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Solar Industrial Process Heating: A Case Study of Dairy Industry in South Central India

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Abstract: *The dairy industry is one of the major energy consuming sectors in India. The various processes in dairy industry include pasteurization, cream separation, homogenization, chilling of milk and packaging of milk and value-added products. Currently, the thermal and electrical demand required for various dairy processes is satisfied by conventional fuels like furnace oil, coal, natural gas and electricity. The case study undergone at Karimnagar Milk Producers Company Ltd (KMPCL) uses coal as a conventional fuel for boiler, which provides steam to various processes in dairy. The proposed Photovoltaic system array simulated at KMPCL can provide an electrical demand for homogenizer and other basic electrical equipment's.*

Keywords*: Dairy industry, Solar energy, Industrial Process Heating, PVSYST, Normalized energy, Performance ratio*

I. Introduction

The Karimnagar district one of the 33 districts in Telangana state in India. The latitude and longitude of Telangana are 18.43o N and 79.12o E respectively. According to 2011 census the population of Karimnagar is 10, 05,711, whereas literacy rate is about 69.16%. The urban population accounts for about 3, 08,984 which is about 30.72 % of total population of the district.

The district is divided into two divisions based on the revenue generated i.e., Karimnagar and Huzurabad respectively. The Karimnagar is divided into 4 municipalities Huzurabad, Jammikunta, Choppadandi and Kothapalli.[1]

The details of Telangana state dairy milk procurement and milk marketing is as follows: -

Table no. 1: Details of dairying in Telangana State

S. No	Details	Quantity
1.	Dairy Milk Cooperative Societies	5, 189
2.	Milk Procurement	737 (Thousand kg/day)
3.	Liquid Milk Marketing	97 (Thousand liters/day)
4.	Cold Chain Infrastructure	
A	Bulk Milk Chilling	635 Thousand Litres
B	Chilling Centre	363 TLPD
C	Dairy Plant	1,250 TLPD

The present study has been carried out at Karimnagar Milk Producers Company Ltd. (KMPCL). It is one of the leading milk producing firm in Telangana State. Presently the KMPCL is procuring milk of about 2 LLPD, total milk sale is about 40,000 LPD. The KMPCL are using various processes for milk which involves use of steam for various processes. The steam is made available through boiler installed at milk processing plant. The boiler is simple horizontal Lancashire boiler which is coaloperated.

II. Material And Methods

Overview of Karimnagar Milk Producers Company Ltd

The present study is done on Karimnagar Milk Producers Company Ltd (KMPCL). It is a private dairy sector incorporated on 19th October 1992. It is one of the leading milk producers' company in Telangana state. The details of the dairy are as given below: -

1. Milk Processing Capacity = 2LLPD
2. Number of Pasteurizerunits
    a. Unit 1 = 10,000LPH
    b. Unit 2 = 10,000LPH
3. Number of Cream SeparatorUnits:
    a. Unit 1 = 10,000 LPH
    b. Unit 2. = 10,000LPH
4. Homogenizer Capacity = 20,000LPH
5. Chiller = 20,000LPH
6. Automatic Packaging Machine = 16units
    a. Total packaging = 1, 50,000 packets
7. Boiler = 01 Unit (Coal firedBoiler)

Processed Products at KMPCL

The major processed products at KMPCL are milk, curd, buttermilk, lassi, paneer, ghee. Milk packaging is available in 200 ml, 500 ml Tea Special, 500 ml Pure Milk, 500 ml Gold and 1 litre respectively. The curd is available in 400 g cup, 150 g, 200 g, 500 g, 1 kg and 15 kg tin packing. The ghee is available in 200 ml, ½ kg and 1 kg packing. The paneer is available in 100 g, 250 g, 500g and 1 kg packing.

Total Sales Per Day

The estimated average sale of milk and value-added products is as givenbelow: -

Table no. 2: Total Sales per day by KMPCL

S. No	Name of product	Sale per day
1.	Milk	1.30 LLPD
2.	Curd	40,000 LPD
3.	Ghee	1 TPD
4.	Paneer	150 KGPD
5.	Lassi	1,500- 7,000 glasses per day
6.	Sweets	250 KGPD

Processes at KMPCL

1. Raw Milk Reception

The raw milk is collected across 960 villages of Karimnagar district. There is total 19 Raw Milk Receiving Dock (RMRD). The milk from the RMRD is collected at local level and is been sent to milk processing plant through tankers with more than 10,000 litres capacity respectively.

2. PRE-TESTING OF RAWMILK

Before the milk is sent to further pre-processing the raw milk from the tankers is first tested. The QC lab does follow tests: -

A. Clot on boiling (COB)
B. HeatStability
C. Acidity
D. Corrected Lactometer Reading (CLLR)
E. O. T – colour, flavour,aroma.
F. Adulterants
G. Methyl Blue Reduction Test(MBRT)

3. PASTEURISATION

The pasteurisation is a process that purifies milk and helps milk to stay fresher and for longer time duration. The pasteurisation process has temperature of about 72o C, but at KMPCL pasteurisation takes place at 81.3o C. There are two units of pasteurisation of capacity 10,000 litres/ houreach.

4. HOMOGENIZER

The fat in the milk will rise at the top and get separated from raw pasteurized milk. Homogenisation is a process in which the fat content in milk is spread out evenly in each unit quantity of milk. Due to homogenisation the milk gets its texture and delicious flavour. The processed pasteurised milk is transferred to a piece of equipment called homogenizer, where fat is forced under high pressure through tiny holes that break fat cells up into tiny particles i.e., 1/8th of its original size. The protein contained in milk quickly forms around each particle and these prevent fat from re-joining. The milk fat cells then stay suspended evenly throughout themilk.

5. CREAMSEPERATION

The cream can be either supplied by fluid milk or it can be separated from whole milk by butter manufacturer. The pH of cream is maintained between 6.6. The value-added product are made by cream obtained from pasteurized milk. Further cream is heat up to 95o C in pasteurizer. There are total two units of cream pasteurizer with capacity of 10,000 LPH each.

6. PACKAGING OF MILK

The pasteurized milk is pumped to automatic filling machine. There is total 15 milk packaging units which pack about 1, 50, 000 pockets of milk every day. During this process milk is kept at 1 to 2oC temperature which prevents development of extra bacteria and keeps milk fresh.[2]-[4]

Process Calculations

ENERGY REQUIREMENT FOR VARIOUS PROCESSES AT KMPCL

The energy requirement for various processes at KMPCL is given below: -

1. Pasteurization
2. Cream Separator-Pasteurisation
3. Cold Storage
4. Chiller

Table no. 3: Milk Procurement at KMPCL

S. No	Total Milk Procurement per day	Total Milk Processing per hour
1.	2 LLPD	8333.33 LPH

1. Pasteurisation Process

The process calculation for pasteurisation process is done by formula: - Q = m × Cp × (Tf-Ti)

Q = 10300× 0.94× (81.3-4)

Q = 748418.6 Kcal

Where, m= mass of milk in kg

Cp= Specific Heat of milk in kcal/kgoC.

Tf = Final Temperature of Pasteurisation process 81.3oC. Ti= Initial Temperature of milk i.e.,4oC.

Now we convert heat required for pasteurization in kW. Q = 748418.6× 4.187 J/ 3600

Q = 870.41 kW-hr

Table no. 4: Details of Pasteurization Process

S. No	Units	Capacity	Energy Requirement for Pasteurisation (kW-hr)
1.	Unit I	10,000 LPH	870.41
2.	Unit II	10,000 LPH	870.41
Total			1740.82 W-hr

2. Cream Separation Process

The process calculation for pasteurisation process is done by formula: -Q = m × Cp× (Tf-Ti)

Q = 10300 × 0.94 × (95-81.3)

Q = 132643.4 Kcal

Where, m= mass of milk in kg

Cp= Specific Heat of milk in kcal/kg oC

Tf = Final Temperature of cream separation process 95 oC Ti= Initial Temperature of milk i.e., 81.3 oC

Now we convert heat required for cream separation process in kW. Q = 132643.4 × 4.187 J/ 3600

Q = 154.27 kW-hr

Table no. 5: Details of Cream Separation Process

S. No	Units	Capacity	Energy Requirement for Cream Seperation (kW-hr)
1.	Unit I	10,000 LPH	154.27
2.	Unit II	10,000 LPH	154.27
Total			308.54 W-hr

3. Chilling

The process calculation for chilling process is done by formula: -Q = m× Cp× (Tf-Ti)
Q = 20600× 0.94× (25-4)
Q = 406644 Kcal
Where, m= mass of milk in kg
Cp= Specific Heat of milk in kcal/kg oC. Tf = Final Temperature of milk
Ti= Initial Temperature of milk.
Now we convert heat required for pasteurisation in kW. Q =406644 × 4.187 J/ 3600
Q = 26.97 kW-hr
Electrical load = 26.97 kW-hr
Now we calculate refrigeration load Refrigeration load = 26.97 /3.5
Refrigeration load = 7.70 TR

Table no. 6: Details of Chilling Process

S. No	Units	Capacity	Refrigeration Load (TR)	Electrical Load (kW-hr)
1.	Unit I	20,000 LPH	7.70 TR	26.97 kW-hr
Total			7.70 TR	W-hr

4. Cold Storage

The process calculation for pasteurisation process is done by formula: - Q = m× Cp× (Tf-Ti)
Q = 8583.32× 0.94× (25-4)
Q =169434.73 Kcal
Where, m= mass of milk in kg
Cp= Specific Heat of milk in kcal/kg oC. Tf = Final Temperature of milk
Ti= Initial Temperature of milk.
Now we convert heat required for pasteurisation in kW. Q =169434.73 × 4.187 J/ 3600
Q = 197.06 kW-hr

Electrical load = 196.06 kW-hr
Now we calculaterefrigeration load Refrigeration load = 196.06 /3.5
Refrigeration load = 56.30 TR

Table no. 7: Details of cold storage

S. No	Units	Capacity	Refrigeration Load (TR)	Electrical Load (kW-hr)
1.	Unit I	8333.33	56.30	196.06
Total			56.30 TR	196.06 kW-hr

Total Energy Consumption at KMPCL

The total energy consumption at KMPCL is as follows: -

Table no. 8: Details of total thermal energy consumption per hour.

S. No	Process	Thermal Consumption (kW-hr)
1	Pasteurisation	1740.82
2	Cream	308.54
Total		2049.36 kW-hr

Table no. 9: Details of total thermal and electrical energy consumption per hour

S. No	Process	Electrical Load per hour (kW-hr)	Refrigeration Load per hour (TR)
1	Chilling	26.97	7.70
2	Cold Storage	197.06	56.30
3	Homogenization	80	-
Total		303. 03 kW-hr	64 TR

Scope of Renewable Energy in KMPCL

The Telangana State has a vast potential for solar and wind energy. The Karimnagar district has implemented a rooftop solar panels mandatory for large structures like houses, apartments, large community halls, and various commercial buildings. It is mandatory to install solar roof top for buildings whose build up area is more than 2700 square feet. The Telangana State produces energy of about 1334 MW from solar energy. The average solar insolation in Telangana state is about 5.5 kWh/m2. There are nearly 300 sunshine days instate.

As far as wind energy is considered Telangana state has a potential of about 4500 MW. The prominent districts for wind power projects are in Medak, Ranga Reddy and Mahaboobnagar. There are projects at Nazeerabad in Vikarabad district of 108 MWcapacity.

Hence there is a wide scope for various process industry for implementation of renewable energy for process heating and cooling. The Karimnagar district also has potential of solar energy. The latitude and longitude of Karimnagar district are 18.43o N and 79.12o E respectively.[5]-[8]

Solar Data Assessment at Karimnagar

The latitude and longitude of Karimnagar district are 18.43o N and 79.12o E. The software used to solar data forecasting is NASA Prediction of Worldwide Energy Resources (POWER). It is a satellite-based system which gathers all renewable data worldwide. The data collected from NASA POWER for year 2019 in Karimnagar district is as follows:

Table no. 10: NASAPOWER Solar Radiation Data

S. No	Month	All sky Insolation Incident on horizontal surface(kW-hr/m2/day)
1.	January	146.95
2.	February	156.77
3.	March	197.91
4.	April	205.67
5.	May	207.69
6.	June	157.51
7.	July	124.39
8.	August	120.39
9.	Septembe	122.94
10.	October	141.45
11.	November	149.8
12.	December	131.43
Total		1862.9

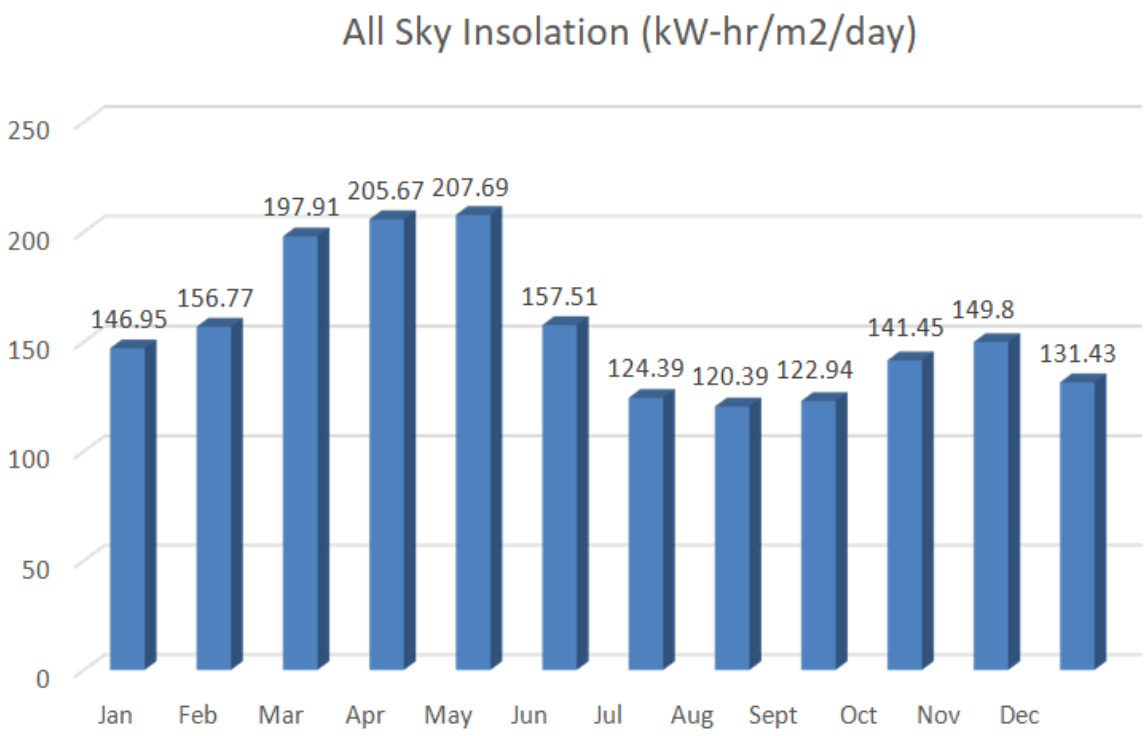

Figure no. 1: All Sky Insolation (kW-hr/m2/day) at Karimnagar

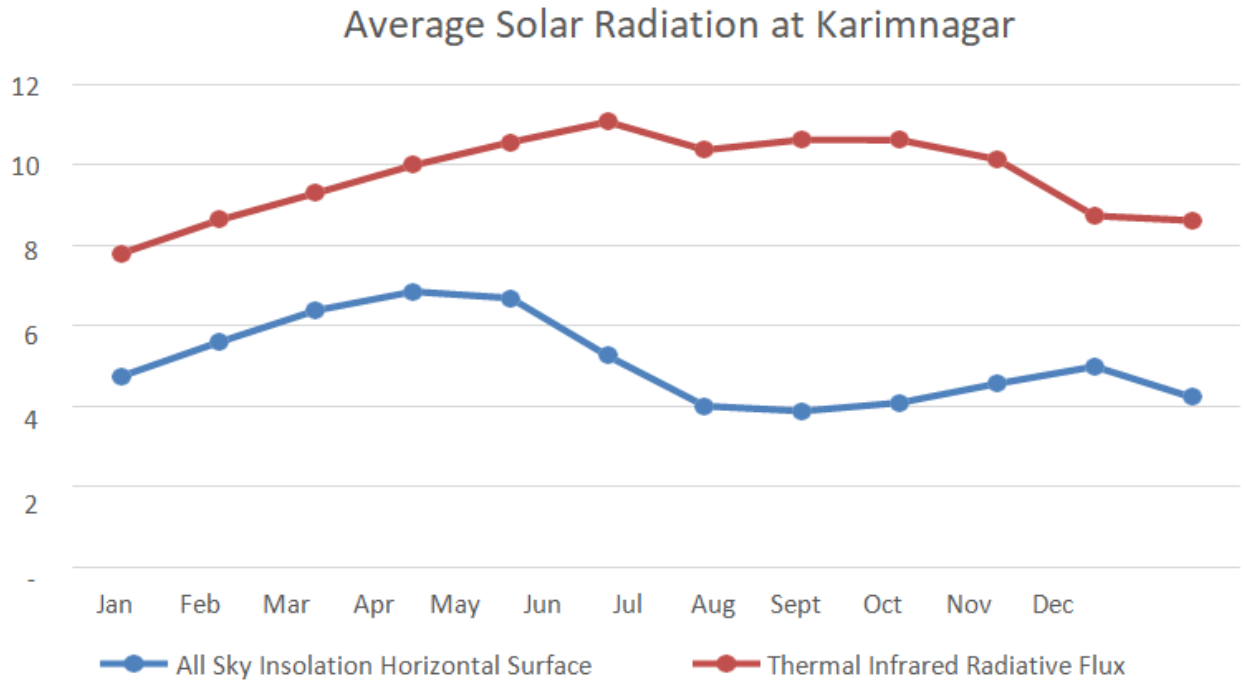

Figure no. 2: Average Solar Radiation at Karimnagar

III. Result and Discussion

PV SYST Simulation at KMPCL

Specifications of Proposed System for pasteurization process

We have selected Poly- Silicon Solar Panel which is grid connected to satisfy the thermal requirements and electrical requirements of industry.

PV Array Characteristics

Table no. 11: PV Array Characteristics

S. No	Parameters	Specifications	Quantity (Specification)
1.	PV Module	Poly- Silicon CS3K-275P-AG-1500V- Canadian Solar Inc.	35 Modules (In Series) 52 strings (In Parallel) 1820 (Total PV modules)
2.	Array Global Power	Nominal STC	501 kWp At Operating Condition (454 kW)
3.	Array Operating Characteristics	UmppI mpp	985V 460A
4.	Module area	Area	3024 m^2

Inverter Characteristics

Table no. 12: Inverter Characteristics

S. No	Parameters	Specifications	Quantity (Specification)
1.	Inverter Model	Wynnertech ALBA 4×1500550 Vac	01
2.	Unit nominal power	2669 kWac	Operating Voltage = 800 to 1200 V
3.	Total power	667 kWac	Pnom ratio = 0.75

The simulation obtained by the use of above PV array and inverter specifications the simulation results obtained are as follows: -

1. Produced energy = 892MWh/year
2. Specific production = 1787kWh/kWp/year
3. Performance ratio = 80.81%

A. Normalized Energy

The normalized energy bar chart for each month in a year resembles various losses i.e., collection loss (Lc); System loss (Ls); and Produced useful energy (Yf) respectively. Following graph shows the details of normalized energy in kWh/kWp/day at study location.

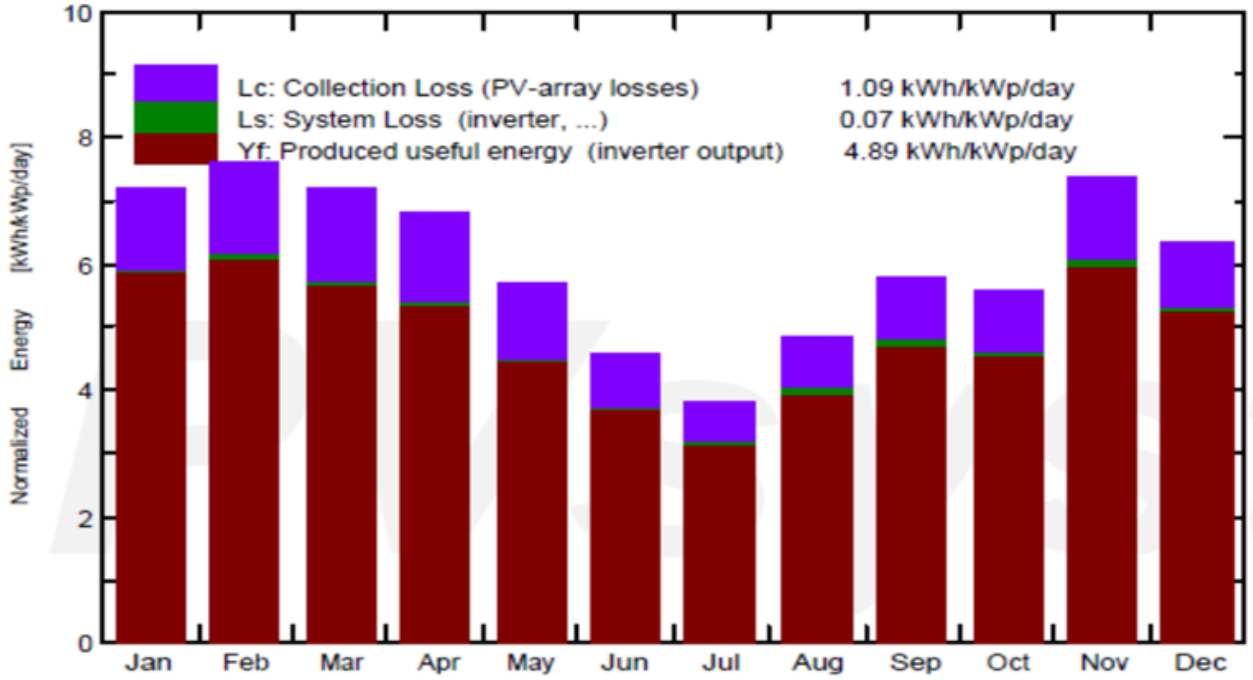

Figure no. 3: Normalized Energy for Proposed System

B. Performance ratio

Performance ratio describes the relationship between actual and theoretical energy outputs of simulated PV system. The performance ratio (PR) obtained was 80.81% respectively

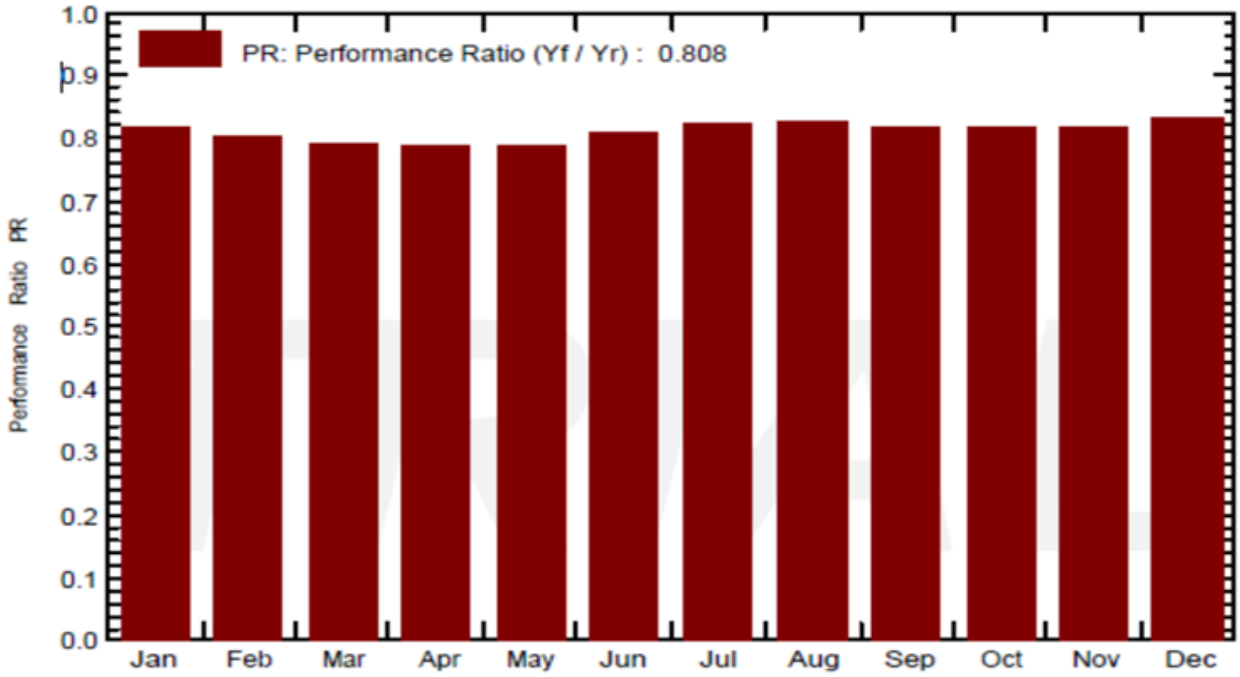

Figure no. 4: Performance Ratio for Proposed System

IV. Summary

The proposed system for Karimnagar Milk Producers Company Ltd. (KMPCL) i.e., Solar Photovoltaic System gives specific production as 1787 kWh/year. The proposed system has a performance ratio of about 80.81%. The total energy produced per year is about 892 MWh/year. The total modules required for the simulated system is 1820 polysilicon photovoltaic panels. The modulearea required is nearly 3024 m2. The proposed photovoltaic system can be utilized for electric load satisfaction, as the system is grid connected. It is feasible to utilize the proposed photovoltaic system for electrical usage. It can be utilized to satisfy demand of homogenizer and other lighting equipment's in dairy industry.

V. Conclusion

The Karimnagar Milk Producers Company Ltd, is currently using coal as a conventional fuel in boiler. The steam required for pasteurization and cream separation process is supplied by conventional boiler technique. The chilling and cold storage demand is fulfilled by using grid electricity. The average solar insolation in Telangana state is about 5.5 kWh/m2. There are nearly 300 sunshine days in state. The potential for solar and wind have been studied at Karimnagar district, under the value of all sky solar insolation condition at horizontal surface is in the range of 207.63 to 120.39 kW-hr/m2/day. And thermal radiative flux it is in the range of 332.26 to 241.86kW-hr/m2/day.The designed solar PV system can provide 892 kWh/ year of energy, which can be implemented for electrical load like homogenizer, other electrical appliances.

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