Sustainable Energy Solutions for Community Housing

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Abstract: With increasing population, it is resulting in faster depletion of combustible resources for energy, hence it is needed to implement renewable resources to cater to energy demands of community housings for a sustainable future. Our work integrates renewable resources like solar, wind along with grid energy to provide a hybrid system, to cater to the above stated energy needs. The above integration is done with the help of trial version of an energy software known as HOMER Energy Pro, which is used for microgrid and any dispersed power generation system planning and its effective development. This helps decide the best system configuration based on the geographic location and resources available, leading us to provide with a sustainable hybrid system solution for 250 average 2 BHK houses for the best possible economy and efficiency with a better future scope. Good improvement in Carbon Credit is seen.

Keywords: Renewable; Hybrid; Sustainable; Power system; Carbon credit; Microgrid.

1. Introduction

With increasing population, the demand for housing and the energy resources to meet the same need is shooting out of the sky day by day. Even though the conventional resources (grid power) is sufficient, they are also depleting at a very fast rate. Hence there is a need for a system that is sustainable on a long run. For this purpose, we need to tend towards the readily and abundantly available renewable resources like solar, wind, water runoff etc. Using these resources, the dependency on the grid sources can be reduced to a nominal extent, hence contributing to at least a fraction of a time in naturally restoring the combustible Petroleum resources. This can be achieved by designing a hybrid system that uses both renewables and grid sources.

Many studies have already been done on hybrid system and their application to the societal needs, Rachit Srivastava et al. [1] have developed a hybrid energy optimized system that utilises PV cells and wind turbine as primary source, diesel genset and batteries as a backup. This system is optimized using the HOMER software. Md Nurunnabi et al. [2] in his study on grid connected hybrid system, analysed the energy system using the optimization software HOMER. Kenneth E.O et al. [3] compared the energy efficiencies of two energy systems one of which consisting of AC diesel generator and another with a PV cells, three batteries and a converter. HOMER was used to analyse both the system and to suggest a better alternative. A background is also needed for the energy trends in the site of the study L. Rajkumari et al. [4] studied the tendency and the form of
electricity consumption in Karnataka to establish a relation between consumption and economic growth and the prediction the impending energy consumption trends in the state. Apart from use of the obvious aid like PV cells, Turbines etc… many systems also incorporated the use of solar water heaters, microturbines etc… in them [5-11].

1.1. An Overview of HOMER Energy Pro Software

Integrating the grid resources and the renewables needs a special tool or a software, though many software’s are available for this purpose one such robust software is HOMER Energy Pro. HOMER stands for Hybrid Optimization Model for Multiple Energy Resources. This tool is used for microgrid design and distributed generation power system design and optimization. The process for designing a hybrid microgrid or a distributed in this software follows three steps, first is defining the system inputs, life time of simulation, amount of energy demand, second step is running the simulation, the last step is reviewing the result and correcting the previous steps for any errors until a desirable result is obtained. The advantage of using this software is that, after the load demand is defined the software automatically generates the load distribution for that given day or month based on the geographical location or if the load is not know for the simulator the software itself give the load trends for the given geographical location. It also has prefeed data for many components like solar cells, turbines etc. their pricing, capacity etc. The software also generates not one but up to five optimized system configurations for the simulators disposal [12].

2. Methodology

The methodology follows four steps. Selection of location site, Definition of system configuration, simulation of the system using HOMER, Result analysis.

2.1. Selection of location site

A pre survey was done in and around the capital city Bangalore of Karnataka state for the site locations, of which four prime locations were chosen whose details, is listed in Table 1.

| Serial number | Location name | Location information [12] |
|---------------|---------------|--------------------------|
| 1             | Devanahalli   | 13.23°N 77.7°E           |
| 2             | Hosakote      | 13.07°N 77.8°E           |
| 3             | Yelahanka     | 13°06'50" N 77°35'54" E |
| 4             | Kanakapura    | 12.55°N 77.417°E         |

Amongst these four sites Yelahanka and Hosakote are relatively closer to the city and Kanakapura is the farthest from the city. The land price is the cheapest in Kanakapura. Whereas, Devanahalli and Hosakote fall in the median range. Yelahanka is the costliest of all. The city’s international airport is situated in Devanahalli, the pollution levels are considerably lesser in Devanahalli and Kanakapura. Whereas it is higher in Hosakote and Yelahanka. Devanahalli, Yelahanka, Hosakote are more accessible by bus and metro(upcoming), whereas Kanakapura is the least accessible. Hence considering the above, “Devanahalli” is considered for our present work. Once the location is set in the software, it automatically generates the location information, resources available, energy consumption trends for that geographical location Devanahalli.

2.2. System configuration

The system for the present study is “hybrid” meaning that it contains both grid sources as well as renewables. Grid source is provided by the electricity board of Bangalore [13]. The renewables used are PV cells (for solar energy) and Wind turbine (for wind energy). HOMER provides a list of suitable models of PV and turbine based on the location and the weather conditions [12]. Along with these a
storage battery, a converter and a standby diesel generator are used, the details of which are mentioned in Table 2.

Table 2. Specifications of the Proposed System

| Particular       | Model name                  | Specifications                                                                 |
|------------------|-----------------------------|-------------------------------------------------------------------------------|
| Grid source      | BESCOM                      | 230V AC, 50HZ                                                                |
| Solar cells      | Peimar SG315M (BF)          | Monocrystalline, Max output of each cell =315W, No. of units =1000.           |
| Wind turbine     | Eocycl EO25 Class III       | Horizontal hub type, Direct gear drive, Rotor dia. = 12.6 m, Cut-in speed = 3.2 m/s. |
| Battery          | NEC DSS 510kWh 1108kW       | Distributed energy supply system Li-ion type (inbuilt BMS with thermal management). |
| Converter        | ABB PVS800-315kW           | DC-AC 315kW                                                                  |
| Diesel generator | CAT-3412C Prime             | 4 stroke diesel engines, fixed fin cooled.                                    |

2.2.1. Demand Details
The system caters to the demand of 250 average 2BHK (bedroom hall kitchen) the energy consumption details of individual (considering TV, fridge, AC, 2 fans, washing machine, 12 LED bulbs, kitchen exhaust) and the combined energy demand is listed Table 3.

Table 3. Energy Demand Details

| Particulars     | Energy Demand |
|-----------------|---------------|
| Individual house| 17.3 Kw       |
| 250 houses      | 4320 Kw       |
| Peak load       | 478.08 Kw     |

2.3. Simulation of the system
Once the site location, demand details and the system configuration are defined the next step is to simulate the system. The span of the simulation (25 years considered) is required to be specified. Now the results are generated. The software generates up to five sets of results. (Five different systems).

3. Result analysis
The software generates five system configurations as results (Table 5), which includes their capital setup cost (CAPEX), annual maintenance cost (OPEX), annual savings etc. The carbon credits also are shown as a part of the results in (Table 4) which includes the CO₂ emitted from the different systems.

Table 4. CO₂ Emissions for different systems

| CO₂ emission in (metric ton/year) | Base Case (simple) | Solar + Wind + simple | Solar + Wind + Generator + simple | +Wind + Generator + simple | Solar + Wind + Storage +Simple | Solar +Wind+ Generator +Storage +Simple |
|----------------------------------|--------------------|-----------------------|-----------------------------------|---------------------------|-------------------------------|--------------------------------------|
|                                  | 928.9              | 660.7                 | 660.7                             | 928.9                      | 614.9                         | 614.9                                |
Table 5. Results of five different systems proposed by HOMER

| Particular                        | Base Case (simple) | Solar + Wind + simple | Solar +Wind+ Generator +simple | Wind + Generator +simple | Solar +Wind+Storage +Simple | Solar +Wind+Generator +storage +simple |
|-----------------------------------|--------------------|-----------------------|--------------------------------|--------------------------|-----------------------------|----------------------------------------|
| CAPEX                             | ₹70,00,000         | ₹3,46,55,890          | ₹3,46,82,890                  | ₹70,27,000                | ₹6,26,55,890                 | ₹6,26,82,890                           |
| OPEX                              | ₹88,58,868         | ₹62,11,379            | ₹62,11,198                    | ₹88,58,688                | ₹64,63,310                   | ₹64,63,129                             |
| Annual Total Savings (₹)          | ₹0                 | ₹26,47,489            | ₹26,47,670                    | ₹180                     | ₹23,95,558                   | ₹23,95,740                             |
| Annual Utility Bill Savings (₹)   | ₹0                 | ₹30,11,342            | ₹30,11,342                    | ₹0                       | ₹29,93,208                   | ₹29,93,208                             |
| Annual Demand Charges (₹/yr)      | nil                | nil                   | nil                            | nil                      | nil                          | nil                                    |
| Annual Energy Charges (₹/yr)      | ₹88,27,342/yr      | ₹58,16,000/yr         | ₹58,16,000/yr                 | ₹88,27,342/yr            | ₹58,34,134/yr                | ₹58,34,134/yr                          |

3.1. System chosen for the present study

Of all the five-systems available for the study, we choose the fifth system for the present study which includes the solar cells, wind turbine, converter, battery, diesel generator and the grid source connection as shown in Figure 1. The reason being it includes both solar cells and wind turbine along with the grid source and has comparatively lesser CO2 emission. The system details and configuration, economic comparison between only grid source connections, the systems cashflow diagrams are discussed in Table 6 given below.

Table 6. Details of the Fifth System

| Particular                | Cost of unit       | Capacity | Capital cost         | Yearly expenses         |
|---------------------------|--------------------|----------|----------------------|-------------------------|
| Peimar SG315M (BF)        | ₹82.55/watt        | 315 kw   | ₹2,60,03,054         | ₹3,14,000/year          |
| Eocycle EO25 Class III    | ₹70,00,000/each unit | 25 kw   | ₹70,00,000           | ₹10,000/year            |
| NEC DSS 510kWh 1108kW     | ₹2,80,00,000/each unit | 1108 kw | ₹2,80,000,000        | ₹10,000/year            |
| CAT-3412C Prime           | ₹27,00,000         | 580 kw   | ₹27,00,000           | ₹20,000/year            |
| ABB PVS800-315kW          | ₹57,00,000         | 315 kw   | ₹57,00,000           | ₹10,000/year            |
| Grid connection           | ₹5/unit + ₹750 fixed | -       | ₹70,00,000           | ₹10,000/year            |
Figure 1. Proposed Polygeneration System

As important as the technical results the economic results also matter, the Figure 2 and Figure 3. shows comparison of the systems and the cash flow diagram of the system chosen.

Figure 2. Comparison of the system

The blue line in the Figure 2 shows the present system the grey line depicts the base case that is grid source and the turbine, the payback time (time after which the system is profitable) of the present system is 11 years i.e. after 11 years the present system is profitable.

The cash flow diagram shown in Figure 3 is revenue dominated owing to the capital cost and the yearly maintenance costs of the renewables and the other equipment, this predominates the fact that it also reduces the cost on purchase from grid sources.
Figure 3. Cash flow diagram

There may arise a question that, in which season one of the renewable resources is deficient or may be in excess as well it is depicted in the Figure 4, which shows the energy generated by renewables and the grid sources.
4. Plan for housing

As mentioned earlier, the choice of site was Devanahalli, considering an average of ₹ 6663 /square feet land price [14] and 90% of total land price as the construction cost for 250 average 2BHK houses. The costing details have been mentioned in the Table 7 given below.

Table 7. Cost Details of 250 Average 2BHK houses

| Serial Number | Particulars                  | Approximate total cost (₹) |
|---------------|------------------------------|-----------------------------|
| 1             | Total land cost              | 38,00,00,000                |
| 2             | Construction cost            | 30,00,00,000                |
| 3             | Energy system capital        | 12,00,00,000                |
| 4             | Miscellaneous                | 5,00,00,000                 |
| 5             | Total                        | 85,00,00,000                |

From the Table 7, it is evident that the total cost for 250 average 2BHK houses would be ₹ 85 crore approximately. So, it is evident that it would cost around ₹ 34 lakhs only as the cost price per 2 BHK house, which is a nominal selling price and could be developed further.

5. Conclusion

Table 8. Sustainability in Energy Details

| Particular                      | Energy demand |
|--------------------------------|---------------|
| Net energy demand/day          | 4320kw        |
| Estimate output from solar/day | 350kw         |
| Estimate output from wind turbine/day | 30kw    |
| Estimate output used from genset/day | 20kw      |
| Estimate purchase from grid/day | 3920kw        |

Hence from the Table 8, it is evident that dependency on grid source is decreased by as much as 10% per day and up to 12% a year, with just the use of solar and wind turbine in the hybrid system. This contributes a significant amount to sustainability on a longer run. Thereby providing with a sustainable housing solution for community housing. Hence a cost effective, hybrid sustainable housing is provided. Good improvements in carbon credits is achievable by the use of renewable energy resources.
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