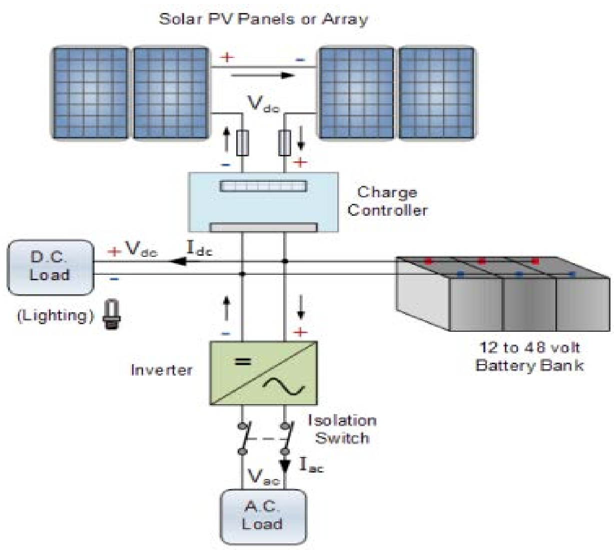

Figure 1: Off-Grid PV system [6]

2.2 Grid-tie

A grid-connected (figure 2) small solar electric or photovoltaic (PV) system receives back-up power from a utility's grid when the PV system is not producing enough power. When the system produces excess power, the utility is required to purchase the power through a metering and rate arrangement. Net metering is the best arrangement. Under this arrangement, the power provider essentially pays you retail price for the electricity you feed back into the grid [8].

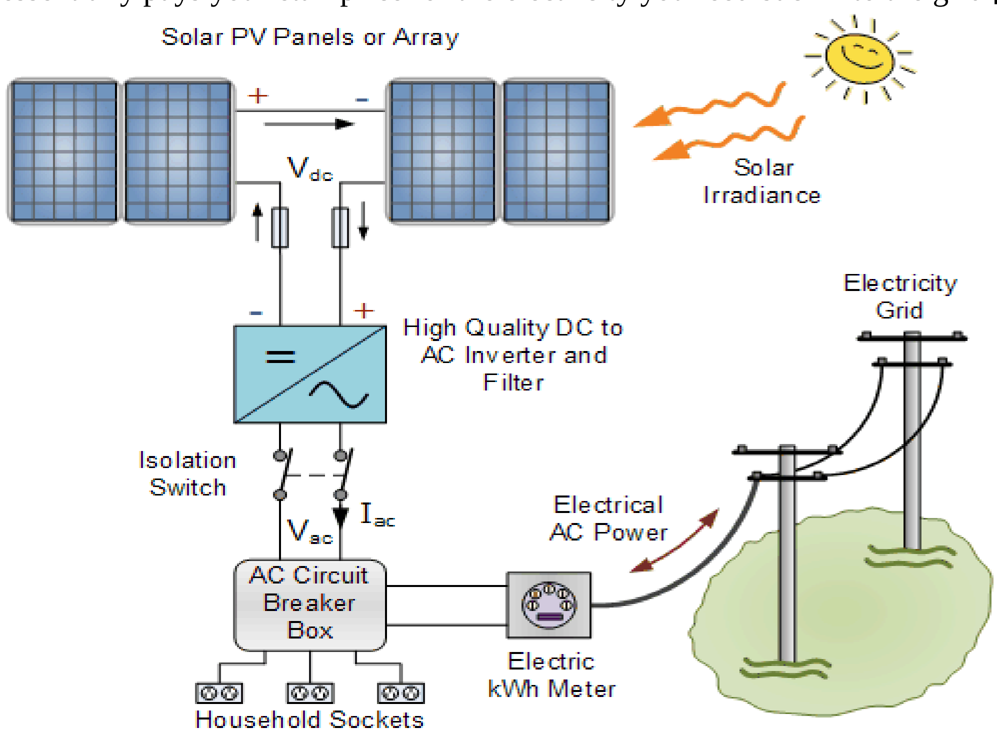

Figure 2: Simplified Grid Connected PV System [9]

In Nigeria, this is not encouraged as there is no provision for that. In a grid-tie system, your home runs on solar power during the day. Any surplus energy that you produce is then fed into the grid. In the evenings and at night, when your solar energy system is not producing electricity, you then buy your power from the electricity companies in the usual way. The benefit of grid-tie solar installations is that they reduce your reliance on the big electricity companies and ensure that more of your electricity is produced in an environmentally efficient way. One disadvantage of most grid-tie systems is that if there is a power cut, power from your solar array is also cut. Grid-tie can work especially well in hot, sunny climates, where peak demand for electricity from the grid often coincides with the sun shining, thanks to the high power demand of air conditioning units. Grid-tie also works well where the owners use most of the power themselves.

2.3 Grid-tie with backup or a grid interactive power system

A grid interactive solar power system (figure 3) is also connected to the traditional utility power grid and adds battery-backup to the system. The addition of a battery backup enables the system to balance production and demand and protects against power outages. Solar electric system production depends on the available sunlight. When sunlight is abundant, production can exceed demand. When production exceeds demand, the excess power can charge the batteries, which store the electricity. When the system is producing less electricity than demanded by the home, the batteries can make up the shortfall. Grid interactive systems are also connected to the utility power grid. This enables the homeowners to draw from the grid during periods of excess demand and to sell power to the grid when there is excess production. While grid interactive systems offer more flexibility, they are not without disadvantages. Charging and discharging batteries reduces the overall efficiency of the system and these systems are more complex to design and install and therefore more expensive. The cost of a grid-tie system with power backup is higher than a standard grid-tie system, because of the additional cost of batteries and battery controllers. Typically, having power backup will add 12–20% of additional costs over a standard grid-tie system.

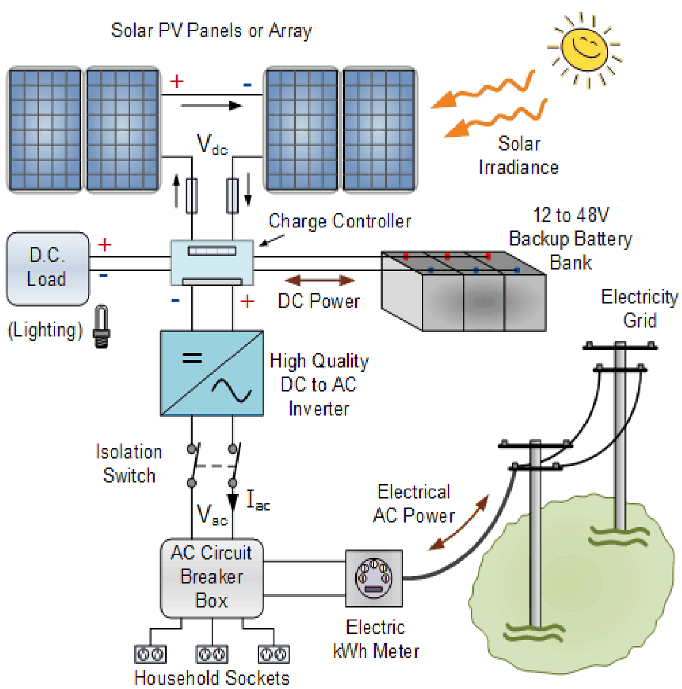

Figure 3: Grid Connected PV System with Battery Storage [9]

The additional cost of installing a grid interactive system over a standard grid-tie system is more than offset by the low running costs and ease of use of the system. Farmers do not need to buy and run generators and the system is almost entirely maintenance-free.

2.4 Grid fallback is most reliable and stable system mainly used for electrifying smaller households. Here solar modules charge a battery bank which in turn supplies distribution boards through an inverter. When the batteries are discharged to a pre-specified level, the system automatically switches back to the grid power supply. The solar modules then recharge the batteries and after the batteries are being charged up to a pre-specified level again the system switches back to solar power. We do not sell electricity back to the electricity utility companies through this system. All the power that we produce is utilized for ourselves only.
There is another type of PV system configuration, this is call grid failover

Grid failover
Alternatively, you can configure a grid fallback system as a grid failover system. A grid failover system kicks in when there is a power failure from your main electricity supply. In effect, it is an uninterruptable power supply, generating its power from solar energy. The benefit of this configuration is that if you have a power cut, you have contingency power. The disadvantage of this configuration is that you are not using solar power for your day-to-day use. In Africa and in many parts of Asia, grid failover systems reduce the reliance on power generators for lighting and basic electricity needs. However, in most cases, customers have found that a grid fallback or grid interactive system is more suitable for their needs. There are two types of grid failover systems that have been installed in the past: both of these have since been reconfigured as grid fallback systems.

3. DETERMINATION OF DC LOAD

The main objective of this paper is to design a PV system to power Polytechnic Medical Centre in the case of light out at the clinic vicinity. In emergency cases, it is not required to power the whole clinic but some points designated for DC loads. The designated DC load as a case study in this paper is tabulated in table 1. The system was designed to power the required loads for 10 hours per day

Table1: Total DC Loads

S/N	Appliances	Quantity	Actual load in Watts	Total load in Watts	Operating time (Hours/Day)	Watts-Hour/Day
1	LED Lights	10	5	50	10	500
2	LED TV	3	25	75	10	750
3	Cell Phone	5	4	20	10	200
4	Fans	5	20	100	10	1000
5	Imaging Diagnostic	1	400	400	10	4000

	Equipment					
6	Genotype Machine	2	100	20	10	200
	Total Load (Watts)			**665**		
	Total Watt-Hour Per Day					**6650**

4. BACKUP DESIGN

In selecting the size of back up within the time frame per day, the formula in equation 1 was used. A block type of battery was assumed to be used for this design and it's of the rating of 200AH Quanta product.

$$C_{BAh} = \frac{E_{db} \times DOA}{DOD \times \eta_{BA} \times V_B} \quad [10] \qquad 1$$

Where

E_{db} = Daily energy required from battery

C_{Bah} = Battery capacity

AD = DOA = Autonomy days or Days of autonomy

DOD = Depth of discharge = 80%

η_{inv}= Inverter efficiency = 95% (1.0 if there is no inverter)

η_{BA}= Ampere efficiency of battery = 80%

V_B = Selected nominal DC Voltage of the block battery (12V)

To calculate the number of series and parallel batteries needed for this design, the formula by Ayaz was used as we have it in equation 2 and 3.

$$N_{Pb} = \text{Total Number of Batteries} = \frac{\text{Total Capacity of battery (AH)}}{\text{Battery Capacity (AH)}} = \frac{C_{tb}}{C_b} [11] \qquad 2$$

$$N_{Sb} = Number\ of\ series\ batteries = \frac{VDC}{V_b} = \frac{System\ Voltage}{Battery\ Voltage} \qquad 3$$

Where, N_{sb} and N_{pb} are number of series and parallel batteries respectively

Recall from equation 1 that, $C_{BAh} = \frac{6650 \times 1}{0.8 \times 0.9 \times 12} = 769.7AH$

Therefore the backup battery would be 800AH.

The series and parallel backup are calculated as ths:

From equation 2, $N_{Sb} = \frac{12}{12} = 1$ and $N_{Pb} = \frac{800}{200} = 4$

5. PV SYSTEM DESIGN AND SIZING

In this section, the design of the various part of the PV system is presented. Figure 3 shows the required PV system to be implemented for powering the Polytechnic Medical Centre Bida, Niger Sate Nigeria. To calculate the wattage of the Solar Panels, the method adopted by Bhatia was used.

$$W_{PV} = \frac{E}{PSH \times \eta_{sys}} \quad [\mathbf{6}] \qquad \mathbf{4}$$

Where

W_{PV} = Peak wattage of the array, Wp

E = is the daily energy required, Wh

PSH = Average daily number of peak sun hours in the design month for inclination orientation of the PV array (6.2kwh/m^2).

η_{sys} = total system efficiency = 95%

$$Total\ DCCurrent, I_t = \frac{Average\ Peak\ Power\ (Watts)}{System\ Voltage(V_{SP})} \qquad 5$$

$$Number\ of\ Series\ Module, N_S = \frac{System\ Voltage(V_{SP})}{Max.Panel\ Voltage\ (Panel\ Short\ Circuit\ Voltage)} \qquad 6$$

$$\text{Number of Paralell Module, } N_P = \frac{I_t}{I_m} \qquad 7$$

Where I_m = Module Current or PV Current

$$N_t = \ N_S \times \ N_P \qquad 8$$

Therefore, Peak wattage of the array (4), $W_{PV} = \frac{6650}{6.2 \times 0.95} = 1129Wp$

Obtaining the total DC current, equation 5 was adopted;

$I_t = \frac{665}{12} = 55.4A$

Similarly number of series module, parallel modules and total number of panels can be obtained as follows from equation 6, 7 and 8 respectively.

$$N_S = \frac{12}{30} = 0.4$$

This result translated to 1 number of panel to be connected in series (no series connection) and for parallel,

$N_P = \frac{55.4}{7.9} = 7.1$ and the total number of panels would be;

$N_t = \ 1 \times \ 7.1 = 7.1$

From equation 4, peak wattage of the array was obtained to be 1129Wp, equation 7 give a total of 7.1 numbers of parallel panels, and equation 8 produced a round figure of 7panels in total. therefore, for a good yield, a total number of 8 panels was selected each rated at 200Wp. The electrical specification of the solar panel used is shown in table 2

Table 2: Electrical Characteristics of Solar Panel used:

Item No.	XRM-200W
Maximum power (Pmax):	200 Watts
Open circuit voltage (Voc):	30.0 Volts DC
Maximum power point voltage (Vmpp):	25.5 Volts DC
Short circuit current (Isc):	7.83 Amps
Maximum power point current (Impp):	7.9 Amps
Module efficiency:	17.89%
Power sorting:	-0Wp / +5Wp
Maximum system voltage:	1000 Volts DC
Cells per module:	60
Cell type:	mono crystalline
Connector:	PV wire (UL4703) with Amphenol UTX interlocking connectors

6. SELECTION OF CHARGE CONTROLLER

Calculate PV Array Current (Minimum Controller Input Current)

PV Array Current = I_{SC} x P_{VP} x Safety Factor 9

I_{SC} = Module short circuit current = 8.7 amps

P_{VP} = PV modules in parallel = 8 no.

Safety Factor = 1.25

PV Array Current = 7.8 x 8 x 1.25 = 78A

Therefore, a 12V/100A charge controller was selected.

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7. SYSTEM BLOCK DIAGRAM AND SCHEMATIC DIAGRAM

Overall block diagram and schematic diagram of 665W PV system is as shown in figure 3.1 and 3.2 respectively

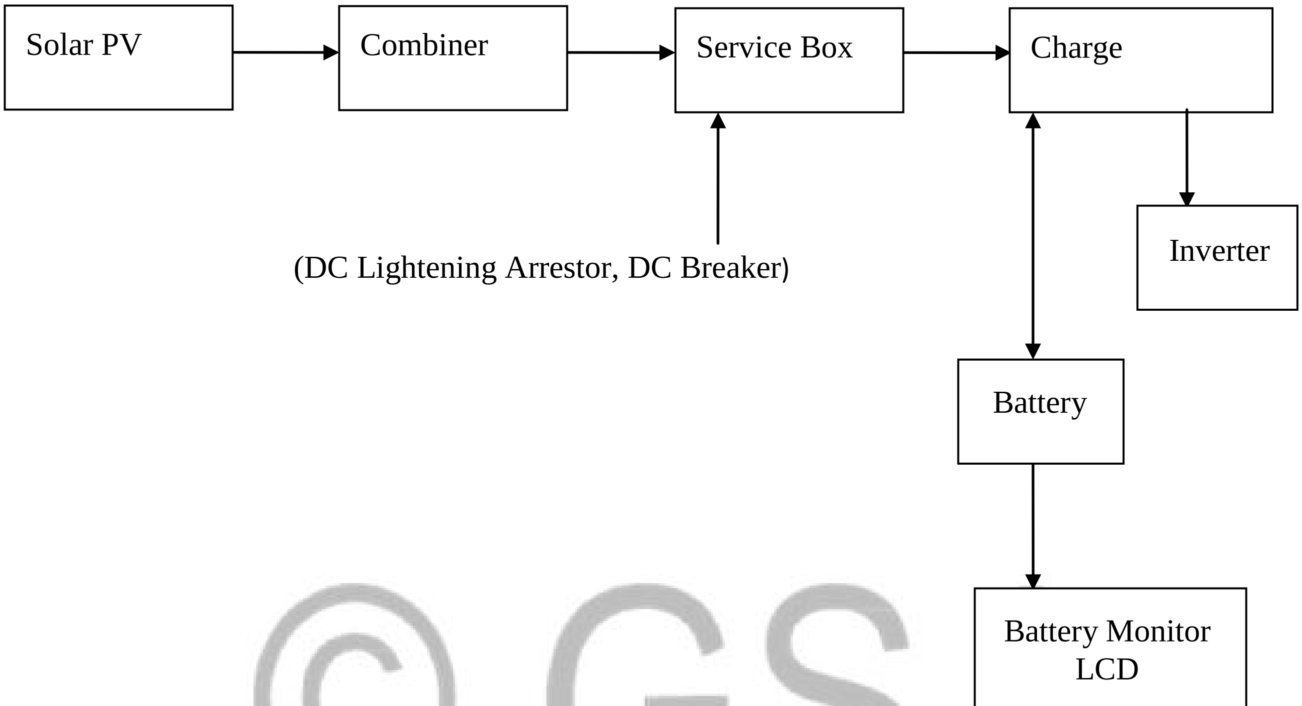

Figure 3.1: Block Diagram of 665W Solar PV System

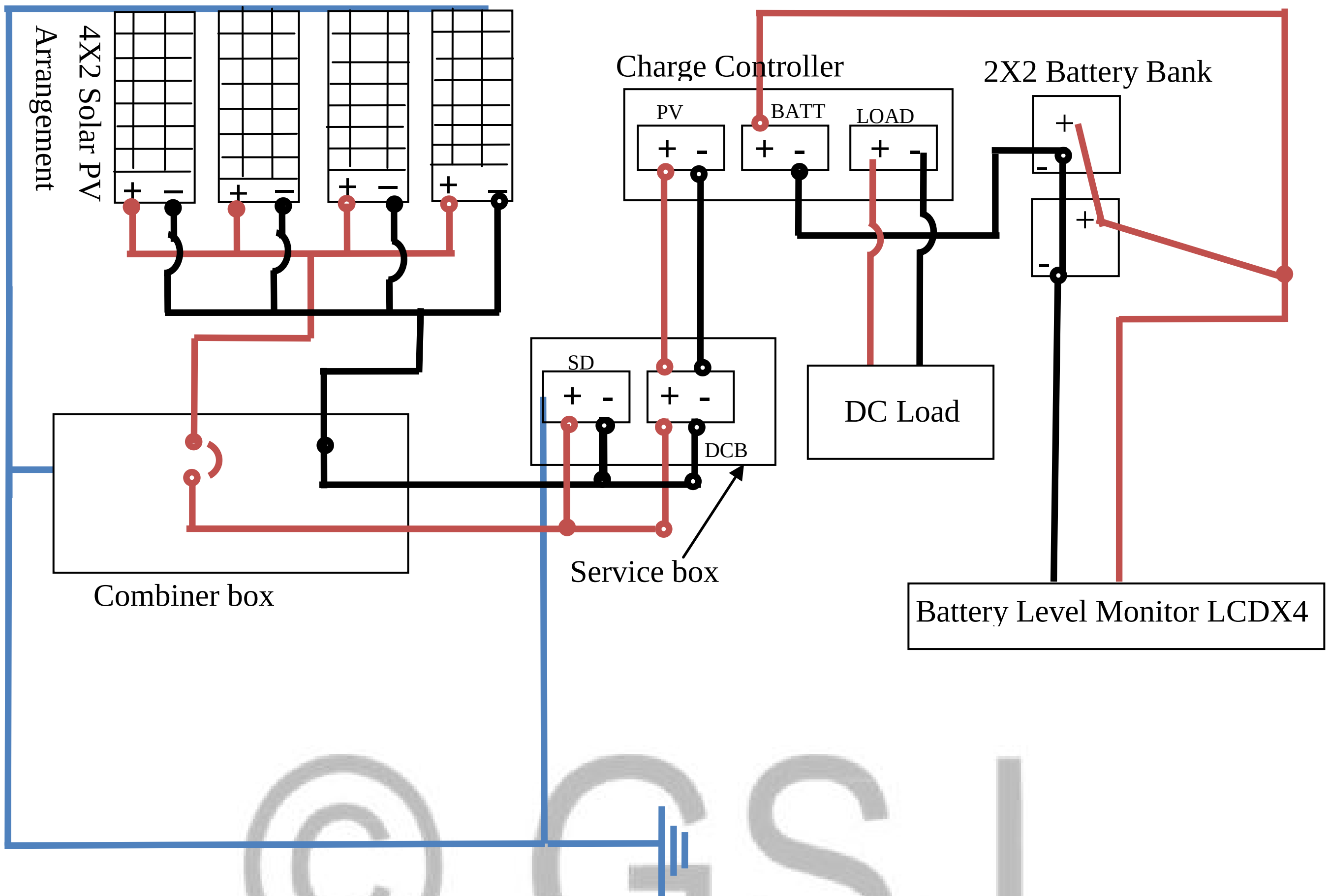

Figure 3.2: Schematic Diagram of 665W Solar PV System

8. CONCLUSION

A PV system for powering the Federal Polytechnic Medical Centre Bida was implemented. The Dc loads was used instead of the normal loads. It consumes less power. Thus it reduces the overall cost of the PV system. The required load is completely determined. Each part of the PV system is designed and sized. The implemented system was tested. It works effectively. It powers the required load for ten continuous hours when light goes out.

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