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PV/Wind Hybrid Power Systems Energy Controller Based on Narma-L2 Network

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Abstract: This writing article explains a novel application for power management in self-contained hybrid energy systems. Using Matlab / Simulink software package, this hybrid power system is executed. The presented power management network is designed by the aim to make possible the flow of the power among the hybrid energy networks and power storage devices for carrying out the load requirements on the basis of Narma-L2 neural controller model. The chief energy sources of the system are wind and PV renewable resources. For the backup and long term storage purpose, lead-acid battery is utilized. Actual scheduled calculated factors are utilized as inputs for the designed network. For smart grid performance optimization, the developed system and their methodology for supporting gives a appropriate mechanism.

Keywords: Hybrid Energy Networks, Matlab/Simulink, PV, wind, Energy Management, battery, Narma-L2 controller.

I. INTRODUCTION

The establishment of renewable energy resources with small outflow and good productivity became exceptionally dominant with the reasons of growing responsibility on global warming, scarcity of fossil power source, unreasonable oil cost and destruction to the atmosphere. Among the different alternative energy resources , the energy of the PV system can be examined as the chief prime and foremost resource as solar energy is widely available and it has the ability to be maintained at a certain level . Instead of the interruptions in sunlight, solar energy is plentiful and inexpensive. Because of this reason, photovoltaic string is increasing widely used in the different applications of electric power system . The chief features of Photovoltaic system are in either grid-connected or stand-alone configurations. The PV module presents the basic power conversion unit for the PV generator system.The output curves (current-voltage and Power-voltage) of the PV string depends on three input factors which are load, solar irradiance and temperature. On the basis of various conditions of solar radiation and temperature, the output curves of the photovoltaic string are nonlinear.

Wind and solar renewable resources are the prime, supreme and dominant power generation sources. The growing power generation of wind and Photovoltaic system has overshadowed the maximum bright evaluation. The distinct renewable power sources can company one another to some level, hybrid renewable power systems generated with multiple sources with appropriate direction have major possibilities to supply best quality and most sustainable power to customers as compared with a system generated with a single source. Because of this advantage , hybrid power systems have captured global research concentration . For framing a hybrid energy system , different and various renewable power resources like wind, PV, diesel system, gas turbine are utilized. The prime and main renewable power resources utilized and studied are wind and PV system. Because of the scattered features of wind and solar energy , self-contained wind and PV energy systems usually requires energy captured elements or some other different types of generation sources to build a hybrid system. Battery bank, supercapacitor bank, superconducting magnetic energy storage or an FC-electrolyzer system can be used as a storage device..

There are many reports about power management of hybrid energy system in the published writings [2]. Among them, Wang and Nehrir [3], designed a energy management strategy on an ac-linked hybrid wind/PV/FC energy system. Ahmed et al. [4], developed a energy management strategy which studied power fluctuations in a hybrid PV/wind turbine/FC power system. Onar et al. [5], designed a power management strategy algorithm which allocated with a hybrid PV/wind/FC energy system comprising an ultra capacitor bank. Thus, previously observed procedures have been utilized conventional techniques for maintaining hybrid energy systems, like linear PI controller which has been proven its instability in controlling different variations in weather conditions [6,7]. This resulted in developing other approaches led to more robust algorithms with ability to handle various changes dynamically without any major problems; by establishing new management criteria depending upon informational data and the environmental changes. Moreover, previous studies showed [8,9] that by utilizing the artificial intelligence techniques in the hybrid vehicle can control the FC system at a observed high-efficiency area. However, this article describes an optimized energy management strategy for the flow of energy in stand-alone hybrid power systems based on neural network. The designed method explains an online energy management by an effective controller among three power sources comprises PV panels, wind turbine, battery storage. The main objective is to maintain the flow of the active power among various power sources and to control the state-of-charge (SOC) of the battery at a rational amount.

In this case study, a self-contained hybrid renewable power generation network is designed containing wind, PV and battery components . To take full advantage of renewable energy, wind and PV are the chief foremost energy generation resources of the network . For short-time backup to deliver transitory power, a battery bank is utilized in the hybrid network .The various energy captured devices can be connected in the developed network with the help of an ac-link bus. The description of the network arrangement , network unit-sizing and the attributes of the main network elements are studied in this article. An overall technique for managing the power is designed for the network to maintain the flow of the power among different and various types of power generation sources. To investigate the efficiency of the system under various conditions , different types of simulation studies have been conveyed out .

II. NETWORK ARRANGEMENT AND UNIT-SIZING

A. NETWORK ARRANGEMENT

Fig.1 explains the system layout for the designed hybrid renewable energy system [2]. The alternative energy wind and PV sources are utilized as the chief and prime source whereas the battery is used as a backup and storage device. The whole hybrid power network can be observed as a absolute “green ’’energy creation network as all the primary renewable energy generation sources and energy captured devices are environment friendly.

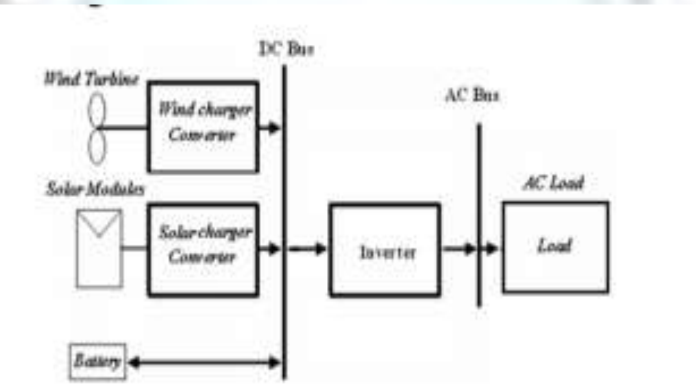

Fig 1. Block diagram of the proposed system

Several different methods are proposed with the help of which we can connect various renewable power resources to design a hybrid system. Each method has as many advantages as disadvantages. With the help of proper power electronics interfacing circuits , different power resources can be integrated to the ac bus. We can combined different power resources to the network when they are available and due to this reason the system can be easily extended.

B. NETWORK UNIT-SIZING

The unit-sizing process implemented in this article is adopted for a self-contained hybrid power system with the developed design.

III. SYSTEM ELEMENTS ATTRIBUTES

To explore the network presentation and to design an overall technique for managing the power for the system, dynamic models for the prime elements in the developed hybrid power system have been created with the help of MATLAB/Simulink. The models used for the following are : wind energy conversion system, PV, battery and neural network controller.

A. Wind Energy Conversion System

Various reviews have been discussed on Wind Turbine and wind generators. In this article, the designed Wind Turbine model depends on the wind speed and Wind Turbine output power attributes .The output power of the wind turbine is explained by the equation given below:

$P_m = c_p(\lambda, \beta)\, \rho A/2\, v_{wind}^3$

Where, P_m defines the mechanical output power of the turbine, c_p defines the performance coefficient of the turbine, λ defines the tip speed ratio of the rotor blade, β defines the blade pitch angle, ρ defines the air density, A defines the turbine swept area and v_{wind} defines the wind speed. The explained model of the Wind Turbine is proposed as given in Fig 2. The inputs of the wind turbine are the speed of the wind and the speed of the generator , the output of the wind turbine is the torque applied to the generator shaft in the proposed model. The torque of the generator is based on the speed and the power of the generator .

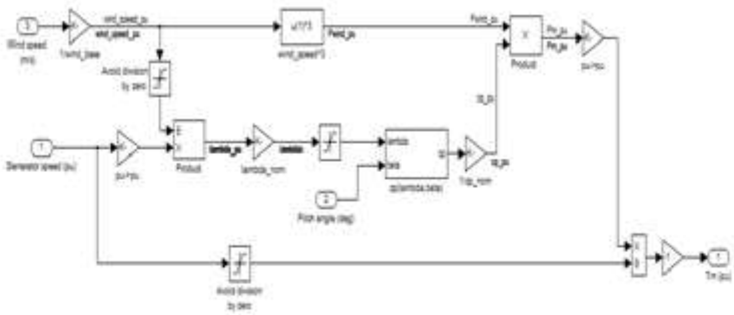

Fig 2. Subsystem Implementation of the WT model

In this article , we have studied about a variable-speed pitch-regulated wind turbine , whereas the participation of pitch angle controller is also very important . Fig 3. explains the wind turbine output power and speed attributes .

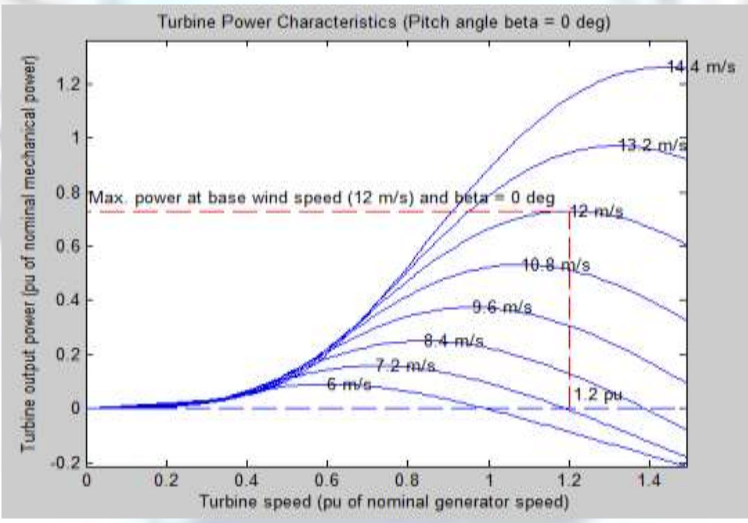

Fig 3. Wind Turbine Speed-Power Characteristics

B. The Photovoltaic Module

An electrical equipment of converting the light energy directly into electrical energy with the photovoltaic effect is called a solar cell (also called a photovoltaic cell). It is a type of photoelectric cell where its electrical characteristics like current, voltage, or resistance changes when light is directed on it. This solar cell when disclosed to light, can creates and produces an electric current excluding external voltage source , but it requires an exterior load for power utilization.

I. Solar cell model

The solar cell , which is a type of p-n junction manufactured in a fine layer of semiconductor substance ,commonly silicon is comprised by the photovoltaic PV generator. When the solar cell is striked by the light energy, electrons are hammered free from the atoms in the semiconductor material. The electrons can be caught in the shape of an electric current which is called electricity when electrical conductors are combined to the positive and negative sides, framing an electrical circuit . This electricity can be utilized to power a load, like a light or a tool.

A photovoltaic module is a support structure or frame in which multiple solar cells are connected to each other electrically . Modules are developed to supply electricity at a optimum voltage. The current produced is based on how much light strikes the PV module.

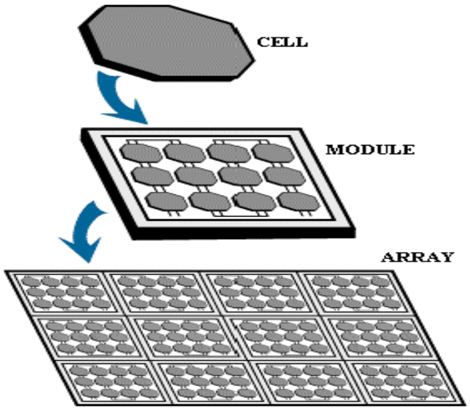

Fig 4. PV cell, module and array

To frame an array, multiple modules can be integrated together as shown in Fig 4 [12]. The electricity produced is directly proportional to the area of the module or array. Photovoltaic modules or arrays generate direct-current (dc) electricity. To generate any required voltage and current combination, PV modules or arrays can be connected in both series and parallel electrical arrangements.

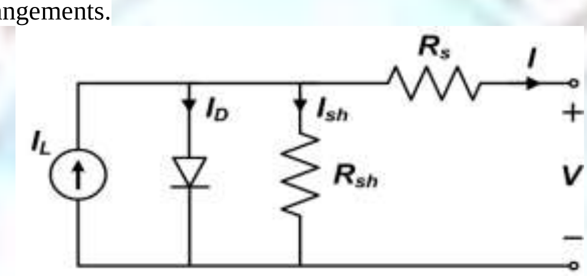

Fig 5. Single diode PV cell equivalent circuit [12]

The circuit of the solar cell model is described in Fig 5 [12] which contains of a photocurrent, diode , parallel resistor(leakage current) and a series resistor elements. The photovoltaic current can be presented according to the PV cell circuit and according to Kirchhoff's circuit laws

$$I_{pv} = I_{gc} - I_o\,[\exp(e*v_d/KFT_c)-1] - v_d/R_p$$

where, I_{gc} is the light generated current, I_o is the dark saturation current dependent on the cell temperature, e is the electric charge = $1.6*10^{-19}$ coulombs, K is the Boltzmann's constant = $1.38*10^{-23}$ J/K. F is the cell idealising factor, T_c is the cell's absolute temperature, v_d is the diode voltage and R_p is the parallel resistance

II. Layout of a PV model

Photovoltaic model is a primary procedure of converting solar energy directly into electrical energy with I-V output attributes. To explore the nonlinear output attributes for the PV module, a PV model is designed.
The developed and proposed model is implemented as shown in Fig 6 [4] .

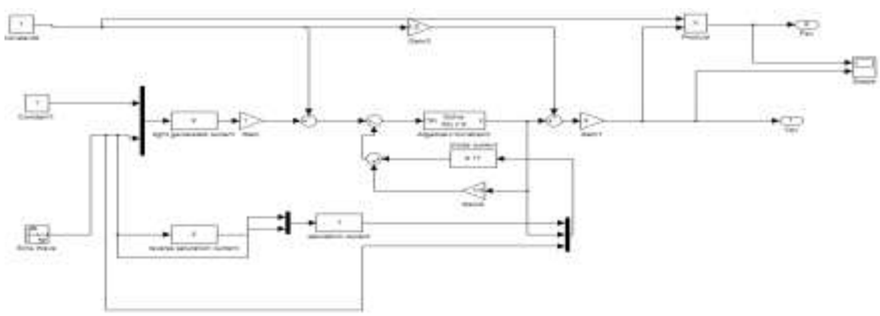

Fig 6. Subsystem implementation of the PV model

The I-V characteristics are shown in figure 7.

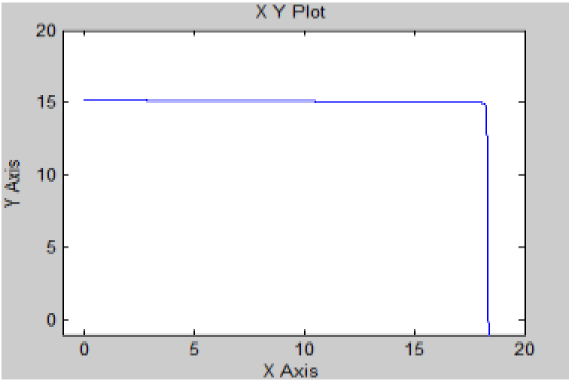

Fig 7. I-V curves of the PV model

C. Lead-acid Battery model

Battery is one of the main essential parts in hybrid energy system. Batteries are difficult to model because they underwent through typical thermally dependent electrochemical procedures. Therefore, the battery explains the nonlinear function of the different types of cvarious factors. Lead-acid batteries are the supreme utilized devices to capture and supply energy. There are many different types of batteries like Nickel-Metal Hybrid, Lithium-Ion, Nickel-cadmium. The simulink model of the Lead-acid battery is implemented as shown in Fig 8 [13].

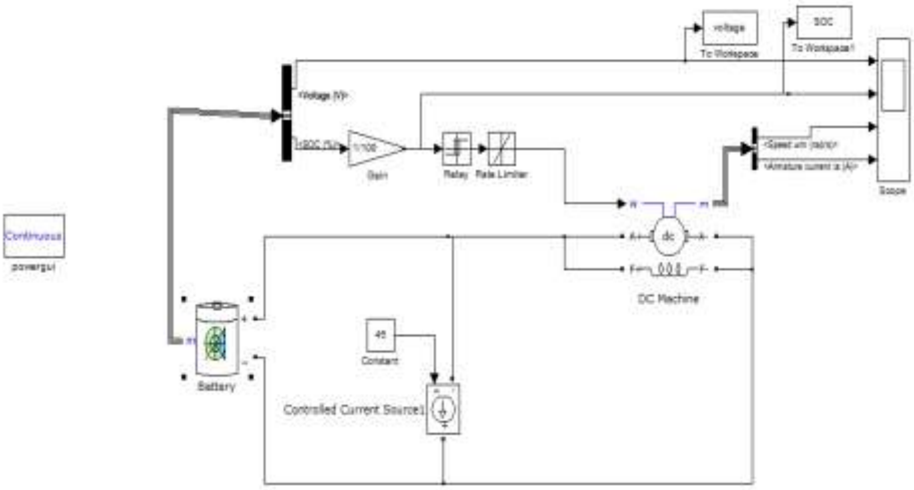

Fig 8. Subsystem implementation of the battery model

The battery curves are given in figure 9.

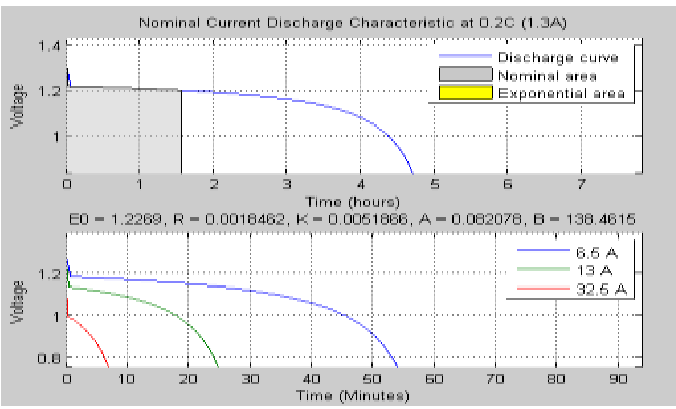

Fig 9. Lead-acid battery characteristics

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IV. NEURAL NETWORK CONTROLLER

For the identification and control of dynamic systems, different types of neural network architectures have been designed successfully. Narma-L2 controller is the prime and paramount neural network control architecture. In this method, training is straightforward because the controller is a rearrangement of a neural network plant model, which is going to be trained offline, in batch form. In this method, there is no distinct dynamic instruction for the controller. The other merit of Narma-L2 controller is that the only online computation is a forward pass through the neural network controller.

NARMA-L2 is one of the Neural Network architecture for control, as it is a rearrangement of the plant model. NARMA-L2 stands for Non Linear Auto Regressive Moving Average model. It is referred when the plant model is accounted by the associated form. It is known as feedback linearization technique when the plant model is in associated form. System Identification and Control Design are the two stages for developing of NARMA-L2 controller. The block diagram of Narma-L2 controller is explained in figure 10 [14,15].

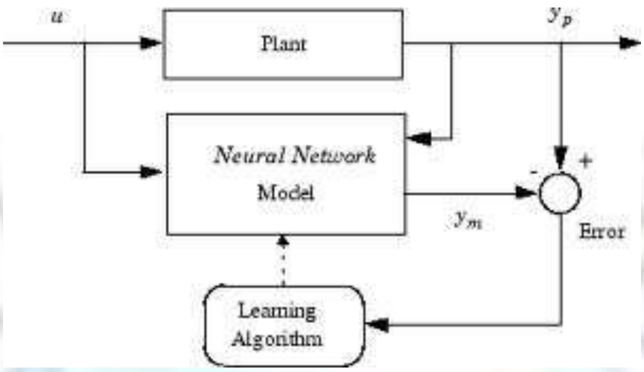

Fig 10. Block diagram of Narma - L2 controller

With the help of Levenberg-Marquardt algorithm using trainlm function, the neural network controller contains 3 hidden layers, 2 delayed input and 3 delayed outputs is trained offline in batch form. Levenberg-Marquardt is estimation of Newton's method. It is fastest back-propagation algorithm in MATLAB Neural Network toolbox. The training output of Narma-L2 controller is explained in Fig 11.

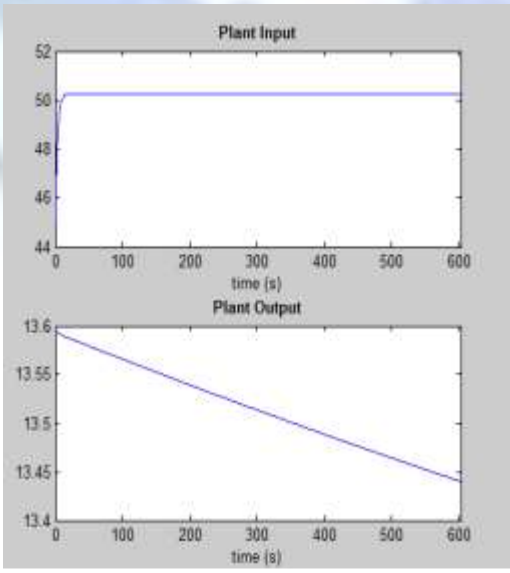

Fig 11. Training output of Narma-L2 controller

V. SIMULATIONS AND RESULTS

The I-V (current-voltage) characteristics of a PV module explains its energy conversion capability at the existing factors of solar irradiance and temperature. The PV module could be operated or loaded, if the solar irradiance and temperature could be held constant at which the I-V attributes describes the combinations of current and voltage . These I-V curves of the PV module are explained in figure 7.

The VSWTG employed at variable speed under normal operation . The VSWTG employs at optimum pitch angle when the wind speeds varies from low to medium. The wind turbine employs at constant speed when the wind speed is high and the pitch angle maintains the speed of the rotor constant.

Until the wind turbine reaches rated speed, the output power of the wind turbine employing in this mode is a cubic relation of the rotor speed. The wind turbine is operated at fixed power by maintaining the pitch angle when the rated speed is reached. Normally, the pitch angle controller employs very smoothly, maintaining the rotor speed so that it does not surpass the rated speed. This pitch controlling mechanism, outhouse aerodynamic power to control the rotor speed from outstretching a runaway condition. If the blade pitch control fails, the wind turbine brakes will be exploited.

The wind turbine characteristics are explained in figure 3.
For controlling the energy flow between PV and Wind hybrid system , Narma- L2 controllers are successfully implemented in Matlab Simulink environment. The simulation results of the hybrid system are given in figures 12 and figures 13.

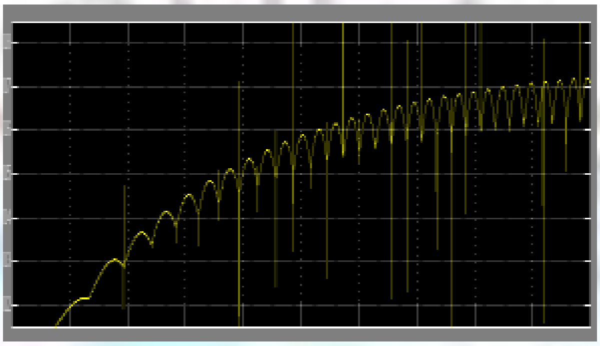

Fig 12. Rectified DC voltage of wind turbine generator

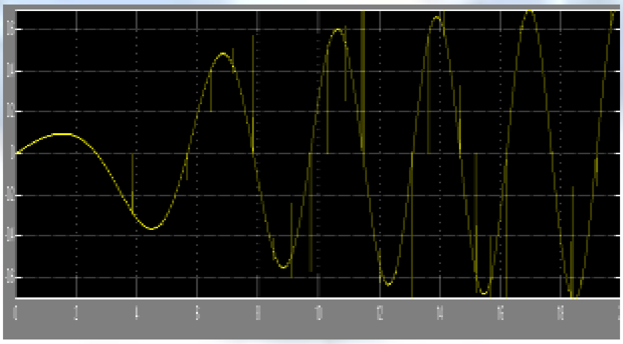

Fig 13. Output AC line voltage of wind turbine generator

CONCLUSIONS

For developing stand-alone hybrid power systems, an effective online power management based on the NARMA-L2 controller is created. In this article, a novel PV/WT hybrid power system is designed and modelled. The developed algorithm comprises system components and an appropriate energy flow controller. The model has been designed with the help of MATLAB or SIMULINK software package . The designed PV model has temperature and solar irradiance as its input factors and gives the power under various conditions. This PV model has been developed with a dialog box like SIMULINK block libraries, it helps the users to easily develop the designed model. Such a model is helpful for the implementation on MATLAB/SIMULINK modelling and simulation platform. The proposed PV model with its control system gives excellent performance under variable solar radiation and temperature. The PV module was integrated with the wind turbine system to outstrip the scarcity of the PV system.

APPENDIX:

Table 1. System Component Parameters

	WINDTURBINE	
S.NO	**PARAMETERS**	**VALUES**
1.	Rated output power	300W
2.	Rated wind speed	12m/s
3.	Pitch angle	0
	SOLAR PV	
4.	Light intensity	$100mW/cm^2$
5.	Atmospheric temperature	25°C
6.	N	1.11
7.	Rs	0.141ohm
8.	Rsh	2000ohm
9.	Cd	10
10.	Eg/eV	1.13
	LEAD-ACID BATTERY	
11.	Nominal capacity	200AH
12.	Nominal Voltage	12V
13.	Max.Charging current	60A

The details of the system component parameters are listed in Table 1 [1] .

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