A Proposed Mathematical Model of Hybrid System in MATLAB/Simulink

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Abstract *—**this** paper present the Mathematical model of the solar photovoltaic **and wind (dc generator)** module using MATLAB Simulink. The proposed model relates the electrical output of the **hybrid** system to various input environmental parameters. This Paper focuses on the combination of solar wind systems for sustainable power generation. The solar energy also varies with the hourly, daily and seasonal variation of solar irradiation. The wind turbine output power varies with the wind speed at different conditions. However, a drawback, common to solar irradiation and wind speed options, is their unpredictable nature and dependence on weather and climatic changes, and the variations of solar and wind energy may not match with the time distribution of load demand.*

Keywords-Photovoltaic modules, wind (dc-generator), MATLAB/Simulink.

I. INTRODUCTION

Modern world fossil fuels are fast utilizing and also pollute the environment which will result in global warming. Limited reserves of conventional sources with their impact on environment led us to use green energy i.e. non-conventional energy sources like solar energy, wind energy, biomass, tidal energy etc. Among all these sources Photovoltaic systems and wind energy are becoming popular because of its decreasing cost, low maintenance because, pollution free, distributed throughout the world and recyclable. It also has some demerits viz. high setup cost, low efficiency. Although such demerits government tries to implement it by launching different promotion schemes, subsidies so it will lead to its competitiveness in future era [1].

The advantages of using renewable energy sources for generating power in remote islands are obvious such as the cost of transported fuel are often prohibitive fossil fuel and that there is increasing concern on the issues of climate change and global warming. The electric power generation system, which consists of renewable energy and fossil fuel generators together with an energy storage system and power conditioning system, is known as a hybrid power system.

A Hybrid power system has the ability to provide 24 hour grid quality electricity to the load. This system offers a better efficiency, flexibility of planning and environmental benefits compared to the diesel generator stand-alone system. The maintenance costs of the diesel generator can be decreased as a consequence of improving the efficiency of operation and reducing the operational time which also means less fuel usage. The system also gives the opportunity for expanding its capacity in order to cope with the increasing demand in the future. This can be done by increasing either the rated power of diesel generator, renewable generator or both of them. The disadvantage of standalone power systems using renewable energy is that the availability of renewable energy sources has daily and seasonal patterns which results in difficulties of regulating the output power to cope with the load demand. Also, a very high initial capital investment cost is required. Combining the renewable energy generation with conventional diesel power generation will enable the power generated from a renewable energy sources to be more reliable, affordable and used more efficiently. Solar and wind energy systems are being considered as promising power generating sources due to their availability and topological advantages for local power generations in remote areas. This Paper focuses on the combination of solar wind systems for sustainable power generation. The solar energy also varies with the hourly, daily and seasonal variation of solar irradiation. The wind turbine output power varies with the wind speed at different conditions. However, a drawback, common to solar irradiation and wind speed options, is their unpredictable nature and dependence on weather and climatic changes, and the variations of solar and wind energy may not match with the time distribution of load demand [7].

II. PV SYSTEM: EQUIVALENT ELECTRICAL CIRCUIT OF PV CELL

Basically PV Power generation use the principle of the photovoltaic effect. It is basically made up of silicon cells. These solar cells can give around 0.5 to 0.7 V under open condition which can be increased by connecting them in series which is known as solar module and further can connect them in parallel for more output Power [1].

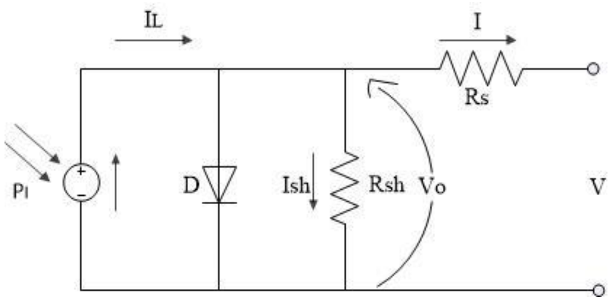

Figure 1. Equivalent electrical circuit of PV cell [4]

The circuit parameters are as follows

- I is the output-terminal current
- I_L is the light-generated current
- I_d is the diode current
- I_{SH} is the shunt-leakage current
- R_S is the series resistance which represents internal resistance to the current, and depends on the p-n junction formation, the impurities and the contact resistance.
- R_{SH} is the shunt resistance which is inversely related with leakage current to the ground.

In ideal PV cell we take RS = 0 and $R_{SH} = \infty$. The PV module efficiency is very sensitive to small variation in series resistance and independent on variation of shunt resistance [3].

MATHEMATICAL MODEL FOR A PV MODULE [4]

From the equivalent circuit in Figure 1 the load current is given by the expression:

$$I = I_L - I_d - \frac{V_0}{R_{sh}} \quad (1)$$

The cell could be represented by a voltage-current Equation as follow

$$V = V_0 - R_S I \quad (2)$$

Where:

$V_0 = V_{sh}$ = voltage on the diode and the shunt resistance

I_d = diode Current (A).

V = cell output voltage (V).

I = load (cell) output current (A).

I_L = Photocurrent (A).

I_0 = Reverse diode saturation current (A).

Module output current is given by following Equation [Egypt]

$$I = I_L - I_O(e^{\frac{q(V+IRs)}{nKTr}} - 1) \quad (3)$$

Where:

q = electron charge = 1.6×10^{-19} Coulombs.

n = ideality factor = 1 to 2.

K = Boltzmann constant = 1.38×10^{-23}Joule/K

Tr = rated cell temperature in Kelvin.

Rs = cell series resistance (ohm).

The value of the saturation current Io at different operating temperatures is calculated as follow:

$$I_o = I_{o(Tr)} * (T/Tr)^{\frac{3}{n}} * e^{\frac{qVg}{nk} * \{\frac{1}{T} - \frac{1}{Tr}\}} \quad (4)$$

$$I_{o(Tr)} = I_{SC(Tr)}/[e^{\frac{qV_{oc(Tr)}}{nKTr}} - 1] \quad (5)$$

Where:

Vg = The band gap voltage

$V_{oc(Tr)}$ = Open Circuit voltage at rated operating conditions.

$I_{SC(Tr)}$ = Short circuit current at rated operating conditions.

The photocurrent $I_L(A)$ is directly proportional to solar radiation level G (W/m2), as follow:

$$I_L = I_{L(Tr)}(1 + \alpha_{I_{SC}}(T - Tr)) \quad (6.1)$$

$$I_{L(Tr)} = G * I_{SC(Tr,nom)}/Gr \quad (6.2)$$

$$\alpha_{I_{SC}} = d_{I_{SC}}/dT \quad (6.3)$$

Where, α_{Isc} = the short circuit temperature coefficient (A/sec).

The open circuit voltage is varied with temperature as illustrated follow:

$$V_{OC(T)} = V_{OC(Tr)}(1 - \beta_{V_{OC}}(T - Tr)) \quad (7)$$

Where, β_{Voc} = the open circuit temperature coefficient (V/sec).

All the constant in above equations are provided for standard condition of 25˚C temperature and 1000W/m^2 radiation level, and zero angle of incidence [4].

SIMULATION OF SOLAR PV SYSTEM IN MATLAB/SIMULIM

The parameters for modeling are chosen from the datasheet of AMERICAN SOLAR WHOLESALE ASW-250P as shown in Table 1.

Table 1. Key specification of AMERICAN SOLAR WHOLESALE ASW-250P

Parameter	Value
Typical Maximum Power (Pmax)	250W
Voltage at Pmax (Vmp)	35.2V
Current at Pmax (Imp)	8.48A
Short circuit current (Isc)	7.76A
Open circuit voltage (Voc)	43.22V
Module efficiency	16.16%
Temperature coefficient for Isc = $\boldsymbol{\alpha}_{Isc}$	0.035271%/deg.C
Temperature coefficient for Voc = $\boldsymbol{\beta}_{Voc}$	-0.3028 %/deg.C

SOLAR PV SYSTEM WITH DC-DC BOOST CONVERTER

The solar PV system has variable output due temperature and irradiation. Now this output always variable and its compulsory to fixed or constant. For this purpose step up or step down is required as per the required voltage level. In this paper required 110V fixed the step up or boost converter is used which input is 30-38V variable as per the irradiation and temperature but its output voltage is fixed at 110V. This is done by boost converter and load is fixed 25 Ω. Use MPPT algorithm as perturb and observe method to take maximum output from the solar panel. This technique control or adjust the voltage by a small amount of the power measured by array, adjust the voltage as per the increased or decreased power.

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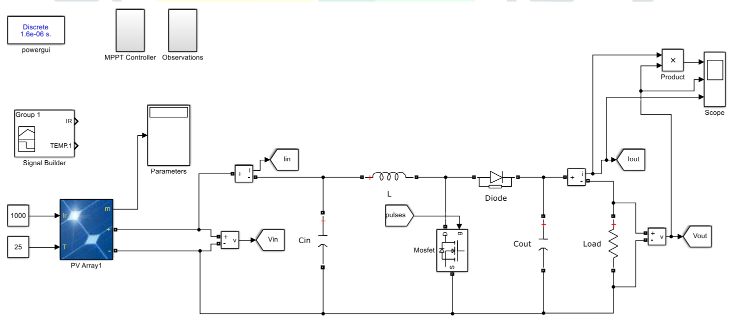

Figure 2. DC-DC Boost Converter with ASW-250P

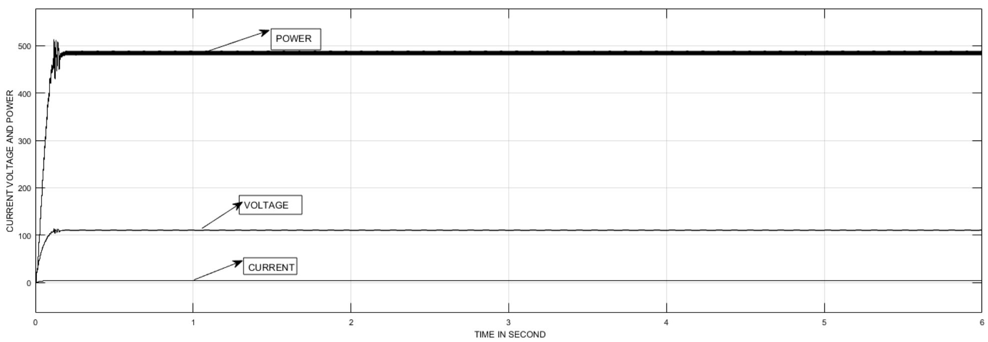

Figure 3. Output of DC-DC Boost converter

III. WIND POWER:

Wind is abundant almost in any part of the world. Its existence in nature caused by uneven heating on the surface of the earth as well as the earth's rotation means that the wind resources are always be available. The conventional ways of generating electricity using nonrenewable resources such as coal, natural gas, oil and so on, have great impacts on the environment as it contributes vast quantities of carbon dioxide to the earth's atmosphere which in turn will cause the temperature of the earth's surface to increase, known as the greenhouse effect. Hence, with the advances in science and technology, ways of generating electricity using renewable energy resources such as the wind are developed. Nowadays, the cost of wind power that is connected to the grid is as cheap as the cost of generating electricity using coal and oil. Thus, the increasing popularity of green electricity means the demand of electricity produced by using nonrenewable energy is also increased accordingly [8].

Wind Turbines There are two types of wind turbine in relation to their rotor settings. They are: Horizontal-axis rotors, and Vertical-axis rotors. In this report, only the horizontal-axis wind turbine will be discussed since the modeling of the wind driven electric generator is assumed to have the horizontal-axis rotor. The horizontal-axis wind turbine is designed so that the blades rotate in front of the tower with respect to the wind direction i.e. the axis of rotation are parallel to the wind direction. These are generally referred to as upwind rotors. Another type of horizontal axis wind turbine is called downwind rotors which has blades rotating in back of the tower [9].

Nowadays, only the upwind rotors are used in large-scale power generation and in this report, the term .horizontal-axis wind turbine refers to the upwind rotor arrangement. The main components of a wind turbine for electricity generation are the rotor, the transmission system, and the generator, and the yaw and control system. The following figures show the general layout of a typical horizontal-axis wind turbine, different parts of the typical grid-connected wind turbine, and cross-section view of a nacelle of a wind turbine [10].

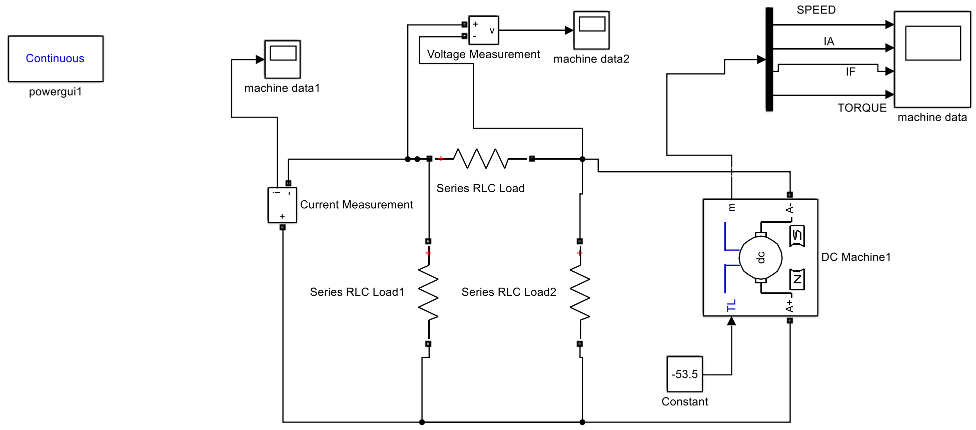

Figure 4. DC Generator with 110V fixed dc output

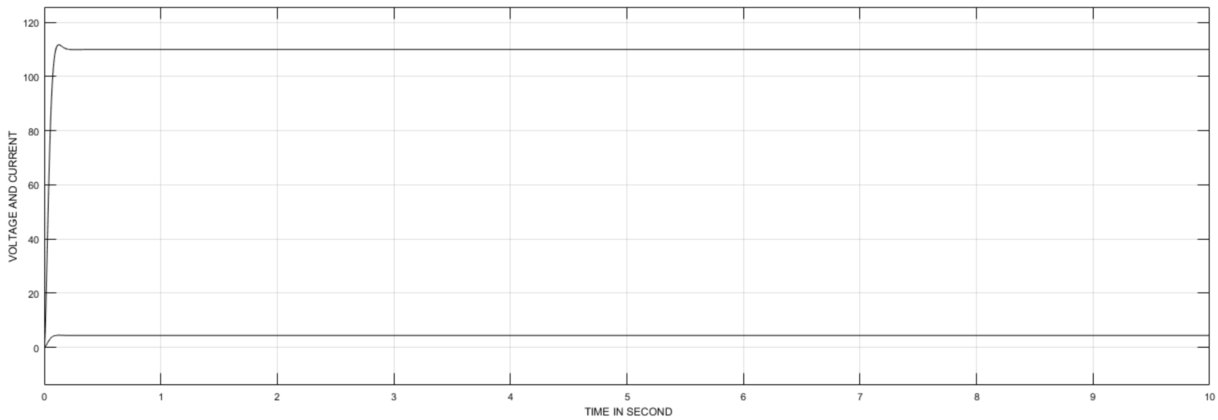

Figure 5. 110V fixed DC Output of DC Generator

IV. HYBRID SOLAR-WIND (DC-DC GENERATOR) SYSTEM

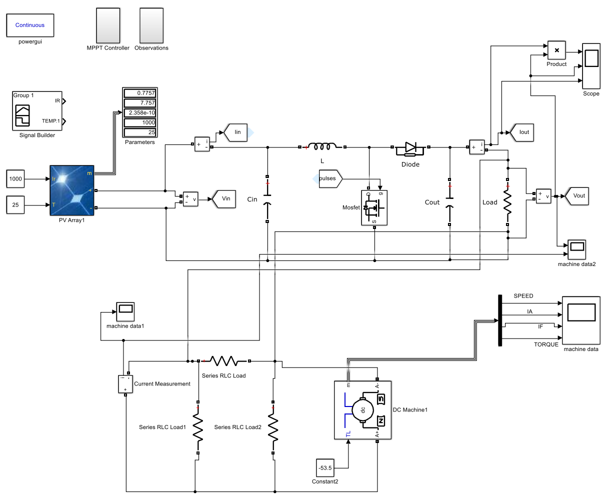

Figure 6 Simulation of Hybrid System with fixed DC output voltage

This hybrid system developed by solar and wind (dc-dc generator) system. This hybrid system connected with common load 130Ω and tries to balance the constant output voltage 110V for the system. All are the parameters of generators and PV system are considered as per the given references. The results are shown in the given figure.

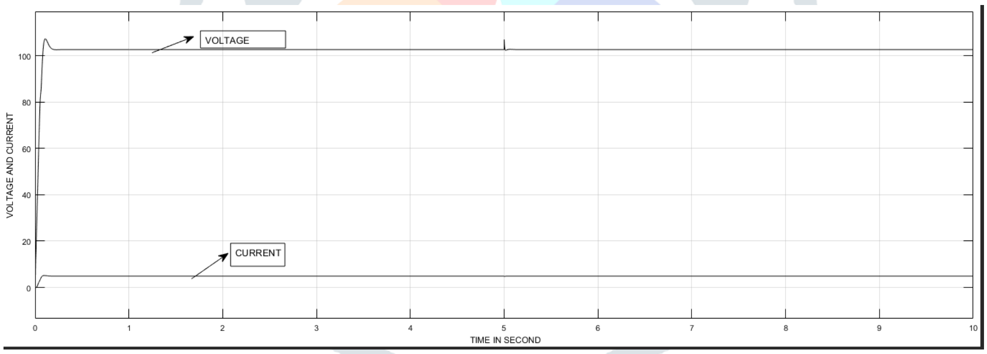

Figure 7 Results of Hybrid System with fixed DC output voltage

CONCLUSIONS

This paper represent a mathematical model of PV module and dc generator (equaling to wind generator) and hybrid wind/PV energy system for standalone system in Matlab/Simulink. The standalone hybrid system is better than a single energy source. The PV sources are only available at day time but at night the wind energy is fulfil the demand of the load. The wind energy systems may not be technically viable at all sites because of low wind speeds and being more unpredictable than solar energy. The combined utilization of these renewable energy sources is therefore becoming increasingly attractive. This Paper also highlights the future developments, which have the potential to increase the economic attractiveness of such systems and their acceptance by the user.

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