# Design of Hybrid Power Generating System for Educational Institute

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***Abstract* - Sufficient and reliable source of electricity is a major prerequisite for a sustained and successful economic development. Electricity is the major necessity for educational sector but the educational institutes are facing a major problem of energy crisis due to load shedding in national grid. So educational institutes have to depend on alternative sources of energy like diesel generator, solar energy, inverters, wind energy etc for power backup. The diesel generator is mostly used as the backup system. This paper presents the techno-economic viability of a hybrid system of solar photovoltaic and biogas generator with the unreliable grid; i.e. biogas-powered system and solar photovoltaic system along with the unreliable grid of Nepal, has been analyzed for energy demand through optimization and sensitivity analysis using energy modeling software HOMER.**

**The model discussed in the paper compromises of solar PV, biogas and unreliable grid for Khwopa College of Engineering, Bhaktapur, Nepal which is used as a case study. The concept of hybridizing is that the base load is to be covered by largest and firmly available renewable energy source(s), and other intermittent source(s) should augment the base load to cover the peak load. The model has been designed to provide an optimal system configuration based on hour-by-hour data for energy availability and demands. The optimized hybrid system shows a unit cost of NRs.16.744/kWh which is obtained after the simulation considering contribution of individual renewable resources participating in the system.**

***Keywords: Hybrid System, Solar Photovoltaic, Biogas Generator, Unreliable Grid, Optimization, Total Net Present Cost, HOMER***

## I.INTRODUCTION

The development of any country or society depends on the energy supply it has/uses. The history of human evolution and civilization is a history of energy consumption.

Most of the energy needs of the world we live in at present are being fulfilled by non-renewable sources of energy which not only is in short supply but is polluting as well. While the short supply can lead to global economic meltdown the pollution can be hazardous to all life on earth. As the supply on non-renewable energy dwindles, the deficit must be sufficed by energy from renewable sources which will and must ultimately replace them.

Nepal is a land-locked country located in South Asia between India and China. Although, Nepal is the second richest country in water resources, Nepalese people are facing the load shedding problem. The Government of Nepal declared a nationwide power crisis starting in early 2009. The load shedding hours goes on increasing with the beginning of dry season. During the rainy season of 2069 Ashad, the load shedding was 35 hours weekly and in Bhadra 2069, the load shedding hours increased to 92 hours weekly [9].

There are multitudes of consequences of load shedding, affecting all sectors of economy, such as, industry, education, construction and business. All sections of population are also equally affected by recurrent load shedding events. This would also mean loss of livelihood to small entrepreneurs and poor and marginal sections of population who earn their living in the industries where production gets stopped due to power cut-off.

Some of technologies have been in practices to avoid the effect of load shedding. Diesel generator (DG) is one of them. Diesel generator generates the needed electricity in absence of grid electricity. Diesel generator consumes diesel to operate. Nepal Oil Corporation (NOC) has claimed that the country has been generating around 531 megawatt (MW) of electricity through the use of diesel (NEA, May 2012) [9]. According to them, around 30 to 40 per cent of diesel has been utilized to generate electricity during load-shedding. Despite of providing electricity in absence of grid by using diesel generator is not economical as it has some serious drawbacks.

The key issues faced by DG are the variation in the load, and its operative cost. Severe variation in the load results in poor engine performance. The generator performs efficiently when it is operating close to its rated capacity. Continued operation at lower loads results in an inefficient plant performance and higher cost of energy [2]. Fuel used in DG is not locally available and has to be imported from foreign country. Reports have shown that about nations' 50% revenue is expensed in importing such fuel. [1]

Another technology being used to avoid the load shedding is Solar Photovoltaic (SPV). SPV system includes solar module, battery as backup storage, charge controller and converter (if necessary). It uses sun light as its energy source to produce electricity. The amount of power produced by photovoltaic cells varies significantly on an hourly, daily and seasonal basis due to the variation in the availability of sun [5]. This variation means that sometimes power is not available when it is required, and on other occasions there is excess power. To deliver continuous uninterrupted power supply, the photovoltaic (PV) array and battery of a standalone solar

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photovoltaic system have to be excessively over-sized leading to high capital cost. For undersized systems, power shortages will be experienced and the batteries may be damaged by excessive discharge.

The certainty of meeting load demands at all times is greatly enhanced by the hybrid system using Biogas and SPV. This paper, analyses the optimum configuration of SPV/BIO gas with unreliable grid system. The optimum configuration indicates the optimum PV array and Biogas generator capacities that lead to minimum system cost.

## II.OVERVIEW OF STUDY AREA-PROBLEM STATEMENT

Khwopa College of Engineering is the community engineering college run by Bhaktapur Municipality in Nepal. Currently, two engineering programs (Civil and Electrical) are running at bachelor level. The bachelor programs runs at day time. The college is well equipped with all infrastructure and providing the world class standard engineering education to its students.

Currently, the country is facing serious energy crisis with daily load shedding ranging from eight to fourteen hours daily with seasonal variation. This current scenario of load shedding have adverse affect in conducting day to day academic activities and teaching standard of the college. Hence it is necessary for the college to manage alternative way to fulfill electricity need during loadshedding. Electicity generation from hybrid solar photovoltaic and biogas hybrid system may be a solution.

## III.SIMULATION AND OPTIMIZATION TOOL

Analysis is done by using HOMER software (Hybrid Optimization Model for Electric Renewable). This software which simulates the different operating conditions was developed by the National Renewable Energy Laboratory (U.S.A) and has been used for choosing, in an optimal way, the various components of the plant.

One of the major applications of HOMER is the design of micro-power systems for the efficient evaluation of various renewable energy power generation technologies. It compares wide range of equipment with different constraints and sensitivities to optimize the system design. Simulation, optimization and sensitivity are the three major actions run by HOMER. In the simulation process, different micro-power system configurations for every hour of the year are generated with their technical feasibility and life cycle cost (LCC). In the optimization process, it selects one system configuration out of all configuration generated in the simulation process that satisfies all technical constraints and has the lowers LCC[10]. In the sensitivity analysis, multiple optimizations are preferred on the selected configurations by HOMER with a range of uncertain input parameters that is assumed to affect the model inputs with time.

As HOMER does both optimization and sensitivity analysis it makes easier to evaluate many possible system configurations of the large number of technology options and the variation in technology cost and availability of energy resources. It produces results in the shape of feasible configuration according to the increase in the Net Present Cost (NPC). The best configurations have been compared and examined on their economic and technical merits.

## IV.SYSTEM DESIGN

In order to design a power system, it is necessary to provide some information from a particular location. This information includes the load profile that should be met by the system, solar radiation for solar PV generation, initial cost of each component (biogas generator, battery, and converter), annual interest rate, project lifetime etc. The simulation was performed to obtain the best power system configuration by utilizing HOMER software from NREL.

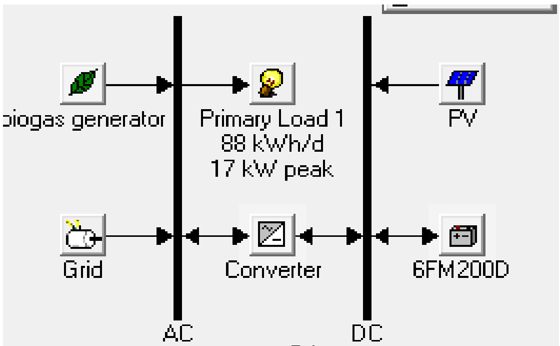


Figure 1 Hybrid system configuration

The hybrid system consists of biogas generator, unreliable grid, solar array as energy sources, battery as a storage device and converter for converting power produced from the energy sources as shown in Figure 1. The primary load is supposed to be AC load and is tied to AC bus. The output from generator is alternating in nature, hence it is tied to AC bus bar and the output of solar panel is DC in nature and is tied to DC bus bar. The battery is also tied to DC bus bar so that it can store the power delivered by solar panel when there is excess solar radiation during peak sun hours and deliver the required amount of power when the solar panel is not in operation. The converter is tied between AC and DC bus bar as it is bidirectional converter.

## V.DATA COLLECTION

The proposed hybrid energy system is incorporated of renewable sources PV and Biogas and unreliable grid. A power converter has been used for changing the source bus from DC to AC and vice versa. This integrated system is totally designed for supply electrification to the selected load i.e. 88 kWhr/day and 17kW peak.

The location chosen for this study is Khwopa College of Engineering with latitude $27^0$ 40 'N and longitude $85^0$ 25' E respectively [11].

### A. *Electrical load Demand*

In order to calculate the load, different section of KHCE was visited. A number of interviews with the key personnel and number of discussions were carried out. Maintenance section was visited for collecting data regarding electricity consumption and to know the diesel consumption pattern as shown in Figure 2.

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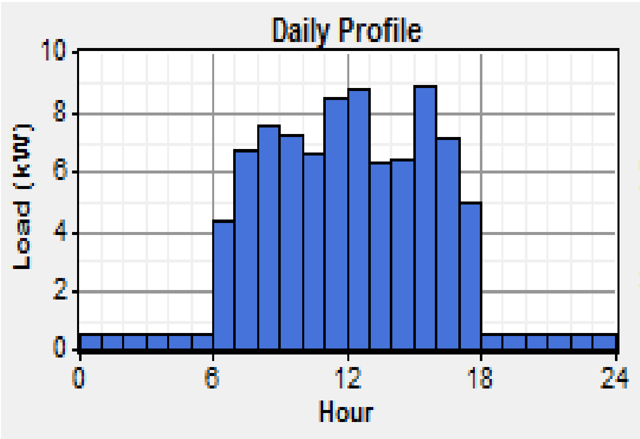


Figure 2 : Daily average load variation for KHCE

## B. *Solar radiation*

The solar resource input for the various months throughout the year is obtained from the report provided by Alternative Energy Promotion Center (AEPC) [4]. According to the report, Nepal is located at favorable latitude that receives ample amounts of solar radiation. Figure 3 shows the monthly average ground measured horizontal solar radiation data and clearness index of Kathmandu valley located at $27^0 40'$N and $85^0 25'$E. The scaled annual average daily solar radiation is 5.16 kWhr/m$^2$/day.

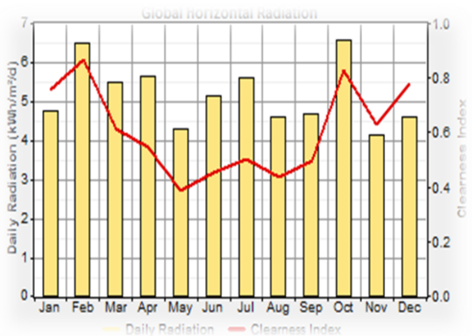


Figure 3 Monthly average ground measured global horizontal solar irradiance at $27^0 40'$and $85^0 25'$E.

## C. *Biogas Resource*

Table 1 shows the daily and annual biomass input available. The annual scaled biomass input is 0.07 tones/day. The lower heating value of biogas is 5.5 MJ/kg and its average gasification ratio is 0.7 kg/kg [11] and the maximum carbon content of biomass is about 5% and the cost of buying the biomass is approximated as Nrs. 1000/ton.

Table 1 Biomass availability with month

| Months | Biomass(tones/day) |
|---|---|
| January | 0.070 |
| February | 0.070 |
| March | 0.090 |
| April | 0.090 |
| May | 0.090 |
| June | 0.090 |
| July | 0.090 |
| August | 0.090 |
| September | 0.090 |
| October | 0.090 |
| November | 0.090 |
| December | 0.090 |

## D. *Grid as a Generator input*

As the country's grid is unreliable and has problems of frequent load shedding and voltage fluctuation. Here the grid is simulated as generator with 100 percent efficiency as shown in figure1 and the scheduled of its operation has been inputted based on the load shedding scheduled of the country.

# VI. MODELING ENERGY SYSTEM

HOMER has been used to simulate and obtain optimized energy to supply the load demand at KHCE. The proposed hybrid energy system comprises components to utilize locally available resources as well as providing electricity with 0% annual capacity shortage. Solar PV has been incorporated to utilize the solar radiation and biogas generator has been added to the system with unreliable grid, as a reliable source of electricity to supply load demand during loadshedding. Battery has been considered for facilitating electrical storage during off peak power generation.

## A. *Solar PV*

The SPV panels are connected in series parallel. When the sunlight is incident on a SPV panel it produces electricity. The capital cost for a 1 kW SPV is taken as NRs. 100000 [11] and the replacement cost is taken same of the capital cost. As there is very little maintenance required for PV, only NRs. 200/year is taken for O&M (Operation & Maintenance) costs (Mondal et al, 2011). Like for all other components considered in the following sections, the costs per kW considered include installation, logistics and dealer markups.

## B. *Biogas Generator*

The biogas generator chosen for this study is Weifang Nueput Genset. The capital cost of 25kW generator is NRs. 4000000 and O&M costs are NRs. 10/hr. It has a lifetime of 15000hrs and is run with minimum load ratio of 30 percent.

## C. *Battery*

As renewable energy resources have intermittency nature storage is necessary to provide uninterrupted electric power supply. The most common technique used to store electrical energy is the use of battery bank. HOMER models a number of individual batteries to create a battery bank connected in series-parallel connections. The battery chosen for this study is maintenance free Vision 6FM200D with a nominal capacity of 12V, 200 Ah (2.4 kWh). It has a lifetime throughput of 917 kWh. The capital cost and O&M costs for one unit of this battery were considered as NRs. 20000 and NRs.0 respectively. The system voltage for battery system is maintained 48V. Hence, four batteries are joined in series per string. HOMER models the batteries on charging and discharging cycles.

## D. *Converter*

Converter is used as an inverter to convert DC to AC or it is used as a rectifier to convert AC to DC. Since solar PV and battery has been used in the system it provides DC and it is to be used by AC load. the capital cost of converter and O&M costs for 21 kW systems, which were considered as NRs. 37,359 for 21 kW and NRs. 5,529/year respectively [11]. The replacement cost of converter is considered equal to capital cost. The converter used in simulation has lifetime of 15 years, with inverter efficiency of 85% and rectifier efficiency of 85%.

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### *E. Energy system constraints and parameters*

For simulation process, few parameters are to be set for the project. In this simulation, a project life time of 25 years with an annual interest rate of 10% have been considered. Among the system constraints, maximum annual capacity shortage has been considered as 0%, operating reserve as 10% of the hourly load.

## VII. RESULTS AND DISCUSSION

HOMER simulates all the possible variation in system configuration to meet the load demand based on the data given. It discards the system configuration which does not adequately supply the load demand with specified constraints. Only the feasibly configuration are presented categorically based on total NPC in an increasing order. It also presents sensitivity analysis based on different sensitivity variables (load demand, PV capital multiplier, project life, biogas generator).

### *A. Optimized System Architecture*

HOMER reveals a optimized system architecture comprised of 20kW PV, 4kW Biogas Generator, 12 Vision 6FM200D batteries, 14kW converter. The cost of electricity is NRs. 16.744/kWhr with a net present cost of Nrs.4902748 as presented in Table 2.

The hybrid system of photovoltaic and biogas generator with battery backup standalone system costs NRs. 5511937 and cost of electricity is NRs. 19.233/kWh, nearly 1.14 times costly than the proposed hybrid system. Similarly, the hybrid system comprising of Solar PV, battery and unreliable grid costs NRs.5720071 and cost of electricity is NRs. 19.892, nearly 1.18 times the proposed hybrid system. The hybrid system of diesel generator and grid with battery backup cost NRs. 91,70,834 and the cost of electricity is NRs. 31.515/kWhr, nearly 1.88 times the proposed hybrid system [11].

Table 2 Optimized system architecture

| | |
|---|---|
| PV Array | 20kW |
| Biogas Generator | 4kW |
| Battery | 12Vision6FM200D |
| Converter | 14kW |
| COE | 16.744(NRs/kWhr) |

### *B. Electricity Share*

Table 3 Electrical power share by different component

| Components | Production(kWh/yr) | Fraction (%) |
|---|---|---|
| PV array | 36,008 | 77 |
| Biogas generator | 5,030 | 11 |
| Grid | 5,815 | 12 |
| Total | 46,853 | 100 |

The optimized system architecture reveals that, the largest share in electricity generation is from PV array having 77% share. The biogas generator generates 11% and the unreliable grid provides 12% of the total generation. The system has excess electricity of 9911 kWh/yr.

### *C. Sensitivity Analysis*

One way to glean a sense of the possible outcomes of investment is to perform a sensitivity analysis. In this study, the sensitivity analysis determines the effect on the levelized cost of energy of variations in the input variables. The input variables are cost of Bio-generator, PV, battery, inverter, interest rate, and operation and maintenance cost of Bio generator and PV. A sensitivity analysis reveals how much the cost of energy will change in response to a given change in an input variable. Some items have a greater influence on the final result than others.

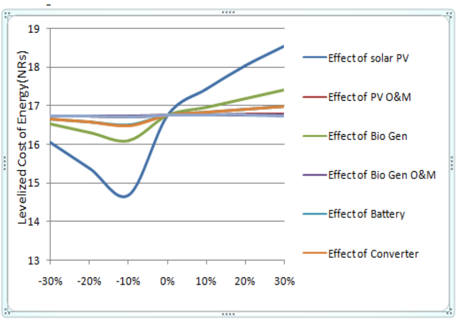


Figure 4 Sensitivity analysis of the system with variation in cost of component

### *D. Future Energy Demand Analysis*

Table 4 Change in excess energy due to demand increase

| SN | Annual Increment @5% (kWh/yr) | Demand (kWh/yr) | Excess energy (kWh/yr) |
|---|---|---|---|
| 1 | 0 | 32257 | 9911 |
| 2 | 1612.85 | 33869.85 | 8298.15 |
| 3 | 1693.49 | 35563.34 | 6604.66 |
| 4 | 1778.167 | 37341.50 | 4826.493 |
| 5 | 1867.07 | 39208.57 | 2959.42 |
| 6 | 1960.42 | 41168.99 | 999 |
| 7 | 2058.44 | 43227.43 | -1059.44 |

The described configuration of the Bio, solar and grid hybrid electric system, optimized result from the HOMER analysis, has an energy excess of 9911 kWh per year. If there is growth of the considered percentage of annual energy demand, the optimized system meets the projected energy demand at least for the next six years as illustrated in Table 4 above.

## VIII. CONCLUSIONS

This paper simulated and optimized a Solar PV-Bio gas and unreliable grid hybrid energy system for Khwopa College of Engineering. A hybrid system having 20 kW PV and 4 kW Biogas Generator and 12 batteries (Vision 6FM 200D) backup has been identified as the economical and most dependable solution with cost of electricity of NRs. 16.744/kWh if the project life is considered to be 25 years with the current load demand than the presently used hybrid system of unreliable grid and diesel generator. Similarly if the load demands of the college increased by 5 percent per annum, the simulated optimized hybrid system meets the projected energy demand for next 6 years.

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