Design features of Energy storage systems for Green buildings: An economic comparison with off-grid and on grid solutions

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Abstract:

The present power crisis and global scenario trend is favoring renewable energy sources. Where renewable energy sources are available – solar, small hydro, biomass, wind – they can often provide remote communities and businesses with the most reliable and affordable source of electrical energy. But, most of the Renewable energy technologies depend on Battery backup. Batteries can supply power as needed at levels much higher than that generated and during times of low demand the excess can be stored. If enough energy is available from the renewable energies such as PV systems, wind energy, micro hydro powers etc., are key part in Green buildings.

In this paper, an analysis has been done with various strategies for energy storage technologies for Solar PV assisted Green buildings. The work further will be extended for practical implementation in Green building which is going to be constructed in GIET campus.

***Key Words*: Battery storage, Simulation, Homer, Green buildings, autonomy**

1. INTRODUCTION

Today's world is at a critical point due to resource unavailability, increased pollution, changing climate the upcoming generation is going to face problems.

To address these unsecured energy security there is a need to shift towards renewable energy sources. But, the main disadvantages of renewable energy sources are they are non-conventional. There is a technical barrier to generate the energy continuously, hence

That is why we are in a hurry to find the alternatives that will ensure our acquired wealth and further growth on a long term basis. As demand of electricity throughout the world is high, so here comes the use of energy storage which will partly eliminate these problems.

With the rapid development in the field of renewable energy resources, scientists and engineers have already integrated different energy storage technologies with these budding resources. Implementation of different energy storage technologies along with green building is one of the real time examples of this. This energy stored can also be retrieved at the time of high demand which means less chance of grid became overloaded and interrupting the power supply.

1.1 Energy storage systems and Green buildings

A green building is defined as one which optimises energy efficiency as compared to normal conventional building. It also helps us in saving money up to 50% in the form of energy cost. There are several approaches found that can be implemented along with the green building to store energy efficiently. These technologies are broadly divided into six main categories such as fly wheel, batteries, Thermal energy storage (TES), Compressed air energy storage (CAES), Pumped hydro energy storage (PHS), fuel cells. These energy storage technologies has different uses at different stages like PHS, CAES, large-scale batteries, flow batteries, fuel cells, solar fuel and TES can be used for efficient energy management, whereas capacitors/super capacitors, flywheels and batteries are in the group of power quality and reliability. Advancement in technologies has made these more reliable and also helped in reducing its cost by making these more economical. Moreover flywheel, compressed air energy storage,, hydrogen storage, thermal energy storage are large scale methods of energy storage whereas small scale specific storage comprises of flywheel, capacitor, super capacitor, battery bank. If we install banks of energy storage battery into electricity grid the electricity provider can easily add in wind and solar energy. The batteries store the renewable energy and when needed the energy can be easily released to the grid which ultimately makes the system more reliable and smoother.

Green building can lessen energy consumption in various ways. Firstly we can reduce the embodied energy of the building through efficient design. Specific strategy should be adopted for placing windows and skylights so that we can minimize the use of electrical lighting during daytime. High Quality insulation diminishes the temperature regulation cost during summer and winter. Moreover house can increase passive heating and cooling. Energy efficiency is the most sensitive issue and essential component of green building. It also plays a key role in its success. A green building is always equipped with a solution that increases the electrical energy management, reduce consumption and help in sustaining quality energy. In these buildings capacitor bank increases the efficiency of the installation and

network analyzer help to measure the consumption and quality of energy. The availability of renewable energy resources in unlimited quantity is one of its advantages.
Load estimation is the most important factor in designing a green building and must be done carefully. Overestimating known loads is often done by calculating greater energy consumption than actually occurs. Though it is a safe approach, it will lead to design an oversized system and hence greater cost. One more common problem is once power is available, it is obvious for the users to find more loads to connect, rapidly making the system to overload and end up in blaming renewable energy for not satisfying the needs.

1.2 On grid and Off grid systems:

Now days due to lot of advancement in battery technologies, most of the renewable energy resources depend on battery backup. The size of the battery is based on the no. days of "backup" that is required i.e. the number of days the system must operate without taking any input from the power supply. Battery for renewable energy application must withstand regular deep discharging. So the battery must be sized correctly and discharge should be allowed up to the maximum limit prescribed by the manufacturer.
Three basic categories of renewable electricity systems are stand-alone off-grid systems, battery-based on-grid systems, battery less on-grid systems.
Grid-tied, or on grid system refers to a solar system that is connected to the utility power grid. A grid-connection will enable us to save more money with solar panels through better efficiency rates, net metering, and lower equipment and installation costs. Net metering plays an important role in determining how solar power is encouraged. Without it, residential solar systems would be much less feasible from a financial point of view. The utility is like a big, 100% efficient battery that can absorb all surplus energy produced. In addition, we can rely on it as hard as we want to for as much additional electricity as we might need.
An off-grid system is the obvious alternative to one that is grid-tied. To ensure access to electricity at all times, off-grid systems require battery storage and a backup generator. On top of this, a battery bank typically needs to be replaced after 10 years. Batteries are complicated, expensive and decrease overall system efficiency. Independence is the main reason among for wanting an off-grid system where the grid is available. Off-grid systems are not forced to abide by the terms or policies of the local utility, nor are system owners subjected to rate increases, blackouts, or brownouts.
As each of the above technologies have their own benefits and flaws, it is possible that a mixture of all of them will come into action, depending on individual situations until at some point one might advance far enough and emerge over the others.

2. PROCEDURE FOR SIZING OF THE BATTERY:

The calculation proceeds in 3 steps in order to determine:

1. The energy output required from the power supply
2. The size of power supply system given the available energy resource
3. The size of battery required

The key parameter for system sizing is the average daily energy consumption in watt-hours or kWh per day, calculated. The examples below assume a mean load of 1200 Watt-hours per day.

The secret of a successful system is to generate enough energy to meet the demand of the load on at least a monthly basis.

<u>Power supply output</u>
On average, batteries lose 20% of the energy supplied during the charging and discharging process, dissipated as heat. Therefore the average energy supplied to the batteries needs to be 125% of the average energy drawn by the load i.e. Mean daily energy supplied to the battery = 1.25 x Mean daily consumption of the load

For example, a load consuming 1200 Watt-hours per day will require an average energy supply to the batteries of 1.25 x 1200 = 1500 Wh/day.

<u>Battery size</u>
The size of battery is based on the number of days of 'reserve' that is required i.e. the number of days the system must operate without any input from the power supply. Battery size is a balance between the cost of the batteries (which are not cheap) and the risk of a long period of unfavourable weather. It is generally found that the reserve should be not less than 5 days, and at most 20 days' supply. Professional applications normally find it cost effective to err on the cautious side, especially if reliable function in winter months is critical.

Since one should aim not to discharge batteries by more than 50% in normal usage, the reserve battery charge is then doubled to arrive at the actual battery size required. So, if the mean load is 1200 Wh per day, a 10-day reserve would require an available battery capacity of 10 x 1200 = 12,000 Wh. The requested battery size should be double this, so 24 kWh. In a 48V battery bank this amounts to 500 Ampere-hours of charge, since 48V x 500Ah = 24,000 Wh = 24 kWh. If the load application draws a particularly high current from the battery, this acts to reduce its effective capacity. Loads which draw high currents for short periods therefore need a bigger battery than a small, steady load using the same total amount of energy. The system supplier should be able to advise on whether this will be an issue and size the battery accordingly.

Calculation-

Load calculation –

Load	Number	Watt	Total watt
Tube light	8	40	320W
Ceiling fans	4	60	240W
C.F.L	4	18	72W
Total			632 W

Inverter should be greater 25% than the total Load
632 x (25/100) = 158
632+158 = 790 Watts
This is the rating of the UPS (Inverter)
Now the required Back up Time in Hours = 5 Hours
Suppose we are going to install 150Ah, 12 V batteries,
12V x 150Ah = 1800 Wh
Now for One Battery (i.e. the Backup time of one battery)
1800 Wh / 632 W = 2.5 Hours
But our required Backup time is 5 Hours.
Therefore, 5/2.5 = 2→ i.e. we will now connect two (2) batteries each of 150Ah, 12V.
OR
If the number of batteries given, and we want to know the Backup Time for these given batteries, then
1800 Wh x 2 Batteries = 3600 Wh
3600 Wh / 632 W = 5.69hours.

3. Modeling the Solar PV system with Homer

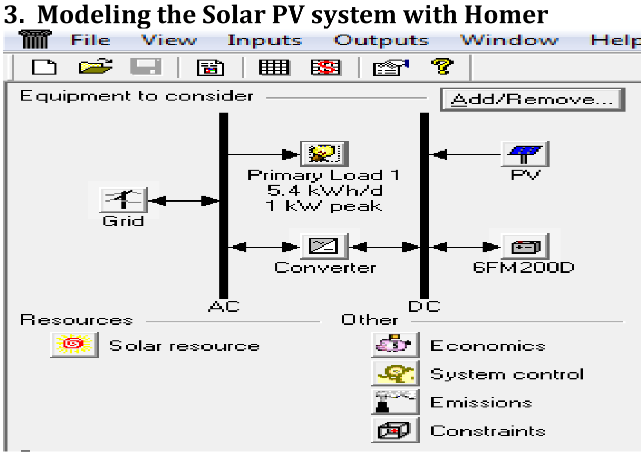


Fig No. 3.1 Home page of homer

3.1 Home page of homer

At first we have to click on the add or remove bar for choosing our equipment. A lot of equipment are shown in a window which is appeared like Fig No: 5.2. We have to choose equipment according to our requirements. As per our requirements we take one primary load, one converter, one battery, one PV and a Grid. The below Fig No. 6.2will shows how to add or remove equipment for simulating purposes.

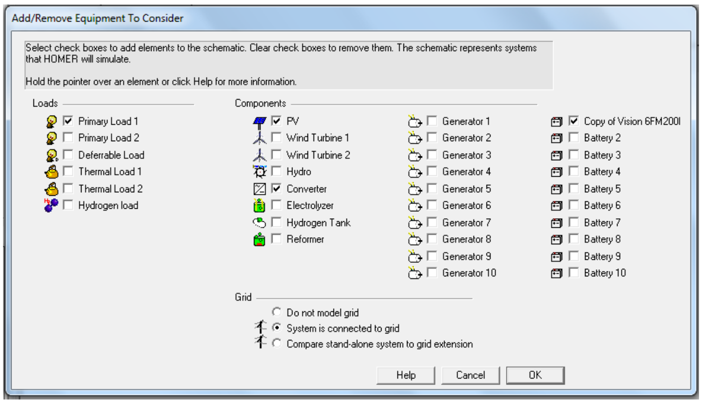


Fig No. 3.2 Add or remove equipments for simulating purposes

3.2 Primary load input

Here we have to first choose type of load. The load type is AC. After that 24 hourly values entered in the load table of every month. Each of 24 values in the load table is the average electric demand for a single hour of the day. The above Fig No. 5.3 show how the primary load gives result.

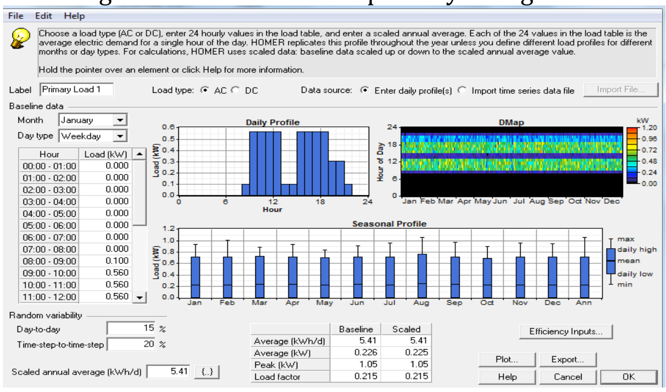


Fig No. 3.3 Primary load input

.3 PV input

PV is one of the equipments we select. Here we have to put size of the PV according to peak load. We have to also enter the cost and replacement value according to the size of PV. Here we got the curve between cost and size. The above Fig No. 5.4 shows that, its life time is 25 years.

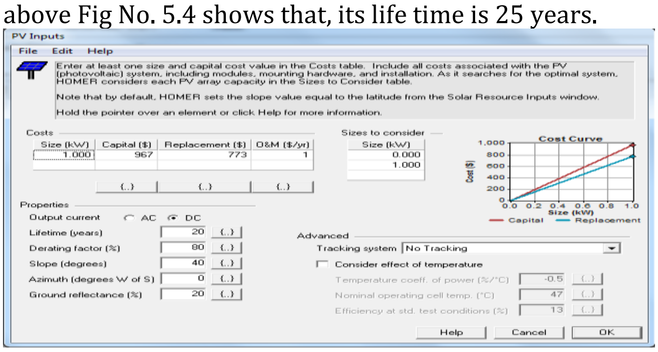


Fig No. 3.4 PV input

3.4 Battery input

Battery is mainly used for backup purpose. Here; we have to choose a battery of appropriate rating which meet our load demand is shown in Fig No. 5.5. After that we have to enter quantity and capital cost to the cost table according to our requirements. Here we get the curve between cost and quantity. We are using battery for back-up supply when there is no grid supply and solar radiation.

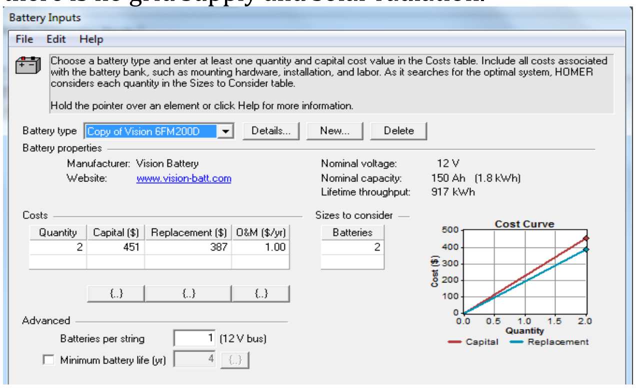


Fig No.3.5 Battery input

3.5 Converter input

A converter may be rectifier or inverter. A converter is required for the system in which DC components serve as AC load and vice versa. Here we have to also enter the cost and size value to the cost table shown in Fig No. 6.6, including labor and hardware installation. Here we get the curve between cost and size. Its lifetime is 15 year.

3.6simulation result

After putting all the desired data, we go for simulating the project. Finally we got optimization result along with complete report which is shown in Fig No. 6.8.

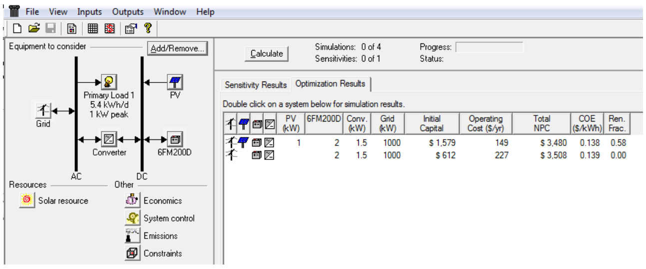


Fig No. 3.6 Final simulation results

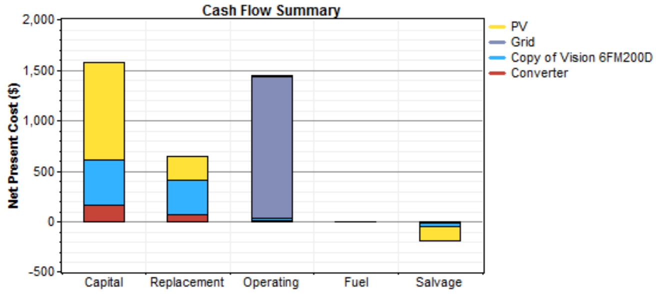
SIMULATION OUTPUT REPORT

Cost summary

Cost summary includes all the expenditure throughout the project. It includes total net present cost; cost of energy and Operating cost details is given. Cost summary also includes cash flow summary which gives detail information about PV, grid, battery and converter net present cost. Here different color shows different net present cost of PV, grid, battery and converter which includes capital, replacement, operating, fuel and salvage cash flow.

Cost summary

Total net present cost	$ 3,480
Levelized cost of energy	$ 0.138/kWh
Operating cost	$ 149/yr



Net Present Costs

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	967	241	13	0	-135	1,086
Grid	0	0	1,410	0	0	1,410
Copy of Vision 6FM200D	451	337	13	0	-45	755
Converter	161	67	13	0	-13	228
System	1,579	645	1,449	0	-193	3,480

Electrical power production and consumption

Every year we got maximum electrical power from PV array and purchased moderate power from grid to fulfill our load profile. Detail information is given.

Below result shows monthly average electric power production in a year. Here PV is represented in yellow color and grid is represented in gray color. Here colors represent PV and grid power consumption in kw every month.

Electrical

Component	Production (kWh/yr)	Fraction
PV array	1,527	58%
Grid purchases	1,103	42%
Total	2,630	100%

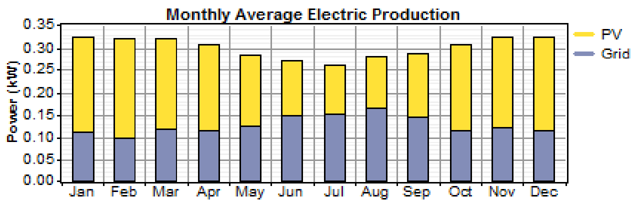
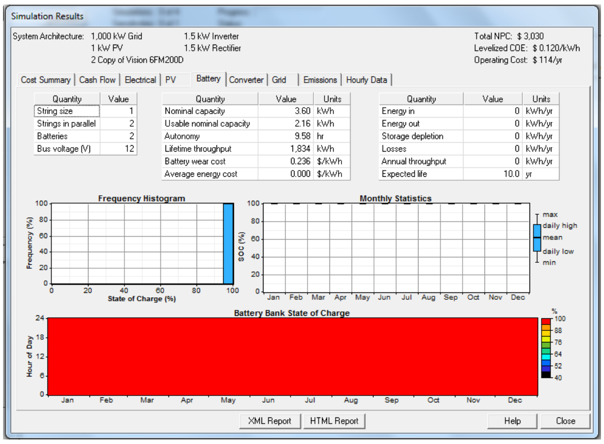


Fig No. 6.10 Monthly average electric production

Battery output results:



Battery

Quantity	Value
String size	1
Strings in parallel	2
Batteries	2
Bus voltage (V)	12

Quantity	Value	Units
Nominal capacity	3.60	kWh
Usable nominal capacity	2.16	kWh
Autonomy	9.58	hr
Lifetime throughput	1,834	kWh
Battery wear cost	0.236	$/kWh
Average energy cost	0.000	$/kWh

4. Conclusion

Using solar energy at home is becoming increasingly popular. Due to government incentives and subsidies on solar systems, the prices of solar panels are becoming more affordable to the everyday consumer. Home solar power can be used independently from a grid system. Excess electricity made during the day is stored for night use. More commonly are solar energy systems that are tied to a grid and trade electricity. During night hours and cloudy days, electricity from the grid is used.

Independent solar power generation systems need to optimize the design. Finding sufficient supplies of clean energy for the future is one of society's most daunting challenges. Renewable energy sources will play a significant role in a sustainable development of the energy supply in the future, due to the minor impact they are expected to have on the environment and their large technological potential. But on the other hand, it still requires a great deal of technological and organizational development before it can contribute substantially to our energy needs in a sustainable way.

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