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A DISTRIBUTED HYBRID MODEL OF SOLAR-WIND-SMALL HYDRO FOR POWER GENERATION SYSTEM

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ABSTRACT

Renewable energy technologies offer the promise of clean, abundant energy gathered from self-renewing resources such as the sun, wind, water, earth, and plants. In this thesis a detailed modeling of hybrid power generation system of solar, wind and small hydro has been developed in Matlab. The simulation includes all realistic components of the system. In this thesis, the power delivered by the combine system component is compared with each other and various conclusions are drawn. We have proposed a model of 5MW that contains 3MW of small hydro plant, 1 MW of solar plant and 1 MW of wind plant. We have prepared a cost analysis report that indicates it is profitable to go for such model as it satisfies our current and future energy demands. Moreover the electricity generated by the proposed model is available at a very lesser rate as compared to our current electricity tariff rates.

Keywords

Renewable Energy : Solar Energy, Wind Energy, small hydro Energy, cost analysis.

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INTRODUCTION TO DISTRIBUTED GENERATION

Distributed generation (DG) [1] refers to power generation at the point of consumption. Generating power on-site, rather than centrally, eliminates the cost, complexity, interdependencies, and inefficiencies associated with transmission and distribution. Like distributed computing (i.e. the PC) and distributed telephony (i.e. the mobile phone), distributed generation shifts control to the consumer. Distributed Generation is gaining worldwide acceptance due to its number of benefits. It eliminates the cost and complexity and reduces the chances of inefficiency which occur in the transmission and distributed network. Basically electricity produced is generated at large generating stations which is then send at high voltages through the transmission lines to the load centers and then through local distribution network distributed to the customers at distribution level voltage. In present scenario there is an increase in demand which is creating gap between demand and supply to fulfill this gap distributed generation can plays the significant role. The main reason for the need of distributed generation is it is clean and continuous. Distributed generation means generating power on site or at a near-by location not centrally. Distributed generation is the best way for rural electrification. Renewable energy technologies offer the promise of clean, abundant energy [8] gathered from self- renewing resources such as the sun, wind, water, earth, and plants. Virtually all regions of the world have renewable resources of one type or another. Renewable energy technologies offer important benefits compared to those of conventional energy sources. Worldwide, 1000 times more energy reaches the surface of the earth from the sun than is released today by all fossil fuels consumed. Photovoltaic and wind generation are also an attractive source of energy because of their benign effect on the environment. Increased population growth and economic development are accelerating the rate at which energy and in particular electrical energy is being demanded. All methods of electricity generation have consequences for the environment, so meeting this growth in demand, while safeguarding the environment poses a growing challenge. Each of the renewable energy technologies is in a different stage of research, development [5], Commercialization and all have differences in current and future expected costs, current industrial base, resource availability, and potential impact on greenhouse gas emissions.

IMPORTANCE OF DISTRIBUTED GENERATION

Several studies were conducted to emphasize the main shortfalls of the centralized generation paradigm. Some of them are listed below:

Distribution costs: The distribution costs amount for up to 30% of the cost of delivered electricity on average. The lowest cost is achieved by industrial customers taking electricity at high to medium voltage and highest for small customers taking electricity from the distribution network at low voltage.

Rural electrification: In an integrated power system, rural electrification is challenging for two reasons[6]. As large capital expenditures are required to connect remote areas due to the distance to be covered through overhead lines, connecting remote areas with small consumption might prove uneconomical.

Fuel diversity: as distributed generation technologies can accommodate a larger range of fuel that centralized generation, distributed generation has been used to diversify away from coal, fuel, natural gas and nuclear fuel. For instance, distributed generation has been used at landfills to collect biogas and generate energy.

Environmental Impact: The environmental impact of the centralized energy system is significant due to the heavy reliance on fuel, coal and to a lesser extent natural gas. Distributed generation has been used to mitigate the impact both in terms of emissions associated with transmission and distribution losses, to increase efficiency through cogeneration and distributed renewable energy.

SOLAR ENERGY

Energy supplied by the sun in one hour is almost equal to the amount of energy required by the human population in one year. Renewable energy sources play an important role in electricity generation.[2] Various renewable energy sources like wind, solar, geothermal, ocean thermal, and biomass can be used for generation of electricity and for meeting our daily energy needs[3,4]. Energy from the sun is the best option for electricity generation as it is available everywhere and is free to harness. A simplest model of power generation through solar energy is shown in Figure 1.

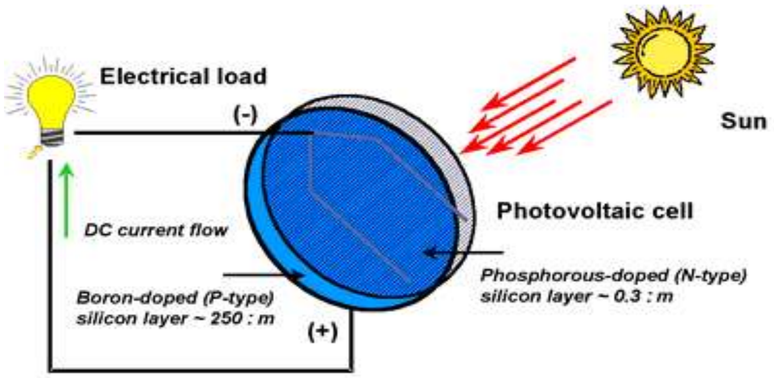

Figure 1. How solar cells Generate electricity

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WIND ENERGY

Wind power systems[9] convert the kinetic energy of the wind into other forms of energy such as electricity. Although wind energy conversion is relatively simple in concept, turbine design can be quite complex[11]. Most commercially available wind turbine uses a horizontal – axis configuration with two or three blades, a drive train including a gearbox and a generator and a tower to support the rotor.

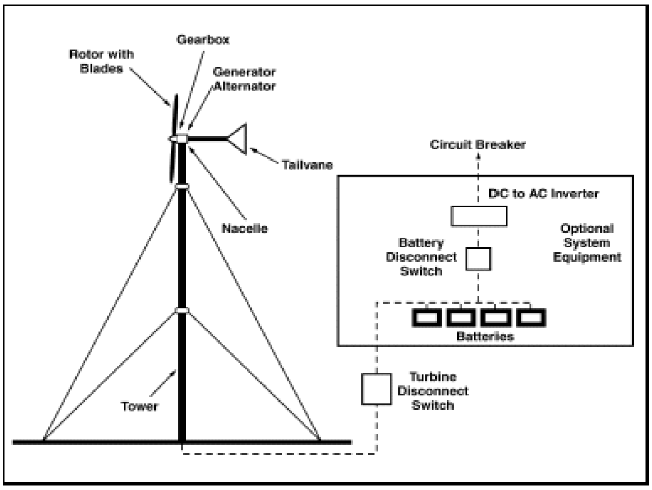

Figure 2. Components of a wind energy system.

SMALL HYDRO PLANT

Small scale hydropower systems capture the energy in flowing water and convert it to usable energy. Although the potential for small hydro-electric systems depends on the availability of suitable water flow, where the resource exists it can provide cheap clean reliable electricity[12]. A well designed small hydropower system can blend with its surroundings and have minimal negative environmental impacts.

Moreover, small hydropower has a huge, as yet untapped potential in most areas of the world and can make a significant contribution to future energy needs. It depends largely on already proven and developed technology, yet there is considerable scope for development and optimization of this technology.

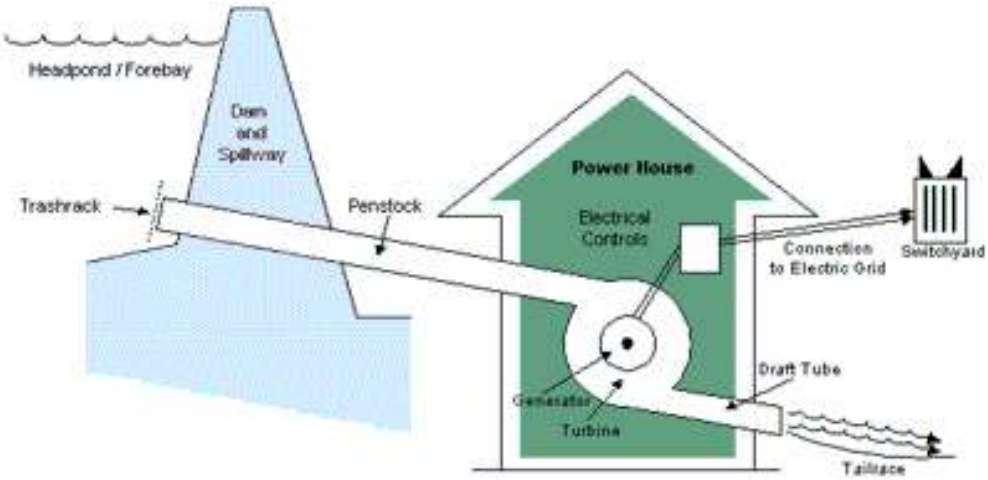

Figure 3. Working of a small hydro plant

RESEARCH MOTIVATION

The rapid depletion of fossil fuel resources on a world-wide basis has necessitated an urgent search for alternative energy sources to cater to the present day demands. Alter-native energy resources such as solar and wind have attracted energy sectors to generate power on a large scale. A drawback, common to wind and solar 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 demand.

Fortunately, the problems caused by the variable nature of these resources can be partially overcome by integrating the two resources in proper combination, using the strengths of one source to overcome the weakness of the other. The hybrid systems that combine solar and wind generating units with battery backup can attenuate their individual fluctuations and reduce energy storage requirements significantly. However, some problems stem from the increased complexity of the system in comparison with single energy systems.

• No electricity will be generated when the wind or the solar is not available. It depends upon the weather as well as geographical locations where the solar and wind is available in abundant.

• Strength of wind is not constant because it varies from time to time. This means that wind turbines do not produce the same amount of electricity all the time.

• Solar energy is also not constant in the night time or during the sunny days.

OBJECTIVES

So taking view of above difficulties of the solar/wind hybrid model, we are introducing small hydro-power generation plants along with the solar and wind plants. Hydro Energy as another generating resource accompany with the above two resources. The hydro energy can generate electricity at any climate conditions which can increase the overall production of the system and decrease the demand of batteries for this system. The individual efficiency of the hydro energy is very high which can improve the efficiency of whole new hybrid model.

• To propose a hybrid model of solar, wind and small hydro for distributed power generation.

• To implement the hybrid model and its components in the Simulink environment.

• To carry out cost analysis whether it's profitable to maintain this hybrid model.

• To compare the current electricity generation costs with the proposed model.

Small Hydro plants have been already implemented and are running successfully all over the world. In this paper, a higher efficiency cost analysis of Solar/Wind/Small Hydro Hybrid System is developed. The modeling and simulation of WIND/SOLAR/Small Hydro of the hybrid model is done using MATLAB/SIMULINK for economization and improving the reliability of the hybrid system.

METHODOLOGY

• Simulate the Solar, wind and small hydro power models in the Matlab/Simulink environment.

• Find out the locations of the proposed hybrid model in India.

• Compute the cost analysis of the proposed hybrid model.

• Compare the evaluated cost of the proposed model with the current scenario.

• Carry out the analysis whether it is profitable to make the hybrid model or not.

IMPLEMENTATION

A Simple Model of PV /Wind/ Small Hydro system is shown in figure 4. This model consist of PV arrays, Wind turbine and small hydro plant combine to work as Hybrid model. The detail modeling of this model is divided in four parts modeling of PV Module, modeling of Wind Turbine and modeling of small hydro plant.

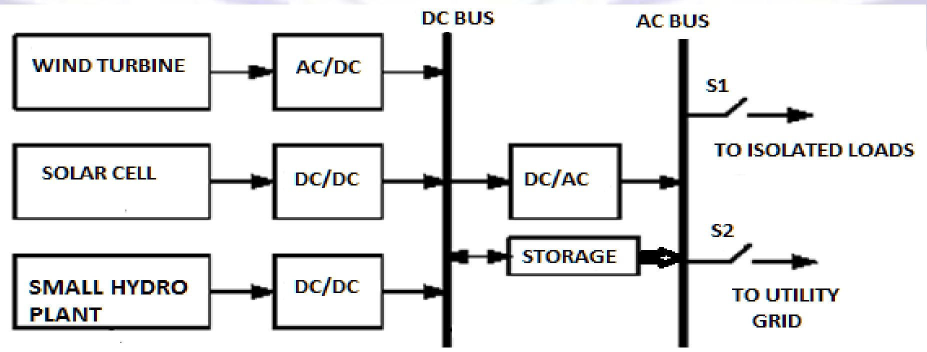

Figure 4. A Simple Model of PV /Wind/ Small Hydro system

SIMULATION OF PV MODULE

The I– V characteristic of the PV module are :

$$I = I_L - I_0 (e^{q(V + IR_S)/nkT} - 1)$$

Where I_L = photo current

I0 = diode saturation current

RS = series current

q = charge of electron

k = constant

T = temperature

N = number of PV module

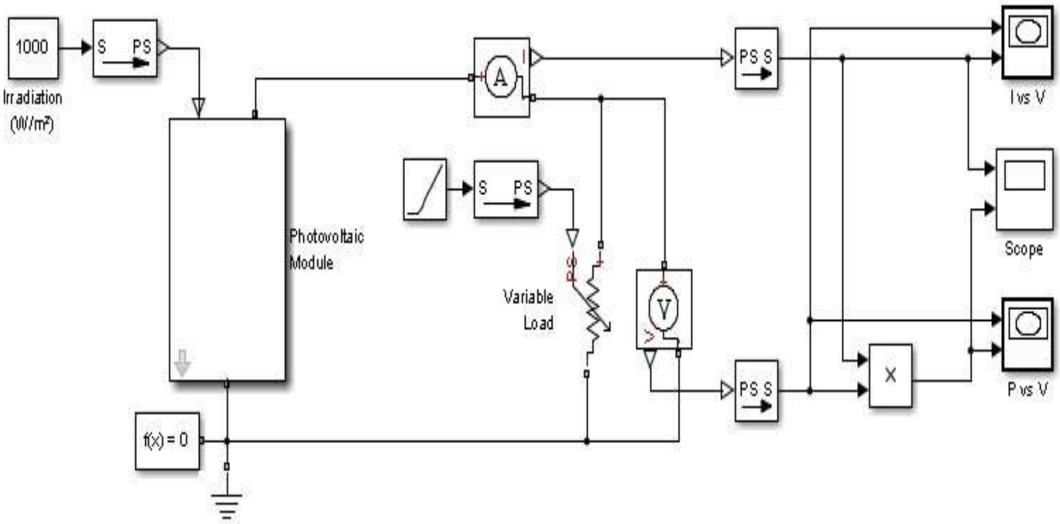

Figure 5. Matlab Simulink model of PV module

SIMULATION OF WIND TURBINE

As we know that power delivered by a wind turbine is given by

Pwin (t) = 1/2 *ℓ*A*V (t) ^3* Cp*Effad

Where ℓ = air density (kg/m^3)

A = area swept of rotar (m^2)

V = wind speed (m/s)

Effad = efficiency of the AC/DC Converter

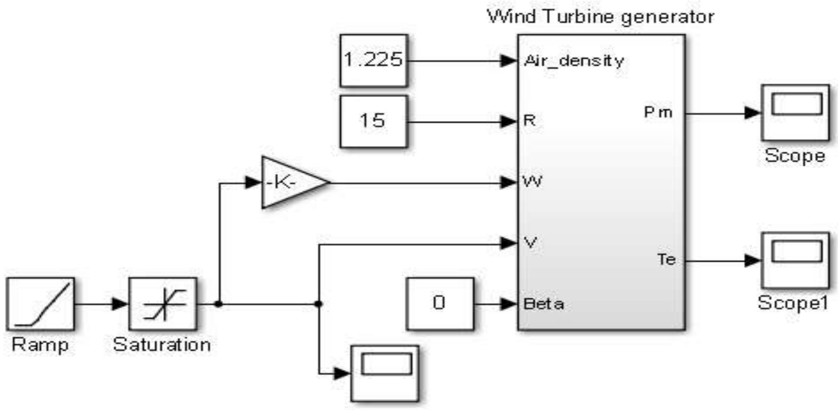

Figure 6. Matlab Simulink model of PV module

SIMULATION OF SMALL HYDRO PLANT

Water is fed from stream/canal to the turbine [15] by a closed pipe (penstock) through diversion works. The turbine in turn rotates the generator for electricity generation.

INTAKE STRUCTURE

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- Assured water supply
- Suitable quality of water
- Control over supply of water
- Safety against flood

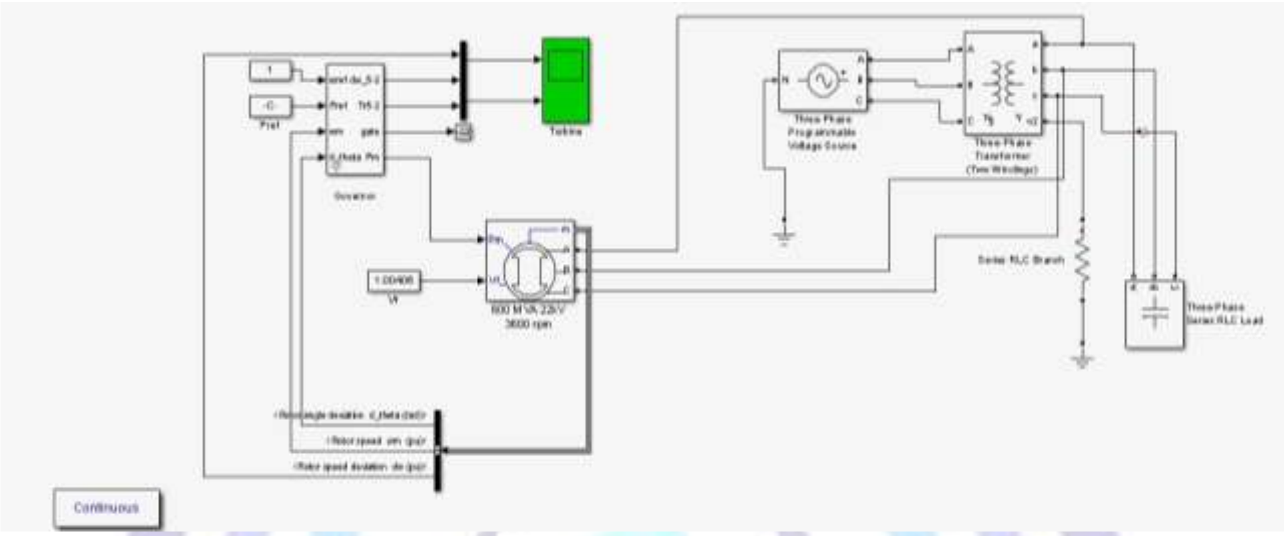

Figure 7. Matlab Simulink model of Small Hydro Plant

COST ANALYSIS

A. TOTAL UNITS PRODUCED BY THE HYBRID PLANT OF 5 MW ANNUALLY

Annual Units Produced by the Solar Plant of 1 MW = (System Size in KW*CUF*No of Days*No of Hours)/100

Solar Plant Production = (1 * 1000 * 30 * 365 * 9.32)/ 100 = 1020540 units

Annual Units Produced by the Wind Plant of 1 MW = (1 * 1000 * 25 * 365 * 24)/ 100 = 2190000 units

Annual Units Produced by the Small Hydro Plant of 3 MW = (3 * 1000 * 25 * 365 * 24)/ 100 = 6570000 units

Total Units Produced by Hybrid Plant = (1020540 + 2190000 + 6570000) units

= 9780540 units

= 97.8 lakh units (Annually)

AEO – ANNUAL ENERGY OUTPUT (Sum of energy produced by hybrid system over each hour over a day * 365 days)

ACS – Total Annualized Cost

COE - Cost of Electricity (Rs /KWh)

COE = ACS / AEO

In table 1, the annual production of 5MW from different energy sources are mentioned.

Table 1. A 5 MW Comparison Table

System Type	Capital Cost (In Crores)	Annual Maintenance Cost (In Lakhs)	Lifetime (Years)	Interest Rate (%)	Annual Production (lakh Units)
Solar Plant (5MW)	34.55	424.96	25	12.75	51.02
Wind Plant (5MW)	29.80	29.80	25	12.75	109.5

Small Hydro Plant (5MW)	28.50	28.50	25	12.75	98.55
Hybrid Plant (5MW)	31.87	109.96	25	12.75	97.80

C. EQUIVALENT ANNUAL COST – EAC

The annual cost of owning an asset over its entire life. Equivalent annual cost is often used by firms for capital budgeting decisions. Equivalent annual cost is calculated as:

$$= \frac{\text{Asset Price} \times \text{Discount Rate}}{1 - (1 + \text{Discount Rate})^{-\text{Number of Periods}}}$$

where

Asset Price = Capital Cost of the Component

Discount Rate = The Rate at which bank provides the loan

Number of Periods = Lifetime of Component.

Annualized Cost of the Component = Equivalent Annual Cost + Maintenance Cost

5.7.4 Comparison of per unit cost of solar/wind/small hydro/hybrid Plant of 5MW.

Table 2. Annualized Cost of Each Plant (In Crores)

Plant Type	Annualized Cost (Capital Cost + Maintenance Cost)
Photo Voltaic Cell (5MW)	494.694
Wind Plant (5MW)	383.740
Small Hydro Plant (5MW)	367.008
Hybrid Plant (5MW)	420.362

Table 3. Comparison of per unit cost of solar/wind/small hydro/hybrid plant

Plant Type	Cost Per Unit
Photo Voltaic Cell (5MW)	9.69
Wind Plant (5MW)	3.50
Small Hydro Plant (5MW)	3.72
Hybrid Plant (5MW)	4.29

CONCLUSION

In this thesis work, a hybrid model of PV/Wind/small hydro energy system is developed. We have also seen that this model is more effective and more reliable as compared to the earlier one. The power delivered by hybrid model of PV/WIND/small hydro is much higher and economical than the current system. The system is more environmental friendly and the waste products of this system do not contain any harmful gases/products, this model use all the renewable energy sources for electric generations which are the need of the time.

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