ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

Concept Design and Parameter Estimation of a Solar Photovoltaic UPS and Supplementation System

Mohd. Abdul Muqeet[1], Ajaz Fatima[2], Md.Ismail.B[3], Md.Abdullah[4]

Associate Professor, Electrical Engg. Dept., Muffakham Jah College of Engineering and Technology, Hyderabad, India[1]

Associate Professor, Electrical Engg. Dept., Muffakham Jah College of Engineering and Technology, Hyderabad, India[2]

Sr. Assistant Professor, Electrical Engg. Dept., Muffakham Jah College of Engineering and Technology, Hyderabad, India[3]

Sr. Assistant Professor, Electrical Engg. Dept., Muffakham Jah College of Engineering and Technology, Hyderabad, India[4]

ABSTRACT*:* This paper aims to demonstrate the application of solar energy as source for battery bank charging to provide backup power to 40 desktop computers (primary load) of a computer lab whose total energy consumption is estimated to be 8KW-hr for approximately 30 min using the existing 10KW Inverter Charger UPS and battery bank with capacity of 8.064 KW-hr (16 batteries x 12V per battery x 42Ahr) supplemented by an additional setup of 3KW inverter. This demonstration is provided by obtaining the theoretical computation of output power, output current and output voltage developed due to solar irradiance. The project also aims to directly feed power to the 40 Desktop computers i.e. primary load when the battery bank is fully charged with the power generated from solar panels. The proposed conceptual design also provides solution to switch over the power to secondary load if the primary load is not in use.

KEYWORDS: Solar Photovoltaic UPS, Inverter, battery bank.

I.INTRODUCTION

Renewable energy is the energy that comes from natural resources such as sunlight, wind, tides, rain, and geothermal heat. These energies are derived from natural processes that are restored constantly. Electrical energy is derived from solar, wind, ocean, hydropower, biomass, geothermal resources, biofuels and hydrogen [1], [2].Conventional power generating station like thermal power generation plant [3], and nuclear power generation plant [3] cause heavy pollution to atmosphere. Therefore, it needs urgent invention and development of systems to utilize non-conventional energy resources. The most popular non-conventional power resource is solar energy which converts solar energy or solar heat to electricity. Off-grid PV systems are not connected to the public electricity grid [7]. A typical off-grid system comprises mainly the components like Solar PV Modules, Charge Controllers, Battery or Battery Bank and an Inverter [7]. The solar energy can be used to charge battery bank and provide the backup power during no sun shine period by storing the excess power or some portion of power from these PV systems. An uninterruptible power source or uninterruptible power supply (UPS) is an electrical apparatus that provides emergency power to a load when the input power source, typically the utility mains, fails without any power interruption unlike in standby generators [4]. The UPS system also prevent undesired feature that can occur within the power source such as outages, sags, surges and bad harmonics from the supply to avoid a negative impact on the devices [9].Authors used a photovoltaic powered standby UPS using smart relay [9] and a battery is charged with the PV solar charger controlled by the smart relay. The authors proposed to use this set-up for a load of 240V, 20W and the load and battery current were 0.1A and 1.56A, respectively [9]. The solar photovoltaic system powered by UPS system requires smart control for efficient battery bank charging. As the solar PV systems output entirely depends on solar radiations the use of Maximum Power Point Tracking (MPPT) technique is quite common in the field of Solar Energy Systems [8]. In [6] the authors presented an energy management system and controller design of the solar aided UPS implemented with the half-bridge converter. The designed DC-DC converter employs the voltage mode control using Maximum Power Point Tracking (MPPT) and the battery charging control loop effectively balance the power from the PV module to the battery and the load [6]. The purpose of this study is to evaluate the technical feasibility combining a solar photovoltaic powered UPS system with an additional supplementation system. The main system consists of solar PV module, solar charge controller and is supplemented by a 3KW inverter and a energy selection switch. The aim is to connect the two systems i.e one existing system of 10KW inverter which is powered by Solar PV module and a supplement system comprising a 3KW inverter and energy selection switch in order to continuously use solar energy to power a primary load. The proposed related

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

computations aims to construct a system for efficiently utilizing the solar energy for providing back up power to 40 PCs (primary load) in addition to charge existing battery bank. Section II describes the hardware description of the proposed design. Section III provides the working description of the proposed design. Results of the proposed estimation are depicted in Section IV and conclusion is provided in Section V.

II. HARDWARE DESCRIPTION OF THE PROPOSED DESIGN

The block diagram for the proposed solar photovoltaic backup UPS and the supplement system is depicted in the Figure. 1. An existing 10KW Inverter Charger UPS is proposed to be used, discarding its charging function using AC supply since the batteries will be charged using solar energy. It will convert DC from the battery to useable AC supply and will also enable the system to function as an UPS (Uninterruptible Power Source). The supplemented system consists of 3KW inverter and an energy selections switch to switch from primary load to secondary load. Since the idea is to use renewable solar energy the first thing to do is to convert the solar energy to electrical energy for which solar panels are being used. The design of our proposed solar photovoltaic (PV) UPS and supplementation system comprises of the following major components:

1. Solar panels
2. Shunt Solar Charge Controller
3. Battery Bank
4. Existing 10kW Inverter Charger
5. 3kW Inverter
6. Automatic Energy Select Switch

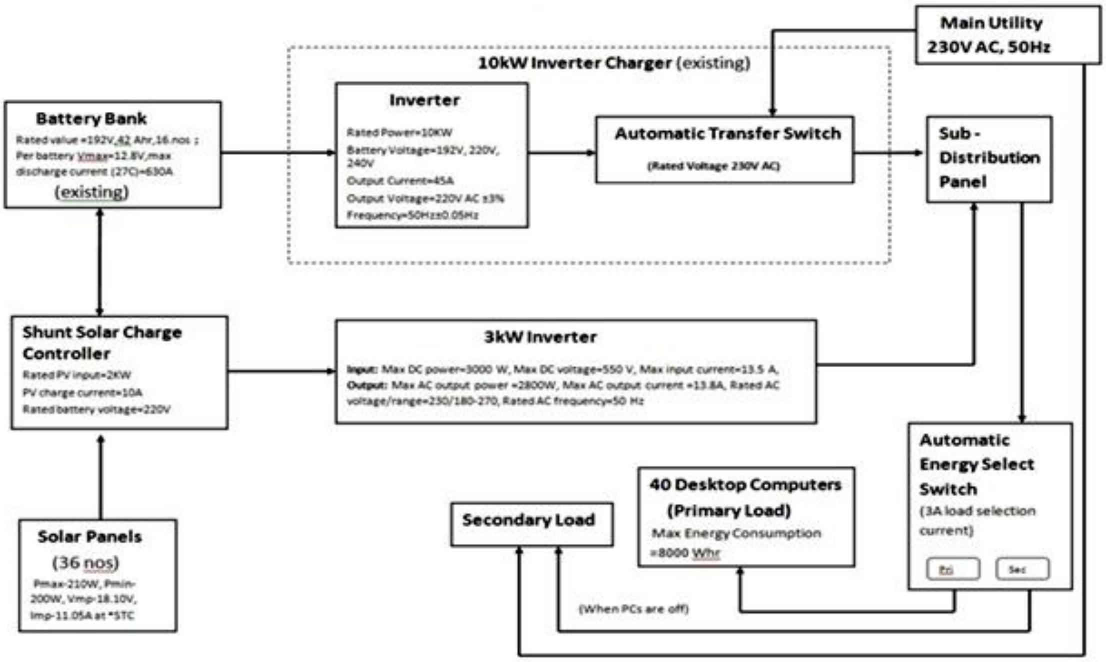

Fig.1 Block Diagram for Solar Photovoltaic powered UPS and the Supplement System

1) Solar Panels

A solar panel (also solar module, photovoltaic module or photovoltaic panel) is a packaged connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each panel is rated by its DC output power under standard test conditions (STC) [10], and typically ranges from 100W to 450W [5]. As a single solar panel can produce only a limited amount of power, most installations contain multiple panels. A photovoltaic system typically includes an array of solar panels, an inverter, and sometimes a battery and or solar tracker and interconnection wiring. In our proposed design computation we considered about 36 crystalline panels, each have a maximum power output of 210W and the voltage and current rating of 18.10V and 11.05A respectively at standard test conditions(STC) i.e at cell temperature 25°C, irradiance is 1000 W/m² and AM 1.5[10].

2) Solar Charge Controller:

A charge controller or a charge regulator or a battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may prevent against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk [2]. It may also prevent complete draining of the battery and also performs controlled discharging which protect battery life. The terms "charge controller" or "charge regulator" may refer to either a stand-alone device, or to control circuitry integrated within a battery pack, battery-powered device, or a battery recharger. We have proposed to select a shunt charge controller with rated photovoltaic input power as 2KW, photovoltaic charge current as 10A and rated battery voltage as 220V.

3) Battery Bank:

A Battery Bank is basically meant for the storage of energy produced by the solar panels to provide backup power in case of power failure. For the proposed work we used the existing battery bank of 16 batteries which are having the rating of 192V, 42A-hr .The maximum voltage per battery is 12.8V and the discharge current from the battery bank at 27^{o}C is 630A.

4) Inverter and Inverter Charger:

A solar inverter, or PV inverter, converts the variable direct current output of a photovoltaic (PV) solar panel into a utility frequency alternating current that can be fed into a commercial electrical grid or used by a local, off-grid electrical network [4]. It is a critical component in a photovoltaic system. Solar inverters have special functions adapted to work with photovoltaic arrays, including maximum power point tracking and anti-islanding protection. For the proposed work we considered two inverters one is already existed which is having 10KW power rating and output voltage and current ratings are 45A and 220VAC. Another inverter with power rating of 3KW is proposed in the supplementation design for providing the backup power to 40 desktop computers. This supplement inverter is having maximum input current of 13.5A DC. The maximum AC output power is 2.8KW and the output AC current is 13.8A.

5) Automatic Energy Selection Switch:

An additional automatic energy selection switch with 3A load selection is proposed which will help to switch the power to primary load of 40 desktop computers from substation panel which is interconnected to 10KW inverter and 3KW inverter. This senses the current drawn by the primary load and controls the power to the secondary load.

III. WORKING DESCRIPTION OF THE PROPOSED DESIGN

For the design and computation of the proposed solar photovoltaic UPS system we proposed to use crystalline solar panels. About 36 crystalline panels, each having a maximum power output of 210W at Standard Test Conditions (STC) (1000W/m^2 of solar irradiance, 25°C cell temperature and 1.5AM) [10] are proposed to be used. An existing 10KW Inverter Charger UPS is utilized here with discarded charging functionality from AC main supply since the batteries will be charged using solar energy. It will convert DC from the battery to useable AC supply and will also enable the system to function as an UPS (Uninterruptible Power Source). As the solar irradiance keeps varying during the day the output of the solar panels is not constant and keeps varying and cannot be effectively used to charge the battery bank, which is used to store the energy produced. To overcome this problem a charge controller is used which regulates the solar panel output and provides the required output for battery bank charging. The charge controller for the design is rated at PV input power of 2KW and rated battery voltage of 192V to suit the existing battery bank. The battery bank capacity is 8064W-hr, 192V (16 batteries x 12V per battery x 42Ahr) .The battery bank should not discharged below 50% of its capacity doing so reduces its life considerably, so the available energy for usage is 4032W-hr. If the battery bank is fully charged form the solar energy and the solar panels are still producing energy which cannot be further fed into the battery bank then supplementation system will help to resolve this issue. In order to avoid this wastage of the power from the panels it will be directly fed to the 40 desktop computers i.e. primary load through a sub-distribution panel. If the primary load is not in use i.e the 40 desktop computers are off even though the battery bank is fully charge, the power will be directed to a secondary load .In order to facilitate the charging of battery bank and to assist the supplementation system a shunt solar charge controller is proposed to be used as shown in Fig.1. A 3KW solar inverter

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

is proposed to be used to convert the electrical power produced by the solar panels which is in DC form to useable AC form after 100% recharging of battery bank. An Automatic Energy Selection Switch is also proposed to be used to select the Primary load i.e. 40 Desktop Computers to be powered under the backup capacity and not the Secondary load in case of power failure.

IV.RESULTS

Now we considered the date as 28/03/2015, Coordinates: 17.4271408, 78.4450324, the Location as Road No.3, Banjara Hills, Hyderabad, Telangana state, India [12]. The amount of solar irradiance for each hour starting from 7:00 to 19:00 is obtained by using the graph and considering the area under each hour [12].The total PV area under the curve during the day is 261.68W/ m2. The value of solar irradiance for the month of March is obtained from the data given in [12].
Solar irradiance when panels are facing in south-west direction onto a horizontal surface in a day in March month is given as 6.28KWh/m2/day [12] which is 261.68W/m2 since 1KW-h/day equals 41.67W of power. We have proposed the use the Solar Panels with Model No: ES-A-210-fa3 with PV-array area of 1 unit is calculated as 1.23 m2 [11]. Thus the total PV-array area i.e. 36 units (12 panels in series and such 3 parallel combinations) is calculated as 44.28 m2.The power output of total PV area due to incident solar irradiance on total PV-area in a day is calculated as 261.68W/ m2 x 44.28 m2 =11.584 KW. As we have considered the 36 crystalline PV panels of Model ES-A-210-fa3, the total maximum current output is 34.49A and the maximum output voltage is 219.6V.Thus the total power generated from the solar systems can be calculated as 7.57KW. The output from the charge controller can be obtained by considering the solar irradiance for an hour say 7:00 a.m to 7:00 p.m [12] falling on the total PV area of 44.28m2.The output power developed thus can be calculated as12.9W.The output current of the charge controller for a rated output voltage of 220V is 0.058A. Thus form the above discussion we can calculate values of these parameters for different solar irradiance with respect to different hours in a day in March [12] as depicted in Table 1.The solar irradiance is calculated for each hour starting from 7:00 in morning to 7:00 pm in the evening for the location mentioned earlier. The incident solar irradiance in watts is computed with respect to the total PV area which is 44.28m2.Thus considering the solar irradiance for each hour and calculating the incident solar irradiance on the total PV area, the total output power generated from the total PV area is also depicted in the Table.1.The voltage and current produced due solar irradiance in each hour on total PV area is also calculated.

Time Duration	Solar Irradiance (W/m2)	Incident Solar Irradiance (W)	Power output of total PV-area(W)	Voltage output of total PV area(V)	Current output of total PV area(A)	Current output of Charge Controller (A)	Recharging level of Battery Bank from 50% (%)	Recharging level of Battery Bank from 75% (%)
7:00-8:00	1.708	75.62	12.9	9.064	1.42	0.058	50.159	75.159
8:00-9:00	3.416	151.25	25.82	12.824	2.013	0.117	50.479	75.479
9:00-10:00	5.833	258.28	44.09	16.758	2.63	0.2	51.025	76.025
10:00-11:00	15.001	660.24	113.4	26.876	4.219	0.515	52.425	77.425
11:00-12:00	32.085	1420.72	242.56	39.307	6.17	1.102	55.432	80.432
12:00-13:00	84.59	3745.64	639.5	63.824	10.019	2.906	63.362	88.362
13:00-14:00	71.255	3155.14	538.68	58.578	9.195	2.448	70.042	95.042
14:00-15:00	27.502	1217.77	207.91	36.392	5.713	0.945	72.612	97.612
15:00-16:00	12.584	557.2	95.26	24.633	3.867	0.433	73.792	98.793
16:00-17:00	4	177.12	30.24	13.879	2.178	0.137	74.167	99.168
17:00-18:00	2.291	101.44	17.31	10.5	1.648	0.0786	74.381	99.382
18:00-19:00	0.791	35.02	5.97	6.166	0.968	0.027	74.455	99.456

Table 1.Paremeter computations for the solar irradiance for different hours

The solar irradiance for each hour time duration is evaluated and current produced from the solar panels is plotted in the Fig.2.The current produced is maximum in the hours of 12:00 to 13:00 due to maximum solar irradiance. The current produced is calculated considering the total PV area of 44.28m^2.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

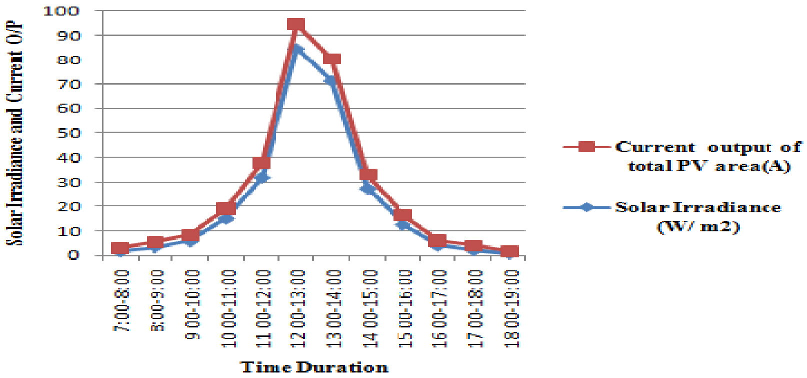

Fig.2 Current Output of Total PV area due to Solar Irradiance in each hour

Now the voltage and current produced from the total PV area are evaluated. The output current from the charge controller is also depicted and recharging level of the battery bank from 50% and 75% is shown in Fig.3.The charging level is not improved in the time duration from 7:00 to 11:00 but after 11:00 the charging is improved and battery bank is almost fully charged till 7:00 p.m. Thus the charged battery bank can be used at night to power the primary load or secondary load.

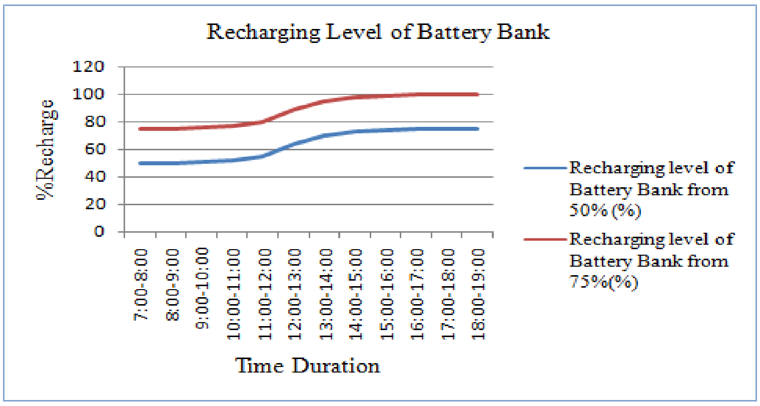

Fig.3 Recharging Level of Battery Bank

V.CONCLUSION

In this paper we have provided theoretical estimation for designing an efficient and economical solar photovoltaic UPS and supplementation system for efficiently utilizing solar power for battery bank charging. The estimation provides the theory of effectively using the existing resources i.e. 10 KW Inverter charger and battery bank in combination with the supplement design comprising a 3KW inverter and an energy selection switch to provide uninterrupted power supply to 8KW primary load of 40 desktop computers. This design also reduces the consumption of power from the main utility by the use of renewable source solar power. Provision of an automatic energy selection switch helps to switch the power to primary load from substation panel during power failure and for efficient supplementation of power to either primary load or secondary load when there is no power failure.

ACKNOWLEDGMENT

We would like to acknowledge the effort of all the sources incorporated in our paper. We would also like to acknowledge the support provided by Dr. Basheer Ahmed, Director, SUES, Dr. Ashfaque Jafri, Dean of Academics, MJCET, Dr.M.P.Soni, Head EED and Dr kaleem Fatima, IEEE MJCET chapter counselor for facilitating and extending their timely valuable support.

.

REFERENCES

[1] P. K. Nag, 2005, Power Plant Engineering, 2nd Edition, Tata McGraw-Hill Publishing Company Ltd, New Delhi.

[2] H. P. Garg, J. Prakash, Solar Energy Fundamentals and Applications, 1st Edition, 2002, Tata McGraw-Hill Publishing Company Ltd, New Delhi.

[3] M. R. Patel, Wind and Solar Power Systems, CRC Press, Florida, 1999

[4] Cavallaro, C.; Musumeci, S.; Santonocito, C.; Pappalardo, M., "Smart photovoltaic UPS system for domestic appliances," in Clean Electrical Power, 2009 International Conference on , vol., no., pp.699-704, 9-11 June 2009

[5] H. Keppner, J. Meier, P. Torres, D. Fischer, and A. Shah, "Microcrystalline silicon and micromorph tandem solar cells," Applied Physics A: Materials Science & Processing, vol. 69, pp. 169-177, 1999

[6] Kanakasabapathy, P.; Gopal, V.K.; Abhijith, V.; Mohan, A.; Reddy, E.H.S., "Energy management and control of solar aided UPS," in Advancements in Power and Energy (TAP Energy), 2015 International Conference on , vol., no., pp.363-368, 24-26 June 2015

[7] German Solar Energy Society, Planning And Installing Photovoltaic Systems; A Guide For Installers, Architects And Engineers (2nd Edition), Earthscan Publications Ltd,London.

[8] Azadeh Safari and Saad Mekhilef, "Simulation and Hardw are Implementation of Incremental Conductance MPPT with Direct Control Method Using Cuk Converter", IEEE Transactions on Industrial Electronics, vol. 58, no.4, 2011, pp. 1154-1161.

[9] Daut, I.; Irwanto, M.; Hardi, S., "Photovoltaic powered uninterruptible power supply using smart relay," in Power Engineering and Optimization Conference (PEOCO), 2010 4th International , vol., no., pp.453-457, 23-24 June 2010

[10] http://sinovoltaics.com/learning-center/quality/standard-test-conditions-stc-definition-and-problems/

[11] http://www.solardesigntool.com/components/module-panel-solar/Evergreen/167/ES-A-210-fa3/specification-data-sheet.html

[12] http://www.sunearthtools.com/dp/tools/pos_sun.php