Design and Simulation of Uninterrupted power supply system of a Clinic With the help of stand by photo voltaic generator

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ABSTRACT

In this research, uninterrupted power supply system is designed to solve the seriously occurring power interruption problem of a clinic found in remote area (chertekel clinic) by interconnecting photovoltaic generator to the grid with advanced control mechanism.

The solar energy potential of the sight was collected from the regional meteorology agency.The load profile of the clinic was collected forload analysis and solar PV sizing .To check whether the PV system can acts as a backup for the clinic in case of grid failure and vice versa,feasibility study was done by HOMER software.

The system was designed to supply uninterruptable energy to the loads with the aid of automatic transfer switch. All the programming and design of the system is done by protues software with the help of ardiuno microcontroller as a brain to control the system. Finally, the total system response is checked in case of grid power failure as well as when the PV system is failed.

Key words: ardiuno, automatic transfer switch, feasibility, uninterrupted,

1. INTRODUCTION

Chertekel town and surrounding communities located (10° 21' 0" North, 37° 44' 0" East) is one of the remote rural towns of Ethiopia which experience for a continuous electric power interruption for a long period of time.Such type of problems can be solved by renewable energy technologies such as solar Energy Systems. Solar energy is one of the major renewable energy resources that can be used for different applications, such as solar power generation, solar water heaters, solar calculators, solar chargers, solar lamps, and so on [1]. There are various advantages of solar energy usage in electric power generation including low pollution, cost-effective power generation (neglecting installation cost), maintenance free power system, etc [2].

Solar PV system includes different components (solar module, solar charge controller, inverter, battery bank, and loads) that should be selected according to the system type, site location and applications [2][3].

A. PV module

A single cell generates very low voltage (around 0.4), so more than one PV cells can be connected either in serial or in parallel or as a grid (both serial and parallel) to form a PV module. When we need higher voltage, we connect PV cell in series and if load demand is high current then we connect PV cell in parallel.

The PV array connects to it in order to provide charging a charge controller. The battery bank is also connected to the inverter to provide power for the AC loads. If the system also uses DC loads, the battery bank is wired to a DC load center.

B. Battery Bank

For systems that require energy storage, like any system that needs to operate without the utility grid. A battery bank, multiple batteries wired together to achieve the specific voltage and energy capacity desired. The battery bank is typically housed in a container to keep the batteries safe.

C. Charge Controller

A charge controller is a piece of electronics that is placed between the PV array and the battery bank. Its primary function is to control the charge coming into the battery bank from the PV array. Charge controllers can vary from a small unit intended to connect a single PV module to a single battery all the way to a controller designed to connect a multiple-kilowatt PV array to a large battery bank.

D. Inverter

Inverters turn the DC power produced by PV arrays or stored by battery banks into the AC power used in homes and community services.

E. Loads

Loads are all the pieces of electrical equipment people want to use in their homes and offices.The Figure bellow manifests the equivalent circuit of PV cell. The circuit has a current source (photocurrent), a diode parallel to it, a resistor in series describing an internal resistance to the flow of currentand a shunt resistance which expresses a leakage current.

The current supplied to the load can be given as.

$$I = IPV - [Io\left[\exp\frac{V + IRS}{aVT}\right] - 1] = [\frac{V + IRS}{RP}]$$

(1)

Where

IPV–Photocurrent current

Io–diode’s Reverse saturation current

V–Voltage across the diode

A – Ideality factor

VT–Thermal voltage

Rs– Series resistance

Rp–Shunt resistance

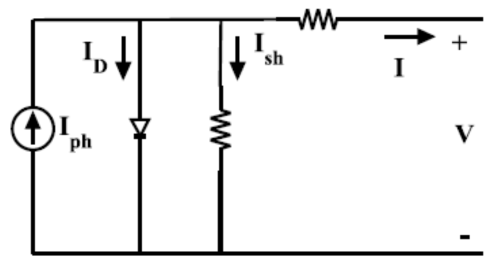

Figure 2.**1** equivalent circuit of single diode modal of a solar cell

3. MATERIALS AND METHODOLOGY

3.1. BASIC BLOCK DIAGRAM OF THE SYSTEM

To solve the power interruption problem of the selected clinic at the desired area, the following general scheme was developed.

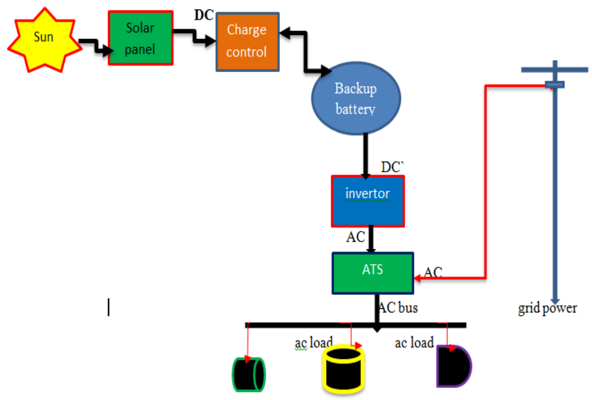

Figure.3.1 Block Diagram of Stand by Solar Power Generation System

When the grid power is on, the photo voltaic generator will be at off state. But when the grid power is interrupted, the generated power from the PV generator is automatically on and starts to feed the load as a means of compensation. Once the grid power starts up again the PV system automatically switches back to normal operation. This can be done by using automatic transfer switch.

3.2. MATERIALS USED FOR THE SYSTEM

Automatic transfer switch (ATS): is an electrical switch that switches a load between two sources.

Relay: it is an electrical protective element used to protect the power system from any damage by tripping on and off whenever fault is occur. So, for this research, it is used as a switch between the two sources by energizing and de-energizing itself.

Transformer: I use two transformers as source.

Voltage sensor: is a device that converts voltage measured between two points of an electrical circuit into a physical signal [5].

Current sensor: is a device that detects electric current (AC or DC) in a wire, and generates a signal proportional to it. The generated signal could be analog current or even digital output.

Microcontroller: A microcontroller is a computer present in a single integrated circuit which is dedicated to perform one task and execute one specific application. It contains memory, programmable input/output peripherals as well a processor

3.2.1. Hospital Arrangements of ATS

Automatic Transfer Switch (ATS) have very unique requirements for the design of a hospital emergency system. The emergency system is classified into the essential electrical system and the emergency system itself.

Emergency system is "a system of circuits and equipment intended to supply alternate power to a limited number of prescribed functions vital to the protection of life and safety". The emergency system is a part of the essential electrical system.

The essential electrical system supplies the equipment system, defined as "a system of circuits and equipment arranged for delayed, automatic, or manual connection to the alternate power source and that serves to the equipment.

The emergency system supplies, which itself part of the essential electrical system, supplies the life safety branch, which is "a subsystem of the emergency system consisting of feeders and branch circuits intended to provide adequate power needs to insure safety to patients and personnel". The emergency system also supplies the critical branch, which is "a subsystem of the emergency system consisting of feeders and branch circuits supplying energy to task illumination, special power circuits, and selected receptacles serving areas and functions related to patient care".

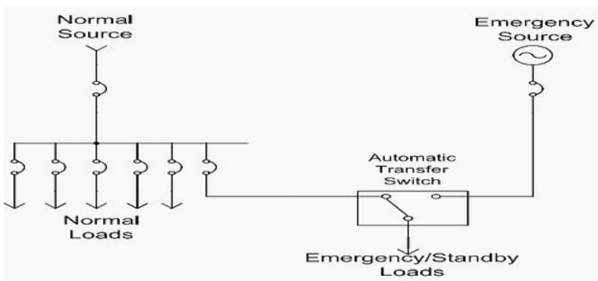

Figure 3.2. Over all Diagram of ATS

3.3. DATA ANALYSIS

The proposed system is designed to solve the problem of the clinic and community as a hole whenever the grid power is interrupted, and if no presence of sun for a minimum of three days. Therefore, all the design considerations were done based on this. In the selected clinic, the following load analysis was done as

Power × Quantity × Time= Energy

In this section all site power loads are calculated according to the quantity of each appliance, wattage of the appliance and the timesused in each load. As mention before, this research considered certain load forecasting.

Lamp: there are around 25 lamps with 32w and each works for 12 hours aday

Total power consumption for lighting= No of lamp x Wattage of lamp

Total power consumption for lighting =50x 32w= 1.6kW.

Television: there is around 1 TV with 200w and those works 9 hour aday,

Power consumption = No of TV wattage

So Power consumption = 1.8kwh/day.

Fridge: there are 2 fridges with 250w and the operation time is 6 hour day .So power consumption can be calculated as:

Power consumption = No of fridge × Wattage = 2×250w= 0.5kw

Total watt hour /day=No of fridge × wattage × hour = 2 × 250w × 12hr = 6kwh/day

Computer: there are 5desktop computer with 200w and works for 12 hour per day.

Power consumption = No of computer × wattage = 5 × 200w = 1kw

Total watt hour /day = no of computer × wattage × hour = 5 × 200w × 12hr = 12kwh/day

Total power consumption is 12kwh/day.

Stove: there are around 2 stove with 1,000 w and they operate 4 hours a day.

So, power consumption calculated as = 2kw.

Total watt hour /day = (no of computer) (wattage)(hour)

= 8kwh/day.

Slit lamp: currently no slit lamp but there will be 5 slit lamps with 20 watt ratting and they operate 6 hour a day.

Therefore the power consumption of this machine can have 0.600kwh/day.

Ultrasound: there are around 2 currently with wattage of 15w and operates 11 hour aday.So power consumption of this machine can be calculated as 0.33kwh/day.

Portable Autoclave: there will be around 12autoclave with 75w and operates 12hour perday. Therefore the power consumption of this machine is about 1.71kwh/day.

Operational Microscope: there 2 operational microscopes with wattage of 27w and prate12 hours aday. The power consumption of this machine is 0.65kwh/day.

Chemistry Analyzer: currently no but there will be 3 with ratting of 40w and operate 16 hour a day, so the power consumption of this machine is 1.92Kwh.

Hematology Analyzer: currently no but there will be around 3 with wattage of 100 w and operate 12 hours a day on average.

The Power consumption is 3.6kwh/day.

Oxygen Concentrator: There are be 5 Oxygen concentrator with wattage of 400w and operate 24 hour a day. Power consumption is about 48kwh/day.

Dental Machine: There will be 3 with 6w and operate 7hour a day on average so power consumption is 0.126kwh/day.

Cellphone Charger: According to the interview that I have conducted there are around 10 cellphone charger currently of 3w and operate 6hour on average. So power consumption is 0.45kwh/day.

Straight light (MASTER LED spot 230V):currently there are around 4 with wattage of 16w and operate 12hour per day. So the power consumed by the Straight light will be 0.3kwh/day.

Printer: there is one printer but there will be 2 printer machine with wattage of 60w and operate 10 hours a day on average. So power consumption is: 1.2kwh/day.

So the total power consumption after doing load analysis, in the clinic is about 8.8KW. With the consideration of population growth rate of 1.015, the total energy with in the clinic is about 79.27 KWh/day.

4. DESIGNING AND MODELING

The solar Optimization Model for Electric Renewable (HOMER) is used to model a power system physical behavior and its life-cycle cost, which is the total cost of installing and operating the system over its life time. The design of a stand-alone PV power supply system to a model clinic is carried out based on the theoretical background discussed so far. HOMER software was used as a tool to accomplish the feasibility study for the research. HOMER performs three principal tasks: simulation, optimization, and sensitivity analysis based on the raw input data given by user

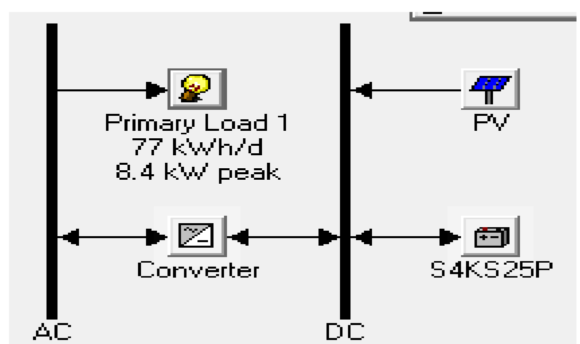

Fig.4.1. HOMER diagram for the solar system

5. OPTIMIZATION RESULTS

The simulation process models a particular system configuration, whereas the optimization process determines the best possible system configuration. The best possible or optimal system configuration is the one that satisfies the user-specified constraints at the lowest total net present cost [6]. Finding the optimal system configuration may involve deciding on the mix of components that the system should contain, the size or quantity of each component, and the dispatch strategy the system should use. In the optimization process, many different system configurations are simulated; the infeasible ones are discarded, the feasible ones are ranked according to total net present cost, and the feasible one is presented with the lowest total net present cost as the optimal system configuration.

Based on the HOMER modeling, the optimal system for the clinic in figure 5.1 a first row, a solar PV /Battery/Converter, with 22 kW of solar, 30 S4KS25P batteries (each 1900AH capacity) and 8 kW inverter are required power supplied for the clinic . This “optimal” system uses 100% Renewable energy, and the cost of electricity is $0.359/kWh including depreciation on capital and leveled Operation &Maintenance with net present cost of $135416.Based on the HOMER modeling, the optimal system for the clinic in figure 5.1.a first row, a solar pv /battery/converter, with 22 kW of solar, 30 S4KS25P batteries (each 1900AH capacity) and 8 kW inverter are required power supplied for the clinic . This “optimal” system uses 100% renewable energy, and the cost of electricity is $0.359/kWh including depreciation on capital and levelized O&M with net present cost of $135416.

Sensitivity Results | Optimization Results

Double click on a system below for simulation results.

PV (kW)	S4KS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Batt. Lf. (yr)
22	30	8	$ 73,400	4,400	$ 135,416	0.359	1.00	0.10	12.0
23	30	7	$ 73,600	4,390	$ 135,476	0.360	1.00	0.09	12.0
22	30	9	$ 74,400	4,447	$ 137,080	0.363	1.00	0.09	12.0
23	30	8	$ 74,600	4,437	$ 137,140	0.360	1.00	0.08	12.0
23	30	9	$ 75,600	4,485	$ 138,805	0.364	1.00	0.07	12.0
20	36	7	$ 77,800	4,583	$ 142,394	0.380	1.00	0.09	12.0
19	36	9	$ 78,600	4,640	$ 143,999	0.384	1.00	0.10	12.0
20	36	8	$ 78,800	4,630	$ 144,059	0.380	1.00	0.08	12.0
22	36	6	$ 79,200	4,610	$ 144,180	0.389	1.00	0.10	12.0
20	36	9	$ 79,800	4,677	$ 145,723	0.384	1.00	0.07	12.0
22	36	7	$ 80,200	4,658	$ 145,844	0.384	1.00	0.07	12.0
23	36	6	$ 80,400	4,648	$ 145,904	0.392	1.00	0.09	12.0
22	36	8	$ 81,200	4,705	$ 147,508	0.383	1.00	0.05	12.0
23	36	7	$ 81,400	4,695	$ 147,569	0.386	1.00	0.06	12.0
22	36	9	$ 82,200	4,752	$ 149,173	0.387	1.00	0.05	12.0
23	36	8	$ 82,400	4,742	$ 149,233	0.385	1.00	0.04	12.0
23	36	9	$ 83,400	4,789	$ 150,898	0.389	1.00	0.04	12.0
19	42	7	$ 84,400	4,850	$ 152,762	0.408	1.00	0.09	12.0
18	42	9	$ 85,200	4,908	$ 154,367	0.413	1.00	0.10	12.0
19	42	8	$ 85,400	4,898	$ 154,427	0.408	1.00	0.08	12.0
20	42	7	$ 85,600	4,888	$ 154,487	0.409	1.00	0.08	12.0
19	42	9	$ 86,400	4,945	$ 156,091	0.411	1.00	0.07	12.0
20	42	8	$ 86,600	4,935	$ 156,152	0.408	1.00	0.06	12.0
22	42	6	$ 87,000	4,915	$ 156,272	0.419	1.00	0.09	12.0
20	42	9	$ 87,600	4,982	$ 157,816	0.411	1.00	0.05	12.0
22	42	7	$ 88,000	4,962	$ 157,937	0.412	1.00	0.06	12.0
23	42	6	$ 88,200	4,952	$ 157,997	0.421	1.00	0.08	12.0

Figure 5.1.Overall optimization results for PV of the system

The energy yield from the System is shown in figure 3.2 of the total primary energy requirement (28105kwh/yr) for this clinic; solar PV produced almost 100% of the energy.

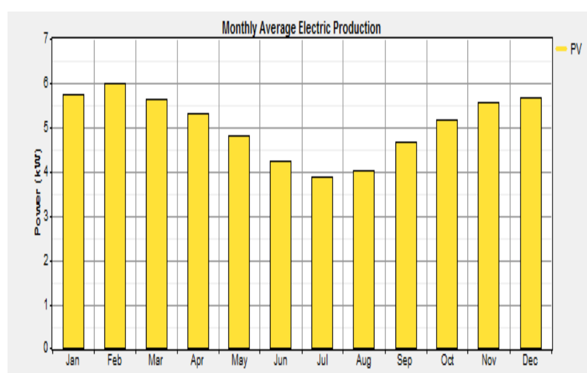

Figure 5.2. Monthly average Electric production of the clinic from the system

5.1. Economic Analysis

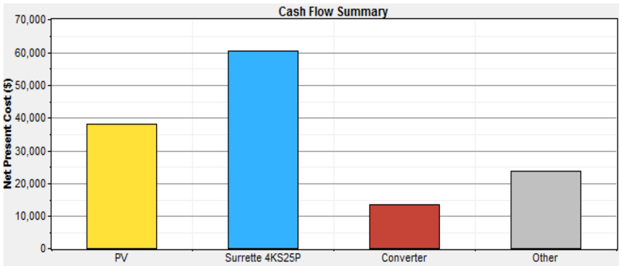

Figure 3.3. Cash flow summery for the systems

Quantity	Value	Units
Rated capacity	22.0	kW
Mean output	5.1	kW
Mean output	121	kWh/d
Capacity factor	23.0	%
Total production	44,261	kWh/yr

Quantity	Value	Units
Minimum output	0.0	kW
Maximum output	24.7	kW
PV penetration	157	%
Hours of operation	4,464	hr/yr
Levelized cost	0.0608	$/kWh

Figure 3.4 basic information of pv system of the simulation

As observed from the tables above 22kw panels are required to satisfy the need of the clinic.so by selecting the panel with rating of 300w ,panel nominal voltage 12v and system panel voltage 24v,it is possible to determine the total number of panel ie 22kw/300w=73.33 ≈ 74 these are the total number of panel. Now number of panel in series is calculated as system voltage /nominal voltage = 24/12=2.

And no of panel in parallel = total panel /no of panel in series, 74/2 = 37.

Quantity	Value
String size	6
Strings in parallel	5
Batteries	30
Bus voltage (V)	24

Quantity	Value	Units
Nominal capacity	228	kWh
Usable nominal capacity	137	kWh
Autonomy	42.6	hr
Lifetime throughput	317,058	kWh
Battery wear cost	0.127	$/kWh

Figure 3.5.Battery Information of the system.

There are six batteries in series and five batteries in parallel, so totally, there are 30 batteries in the system and the system voltage is 24 V and battery nominal voltage is 4v.

Quantity	Inverter	Rectifier	Units
Capacity	8.00	8.00	kW
Mean output	3.06	0.00	kW
Minimum output	0.00	0.00	kW
Maximum output	8.00	0.00	kW
Capacity factor	38.2	0.0	%

Figure 3.6.Basic Information of invertor of the system

As it have been shown in the result, the total capacity of the inverter is 8kw so by selecting the inverter with 12v and 1200w each, No of inverter = 8000w/1200w = 6.66 ≈ 7 inverters are needed.

6. SIMULATION RESULT AND DISCUSSION OF THE CONTROL SYSTEM

6.1. OVER ALL CIRCUIT DIAGRAM OF THE SYSTEM

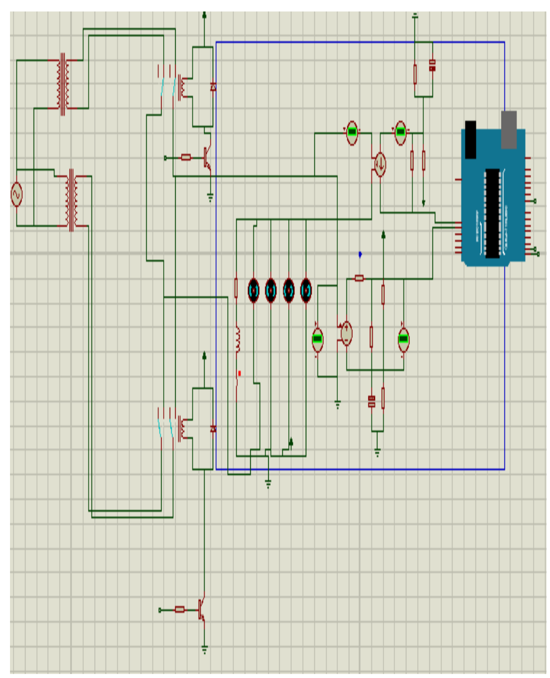

Figure 6.1 general circuit diagram of the system

As shown in fig 6.1 above the two transformers are used as a source the one is as grid and the other is as a generated (solar) power.at normal condition the grid power feeds the load. But whenever the grid power is interrupted due to some fault that occur along the grid power system, the other transformer which act as generated (solar) power is ready and automatically send the power and feed the load.

The two relay are used to switch the system on/off by when they are energized/de-energized depending on the source power. The two transistors are internally interconnected with the ardiuno microcontroller by port and ordered by the program that is written on the ardiuno.

Motors are used as a load of the system. A switch is used to switch ON/OFF the grid power for looking the response of the generated (solar) power. Current&voltage sensor are used to detect the current and the voltage within the system respectively.

Voltmeter and ammeters are used to read the voltage and current with in the circuit.Ardiuno microcontroller is used to coordinate and manage the whole system based on the program.

As simulation results showed as when there is sudden interruption of the grid power, our load can automatically get power from the PV system .This means the loads are consuming power fore ever.

Additionally, when the PV generator is failed to deliver power to the load due to some condition, the grid can supply the load. From the total simulation results of the proposed system, it has been concluded that, the problem of power interruption of the clinic and the surrounding community can be solved by installing solar and grid power to provide a continuous energy supply to the load.

7. CONCLUSION

The results showed that the designed system configuration is enough to supply the overall load demand of the system. Homer has several configuration choices with different Net Present Cost, which gives different possible design options for the designer to choose from.

We concluded that the design of this study is feasible to supply the entire load having economical cost from construction up to its lifetime. Even though its initial cost is so high, it is free from any running cost, and environmental friendly.

Finally the unique merit of this system is being automatic by using (ATS) since no need of manual involvement during operation as well as the problems in the hospital due to the power interruption will be illuminated with a continuous power supply to the load without any need of human involvement.

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