Solar Wind Hydro Hybrid Energy System Simulation

Kavitha Sirasani, S.Y. Kamdi

Abstract: ***The importance of hybrid systems has grown as they appeared to be the right solution for a clean and distributed energy production. So that new implementations of hybrid systems require special attention on analysis and modeling. This paper deals theoretical study of hybrid systems, based on renewable energy is the availability of models, which can be used to study the behavior of hybrid systems and most important, software simulation environments. In this paper we present several models which can be used for the simulation purposes of hybrid power systems.***

KEY WORDS: ***Hybrid energy system; Micro-hydro; Solar; Wind; Modeling; Simulation.***

I. INTRODUCTION

India currently has a peak demand shortage of around 14% and an energy deficit of 8.4%. India is facing an acute energy scarcity that hampers the country's industrial growth and economic progress and setting up of new power plants is inevitably dependent on import of highly volatile fossil fuels. The increasing consumption of conventional fuels coupled with environmental degradation has led to the development of eco-friendly renewable energy sources. The development of remote rural areas could not take place even after more than 50 years independence, as the grid could not be extended due to its high cost, capacity shortage and difficult terrain and environmental considerations. It becomes necessary to take up electrification of remote villages through non-conventional energy sources such as solar, micro-hydro and wind systems. Hybrid power systems consist of a combination of renewable energy sources as photovoltaic (PV) ,wind generators, hydro(etc) to charge batteries and provide power to meet the energy demand, considering the local geography and other details of installation. The solar power we are taking directly from sun, wind energy is obtained from the air movement on the earth's surface determined by the difference in speed and pressure. Small hydroelectric power plants harness the falling water kinetic energy to generate electricity.

The importance of hybrid systems grown as they appeared to be the right solution for a clean and distributed energy production.

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II. SOLAR WIND HYDRO SYSTEM MODELLING

A. Modelling of solar system

Modelling of a solar cell can be realized by an equivalent circuit that consist in a current source in parallel depletion layer becomes wider so that the capacitance is reduced similar to stretching the electrodes of a plate capacitor. Thus solar cells represent variable capacitance whose magnitude depends on the present voltage. This effect is considered by the capacitor C located in parallel to the diode.

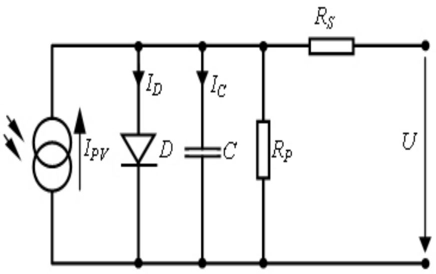

Fig.1 Equivalent circuit diagram of a solar cell

The diode determines the I-V characteristics of the cell. The output of the current source is directly proportional to the light falling on the cell. The open circuit voltage increases logarithmic according to Shockley equation which describes the interdependence of current and voltage in a solar cell .

$$I = I_{pv} - I_o(e^{qU/kT} - 1) \quad (1)$$

$$U = \frac{kT}{q} \ln\left(1 - \frac{I - I_{pv}}{I_o}\right) \quad (2)$$

where:

- k - Boltzmann constant ($1.3806 * 10^{23}$ J/K);
- T – reference temperature of solar cell;
- q – elementary charge ($1.6021 * 10^{19}$ As);
- U – solar cell voltage;
- I_o – saturation current of the diode;
- I_{pv} – photovoltaic current.

B. Modelling the wind system

Modelling of the wind energy converter is made considering the following assumption :

- frictionless;
- stationary wind flow;
- constant, shear-free wind flow;

- rotation-free flow;
- incompressible flow (ρ=1.22 kg/m3);
- free wind flow around the wind energy converter.

On the above condition the maximum physically achievable wind energy conversion can be derived by a theoretical model that is independent from the technical construction of a wind energy converter.

Energy of the flow air mass has certain energy. This energy is obtained from the air movement on the earth surface determined by difference of speed and pressure. The wind turbines use this energy as the main energy for obtaining electric power. The kinetic energy W taken from air mass flow m at speed v1 in front of wind turbine pales and in the backside of pales at speed v2 is illustrated by following equation:

$$W = \frac{1}{2} m(v_1^2 - v_2^2) \qquad (3)$$

Theoretical medium power P which can be obtained is determined as ratio of kinetic energy and unit time in which we want to determine this power by the equation:

$$P = \frac{W}{t} = \frac{1}{2}\frac{m}{t}(v_1^2 - v_2^2) = \frac{1}{2}\frac{V\rho}{t}(v_1^2 - v_2^2) \qquad (4)$$

where

- V air mass volume;
- t time;
- ρ air density.

Assuming the expression of the mean air speed $v_{med} = \frac{1}{2}(v_1 + v_2)$ the mean air volume transferred per unit time can be determined as follows:

$$v_{med} = \frac{V}{t} = Av_{med} \qquad (5)$$

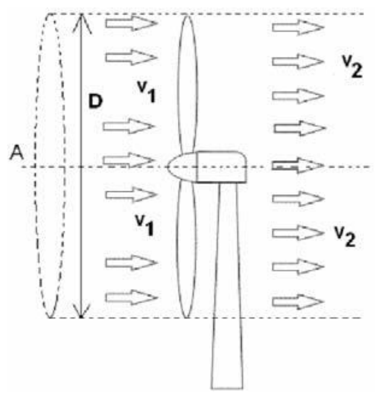

Fig. 2. Flow through an wind energy converter

We can conclude that an adequate choice of v_2 / v_1 ratio leads to a maximum power value taken by wind converter from kinetic energy of air masses, given by equation:

$$P_{max} = \frac{8}{27} A \rho v_1^3 \qquad (7)$$

this power represents only a fraction of the incident air flow theoretical power given by:

$$P_{wind} = \frac{1}{2} \rho A v_1^3 \qquad (8)$$

From (7) &(8) results:

$$P_{max} = \frac{8}{27} A \rho v_1^3 = \frac{1}{2} \rho A v_1^3 \cdot 0.59 = P_{wind} \cdot C_p \qquad (9)$$

where C_p represents the mechanical power coefficient which express that wind kinetic energy cannot be totally converted in useful energy. This coefficient was introduced by Betz with meaning of maximum theoretical efficiency of wind power. Electric power obtained when is considered the electrical and mechanical part efficiency of a wind generator is given by:

$$P_{el} = \frac{1}{2} C_e \rho A v_1^3$$

Where Ce represent total net efficiency coefficient at the transformer terminals .

C.Modelling of Hydroelectric System:

Small hydro electric plants harness the falling water kinetic energy to generate electricity. Turbines transform falling water kinetic energy into mechanical roration energy and then, the alternator transforms the mechanical energy into electricity. The hydrodynamic Bernoulli pressure equation is:

$$p + \rho_{water} gh + \frac{1}{2} \rho_{water} v^2_{water} = const.$$

where:

- p – hydrostatic pressure;
- $\rho_{wa/ter}$ – water density;
- g - acceleration of gravity;
- h - the water height;
- v_{water} – velocity of water flow.

Equation (11) can be transformed so that the first term expresses the pressure level, the second term the level of the site and the third term the water velocity level.

In this case, considering the energy balance between two specific points of a river, and also the energy losses, the hydrodynamic Bernoulli pressure equation can be written according equation (16).

$$\frac{p_{up}}{\rho_{water\ .up}\, g} + h_{up} + \frac{v^2_{water\ .up}}{2g} = \frac{p_{down}}{\rho_{water\ .down}\, g} + h_{av} + \frac{v^2_{water\ .down}}{2g} + \xi \frac{v^2_{water\ .down}}{2g} = cons. \qquad (12)$$

Where :

$\frac{p}{\rho_{wat\ er}\, g}$ - hydrodynamic pressure energy;

h – potential energy of the water;

$\frac{v^2_{water}}{2g}$ – kinetic energy of the water;

$\xi \frac{v^2_{water}}{2g}$ - energy losses;

ξ - loss coefficient.

The energy losses are represented by the part of the rated power which is converted into ambient heat by friction and cannot be used technically.

In the turbine, pressure energy is converted into mechanical energy. The conversion losses are described by the turbine efficiency $\eta_{turbine}$. Equation(13) describes the part of the usable water power that can be converted into mechanical energy at the turbine shaft $P_{turbine}$.

$$P_{turbine} = \eta_{turbine}\, \rho_{water}\, g\dot{q}_{water}\, h_{util} \quad (13)$$

h_{util} is the usable head at the turbine, and the term ($\rho_{water}\, g\dot{q}_{water}\, h_{util}$) represents the actual usable water power.

D. Modelling the Storage Device:

For energy sources like photovoltaic or wind energy systems, the power production depends upon the availability of the resources like sunlight or wind. This makes the nature of power available to loads intermittent, thus making them non-dispatch able sources. However, the energy storage systems with non-dispatch able energy can be deployed as dispatch able energy sources. This only needs a proper design of the energy storage system by looking into the load curve. Batteries are the basic component of an energy storage system.

The parameters associated with battery modeling are:
- internal resistance;
- polarization capacitance;
- discharge type;
  discharge mode;
- rate of charge and discharge;

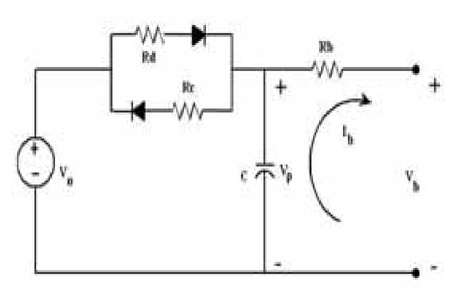

Fig 3.Thevenin equivalent battery model.

The open circuit voltage, internal capacitor voltage and the terminal voltage are represented by V_0, V_p , and V_b.The charging, discharging, and internal resistance of the battery are represented by R_c , R_d and R_b and the polarization capacitance of the battery is represented by C. The current I_b is taken as positive if discharging and negative otherwise.

The equations for the circuit model are :

$$\dot{V}_p = \frac{1}{C}\left(\left(\frac{V_0 - V_p}{R_d}\right) - I_b\right) \quad (14)$$

$$V_b = V_p - I_b R_b \quad (15)$$

III SIMULATION OF SOLAR WIND HYDRO ENERGY SYSTEM

A Solar system model:

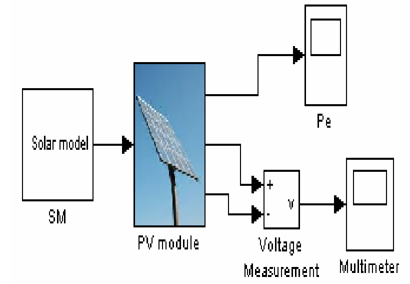

Fig4. Matlab Simulink model of PV module

Solar system model consist of three Simulink blocks: solar model block, PV model block and energy conversion modules.

Solar model block implements the mathematical model of solar radiation. This is done by using standard Simulink and Matlab modules and functions. This block allows selecting different type of patterns for solar radiation.

PV model implements the equivalent circuit of a solar cell presented in Fig. 1. Here standard functions and block of Matlab and Simulink are used.The output of the PV module is processed by an energy conversion block implemented with an PWM IGBT inverter block from standard Simulink/ SimPowerSystems library.

B Wind system model:

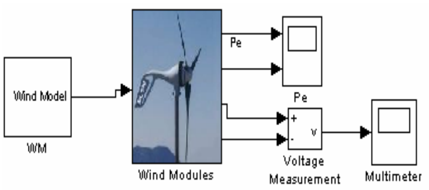

Fig.5 Matlab Simulink model of wind generator module.

Wind system model consist of three Simulink blocks: wind model block, wind generator model block and energy conversion modules.

Wind model block implements the mathematical model of air mass flow. This is done by using standard Simulink and Matlab modules and functions. This block allows selectingdifferent type of patterns for air mass flow.

Wind energy generator model implements the equivalent circuit of a solar cell presented in above mathematical model.

Here standard functions and block of Matlab and Simulink are used. This module has configurable parameters.

The output of the wind energy generator module is processed by an energy conversion block implemented with an PWM IGBT inverter block from standard Simulink/SimPowerSystems library.

C Hydro system model:

In Fig .6 is shown the Matlab Simulink model of hydro electric system.

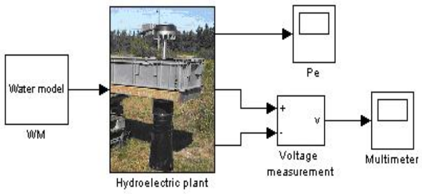

Fig 6 Matlab Simulink model of hydro electric system.

The hydro electric system model consists of three Simulink blocks : the water model block, the hydroelectric plant block and energy conversion modules.

The water model implements the mathematical model of the water pressure..This is done by Simulink model of the hydroelectric system.

The model of the hydroelectric plant(generator) has the same form as the wind generator .

D Battery system model:

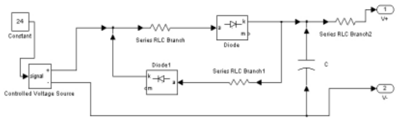

Fig 7 Matlab Simulink model of the battery storage device.

IV HYBRID ENERGY SYSTEM

To implement a real hybrid system a theoretical preliminary study is required. This study can be done on simulation models. A simulation model is presented in Fig.8.

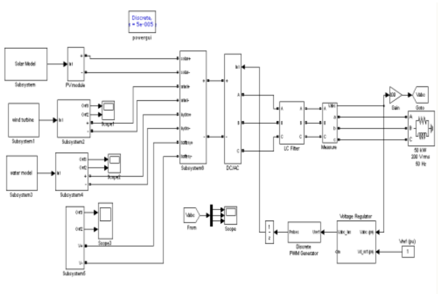

Fig.8 Simulation model of a hybrid renewable energy system

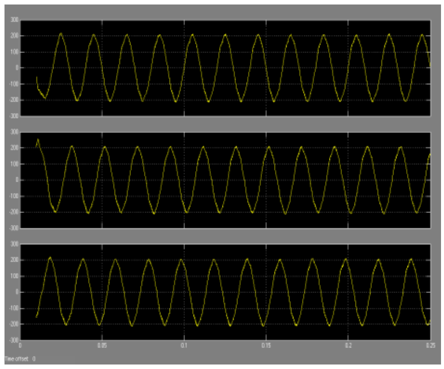

Fig 9. Voltage waveform at the AC three-phased bus bar.

V CONCLUSION

Increasing of energy demand in energy market,we have to adopt and implement some specific resources. The promotion of energy production from renewable sources represents an imperative objective in present times justified by environment protection , the increase of energetic independence by supplying sources diversity and economic and social cohesion reasons.

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