Optimization Of Solar Battery Hybrid [SB- HPS] System

Namrata Poonia, Abhishek Shanghi
Department of Electrial Engineering
JaganNath University, Jaipur, India
namrata90011@gmail.com

Abstract- This work proposes an improved optimal sizing method for wind-solar-battery hybrid power system (WSB-HPS), considering the system working in stand-alone and grid-connected modes. The proposed method is based on following principles: a) high power supply reliability; b) full utilization of the complementary characteristics of wind and solar; c) small fluctuation of power injected into grid; d) optimization of the battery's charge and discharge state; e) minimization of the total cost of system

Keywords- Optimization, Solar panel, Photovoltaic cell, Kinetic Battery Model, Wind Turbine, Loads, Grid

INTRODUCTION

The rapid economic growth of any country requires the injection of large amounts of energy and since energy cannot be created, it is necessary for every country to diversify its sources of energy. Energy is the ability to do work and therefore it is the basic requirement for achieving all tasks. There are many forms of energy which include; mechanical (potential and kinetic) energy, chemical energy, electrical energy, etc. The desirability and usefulness of electrical energy to the world cannot be overemphasized. Electrical energy is useful in industrial, commercial and residential establishments. Electrical energy is useful in all manufacturing, telecommunications, residential (lighting, heating, cooling, entertainment) and commercial activities[1].

Electrical energy can be derived from various sources which include hydro (Electrical energy from water sources) nuclear, wind, solar (Energy from the sun) and thermal sources. The sources of electrical energy can be grouped into two main categories- renewable and non-renewable sources. Renewable sources are sources of energy which can be recovered within one's life time (taken to be 70 years)[9]. Wind is the result of the sun's uneven heating of the atmosphere. Warm air expands and rises, and cool air contracts and sinks. This movement of the air is called wind. Wind has been used as an energy source for millennia. It has been used to pump water, to power ships, and to mill grains. Areas with constant and strong winds can be used by wind turbines to generate electricity.

In the United States, the state of California has about 20,000 wind turbines, and produces the most wind-generated electricity. Wind energy does not produce air pollution, can be virtually limitless, and is relatively inexpensive to produce. There is an initial cost of manufacturing the wind turbine and the costs associated with upkeep and repairs, but the wind itself is free.

Solar energy is the ultimate energy source driving the earth. Though only one billionth of the energy that leaves the sun actually reaches the earth's surface, this is more than enough to meet the world's energy requirements. In fact, all other sources of energy, renewable and non-renewable, are actually stored forms of solar energy. The process of directly converting solar energy to heat or electricity is considered a renewable energy source. Solar energy represents an essentially unlimited supply of energy as the sun will long outlast human civilization on earth. The difficulties lie in harnessing the energy. Solar energy has been used for centuries to heat homes and water, and modern technology (photovoltaic cells)has provided a way to produce electricity from sunlight.

LITERATURE AND PREVIOUS WORK

In 1876 William Grylls Adams and his student, Richard Evans Day, discovered that an electrical current could be started in selenium solely by exposing it to light, they felt confident that they had discovered something completely new[4]. Werner von Siemens, a contemporary whose reputation in the field of electricity ranked him alongside Thomas Edison, called the discovery "scientifically of the most far-reaching importance." This pioneering work portended quantum mechanics long before most chemists and physicist had accepted the reality of atoms[2]. Although selenium solar cells failed to convert enough sunlight to power electrical equipment, they proved that a solid material could change light into electricity without heat or without moving parts[14]. The New York Times praised it as "the beginning of a new era, leading eventually to the realization of harnessing the almost limitless energy of the sun for the uses of civilization. Although technical progress of silicon solar cells continued at breakneck speed - doubling their efficiency in eighteen months - commercial success eluded the Bell solar cell. A one-watt cell cost almost $300 per watt in 1956 while a commercial power plant cost 50 cents a watt to build at that time[6]. The only demand for silicon solar cells came from radio and toy manufacturers to power miniature ships in wading pools, propellers of model DC-4's, and beach radios. With solar cells running only playthings, Daryl Chapin could not help but wondered[10].

During 1950's, While efforts to commercialize the silicon solar cell faltered, the Army and Air Force saw the device as the ideal power source for a top-secret project - earth-orbiting satellites[11]. But when the Navy was awarded the task of launching America's first satellite, it rejected solar cells as an untried technology and decided to use chemical batteries as the power source for its Vanguard satellite[19]. The late Dr. Hans Ziegler, probably the world's foremost expert in satellite instrumentation in the late 1950s, strongly differed with the Navy. He argued that conventional batteries would run out of power in days, silencing millions of dollar worth of electronic equipment. In contrast, solar cells could power a satellite for years[1-11]. Through an unrelenting crusade led by Dr. Ziegler to get the Navy to change its mind, the Navy finally relented and as a compromise, put a dual power system of chemical batteries and silicon solar cells on the Vanguard[20]. Just as Ziegler predicted, the batteries failed after a week or so, but the silicon solar cells kept the Vanguard communicating with Earth for years[14].

ENERGY MODELS

Photovoltaic Energy Model

Solar energy maintains life on the earth and it is an infinite source of clean energy. There is an increasing trend for the use of solar cells in industry and domestic appliances because solar energy is expected to play significant role in future smart grids as a distributed renewable source. Optimal and large-scale integration of renewable sources into smart grid is possible by the aid of computer simulations and hence there is a growing demand for computer modeling and simulation of renewable sources. This study presents a generalized photovoltaic (PV) system simulation model for Matlab/Simulink simulation environment. The proposed model is based on a behavioral cell model for modeling solar radiance to electricity conversion and an electrical driver interface for implementing electrical characteristic of power limited systems in power simulations.

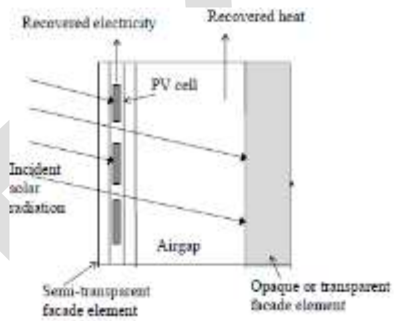

Fig 1. PV Cell Architechture.

As the operation and the performance of PV generator is interested to its maximum power, the models describing the PV module's maximum power output behaviours are more practical for PV system assessment. For estimating the power output of PV modules a mathematical model is used. The estimation is carried out using a computer program which uses a subroutine for determining the power output of a PV module.

Ppv can be calculated according to the following equations

$$P_{pv} = n_g N A_m G_t$$

Where,

η_g is the instantaneous PV generator efficiency,

A_m is the area of a single module used in a system (m^2),

G_t is the global irradiance incident on the titled plane (W / m^2) and N is the number of modules. All the energy losses in a PV generator, including connection losses, wiring losses and other losses, are assumed to be zero.

Kinetic Battery Models

An electrochemical battery cell consists of an anode, a cathode and the electrolyte that separates the two electrodes[12-22]. The electric current derives from the electrochemical reactions occurring at the electrode-electrolyte interface. The two important effects [22] that make battery performance nonlinear (unlike an ideal linear battery model) and sensitive to the discharge profile are:

(i) The Rate Capacity effect

(ii) The Recovery effect.

The battery lifetime relies on the availability and reachability of active reaction sites in the cathode. When the load current goes high, the deviation of the concentration of active reaction sites from the average increases, thus resulting in a lower state of charge as well as less cell voltage, compared with the battery under allow load current. This phenomenon is called Rate Capacity Effect. On the other hand, the diffusion process could compensate for the depletion of the active materials taking place during the current drain, which results in voltage recovery after resting. This nonlinearity in the battery is termed the Recovery Effect.

The Kinetic Battery Model was developed at the Renewable Energy Research Lab specifically for use in quasi-steady time series simulation of power producing systems that incorporate battery storage. It is a kinetic type battery storage model that combines both phenomenological and physical effects. This model is implemented in the hybrid power system simulation software.

Fig 2 Concept of the Kinetic Battery Model

The energy present in the battery is calculated with the formulas:

$$Q_{end} = Q_{1,end} + Q_{2,end}$$

with:

$$Q_{1,end} = Q_1 e^{-k\Delta t} + \frac{(Qkc+P)(1-e^{-k\Delta t})}{k} + \frac{Pc(k\Delta t - 1 + e^{-k\Delta t})}{k}$$

$$Q_{2,end} = Q_2 e^{-k\Delta t} + Q(1-c)(1-e^{-k\Delta t}) + \frac{P(1-c)(k\Delta t - 1 + e^{-k\Delta t})}{k}$$

ENERGY MANAGEMENT AND OPTIMIZATION PRINCIPLES

Electric energy plays an important role for the development of nation. It is the factor responsible for industrial and agricultural development for the development of agricultural sector rural electrification plays main role According to IEA (2009) worldwide 1.456 billion people do not have access to electricity, of which 83% live in rural areas. The technologies are developed to produce energy and satisfy the needs of the nation. The scarcity of fossil fuel resources on a world-wide basis has necessitated an urgent search for alternative sources. The problem can be overcome by the use of renewable energy to meet the energy demand. Using solar and wind energy is one of the best options to generate electricity since these energies are inexhaustible and pollution free. For remote areas i.e., The areas which are far away from the grid hybrid systems have been considered as attractive and preferred alternative sources.

Then optimize the parameters that could achieve the best control configuration. Implement the results using a control algorithm. This model should be connected to a forecast data. This helps in prediction for the best control strategy within the next days. The system simulation models that belong to this category are expected to predict system performance accurately.

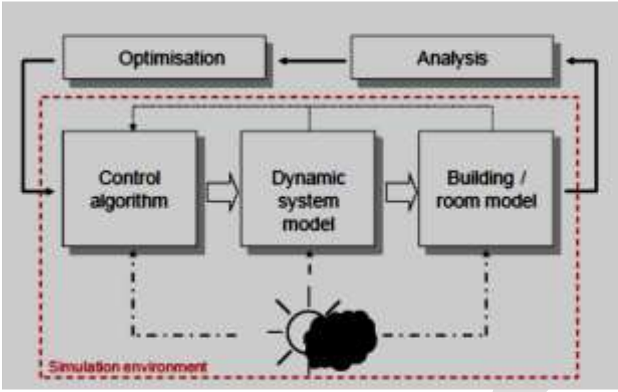

Fig 3 Simulation assisted control process

The reliability and efficiency of a photovoltaic system depends mainly on its energy management system which is done by the proper management and distribution of PV voltage to the battery and to the load to avoid the shortage of power.

In accordance with analysis above, the object optimal sizing method is based on the principles:

(a) To obtain high power supply reliability

(b) Making full use of wind and solar complementary characteristics

(c) To ensure a small fluctuation of power injected into the grid

(d) Optimization of battery charge and discharge state

(e) Minimizing the total cost of WSB-HPS

(A) The proposed method is evaluated indices:-Four evaluation indices are proposed to characterize the optimization performance of WSB-HSP.

(1) Loss of power supply probability:-It is chosen to evaluate the power supply reliability of the hybrid power system.

Defined as

$$LPSP = \frac{\sum_{i=1}^{N}[p_L(t_i) - (P_{wt}(t_i) + P_{pv}(t_i) + P_{bs-dch}(t_i)]}{\sum_{i=1}^{N}[p_L(t_i)}$$

The dependent fluctuation rate, D_L

Defined as

$$D_L = \frac{1}{\overline{P}_L}\sqrt{\frac{1}{N}\sum_{i=1}^{N}(P_{wt}(t_i) + P_{pv}(t_i) - P_L(t_i))^2}$$

D_{gs} are used here to characterize the fluctuation of power injected into the grid, which are defined as)

$$STD = \sqrt{\frac{1}{1-N}\sum_{i=1}^{N}(P_{gs}(t_i) - \overline{p}_{gs})^2}$$

RESULTS

The Simulation is performed on DOS based 1GHz processor. The computing environment used here is MATLAB 2013. The daily temperature, daily load etc parameter are considered here in this work. Our Simulation file takes an input of these data file, and apply optimization according to suggested algorithm to result out optimized number of photovoltaic cells. The plots of solar and load data gathered for the period of investigation are depicted by fig. 4 and 5 respectively.

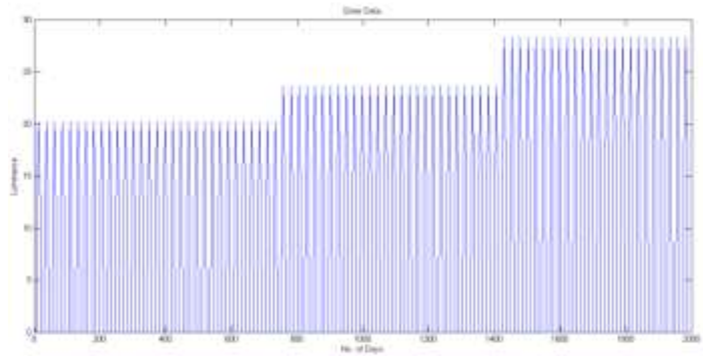

Fig.4 Solar Data

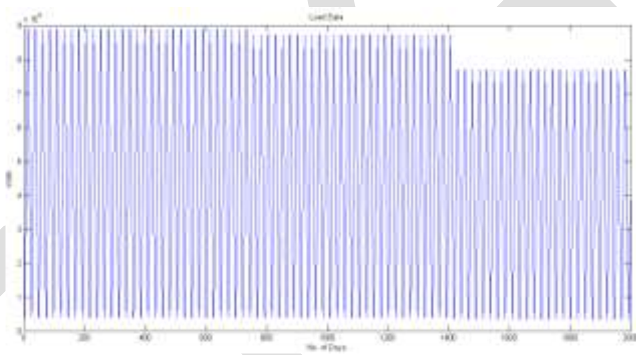

Fig. 5 Load Data

For the whole execution period the profile of power supplied by grid and battery discharging is illustrated by fig. 6 and 7.

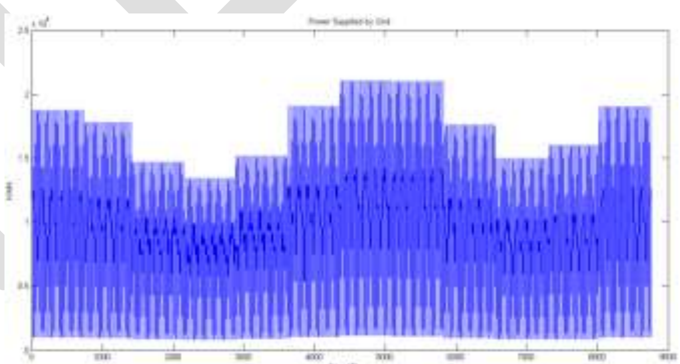

Fig. 6 Power supplied by the grid

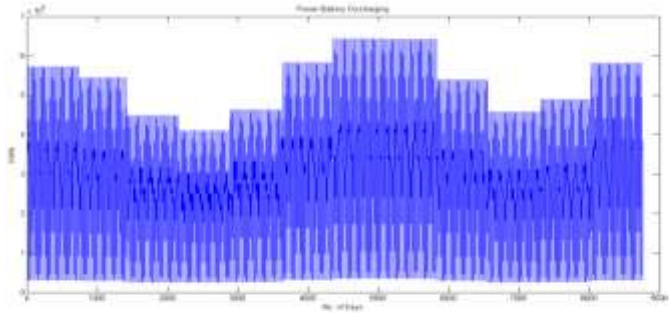

Fig.7 Power supplied due to battery discharging.

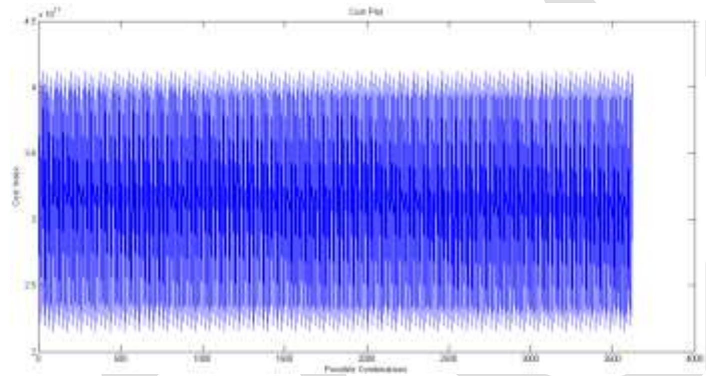

Fig. 8 Cost values for the all possible photo voltaic and battery combinations.

The cost profile accounting all the positive and negative cost function can be represented by fig.8. The optimal no. of batteries and phtovoltaic panel resulted out using the proposed simulation model (subjected to minimal cost) are:

Optimal No. of Batteries:-3345

Optimal No. of Photovoltaic Panel:-4642

CONCLUSION AND FUTURE SCOPE

In this work we optimized the combined performance of photovoltaic cells and grid system. The suggested solution depends on the dataset, more data is available the better optimized will be our results. The retrieved results too confirm us the hypothesis made about model to duplicate the real time WSB HPS model. The inferences can be made from results that as during the summer session the adopted is insufficient to satisty the load demand so some addition emergency land should be aquisited for supporting substation. As a future aspect of this work, we will carry on this work using different optimization techniques like Ant Colony, Flocking Bird, Genetic Algorithms and will compare their inter-performance as well as with the suggested method.

REFERENCES:

[1] S. Rahman and A. de castro,: environmental impacts of electricity generation: A global perspective,"IEEE Trans Energy Convers,. Vol.10, no. 2,pp. 307-314, Jun. 1995.

[2] B.bose, "Global warming: Energy, environmental pollution and the impact of power electronics,"ieeeind. Electron mag.,vol. 4,no. 1,pp. 6-17, Mar.2010.

[3]."The myth of renewable energy Bulletin of the Atomic Scientists". Thebulletin.org. 2011-11-22.Retrieved 2013.

[4]. REN21 (2010). Renewables 2010 Global Status Report

[5] “Conservation of Energy”International Energy Agency (2012). "Energy Technology Perspectives 2012"

[6] C. Chompoo-Inwai,W. J. Lee, and P. Fuangfoo, “System impact study for the interconnection of wind generation and utility system,” IEEE Trans. Ind. Appl., vol. 41, no. 1, pp. 1452–1458, Jan. 2005.

[7] M. Abdel-Akher, A. A. Ali, A. M. Eid, and H. El-Kishky, “Optimal size and location of distributed generation unit for voltage stability enhancement,” inProc. IEEE ECCE, 2011, pp. 104–108.

[8] F. Giraud, “Analysis of a Utility-InteractiveWind-Photovoltaic Hybrid System With Battery Storage Using Neural Network,” Ph.D. dissertation, Univ. Mass., Lowell, 1999.

[9] G. Shrestha and L. Goel, “A study on optimal sizing of stand-alone photovoltaic stations,” IEEE Trans. Energy Convers., vol. 13, no. 4, pp. 373–378, Dec. 1998.

[10] R. Yokoyama, K. Ito, and Y. Yuasa, “Multi-objective optimal unit sizing of hybrid power generation systems utilizing PV and wind energy,” J. Solar Energy Eng., vol. 116, no. 4, pp. 167–173, Nov. 1994.

[11] R. Chedid, S. Karaki, and A. Rifai, “A multi-objective design methodology for hybrid renewable energy systems,” in Proc. IEEE Russia Power Tech., 2005, pp. 1–6.

[12] W.Kellogg, M. Nehrir, G.Venkataramanan, and V.Gerez, “Generation unit sizing and cost analysis for stand-alone wind, photovoltaic, and hybrid wind/PV systems,” IEEE Trans. Energy Convers., vol. 13, no. 1, pp. 70–75, Mar. 1998

[13] Manwell JF, McGowan JG, Rogers AL. Wind energy explained: theory, design and application; John Wiley and Sons Ltd: Chichester, 2002

[14] D. Boroyevich, I. Cvetković, D. Dong, R. Burgos, F. Wang, and F. Lee, “Future electronic power distribution system—A contemplative view—2010,” in Proc. IEEE OPTIM, 2010, pp. 1369–1380.

[15] ArunKumarVerma, Bhim Singh and S. C Kaushik,(2010) 'An Isolated Solar Power Generation using Boost Converter and Boost Inverter,' in Proc. National Conference on Recent Advances in Computational Technique in Electrical Engineering, SLITE, Longowal (India), paper 3011, pp. 1-8. .

[16] R.J. Meador, S. Katipamula and M.R.Brambley D.D. Hatley, "Energy Management and Control System: Desired Capabilities and Functionality," Pacific Northwest National Laboratory Richland, Washington, Technical Report PNNL-15074, 2005.[Online]. Energy Management and Control

[17] A.Rabl, "Parameter estimation in building: Methods for dynamic analysis of measured energy use," Journal of Solar Energy Engineering, pp. 52-66, February 1988.

[18] Markvart, T., 2000. Solar Electricity, second ed. Wiley, USA. "Invert your thinking: Squeezing more power out of your solar panels". scientificamerican.com. Retrieved 2011-06-09.

[19] Lowe, R. A; Landis, G. A.; Jenkins, P (1 May 1993). The efficiency of photovoltaic cells exposed to pulsed laser light (Report). NASA.Retrieved 3 Nov 2012.

[20] V. Rao, G. Singhal, A. Kumar, and N. Navet, “Battery model for embedded systems,” VLSID 2005.

[21] J. F. Manwell and J. G. McGowan, “Extension of the kinetic battery model for wind/hybrid power systems,” in Proc. of EWEC, 1994, pp. 294–289.

[22] X. Ning and C. G. Cassandras, “On maximum lifetime routing in wireless sensor networks,” in Proc. of 48th IEEE Conf. Decision and Control, Dec. 2009, pp. 3757–3762