Good example of pv stand-alone hybrid system research paper

Design

Designing of a Stand-alone heat and power system for a single-family house in Connecticut

PV hybrid System is Considered Assuming the Family House is Grid-Connected

Introduction

PV energy production is one of the most important component of a future energy mix. This is because it’s freely available, clean source and highly reliable. Therefore, these specifics make PV energy component attractive for many hybrid systems and resources. This paper presents a study on the design of a stand-alone hybrid PV system to provide the necessary heat energy and power for a single family house in Connecticut.

The hybrid PV system designed 11 roomed house, namely:

- 1 Kitchen,
- Two Bedroom
- Dining room
- Laundry
- Outdoor and indoor living area
- Garage and Shed
- Bathroom/toilet

Building properties and Materials

The roof design will be light-colored to assist in regulating heat flow and to reduce the need for artificial cooling. Roof ridge vents, eave vents will be fitted to allow air cross flow through the roof cavity. Non-combustible, low formaldehyde content materials, mostly water, will be used as a solvent or low volatile compounds, plywood, gypsum and timber used will be used in ceiling as they poor heat absorbers and have unreflective surface.

Floor, walls and ceiling materials will include linoleum, natural rubber, sisal, coir, ceramic tiles, plant-based timber, and recycled textile underlay that are poor heat conductors and non-reflective. The ceilings will be high enough (2700mm) to encourage high-level ventilation of hot air rising. Rooms with a fan to have a clearance of 2400mm from the floor. All windows are fitted with sills for maximum natural ventilation. Lighting systems will be positioned accordingly to eliminate shadows and surfaces smoothed to aid in light reflection rather than absorption, external cloth drying area open to breeze provided, zoning for passive design where possible.

All water pipes properly insulated, and hot water systems will be located close to areas of utilization to minimize heat losses along the way. All electrical appliances will have at least a minimum rating of 4 stars.

The home will be designed to have access to cooling breezes in summer conditions. Maximum shading on western, eastern walls, the home should not limit daytime light, no obstruction of solar access, access paths at a minimum of 920mm.

Figure 2: Stand-alone PV system

PV SYSTEM CONFUGURATION AND SIZING FOR THE HOUSEHOLD

Step 1: Establish Appropriate Energy Data

The table 1 above displays solar insolation data available with the department of weather within the region of Connecticut for a flat surface and tilted surface in Kwh/m2/day. This is represented below as in a chart.

Step 2: Load determination

Household Load Data

Considering that region is off grid a generator is feed in as a back up source for the PV. Thee household load demand is estimated below for a typical a winter, summer and spring.

During summer time for a typical day it’s extremely hot, most of heat consuming appliances are running for a short time with only cooling systems running for longer duration. This is the season with the lowest power consumption at 18. 6915 kWh/day and heat demand at approximately 1 kWh/day for summer.

This is the season after winter, the skies are clearing and therefore enough light and reasonable solar radiation is received at Connecticut. Most heating appliances are still running even though some like the home heating appliance are running half day. The total power demand for spring is estimated to stand at 22. 83 kWh/day and heat energy demand at 15 kWh/day.

The average daily load demand therefore for all the daily days El from tables 2, 3,& 4 for a typical winter, spring and summer day are estimated as 23. 04 kWh/day, 22. 834kWh/day and 18. 6915kWh/day respectively. The average daily heat demand for a typical winter, spring and summer day are estimated as 30. 00 kWh/day, 15. 00 kWh/day and 00. 0 kWh/day respectively

If it is assumed that the PV panel will be mounted on the roof tilted upward at a latitude and facing south. The PVC system will then be designed to take care of all the electrical energy required using the month with the highest energy (Balfour, Shaw & Nash, 2012). Looking at the weather pattern of Connecticut with the PVC tilted, the month of July is picked.

Step 3: System Peak Power Estimation

It is noted that the average power to be supplied on daily basis by the PV system will be determined by the array area and the efficiency of the system.

Average Daily Output Power (kWh/day) = Array Area (m2) x Insolation (kWh/m2/day)

In this case the PV Area is calculated as:

PV Array Area = Daily Average Power Output (Efficiency X Insolation)

In this case the Daily Average Power Output = 23. 04kWh/day, Insolation = 5. 4 kWh/m2/day and the PV efficiency = 12%:

PV Array Area= 23. 04kWh/day (0. 12 x 5. 4 kWh/m2/day) = 35. 6 m2

Now the Peak Power Rating is the systems output under Peak Power requirements, when the insolation is 1. 0 kW/m2:

Peak Electric power = Efficiency x Array Area x 1. 0 kW/m2

= 0. 12 x 35. 6 x 1. 0 kW/m2

= 4. 27 kW

Assuming then that the inverter efficiency together with other components of the system is 90%, then the required array should produce a Peak electric Power = Peak Electric power/ Efficiency.

= 4. 27 kW/ 0. 9= 4. 74 kW array.

Therefore, the system design will have an array of 4. 74 kW.

Remember the system too has a hybrid diesel generator rated at 25kVA to supplement the PV supply in supplying heat energy.

Step 4: Choosing a PV Module

Using the PV suppliers available online, the following specifications for the PV were found to suffice:

Peak power = 175 W Module

Sharp NT-175U1

Area = 14 sf

Efficiency = 14. 2%

Assuming that after PVC test, the result produces a 155. 6 Watts and an efficiency of 11. 8%

The number required for modules will is calculated as: Number of modules = 4. 74 kW/0. 1556 = 30 modules.

Modules area = 30 x 14. 2 sf = 426 sf

The Array rating = 155. 6 W x 30 = 4. 67 kW.

Overall system rating = 155. 6 x 30 x 0. 9 = 4. 2 kW

Step 4: System Energy Output/Supply Estimation for Connecticut (See table 5)

Power Output of the system rated 4. 2 kW is estimated as.

Daily Energy Output/Supply (kWh/day) = Peak hours (hours /day) X rating of system (kW).

The solar fraction is estimated per month as the ratio of Average Daily

Output Power requirement expressed as a percentage. The power or energy supply for the system at various stages and days of the season can be calculated as

Power Supply and Heat Supply

Winter being the month with a lot of snow and cloud cover has the lowest energy supply and therefore the month with the lowest average daily energy output picked which is December with 2. 7 kWh/m2/day, given by:

Winter Power supply = Insolation on a tilted surface (KWh/m2/day) X Overall system rating kW

= 2. 7 x 4. 2 = 11. 34 kWh/day

Winter Power supply = 11. 34 kWh/day.

The PV stand-alone system being a hybrid has been synchronized a thermal generator specifically designed to supply heat energy in peak demand. Being a new thermal generator, its efficiency is still very high at 80% while on full load, 85% while on a small load and 90% while on no load. The thermal generator is rated at 25 kWh.

Heat Supply from the generator (Full load) = 25 Kwh x 0. 8 = 20 kWh

Winter Heat Supply = 20. 00 kWh

Power supply during the summer is very high as the cloud is clear, temperatures are high, we have daily sun insolation more 4 hours per day and humidity is low.

Summer Power supply = Maximum insolation (KWh/m2/day) X Overall system rating kW

= 5. 4 x 4. 2 = 22. 68 kWh/day

Summer Power supply = 22. 68 kWh/day

Heat Supply from the generator (90%) = 25 Kwh x 0. 9 = 22. 5 kWh

Summer Heat Supply = 22. 5 kWh

Power supply during the spring is the average power supply during the winter and summer

Spring power supply= (winter power supply + summer power supply)/2

Spring power supply = (11. 34 + 22. 68)/2 = 17. 01 kWh/day

Spring Heat supply from generator at (85% load) = 25 kWh x 0. 85 = 21. 25 kWh

The Daily Performance of the system during the winter, summer and spring is therefore evaluated as:

For,

Winter, System Quality = 11. 3423. 04X 0. 5 + 0. 520. 0030 = 0. 6

Summer, System Quality = 22. 6823. 04X 0. 5 +0. 522. 551 = 11. 77

Spring, System Quality = 17. 0123. 04X 0. 5 +0. 521. 2515 = 1. 05

Step 5: Battery Sizing

Battery which is the storage capacity is then estimated as follows:

Storage capacity= Nc EDOD. μ

Where Nc= Largest number of continuous cloudy day of the site

DOD= Depth of discharge of the battery

For Connecticut the maximum number of days with continuous cloud cover is approximately 5 days. Assuming a 0. 8 DODμ, then the calculated storage capacity is 5 x 23 kWh/day/0. 8= 143. 75kWh

Assuming a DC bus voltage of 24 V, then the required battery in amperes would be 143. 75/24 giving approximately 6000 Ah. For single Vision

6FM250D rated 12 V and 250 Ah, then 24 batteries are required. We can then have 2 batteries connected in series of 12 strings.

Step 6: Battery Charge controller design

A charge controller is required to enable safe battery charging and to increase battery life span. It must be capable of sustaining the short circuit current of the PV array (Castaner & Sylvester, 2003). Hence, in this scenario, we can have one handling 120A to keep the DC voltage at to approximately 24V.

Step 7: Inverter Design

The choice of the inverter will be dependent on the AC loads maximum expected power. This should be 20% greater than rated power of the total AC consumed. Hence the inverter rated power should be 20% of 4. 2 kW + 4. 2 = 5. 04 kW.

Step 8: Generator design

Determine the generator size is a simple concept. The nominal power of the generator is equated to 80-120% of the PV nominal power (Badea, 2014). Nonetheless, it’s useful to keep the value at levels below 100%. What this means is that the generator is expected to supply power at optimum load for better fuel utilization.

References

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