Advanced Research in Electrical and Electronic Engineering
Print ISSN: 2349-5804; Online ISSN: 2349-5812 Volume 2, Number 7 April-June (2015) pp. 18-22

http://www.krishisanskriti.org/areee.html

A Novel Method of Integrating Solar-Wind-Tidal Power with Grid

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Abstract—*Performance optimization, system reliability and Operational efficiency are key characteristics of grid systems. This paper deals theoretical study of hybrid integration(solar-wind-tidal) with the grid 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, present several models which can be used for the simulation purposes of hybrid power systems and a novel model of integrating solar-wind-tidal power with grid-connected system is developed. The importance of hybrid systems has grown as they appeared to be the right solution for a clean and distributed energy production based on the climate of the particular place in india. So that new implementations of hybrid systems require special attention on analysis and modeling.*

Keywords: *Hybrid energy system; Solar; Wind; Tidal modeling; Simulation.*

1. INTRODUCTION

In the light of present climate change, the importance of renewable energy systems which are Green energy systems has been recognized all over the globe. Governments worldwide promoting the renewable energy technologies by providing funds, subsidies and many other incentives. Photovoltaic is one of the renewable energy options having huge potential all over world and especially in India.

India is located in sunny belt of earth, thereby receiving abundant radiant energy from the sun. Its equivalent energy potential is about 6,000 million GWh of Energy per year. In most parts of India clear sunny weather is experienced for 250 to 300 days a year. The annual global solar radiation varies from 1600 to 2200 kWh/m^2, which is comparable with the radiation received in the tropical and sub -ropical regions.

2. MODELING OF SOLAR SYSTEM

Modeling 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.

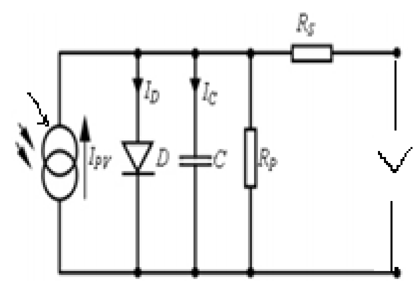


Fig. 1: Equivalent circuit diagram of a solar cell

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 .

$$I = Ipv - Io\left(e^{\frac{qV}{kt}} - 1\right) \quad (1)$$

$$V = \frac{kt}{q}\ln(1 - \frac{I-Ipv}{Io}) \quad (2)$$

Where

V- Terminal Voltage in volts

k-Boltzmann constant(1.3806*10^23 j/k)

T- Reference temperature of solar cell

q- Elementary charge(1.6021*10^19 As)

I_o- saturation current of the diode

I_{pv}- Photo voltaic current

3. WIND POWER

Wind energy is the energy of air motion around the earth surface and it is considered as a mechanical energy source.

The power of wind energy nowadays is used to motion power turbines of the wind generator and generate electricity. The level of generated electricity is depended on the level and quantity of wind speed and design of the turbines. In this paper, a wind turbine parallel to a solar power panel is used to produce the power generation of a hybrid renewable system and study the output when connected to small power grid. The Wind turbines output power is dependent on speed of wind.

This variable feature of wind turbine power generation is different from conventional fossil fuel, nuclear, or hydro-based power generation. Wind energy has become the least expensive renewable and freely available energy technology in existence and has peaked the interest of scientists and educators the world over. A simple theoretical concepts has given below:

4. WIND SYSTEM MODEL:

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

1.less friction;

2. Constantwind flow;

3. constant, shear-free wind flow;

4. simple rotation-free flow;

5. incompressible flow (ρ=1.22 kg/m3);

- free wind flow around the wind mill energy Converter On the above condition the maximum physically achievable wind energy conversion can be derived by a simple 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 movement in air 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 mass of air flow m at speed v_1 in front of wind turbine pales and in the backside of pales at speed v_2 is illustrated by following equation:

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

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:

$$P = \frac{w}{t} = w = \frac{1}{2}\frac{m}{t}(v_1^2 - v_2^2)$$
$$= \frac{1}{2}\frac{Vp}{t}(v_1^2 - v_2^2) \tag{4}$$

where

v- air mass volume;

t time; ρ air density.

Area covered by air

Assuming the expression of the mean air speed Vmed = 1/2(v_1 + v_2) the mean air volume transferred per unit time can be determined as follows:

$$V_{med} = \frac{v}{T} = aV_{med} \tag{5}$$

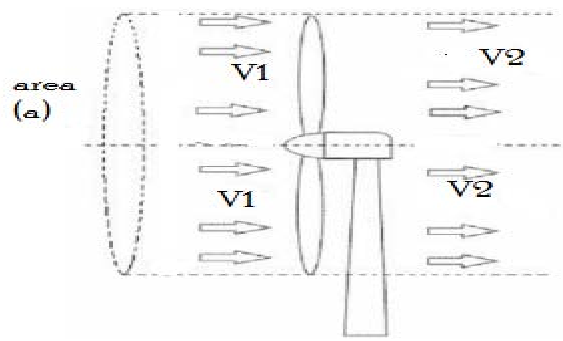


Fig. 2: Air Flow through an wind energy converter

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:

$$P_{max} = \frac{8}{27} a\rho v_1^3 \tag{6}$$

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

$$P_{wind} = \frac{1}{2} a\rho v_1^3 \tag{7}$$

From (6) and (7)

$$P_{max} = \frac{8}{27} a\rho v_1^3$$
$$= \frac{1}{2} a\rho v * 0.59$$
$$= P_{wind} * c_p \tag{8}$$

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:

$$P_{electric\ power} = \frac{1}{2} C_e \rho a v_1^3$$

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

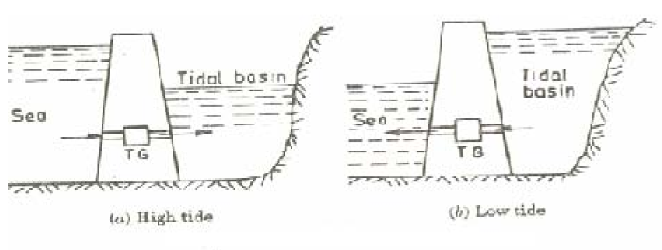
5. TIDAL ENERGY

Basically, tidal energy was extracted from moving masses of water which was known as tides. According to previous published paper; ocean energy is one of the sources with huge potential to generate electricity where it was abundance as almost 70% of our Earth covers with waters which are best describe as a huge reservoir with many kind of energy that can be extracted from it such as waves, thermal differences, tides, salinity gradient and marine current [1].

Generally, there are three methods or approach that were often used in order to harness the energy and generate electricity from the ocean sources, which are tidal barrage, tidal stream and dynamic tidal power.

A.TIADAL BARRAGE

Tidal barrage as shown in figure 1 is a popular method that was builds across a bay or an estuary at high tides differential at least three to eight meters of tidal ranges, to achieve valuable and worth value of electrical power generation. The bottom of the barrage is located on the sea floor and the top is above the highest level that the water can get at high tide. The estuary was characterized by narrow, shallow channels with a relatively constant width and depth. [2] It applies the same principle as hydroelectric generation except that tidal currents flow in both directions. [3]



(a) High tide (b) Low tide
Fig. 3: Tidal Barrage approach

During high tide, the water level on sea side was increased and only then the sluice gates opened and the water was forced to flow through the narrow openings and flow into the basin that create forces. The forces create speeds that rotate the turbines of the tidal plant and generating the electricity. After the basin was filled with water, the sluice gates will close and this process was repeated always to generate electricity. That is why the tidal energy is said to be abundance and highly predictable. By using equation 9 below, the potential energy of a tidal turbine can be calculated [8][9]

$$E_p = \frac{1}{2} C_p(\lambda) g \rho a h^2 \quad (9)$$

Where

E_p – Potential Energy (j)

C_p – Power co-efficient

λ – top speed ratio

g – acceleration dude to gravity (ms^{-2})

ρ – density of the water(sea water is 1025 kgm^3)

a – the sweep area of the turbine (m^3)

h – tide amplitude (m)

B. Tidal Current

Tidal stream is an energy that was extracted from free flowing water[10]. It extracts the energy from currents in similar way with wind turbines but in different density where water is 832 times denser than air which means it will harness the same amount of power although the water speeds are slower (one-tenth) than wind speed in meter per second (m/s) for same size of turbine. [4] Currently, there are two types of turbines which are horizontal and vertical axis turbines. Figure 2 illustrates the types of turbines blade for tidal stream approach In order to harvest tidal stream energy, the conversion systems are required to convert water kinetic energy into motion of mechanical system which can drive the generators [5]. Thus, equation 10 was used to assume the output power from capture kinetic energy [6][7]:

$$P = \frac{\xi \rho a v^3}{2} \quad (10)$$

Where

P – the power generated (w)

ξ—the turbine efficiency

ρ-- density of the water(sea water is 1025 kgm^3)

a – the sweep area of the turbine (m^3)

v—the velocity of the flow(ms^{-1})

There are a numbers of most desirable locations to harness tidal energy which fulfill the requirement of narrow straits between land masses or are adjacent to headlands where large tidal currents were developed.

Tidal stream(knots)

$$= \frac{positive\ \ tidal\ \ stream}{2} - \frac{negative\ \ tidal\ \ stream}{2}$$

Tidal range(m)

$$== \frac{high\ tide}{2} - \frac{low\ \ tide}{2}$$

Hybrid Energy System

To implement a real hybrid system a theoretical preliminary study is required. This study can be done on simulation models. A combined of solar, wind and tidal simulation model is presented in Fig.4. This type hybrid combination possible where the place associated with these three geographically structured like dry place, sea and wind. These three

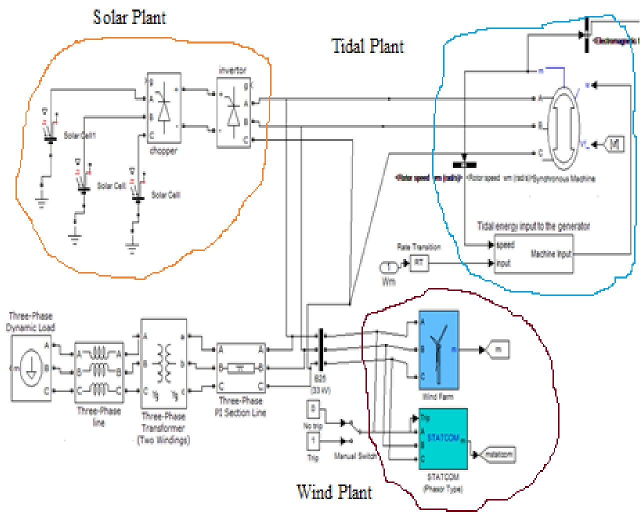


Fig. 4: Schematic connection of above Hybrid Power plants

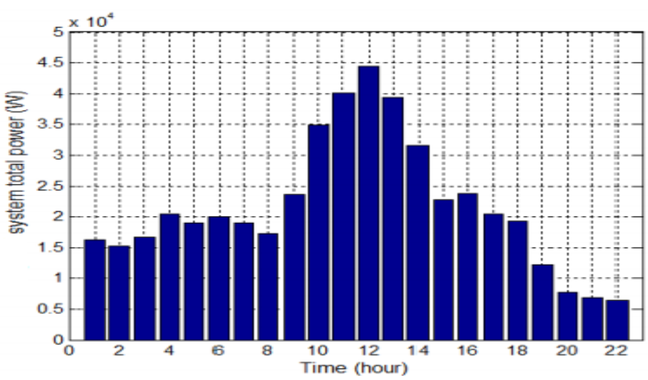


Fig. 5: Total Power Generated by the hybrid system

6. 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. Renewable Hybrid Integration (Solar-Wind-Tidal) With the Grid is possible only in the place which are associated with sunny belt of earth, coastal places in india like tamil nadu, Andrapradesh. In these places continuity of tidal, solar and wind energy so we can generate continuous power.

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