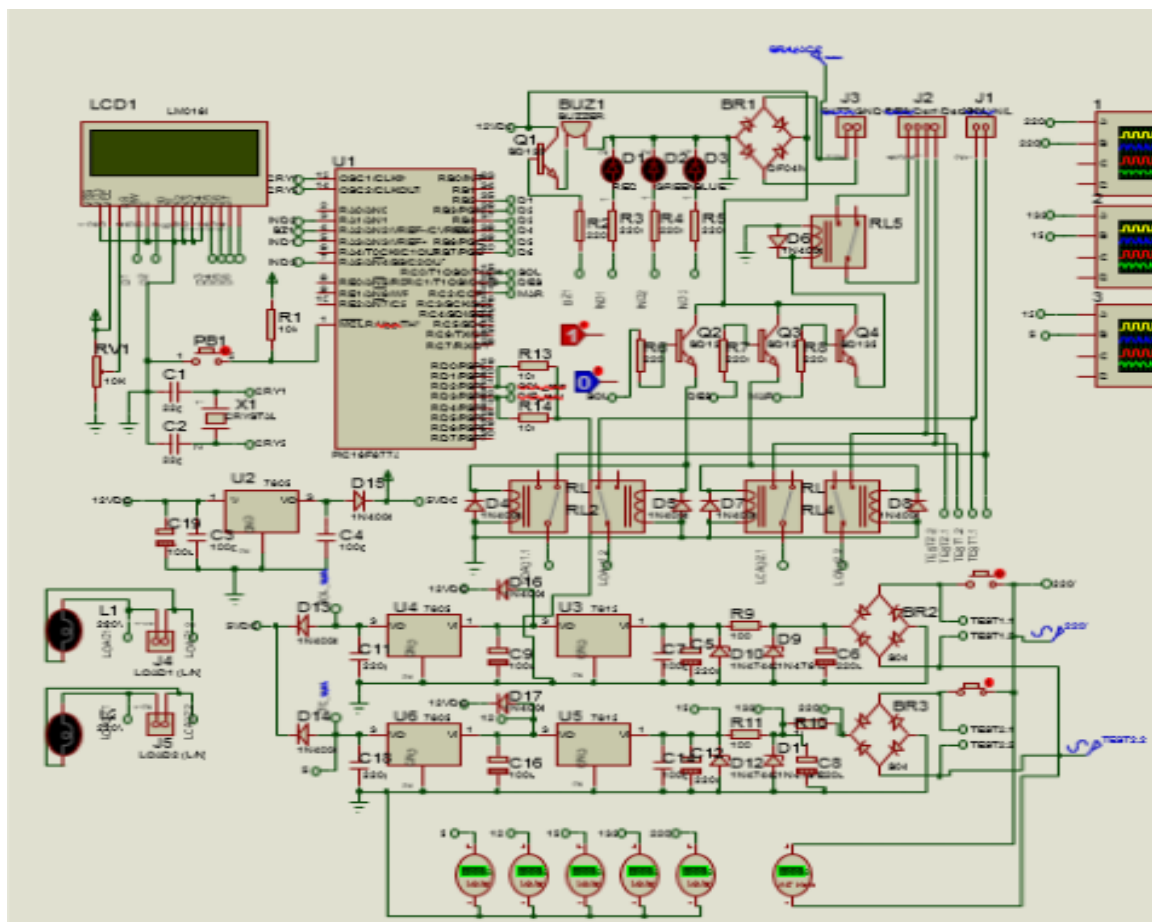


Fig.6. Complete Automatic Transfer Switch Circuit Diagram

V. MODULE SWITCHING AND LOADING RELAY

AN NPN TRANSISTOR WAS USED AS A SWITCH AND RECEIVED 5 VOLTS FROM THE MICROCONTROLLER TO POWER THE RELAY CONNECTED TO IT, WHICH IN TURN WOULD TURN ON THE GENERATOR. THE DESIGN FOLLOWED THE WORKING PRINCIPLE OF THE NPN TRANSISTOR, WHICH REQUIRES A VOLTAGE AT THE BASE OF THE TRANSISTOR TO CONTROL THE ON AND OFF STATES WHILE THE COLLECTOR IS CONNECTED TO THE POSITIVE AND THE EMITTER VOLTAGE TO GROUND. CALCULATE THE DESIGN OF THE NPN TRANSISTOR.

$V_{BE} = V_B - V_E$ 5 volts input voltage

$I_C = 100$ mA is the maximum collector current.

60 volts is the maximum output voltage.

Rated power = 100 mA \times 60 volts = 6 W

Resistor value = $V_I = 5$ volts/ 100 milliamperes = 50 ohms

The calculated resistor value is 50 ohms; this refers to the minimum value of resistance that can be used in the design. The 1 kilohm resistor was chosen because BJTs are current-controlled devices at the base, where a voltage as little as 0.7 volts can turn the base on. The resistance value of 1 kOhm was chosen because it is high enough to limit the current at the base for better functionality.

FIGURE 7 SHOWS THE GLOBAL MEAN SOLAR RADIATION SO THAT THE HIGHEST RADIATION OCCURS DURING THE PERIOD FROM JUNE TO SEPTEMBER WITH APPROXIMATELY 7.5 kWh/M²/DAY WHILE THE DECREASE IN RADIATION OCCURS BETWEEN NOVEMBER AND JANUARY. THE AVERAGE ANNUAL RADIATION IS 6.56 kWh/M²/DAY.

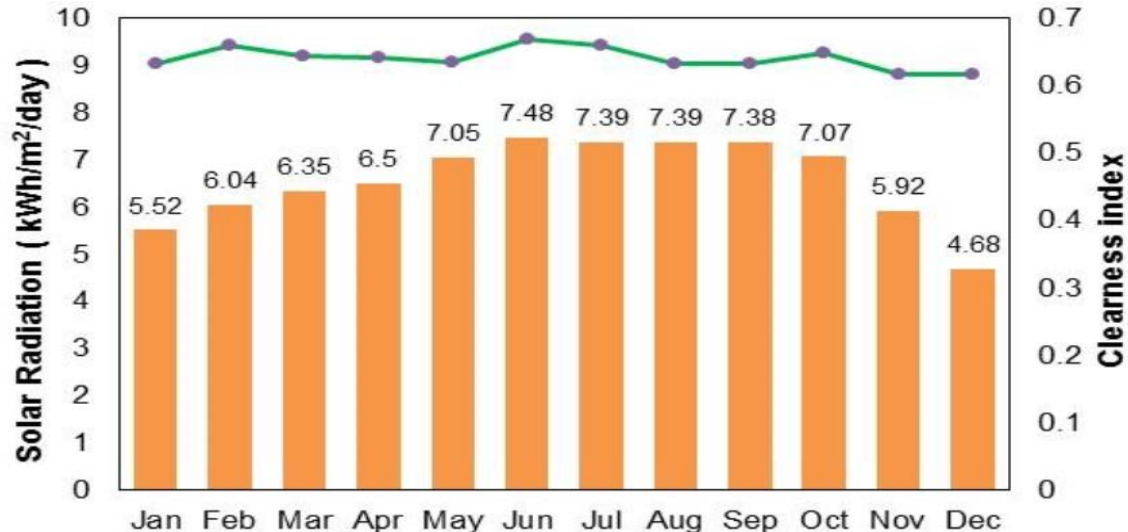


Figure 7. Monthly average solar Global Horizontal Irradiation.

VI. PROGRAM DESIGN AND IMPLEMENTATION

ON ATMEL STUDIO SOFTWARE, THE C PROGRAMMING LANGUAGE IS USED TO PROGRAMME THE MICROCONTROLLER. THIS CODE IS SIMULATED ON A PROTEIN PROGRAMME TO CHECK IF THE HEX FILE WILL MATCH THE REQUIRED

HARDWARE DESIGN BEFORE EXECUTION. PROTEUS SIMULATION SOFTWARE IS USED IN TESTING THIS DESIGN AND THROUGHOUT THE DESIGN PHASE.

VII. PILOT TESTS

The general setup was carried out as shown in the figure8. The voltage waveform of the main source and load

The emergency generator is registered using From Figure 9 it can be seen that using the designed ATS Effectively achieve the required sequence of Operation to power the load from two Of the sources, it is the solar energy source as a primary source and the diesel generator as a backup source under normal and fault conditions.

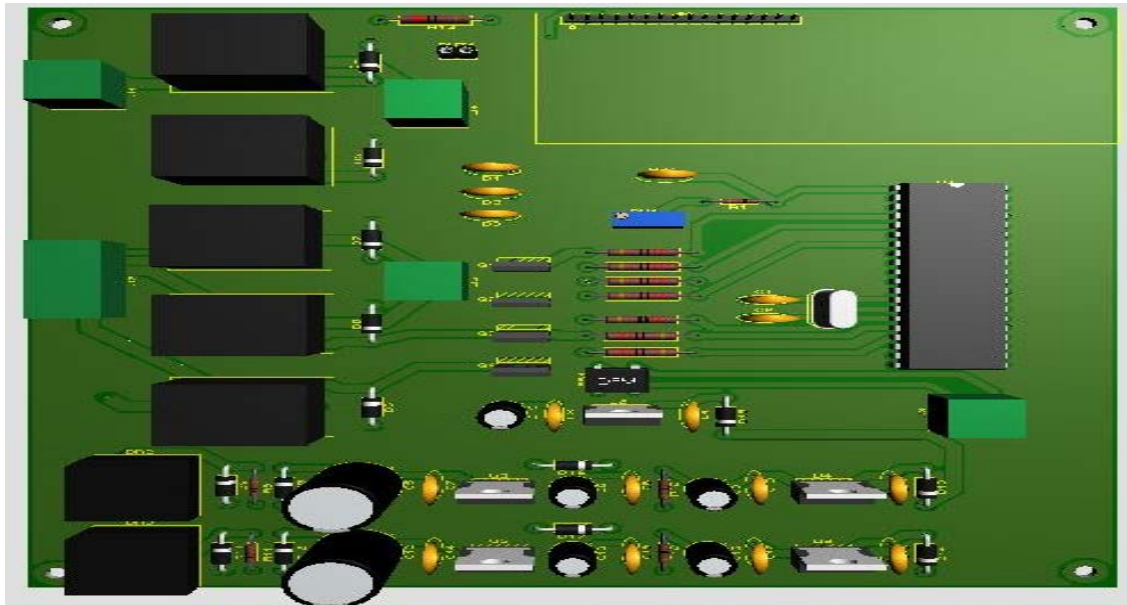
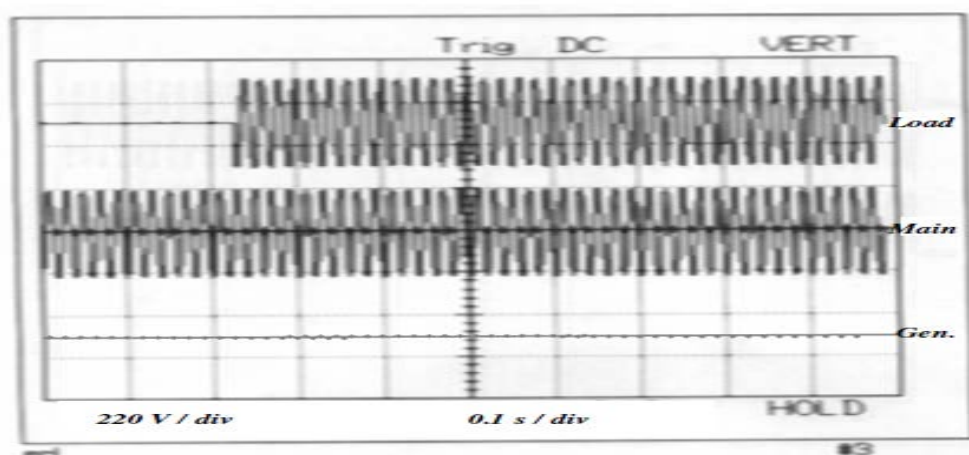
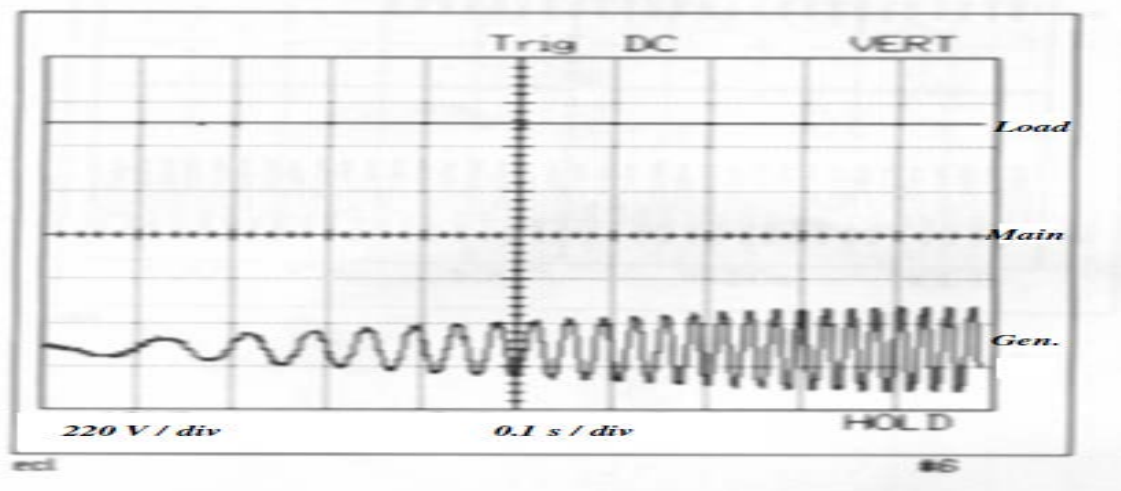


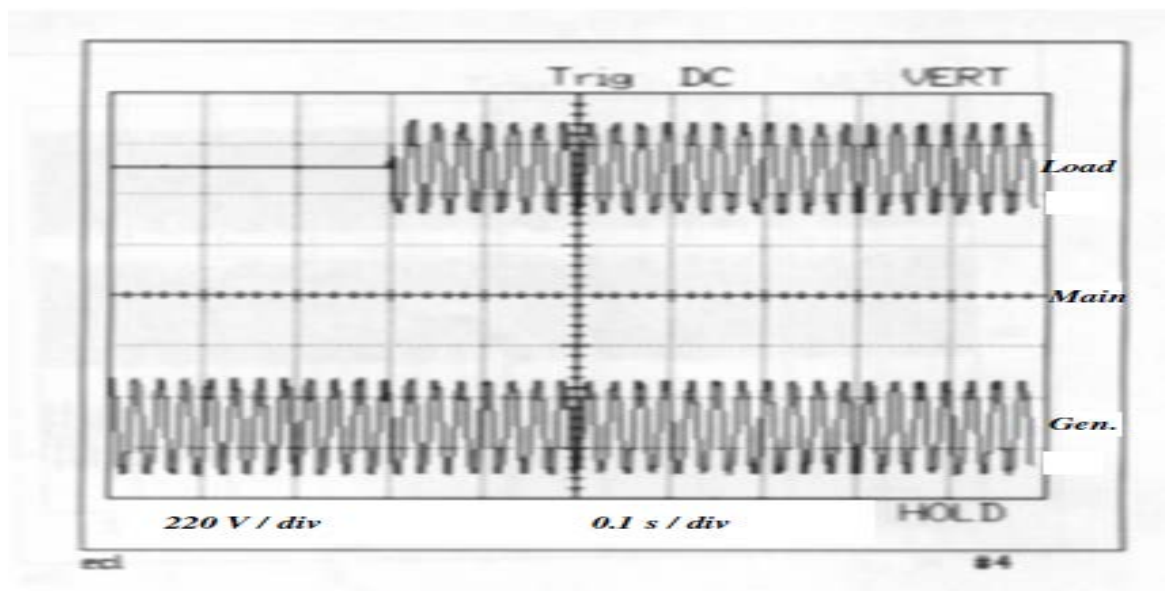
Figure 8: The experimental setup



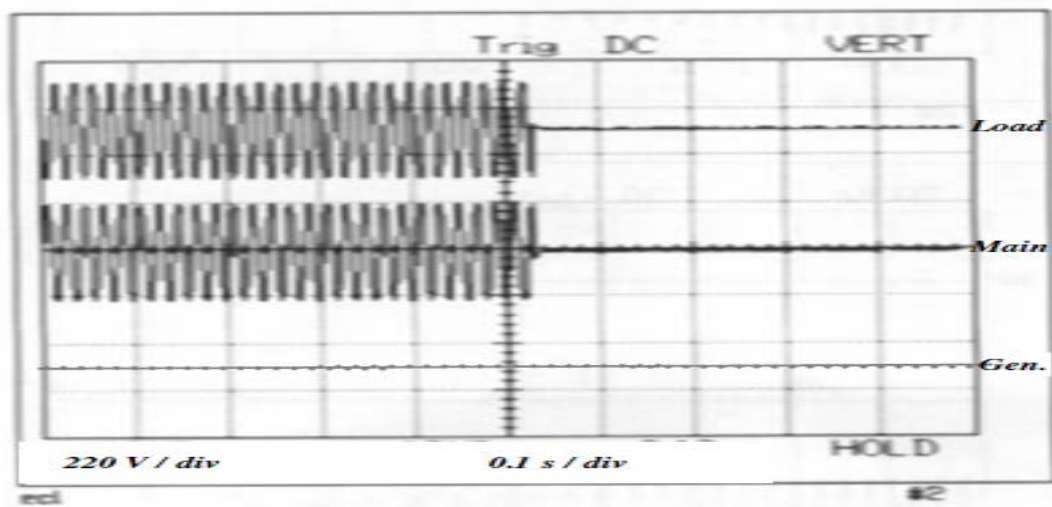
*a) Load : from OFF to ON
Main: ON
Gen. : OFF*



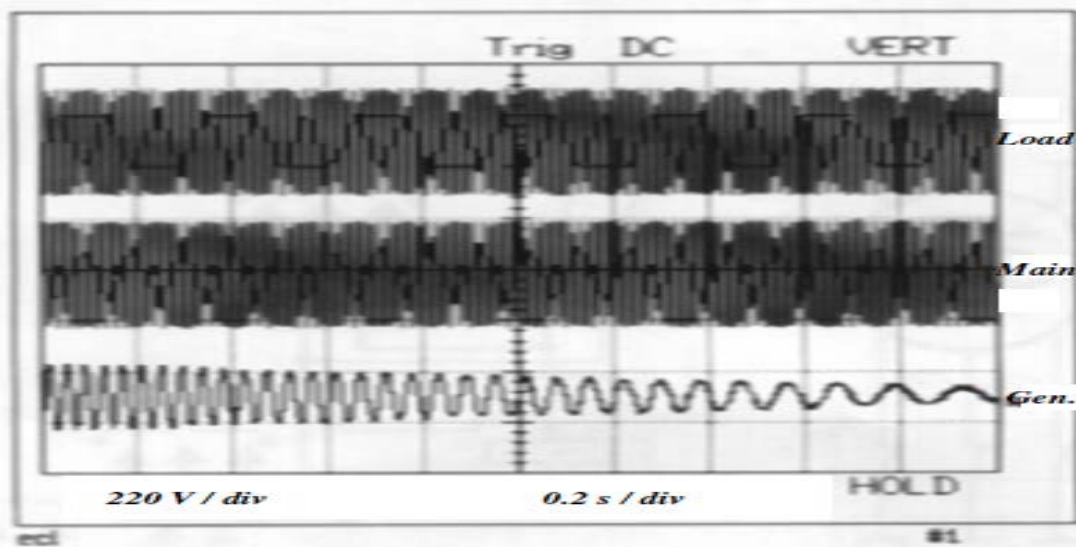
c) *Load: OFF*
Main: OFF
Gen.: from OFF to ON



d) *Load: from OFF to ON*
Main: OFF
Gen.: ON



b) Load: from ON to OFF
Main: from ON to OFF
Gen.: OFF



e) Load: ON
Main: ON
Gen.: from ON to OFF

Figure 9: Experimental voltage waveforms for different cases of operation

VIII. RESULTS AND ANALYSIS

Table 1 shows the classification of design criteria. The effect of surge current on circuit load capacity is shown in the graph in Figure 10. From the relationship between voltage and current, the amount of charge consumed by the system in different time periods was obtained. The strength at such intervals was also calculated. Finally, the efficiency of the system was calculated using power relations. The results are shown in the table as follows. The increase in

the current drawn from the device has a corresponding increase in the load used by the device. Thus, the efficiency of the system increases with increasing time. This means that the system will operate optimally over time and when it draws the large amount of power needed to balance load capacity. Thus, efficiencies are expected to reach a maximum of 300 minutes and 3300 watts. The voltage delivered to the circuit is constant at 220 volts at any variable time. This clearly indicates the reliability of this device. A successive increase in the load will lead to a corresponding decrease in the operating frequency of the device. This obeys the equation $P = IV$ when the voltage is constant. Any further increase in system load capacity beyond the maximum capacity at 3300W is expected to result in a decrease in system efficiency over time. This system operates effectively at a maximum current of 30 amps and a constant voltage of 220 volts.

Table- I: A CLASSIFICATION OF THE DESIGN PARAMETERS.

Tim (minutes)	Voltage (volts)	Current(A) x 100	Charge (Q) $Q = I \times t$	Power (W) $P = I \times V$ $= QV / t$	Efficiency % 100
30	220	3.0	90.0	660.0	10.0
60	220	6.0	360.0	1320.0	20.0
90	220	9.0	810.0	1980.0	30.0
120	220	12.0	1440.0	2640.0	40.0
150	220	15.0	2250.0	3300.0	50.0
180	220	18.0	3240.0	3960.0	60.0
210	220	21.0	4410.0	4620.0	70.0
240	220	24.0	5760.0	5280.0	80.0
270	220	27.0	7290.0	5940.0	90.0
300	220	30.0	9000.0	6600.0	100.0

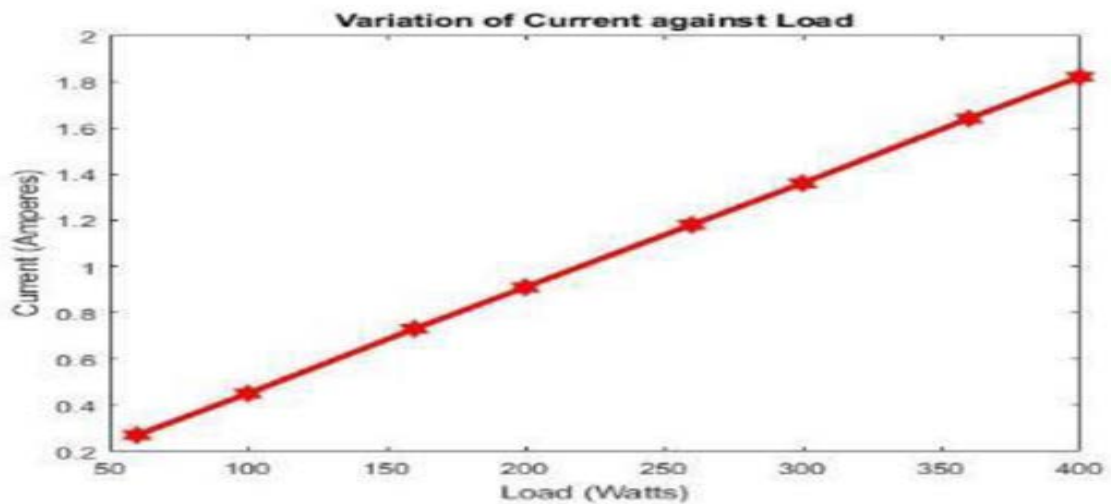


Fig.10.Variation of Current against Load

IX. CONCLUSIONS

A combination of renewable energy sources such as PV with The diesel generator seems to be finding increasing appeal in the implementation Decentralized electricity generation systems for remote areas Actual study of the PV/diesel system

The mixed system without storage was dealt with in this paper. The use of photovoltaic cells as a primary source and the diesel generator as a backup source was presented when voltage fluctuation occurred. An electronic circuit was designed to connect the diesel generator when the photovoltaic voltage fluctuation or interruption occurred, and to re-enter the main source when adjusting its voltage values, so that Unbalanced voltage output from photovoltaic cells May cause harm to users (loads). Thus, caution should be exercised To ensure that the rated PV power of the PV/Diesel hybrid system

connected to each phase of the network as equal as possible The results indicate that in this way the problem of voltage fluctuation was overcome.

REFERENCES

- [1] Passey R, Spooner T, Watt M, McDonald J, McCracken P, Gordon J, et al. Addressing grid-interconnection issues in order to maximize the utilization of new and renewable energy sources. IT power report; 2010.
- [2] Rehman S, Aftab A, Al-Hadhrani LM. Development and economic assessment of a grid connected 20 MW installed capacity wind farm. *Renew Sust Energy Rev* 2011;15(1):833–8.
- [3] Kalantar M, Mousavi G. Dynamic behavior of a stand-alone hybrid power generation system of wind turbine, microturbine, solar array and battery storage. *Appl Energy* 2010;87:3051–64.
- [4] Rehman S, El-Amin IM, Ahmad F, Shaahid SM, Al-Shehri AM, Bakhawain JM, et al. Feasibility study of hybrid retrofits to an isolated off-grid diesel power plant. *Renew Sust Energy Rev* 2007;11(4):635–53.
- [5] Azoumah Y, Ramdé EW, Tapsoba G, Thiam S. Siting guidelines for concentrating solar power plants in the Sahel: case study of Burkina Faso. *Sol Energy* 2010;84:1545–53.
- [6] Deshmukh MK, Deshmukh SS. Modeling of hybrid renewable energy systems. *Renew Sust Energy Rev* 2008;12:35–49.
- [7] Hochmuth GCS. A combined optimisation concept for the design and operation strategy of hybrid-PV energy systems. *Sol Energy* 1997;61(2):77–87.
- [8] Shaahid SM, El-Amink I. Techno-economic evaluation of off-grid hybrid photovoltaic-dieselelectric power systems for rural electrification in Saudi Arabia – a way forward for sustainable development. *Renew Sust Energy Rev* 2009;13:625–33.

- [9] Papadopoulos DP, Maltas EZ. Design operation and economic analysis of autonomous hybrid PV-diesel power systems including battery storage. *J Electr Eng* 2010;61(1):3–10.
- [10] Ashari M, Nayar CV. An optimum dispatch strategy using set points for a photovoltaic PV/diesel/battery hybrid power system. *Sol Energy* 1999;66(1):1–9.
- [11] Ruther R, Martins D, Bazzo E. Hyrid diesel/photovoltaic systems without storage for isolated mini-grids sin Northem Brazil. In: *Proceeding of the 28th IEEE photovoltaic specialists conference, Anchorage, USA; 2000*. P. 1567–70.
- [12] Koutroulis E, Kolokotsa D, Potirakis A, Kalaitzakis K. Methodology for optimal sizing of stand-alone photovoltaic/wind-generator systems using genetic algorithms. *Sol Energy* 2006;80:1072–88.
- [13] Muselli M, Notton G, Poggi P, Louche A. PV-hybrid power systems sizing incorporating battery storage: an analysis via simulation calculations. *Renew Energy* 2000;20:1–7.
- [14] Musseli M, Notton G, Louche A. Design of hybrid-photovoltaic power generator, with optimization of energy management. *Sol Energy* 1999;65(3):43–57.
- [15] Lopez RD, Agustin JLB. Design and control strategies of PV-diesel systems using genetic algorithms. *Sol Energy* 2005;79:33–46.