COST ANALYSIS OF HYBRID MODEL
OF SOLAR-WIND-BIOGAS PLANT

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ABSTRACT

In this paper, the power delivered by the combined system component is compared with each other and various conclusions are drawn. The various advantages and disadvantages of the system are compared, and a cost analysis of the system is carried on with the present system. The power delivered by hybrid model of PV/WIND/biogas is much higher than the PV/WIND. The system is more reliable, environmental friendly and the waste products of this system do not contain any harmful gases and acids. This model uses all the renewable energy sources for electric generations which are the need of the time. With the use of energy from wind, solar, biogas plant it will help to reduce our dependency on fossil fuels. Thus, as future development of the present work, it could be very useful to set up flexible tool to model and to simplify the task of evaluating design solutions for stand-alone and distributed generation's applications. We have proposed a model of 3KW that contains 1 KW of biogas plant, 1 KW of solar plant and 1 KW 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, biogas energy, cost analysis.

INTRODUCTION

Renewable energy technologies offer the promise of clean, abundant energy 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, Commercialization and all have differences in current and future expected costs, current industrial base, resource availability, and potential impact on greenhouse gas emissions. Hybrid power systems consist of a combination of renewable energy sources such as: photovoltaic (PV), wind generators, etc., to charge batteries and provide power to meet the energy demand, considering the local geography and other details of the place of installation. These types of systems, which are not connected to the main utility grid, are also used in stand-alone applications and operate independently and reliably. The best applications for these systems are in remote places, such as rural villages, in telecommunications, etc.

The importance of hybrid systems has grown as they appeared to be the right solution for a clean and distributed energy production. It has to be mentioned that new implementations of hybrid systems require special attention on analysis and modeling. One issue is determined by the variable and unpredictable character of energy supply from renewable sources.

FOSSIL FUEL RESERVES

Crude oil, coal and gas are the main resources for world energy supply. The size of fossil fuel reserves and the dilemma that "when non-renewable energy will be diminished" is a fundamental and doubtful question that needs to be answered. This paper presents a new formula for calculating when fossil fuel reserves are likely to be depleted and develops an econometrics model to demonstrate the relationship between fossil fuel reserves and some main variables. The new formula is modified from the Klass model and thus assumes a continuous compound rate and computes fossil fuel reserve depletion times for oil, coal and gas of approximately 35, 107 and 37 years, respectively. This means that coal reserves are available up to 2112, and will be the only fossil fuel remaining after 2042. In the Econometrics model, the main exogenous variables affecting oil, coal and gas reserve trends are their consumption and respective prices between 1980 and 2006. The models for oil and gas reserves unexpectedly show a positive and significant relationship with consumption, while presenting a negative and significant relationship with price. The econometrics model for coal reserves, however, expectedly illustrates a negative and significant relationship with consumption and a positive and significant relationship with price. Consequently, huge reserves of coal and low-level coal prices in comparison to oil and gas make coal one of the main energy substitutions for oil and gas in the future, under the assumption of coal as a clean energy source.

NON-CONVENTIONAL AND RENEWABLE SOURCES OF ENERGY

To meet the future energy demands and to give quality and pollution free supply to the growing and today's environment conscious population, the present world attention is to go in for natural, clean and renewable energy sources. These energy sources capture their energy from on-going natural processes, such as geothermal heat flows, sunshine, wind, flowing water and biological processes.

Most renewable forms of energy, other than geothermal and tidal power ultimately come from the Sun. Some forms of energy, such as rainfall and wind power are considered short-term energy storage, whereas the energy in biogas is accumulated over a period of months, as in straw, and through many years as in wood. Fossil fuels too are theoretically renewable but on a very long time-scale and if continued to be exploited at present rates then these resources may deplete in the near future. Therefore, in reality, Renewable energy is energy from a source that is replaced rapidly by a natural process and is not subject to depletion in a human timescale. Renewable energy resources may be used directly, such as solar ovens, geothermal heating, and windmills or indirectly by transforming to other more convenient forms of energy such as electricity generation through wind turbines or photovoltaic cells, or production of fuels (ethanol etc.) from biogas.

Advantages of Renewable Energy:

1. Renewable energy is, well, renewable: This means it has infinity of sustainability and we will never run out of it. Other sources of energy like coal, oil and gas are limited and will run out some day.

2. Environmental Benefits: It is clean and results in little to no greenhouse and net carbon emissions. It will not deplete our natural resources and have minimal, if any, negative impacts on the environment, with no waste products of CO2 and other, more toxic take with different sources of energy.

3. Reliable Energy Source: Our dependence on fossil fuels has increased considerably in last few decades. The result is that our national security continues to be threatened by our dependence on fossil fuels which are vulnerable to political instabilities, trade disputes, wars, and high prices.

4. Economic Benefits: Renewable energy is also cheaper and more economically sound than other sources of generated energy. It is estimated that as a result of renewable energy manufacturing, hundreds of thousands of stable jobs will be created.

5. Stabilize Energy Prices: Switching to renewable energy sources also means steady pricing on energy. Since the cost of renewable energy is dependent on the invested money and not the increasing or decreasing or inflated cost of the natural resource, governments would only pay a small amount in comparison to the needlessly heavy pricing of the energy prices we are witnessing currently.

PROBLEM FORMULATION

The promise of a future world dominated by rapid population growth and unparalleled energy demand presents many challenges to the global energy industry and indeed society as a whole. The need to satisfy people's energy needs whilst conserving resources, the environment and maintaining a viable economy gives a vivid impression of the dilemmas faced in piloting a sustainable future. Increased electrification will be central to future world energy development. The distributed generation concept offers many advantages over established electricity generation infrastructures and will play a major role in the provision of world energy needs. Distributed generation involves the deployment of small, modular generator units dispersed throughout the customer population. The close proximity of generation capacity to the regions of demand gives many advantages such as reduced transmission losses, increased network robustness, higher power quality and greater network flexibility. Environmental benefits include reduced fuel usage, lower emissions of CO2 and other pollutants and an increased utilization of renewable power. The evolution to a distributed generation infrastructure is occurring due to existing centralized generator and transmission networks reaching capacity and lifetime limitations, along with the emergence of economically attractive technologies such as natural gas turbine cogeneration plants and advanced information technology based systems management tools. The most significant enabling influences driving the development of distributed generation are primarily regulatory in nature and the impact of policy in this area can be critical. The distributed generation concept embraces many issues central to the need for a sustainable energy future. This paper seeks to present in a general manner, some of the advantages, limitations, technologies and influencing policy mechanisms that are central to the development of distributed electricity generation.

• Individual efficiency of solar system is very low. Moreover no electricity will be generated when the solar is not available.
• The distribution and transmission cost for the centralized generation system are also very high.

• Too many loses are there when the electricity is flowing into the transmission lines.

OBJECTIVES

Distributed generation is emerging as an important option for the future development and restructuring of electricity infrastructure. Possible benefits of distributed generation include lower electricity costs, higher flexibility, improved power quality, higher system efficiency and greater reliability. This research seeks to examine some of the potential benefits associated with distributed generation of solar, wind and biogas plant.

• To propose a hybrid model of solar, wind and biogas 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.

METHODOLOGY

1. Perform the simulation modelling of solar plant, wind plant and biogas plant in Matlab/Simulink

2. Collect the load of a village/industry and compute the analysis on conventional energy sources.

3. Compute the set-up cost, generation cost and life span of the proposed hybrid plant.

4. Compute the cost analysis estimation of solar, wind and biogas plant individually and hybrid plant (solar, wind and biogas) with the conventional energy generation sources.

5. Make the analysis whether it is profitable to design the hybrid system or not.

WORKING OF A BIOGAS PLANT

Controlled fermentation of biomass in biogas plants produces a gas that can be used to produce electrical and thermal energy on account of its high percentage of methane. The raw materials used in biogas plants or their main substrates, are often liquid manure, agricultural products, and some agro-industrial wastes. The biogas plant may use silage maize as one of its renewable raw materials, with the aid of wheel loader, the maize is fed into either a storage bin or solids feeder, which takes a filling up approximately once a day. Silage maize is rich in energy, and on account of it is high degree of production it is very well suited for use in biogas firms. The storage bin is equipped by hydraulic flow discharger that continuously feed the maize onto a conveyor belt. A scale under the conveyor belt registers the weight of the maize silage. Liquid manure is the most important basic substrate used in biogas plants, after short influence storage in big tank, it is

pumped through pipes directly into the blending pumps beside the maize conveyor belt, at the same time the maize fall off from the conveyor belt into separators.
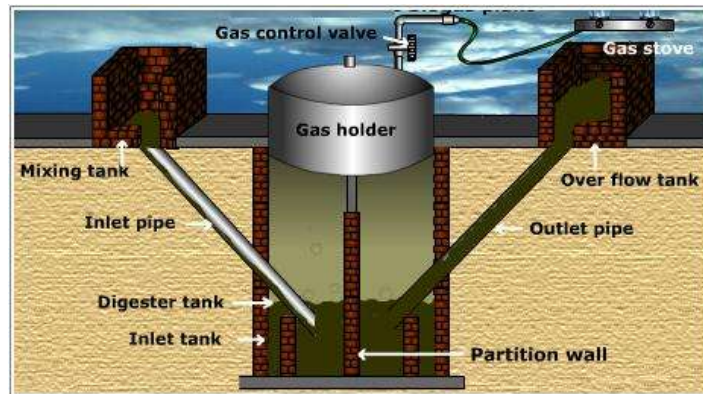

Figure 1. Working of a typical Biogas plant

PHOTOVOLTAIC MODULE

A simple PV module which is used for the power generation in Solar Energy systems is shown in figure 2.
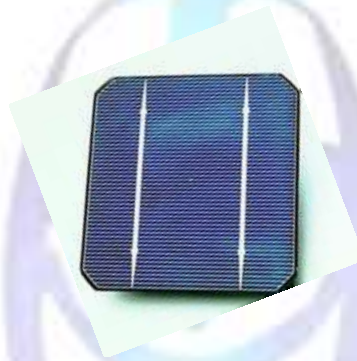

Figure 2. PV MODULE

Photovoltaic devices use semiconductor materials such as silicon to convert sunlight to electricity. They contain no moving parts and produce no emissions while in operation extremely modular, photovoltaic devices can be used in small cells, panel and array. Photovoltaic system require little servicing or maintenance and have typical life time of about 20 years. The capital cost for photovoltaic panels have decreased from more than $ 50/w in the early 1980 to about $ 5/w today. Incorporating photovoltaic systems into roofing materials for generating power on building is another rapid growing area. Thermo photovoltaic uses the energy of heat, or infrared radiation to generate electricity, with the advantage that a generator can operate at night or when the sky is over cast, eliminating the need for batteries. Though it does need a fuel, such as natural gas to provide the heat using semi-conductors for conversion rather than conventional diesel generators result in higher fuel-to-electricity conversion efficiencies, modularity minimal pollutants, quiet operation and higher reliability. The maximum efficiency for the conversion of sunlight to electricity via the photovoltaic is around 30% and for un concentrated sunlight conditions on earth the maximum solar power intensity is close to 1KW/m^ 2

WIND ENERGY SYSTEM

Wind power systems 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.
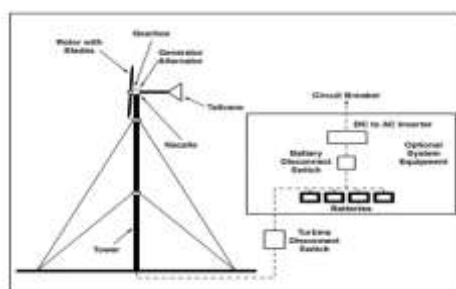

Figure 3. Wind Mill

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. Typical sizes for a wind turbine range from 200-750 KW, and electricity produce within a specific range of wind speed. Capital costs have declined from about $ 2.2/w in early 1980 to less than $ 1/w today. Cooperative research between DOE and manufacturing companies is aimed at increasing the aerodynamics efficiency and structural strength of wind turbine blades, developing variable speed generation and electronic power controls and using taller tower that allow access to the stronger wind found at greater height.

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.
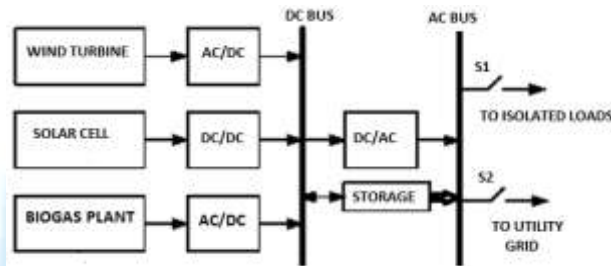

Figure 4. A Simple Model of PV /Wind/ Biogas system

SIMULATION OF PV MODULE

The I– V characteristic of the PV module are :

$$I = IL - I0\ (e^{\wedge}q(V + IRS)/nkT \_ 1)$$

Where IL = photo current

I0 = diode saturation current

RS = series current

q = charge of electron
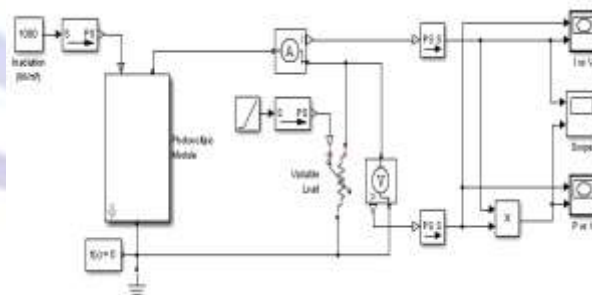
k = constant

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)

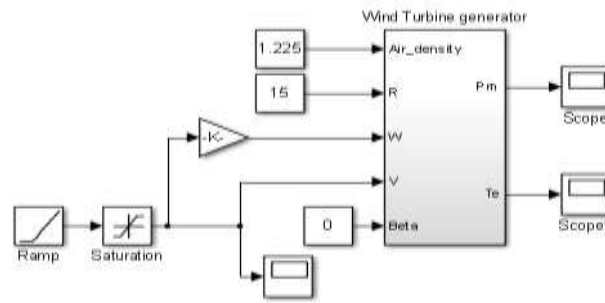Effad = efficiency of the AC/DC Converter

Figure 6. Matlab Simulink model of PV module

SIMULATION OF BIOGAS PLANT

Gross Calorific Value of biogas = 20MJ/Kg

Average Efficiency of biogas Plant n = .25 (25%)

And we all know that 3.6 MJ = 1 KW

So

mj = 3.6;

mj = 3.6 / n   (Assuming efficiency to be .25)

fuel = mj / gcf ;   (fuel required in kg to run 1KW)

fuel = fuel * 3000   (fuel required in Kg to run 3 MW)
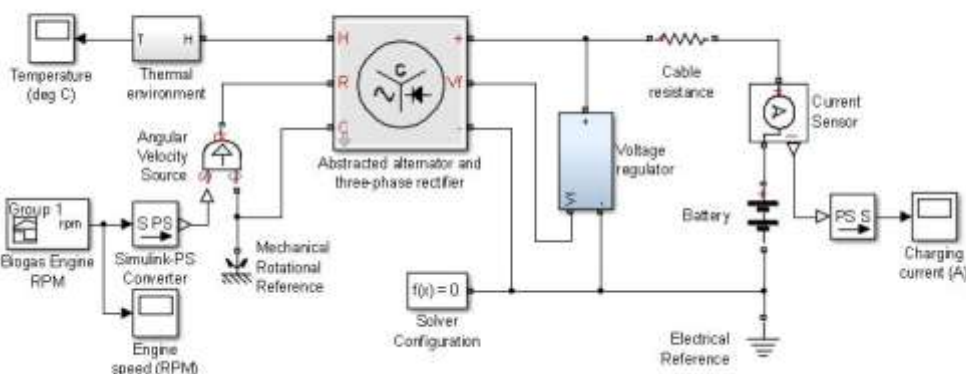
fuel = 2160 Kg

Figure 7. Matlab Simulink model of Biogas Plant

COST ANALYSIS

A. TOTAL UNITS PRODUCED BY THE HYBRID PLANT OF 3 KW ANNUALLY

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

Solar Plant Production = (1 * 30 * 365 * 9.32)/ 100 = 1020.54 units

Annual Units Produced by the Wind Plant of 1 KW = (1 * 25 * 365 * 24)/ 100 = 2190 units

Annual Units Produced by the Biogas Plant of 1 KW = (1 * 20 * 365 * 24)/ 100 = 1752 units

Total Units Produced by Hybrid Plant = (1020.54 + 2190 + 1752) units

= 4962.54 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)

$$COE = ACS / AEO$$

B.In table 1, the annual production of 3KW from different energy sources are mentioned.

Table 1. A 3 KW Comparison Table

System Type	Capital Cost (In Rs.)	Annual Maintenance Cost (In Rs)	Lifetime (Years)	Interest Rate (%)	Annual Production
Solar Plant 3 KW)	210000	2650	25	12.75	3061
Wind Plant (3KW)	189000	2145	25	12.75	6570
Biogas Plant 3 KW)	178000	5478	20	12.75	5256
Hybrid Plant (3 KW)	215000	4750	20-25	12.75	4962

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

D. Comparison of per unit cost of solar/wind/biogas/hybrid Plant of 3KW.

Table 2. Annualized Cost of Each Plant (in Rs.)

Plant Type	Annualized Cost (Capital Cost + Maintenance Cost)
Photo Voltaic Cell (3KW)	27113
Wind Plant (3KW)	24371
Biogas Plant (3KW)	23393
Hybrid Plant (3KW)	28018

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

Plant Type	Cost Per Unit
Photo Voltaic Cell (3 KW)	8.9
Wind Plant (3 KW)	3.70
Biogas Plant (3 KW)	4.27
Hybrid Plant (3KW)	5.64

ADVANTAGES OF THE HYBRID SYSTEM

The hybrid system of solar/wind/biogas plant is environmental friendly.

(i) This hybrid system emits no harmful gases and is an efficient way of supplying electricity.

(ii) Wind speed and sun shine are different in different parts of the world whereas biogas plant can operate anytime, anywhere which make system more reliable.

CONCLUSION

In this paper work, a hybrid model of PV/Wind/biogas 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/biogas 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. With the use of energy from wind, solar, biogas it will help to reduce our dependency on fossil fuels.

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