Solar photovoltaic system in depth study in the dairy farm

Ravi Ranjan Kumar
M.Tech, Research Scholar
Sri Satya Sai University & Medical Sciences

Harjeet Singh
Assistant Professor
BHSBIET, Lehragaga

Prabhodh Khampariya
Assistant Professor
Sri Satya Sai University & Medical Sciences

Abstract: -

The electricity generated from the fossil fuels is around 67.2% share of the gross production of electricity. The fossil fuel is going to be exhausted in future. It is estimated that by 2045 the 80 % of reserve will be exhausted. The use of conventional energy sources for production of electricity poses a serious threat to the environment & hence human life. Keeping in view of issues, the existing power system of dairy farm has been suggested to be upgraded by Solar Photovoltaic (PV) system for making it more cost effective and eco-friendly. In this paper, discussed about electricity load demand in the dairy farm its purpose and energy calculation, available solar radiations and temperature at site and component cost of purposed system etc. has been done.

Key Words:- Fossil Fuel, Solar radiations, Solar PV system, Battery.

I. Introduction

The Lack of electricity in rural areas and the need for low prices cost energy drives the world towards solar energy. Solar energy, through their flexibility in use, offer unique opportunities in the energy sector to provide "packages" for energy services in remote rural areas such as home health care, education, communications, lighting, water supply and agriculture. Based on current policy settings and economic trends, electricity generation from renewable energy sources - including electricity, wind and solar PV - is on track to grow globally over the next two years - by 8% by 2021 and above 6% by 2022 But while this growth is strong, renewable resources will be able to meet half the rate of global demand for electricity over the next two years, according to a new IEA report [1].

Fuel-based power generation will address 45% of additional demand by 2021 and 40% by 2022, which will account for more nuclear power. As a result, carbon emissions in the electricity sector - which fell in 2019 and 2020 - are expected to increase by 3.5% in 2021 and 2.5% by 2022, which will put them at a higher level [1]

However, coal-fired power generation is expected to increase by about 5% this year and another 3% by 2022, which is likely to reach a very high level, according to the Electricity Market Report. Gas production, which fell by 2% by 2020, is expected to increase by 1% by 2021 and by almost 2% by 2022. Gas growth is lagging behind because it plays a small role in the fast-growing Asia Pacific region and is facing competition from renewable energy in Europe and North America [1].

Moreover, PV system and biogas systems are being considered increasingly as a significant option for dairy farm, rural areas, agricultural sites where the solar energy and manure potential is high. It will be very cost effective and can contribute in cutting down the carbon emissions to a very large extent.

II. Brief Literature Survey

Anoune Kamal et al. (2018): This paper provides an updated literature review, of the most applied method and techniques used in sizing and optimization of PV-Wind based hybrid system (PWHS) for an isolated area aiming to reach the best compromise between power reliability and hybrid system costs. Also provides an extensive analysis of software tools and algorithm approach used in sizing optimization.

Zhang Chi et al. (2017): The objective of this study was to quantify electricity usage and cost of milk production with data analysis of dairy farms and evaluate the potential alternative energy supply-solar energy generated by PV water pumping system (PVWP).

Lauer Markus et al. (2018): This paper presented that Farm operations in the USA and Europe have seen a radical change in the last decades: small sized farms are disappearing, and farm size and total livestock on larger farms are increasing. A non-linear optimization model was developed to optimize plant capacity for anaerobic digestion and maximize the net present value for each option by farm size. In this study a higher manure utilization rate could be achieved through joint, cooperative anaerobic digestion plants and manure transportation

Mathias Heiker et al. (2021): The paper addresses modelling approaches from an energy system, as well as from a process optimization. Model approaches of biogas production show different levels of detail. They can be classified as white, gray, and black box, or bottom-up and top-down approaches. On the one hand, biogas modelling can supply dynamic information on the anaerobic digestion process, e.g., to predict biogas yields or to optimize the anaerobic digestion process.

In this Paper the existing power system of dairy farm has been suggested to be upgraded by solar PV system for making it more cost effective and eco-friendly.

III. TYPES OF LOAD AND THEIR RATING IN DAIRY FARM

i. Determine power demands. The first step in designing a solar PV system for dairy farm is to find out the power requirement of all loads that need to be supplied by the solar PV system.
ii. Calculate total Watt-hours per day for each appliance used
iii. Add the Watt-hours needed for all appliances together to get the total Watt-hours per day.

The cost of electrical energy will increase dramatically in the future and awareness of energy consumption in the dairy industry is becoming an issue in the cost of milk production. It is observed that milk sucking pressure pump sets and submersible pump sets consume more energy and on the other hand the milk feeding pump set consume less energy. The power rating operating hours and energy requirement of different load are calculated in following Table 1:-

Table 1:- Power rating, operating hours and energy requirement of different loads

Sr. No	Type of load	Purpose	Rating(KW)	Per Day Kwh
1.	Two Submersible type pump set	for drinking water, washing, spray pump in summer for cattle etc	2set x 2H.P. x 0.7457 =2.98 KW	2.98 x 8Hrs =23.84 Kwh
2.	Milk Mixing System	For milk-mixing	1 HP x 0.7457 =0.74 KW	0.74 x 4 Hrs =2.96 Kwh
3.	Sucking pressure pump set	For milking the cows	4set x 2HP x 0.7457 =5.96 KW	5.96 Kw x 2 times x 2 Hrs =23.84 Kwh
4.	Milk Feeding Pump Set	For feeding milk to transportation tanker from storage tank	1 HP x 0.7457 =0.74 KW	0.74 x 2 Hrs = 1.48 Kwh
5.	Load of Residence of Care Taker and Office	For light and fan etc.	0.4 KW	0.4 x 14 Hrs = 5.6 Kwh
6.	Load of Tube light for cattle	For lighting for cattle in night	0.8 KW	0.8 x 11 Hrs =8.8Kwh
7.	Water Heater load	For hot water required by care taker and other purpose.	2 KW	2 Kw x 2 Hrs = 4Kwh
Grand Total Load/ Energy Used Per day=			**13.62KW (Approx)**	**70.52 Kwh Per Day**

LOAD FLOW DATA

The load flow data is required to analyze the hourly based demand of load of the dairy farm. Figure 1 shown the load taken by dairy farm according to the basis requirement. The demand is maximum at 08:00 to 10:00 and 18:00 to 20:00 due to milking process in dairy farm.

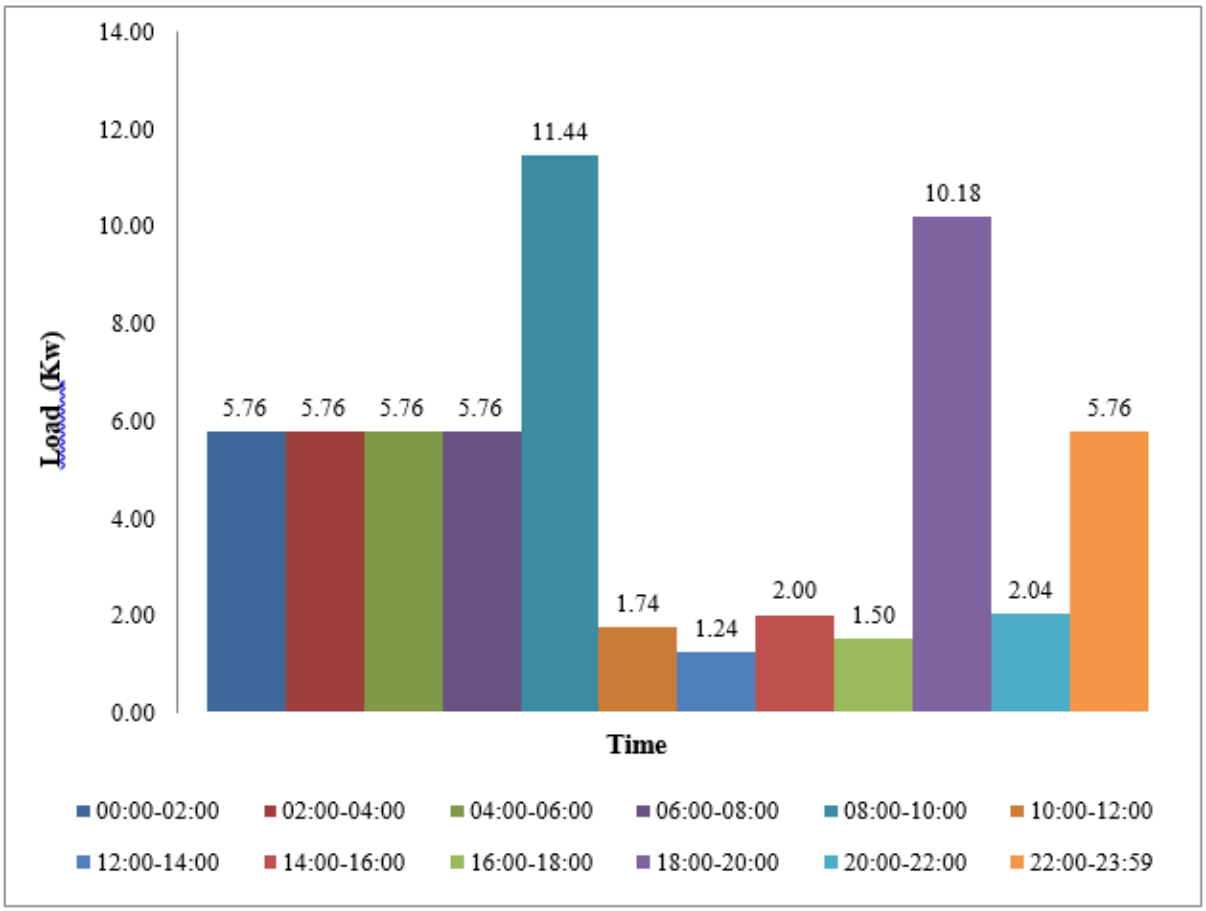

Figure 1: - Hourly based load flow

ANALYSIS OF SOLAR RADIATION

To calculate size of solar PV system, study of solar radiation falling on the said location is important (Latitude 30.5913 and Longitude 74.8115). Data collection in terms of monthly **average clearness indexes (Figure 2), monthly average solar radiations (Figure 3) and monthly average ambient temperature (Figure 4).** The solar radiation data for our location of purposed site is collected from national metrological department (NMD) by using the longitude and latitude of the location [6].

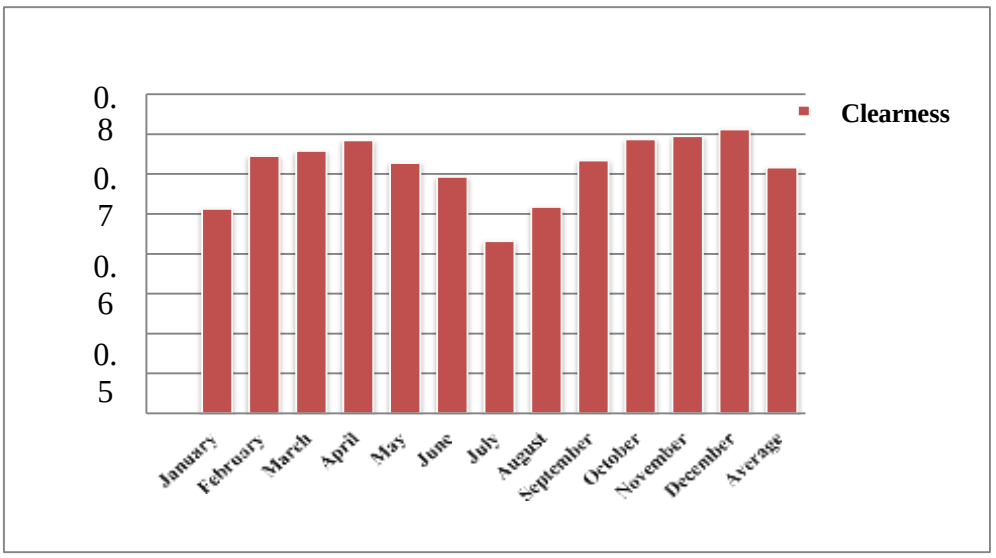

Figure 2:- Monthly average clearness indexes

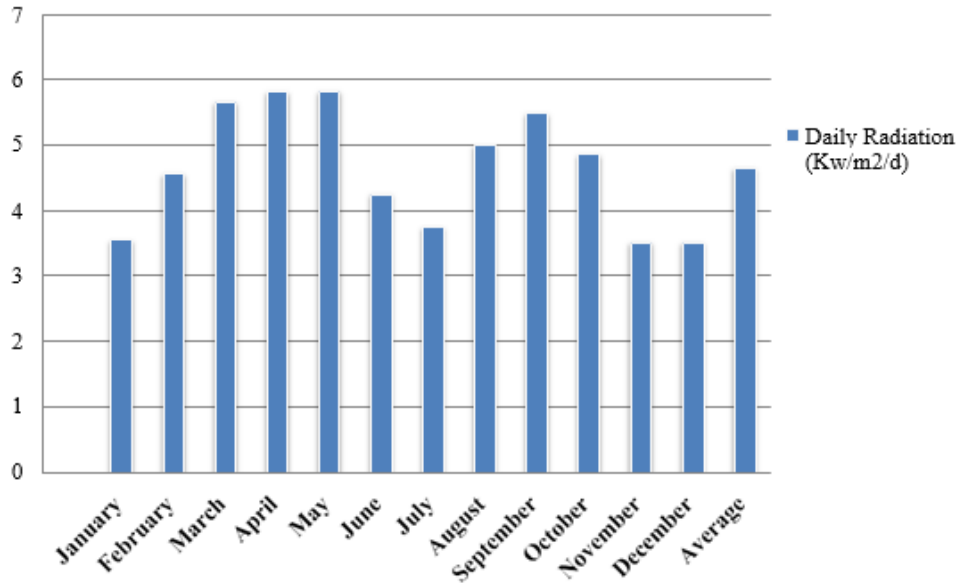

Figure 3:- Monthly average solar radiations

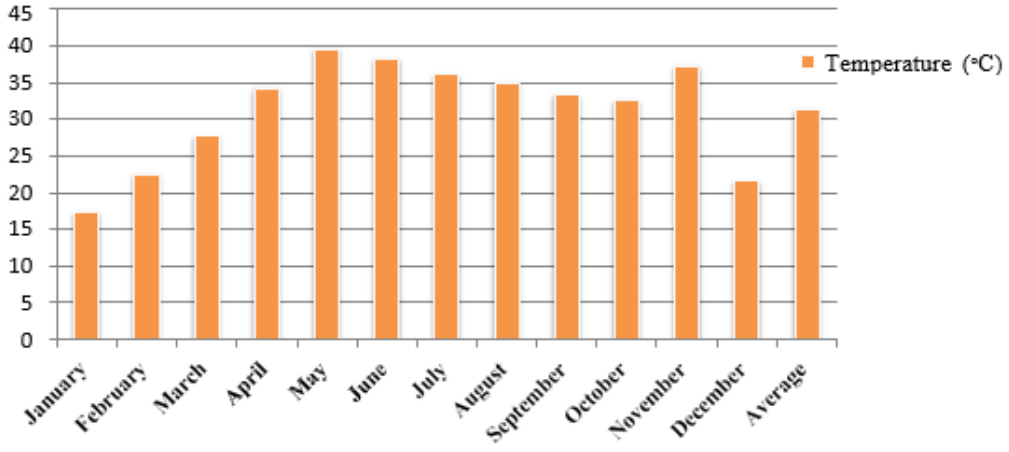

Figure 4 :- Monthly average ambient temperatures

COST OF COMPONENTS USED IN PURPOSED PV SYSTEM

In the purposed system, solar PV, battery-bank and inverter are used. The cost of those components is calculated as per references taken from internet.

Types, Size and Cost of Photovoltaic Cells

The main types of solar panels made up of mono crystalline silicon or poly crystalline silicon. The different parameters like efficiency, advantages and disadvantages of the different type of Solar cells are studied below in the table 3.5.

Table 2:- Different types of solar cells

Solar Cell Type	Efficiency-Rate	Advantages	Disadvantages
Mono crystalline Solar Panels (Mono-SI)	~20%	High efficiency rate; optimized for commercial use; high life-time value	Expensive
Poly crystalline Solar Panels (p-Si)	~15%	Lower price	Sensitive to high temperature, lower lifespan and slightly less space efficiency
Thin-Film: Amorphous Silicon Solar Panels (A-SI)	~7-10%	Relatively low costs; easy to produce and flexible	shorter warranties and lifespan
Concentrated PV Cell (CVP)	~41%	Very high performance and efficiency rate	Solar tracker and cooling system needed (to reach high efficiency rate)

As discussed above in Table 2. Mono crystalline has approx. 20% efficient with high life span. Thus it is preferred over other choices disused in Table.2 for proposed Solar PV system. Ministry of New and Renewable Energy (MNRE) give the 30-90% subsidy on the solar panel as per consumer requirements[7].

Size and Cost of Battery Bank and Inverter

Number of companies and its brands of batteries and inverter types are available in market in marginally fluctuating prices ranges. To calculate the battery price first we must have battery load and backup needed for designed system. It is as follows: -

Parameters of Battery Bank

i. Required Battery Backup (BB) = 4 Hours.
ii. Battery Bank Voltage = 24V DC
iii. Loose Connection/Wire Loss Factor (LF) = 20%
iv. Battery Efficiency (η_e) = 90%
v. Battery Aging Factor (Ag) =20%
vi. Depth of Discharge (DOD) =50%

vii. Battery Operating Temperature =80ºC

Table 3: - Calculation of total load on battery backup

Sr. No	Type of load	Purpose	Rating(kW)
1	One Submersible type pump set	For drinking water, washing, spray pump in summer for cattle etc.	1set,2H.P =1.49 kW
2.	Milk Mixing System	For milk-mixing	1 set,1 HP = 0.74 kW
3.	Sucking pressure pump set	For milking the cows	1set, 2HP =1.49 kW
4	Milk Feeding Pump Set	For feeding milk to transportation tanker from storage tank	1 set, 1 HP =0.74 kW
5.	Load of Residence of Care Taker and Office	For light and fan etc.	0.4 kW
6.	Load of Tube light for cattle	For lighting for cattle in night	0.8 kW
Grand Total Load on backup on battery bank =			**4.86 kW (Approx)+1 kW (Future use) =5.86 kW**

viii. Total Electrical Load on battery backup = 6kW

ix. Total Electrical Load on battery backup =Load in Watt/P.F.=6000/0.8=7500 VA=7.5 KVA

Size of Battery Bank

x. Total Load of Battery Bank= (Total Load in watt X Backup hrs Capacity) / Battery Bank Volt

= [(6000 x 4) / 24] Amp hrs

= 1000 Amp hrs

xi. Temperature Correction Factor for 46ºC (Tp)=1

xii. Size of Battery Bank = [(Load) X (1+LF) X (1+Ag) X Tp] / [η X DOD] Amp Hr

= (1000 X (1+20%) X (1+20%) X 1) / (90% X 50%)

= 3200 Amp Hr (24 V)

Size of Inverter

To find cost of inverter for Solar PV system, first calculate the size of inverter according to load. To calculate the size of inverter following factor to be consider [8]

i. Additional Further Load Expansion (Lf) =20%

ii. Efficiency of Inverter (ηe) = 80%

iii. Size of Inverter= [Total Load in Watt X (1+Lf) / ηe] VA

= 7500 X (1+20%) / 80%

= 11250 VA=11.25 KVA

Cost of Battery Bank and Inverter

Batteries accumulate excess energy created by PV system and store it for further use when there is no other energy input. Batteries can discharge rapidly and yield more current that the charging source can produce by itself, so pumps or motors can be run intermittently. Different brand of battery bank are available in market and cost of battery bank of 24 Volts per Ah is 30 Rs approx. as shown below in Table 4.

Inverter is the heart of any Solar PV system. So while buying a Solar PV system, it is very important to choose the right inverter for the safety and efficient functioning of the system. The cost of 1 KVA inverter with the capital, replacement and maintenance cost is given in Table 4.

Table 4: - Cost of battery bank per Ah and inverter per KVA

Component	Size	Capital Cost (Rs)	Replacement Cost (Rs)	O & M Cost (Rs/yr.)
Battery	1.0 Ah	30	17	13
Inverter	1.0 KVA	3500	0	3500

CONCLUSION

Dairy farming is made more cost effective by suggesting solar PV system according to energy requirements. In this Paper, the different operations of dairy farming have been discussed and accordingly load requirement, operating hours, and energy required per day is calculated. In order to find the optimized size of solar PV system, the analysis of solar radiations, clearness index and temperature of the site has been done. The cost of components which are used for SPV system has been discussed.

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