Original Research Article

"DEVELOPMENT OF SOLAR POWERED COOLING SYSTEM FOR ANIMAL HOUSING STRUCTURE"

ABSTRACT:

A solar power assisted system was developed and installed to create optimum healthy environmental conditions inside the animal house. The renewable energy-based gadgets such as solar panel, charge controller, time-controlled switch and accessories were used inside the animal housing structure to create an optimum healthy environmental condition at University of Agricultural Sciences, Raichur. The improved animal housing structure was capable to shelter for 10 pair animals with manger feed trough and urine collection system. –The solar panel (74 wattsW) with Dc DC pump, water fogging system, battery (12 volts V 22 Ampere hourAh), charge controller, water tank (200 litrel) and time-controlled switch have been installed inside the animal dairy shed. The solar panel acts as a power source for the operation of DC pump and time-controlled fogger system provides the fogging of water and created the cooling effect for animals. The fogging of water was not allowed to fall on the ground and evaporates in an open atmosphere. The atmospheric temperature relatively 4–-5–°0 C was less inside the housing structure and relative humidity at optimum condition was maintained. The diamond shaped wire mesh provided surrounding the animal housing structure protected the animal from mosquito bite and other insects. The fogger assembly installed for fogging of water created the cooling effect and animal parameters were noted, and analysed.

Keywords: Solar panel, pump, heat stress and cooling effect.

1. INTRODUCTION

Energy is the critical input to drive and improve the life cycle. The consumption of energy is directly proportional to the progress of mankind. In many villages of our country, even with a good electrical network, power is not available as per the requirement. Presently, the rural population is largely dependent on conventional sources for thermal applications. India has been generating electricity from conventional energy resources primarily based on fossil fuels, which are depleting day by day. The fast-depleting conventional energy sources and today's continuously increasing energy demand in the context of environmental issues, have encouraged intensive research for new, more efficient and green power plants with advanced technologies.

In addition to new energy and clean fuel technologies being actively explored and studied, environmental protection issues are growing globally these days. Developing electricity from non-conventional energy resources is crucial to provide the power needed in the future. Energy from biomass, solar, wind, tidal, fuel cells, and geothermal sources makes up the majority of non-conventional energy sources. Around the world, solar photovoltaic systems are the most frequently employed non-conventional energy resource (Murni et al., 2012). However, the majority of developing nations have very low rates of electricity (Mphol et al., 2015). As a developing nation, India has enormous potential for solar energy harvesting because it receives solar radiation equivalent to 3000 hours of sunshine annually, which can provide an estimated 5000 trillion kWh of energy (Sudhakar et al. 2015).

A majority of the Indian population is primarily dependent on the agriculture sector, with around half of the population being involved. Apart from the main stream cash-cropping exercise, a majority of this sector is also involved in animal husbandry. In India, a large number of farmers are dependent on animals for their livelihood, through production of milk, meat, eggs, wool and skin.

According to Yousef (1985) and West (2003), dairy animals' thermoneutral zone, which is between 16 and 25°C, has a relative humidity range of 60–80% and a physiological body temperature range of 38.4–39.1°C. India is a tropical nation with hot, muggy summers and a less demanding winter season. The ambient temperature can get to 40 to 45 °C in the summer (Kadokawa *et al.,* 2012). Animals experience heat stress due to the elevated heat uptake during these hot and muggy summer months, which surpasses a threshold limit in the climatic circumstances (Sunil et al., 2011). Rectal temperature (RT) and body surface temperature (BST) rise as a result, impacting the health, feed intake, productivity, and reproductive efficiency of animals.

Various methods can mitigate high temperatures and heat stress in barn environments, such as well-insulated roofs and effective natural ventilation. Shading, whether natural or artificial, can reduce solar radiation and overall heat load outdoors by over 30%. However, it has minimal impact on air temperature and humidity, necessitating supplemental cooling for dairy cows in hot, humid climates. Cooling options include air conditioning, evaporative pads, sprinkler wetting with forced ventilation, and evaporative devices like foggers and misters. Fogging systems, using high-pressure nozzles, release fine water droplets that evaporate quickly, cooling the air as animals are exposed to it (Renaudeau et al., 2012). This study focuses on developing and evaluating a solar-powered cooling system for managing heat stress in crossbred cows.

2. MATERIALS AND METHODS

The solar power assisted cooling system was developed by considering the area of animal housing structure and meteorological parameters. In the current investigation, the type of housing system was a face-out system, in which the cows were housed, fed, and milked during the experiment. The study was conducted at the dairy unit, Main Agriculture Research Station, University of Agricultural Sciences, Raichur. It lies at 16.2012° north latitude and 77.3245° east longitude. The climate of the Raichur district was characterised by dryness for the major part of the year and a very hot summer. The summer season starts in March and extends until May. April and May were the

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hottest months. During these two months, the weather becomes very dry and uncomfortable and the temperature may reach up to 42 °C. The total floor area selected was 48 m^2 (*i.e*. length of 9.2 m and width of 5.22 m). The manger is 1.1 m wide with front and back heights of 70 and 60 cm, respectively. The study area was isolated from the other half of the house by covering it with an HDPE green shade net with a 50% opening.

2.1. System development parameters

The solar power assisted cooling system was developed with fogger assembly, which require power to pump the water by the pump. The power requirement for the system at maximum discharge and pressure were calculated to select the suitable pump and solar panels.

1. Pump and solar panels

The solar photovoltaic modules act as power source for operating the fogger assembly of the cooling system. The power [direct current (~~dc~~DC)] generated by the modules was transferred to the motor coupled with the pump. Based on the maximum number of foggers required for the study and maximum operating pressure, the power required for the pump was calculated using the following equation.

The solar energy flux per unit area (solar constant) is 1353 W m^{-2} (Rai, 2011).
1 m² solar array produces 0.5 kWh energy.
Number of foggers: 18
Discharge rate of one fogger: 0.2 1 min^{-1}
Operating pressure of fogger: 4 kg cm^{-2}

$$\text{Water horse power} = \frac{Q \times H}{4500}$$

Where,

Q = discharge from the pump, l min^{-1}
H = total head, m
Total discharge (Q) = (discharge of one fogger) × (number of foggers)
= 0.2 × 18
= 3.6 l min^{-1}
Total head (H) = (Fogger pressure head) (Delivery head)

$$\text{Water horse power} = \frac{3.6 \times 40 \times 2}{4500}$$

= 0.064 hp

$$\text{Shaft horse power} = \frac{\text{Water horse power}}{\text{Pump efficiency}}$$

$$\text{Shaft horse power} = \frac{0.064}{0.80}$$

= 0.08 hp

Shaft horse power = 0.08 × 0.746

= 0.05968 kW

= 59.68 W

2) Selection of solar panels

The solar panels were selected based on the power requirement of the motor and the pump. The main parameter which influences the solar panel is the temperature of the region and maximum sunshine hours. Based on power requirement by the pump, two solar panels of capacity 37 W each were selected (fig 1). The specification of single panel module is presented in Table 1.

Fig 1. Solar panel

Table 1. Specification of selected solar panel

Sl. No.	Particulars	Specification
1	Panel capacity	37 W
2	Irradiance	1000 W m^{-2}
3	Ambient temperature	27.2 ^{o}C
4	Voltage	12 V
5	Current	2.08 A
6	Model efficiency	15.3 per cent

3) Selection of DC motor coupled with pump

The selection of dc pump involves the discharge rate and the operating pressure required for the cooling system. The actual power required to pump the water and power available from the solar panel modules should be matched. Thus the ~~dc~~ DC motor coupled with pump was selected based on the power requirement for the operating the cooling system and the power calculation has been explained in the section 1. The specification of the selected pump is presented in Table 2.

Fig 2) DC pump

Table 2. Specification of selected dc motor coupled with pump

Sl. No.	Particulars	Specification
1	Model	2100-134
2	Voltage	12 V
3	Current	7.0 A
4	Flow rate	4.5 l min^{-1}
5	Pressure	4.1 kg cm^{-2}
6	Capacity	84 W

4) Battery

The lead acid battery of 12 V and 22 Ah capacity was used for storing the electricity. The ~~pv~~ PV modules produces 12V. The battery was connected to the pump through digital timer. The current from the PV modules was continuously stored into the batteries during the sunshine hours. The batteries basically provide the power to the motor due to stored electricity. Specification of selected battery is presented in Table 3.

Table 3. Specification of selected battery

Sl. No.	Particulars	Specification
1	Type	Dry lead acid type

2	Voltage	12 V
3	Capacity	22 Ah

4.1 Analytical calculation of current produced by the solar panel, charging and discharging time of the battery

a) Current (I):

The current (I) produced by the solar panel was calculated by knowing the maximum power (P) of the solar panel and the voltage rating (V) of the battery. The capacity of each solar panel was 37 W and voltage rating of the selected battery was 12 V.

$$I = \frac{P}{V}$$

$$I = \frac{74}{12}$$

I = 6.16 A

b) Charging time (T):

Charging time was computed by taking the ratio between rating of the battery in ampere hour (Ah) to the total current generated by the solar panel. The voltage rating of the battery was 22 Ah and the current generated by the panels was 6.16 A. The calculations were given by:

$$T = \frac{\text{Battery rating in ampere hour}}{\text{Total current generated by the solar panel}}$$

$$T = \frac{22}{6.16}$$

T = 3.57 h.

c) Discharge time:

The battery discharging characteristics of solar power assisted cooling system was studied to determine the discharge time and battery voltage reduction. The solar panels were disconnected from the battery to avoid charging while testing and fully charged battery was discharged by operating the cooling system at maximum discharge and pressure. The voltage of battery was measured at an interval of 30 minutes. The voltage reduction was noted till the full discharge of battery, which stopped the working of cooling system.

5) Charge controller

The charge controller was used to control the condition of the charging, indicating that the battery is fully charged, 50% charged or discharged and controls itself indicating whether the panel is in operation or not. As the battery voltage rises to a certain amount, the charge controller regulates the system voltage and opens the circuit, stopping the charging. A digital PWM Solar Charge Controller was used for the dry lead-acid battery connected to a solar power system (~~fig~~ Fig. 3). When connected to the battery, this charge controller automatically detects the battery voltage from 12-24 V.

6) Timer switch

The digital timer device was used to operate the fogging system at a certain time interval, as per the requirement i.e. cyclic time interval (~~on~~ON/~~off~~OFF). A 48 x 48 mm digital timer with 3 digits, 7 segment LED, dual display was mounted between battery and pump. It has different modes of operation (~~fig~~ Fig 4). They are ON delay, Interval, Cyclic ON first and Cyclic OFF first. The specifications of timer switch are listed in Table 4.

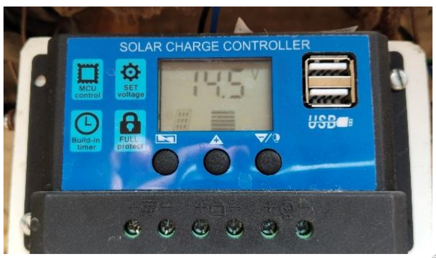

Fig 3. Charge controller

Fig 4. Digital Timer

Table 4. Specification of selected digital timer

Sl. No.	Particulars	Specification
1	Display	Dual, 3-digit seven segme LED display
2	Supply voltage	85 to 270V AC, 12-24V AC / DC
3	Operating modes	ON Delay / Interval / Cycli ON First / Cyclic OFF First
4	Time ranges	9.99 / 99.9 / 999sec 9.59 min:sec, 99.9 / 999 min, 9.59 hour:min, 99.9 999 hour
5	Accuracy	± 0.05% or 50 ms
6	Mounting type	Panel Mount

7) Fogger assembly

The four-way foggers were used for discharging the water in the form of fog. It consists of fine nozzle orifices through which water was discharged in the form of water droplets in the fog range. The droplets size of water discharged through the fogger ranges from 50-60 micron, which will cause the water droplets to evaporate quickly in the air. The desired rate of application with sufficient pressure was possible in this system. The rated operating pressure of the selected four-way fogger was 4 to 5 kg cm^{-2}. The maximum discharge of the selected fogger was 12 l h^{-1} when the fogger was operated at rated pressure. The specification of fogger is presented in Table 5.

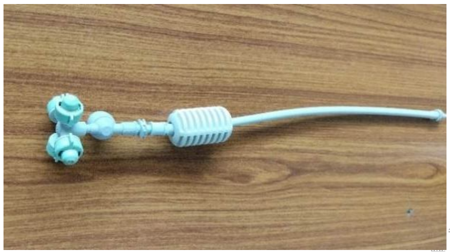

Fig 5. ~~fogger~~**Fogger**

Table 5. Specification of fogger used for discharging water

Sl. No.	Particulars	Specification
1	Brand	Netafim
2	Model	Coolpro net 055
3	Colour	Light Green
4	Material type	Plastic
5	Operating pressure	4.0-5.0 Bar
6	Droplet size	65 Micron
7	Flow rate	12 l h^{-1}

8) Water tank

Cubical shaped water tank was used, which stores the water required for the cooling system. A white coloured tank made up of PVC material was selected, which was light weight, durable and heat resistant. The maximum discharge of the cooling system was estimated to be 216 l h^{-1}. Thus, based on the increase in number of foggers and maximum water requirement by the cooling system, the 250 l capacity water tank was selected. The tank was fixed on a stand just below the pump for the easy suction of water.

9) Pressure gauge

An analog water pressure gauge was used to measure the operating pressure and to set the pressure in the cooling system. This analog pressure gauge was filled with glycerine which has pressure range of 0-7 kg cm^{-2}.

10) Lateral pipe

The lateral pipe was selected according to discharge and capacity to withstand the pressure. The lateral pipe of 16 mm, made of lLinear Linear low-density polyethylene (LLDPE) material was selected to deliver the water to the foggers from storage tank.

Fig 6. ~~pressure~~ Pressure gauge

Fig 7. ~~lateral~~ Lateral pipe

2.2. Installation of the developed cooling system:

The solar power assisted cooling system was developed and installed in the face out dairy house selected for the study (Plate 1). The cooling system consists of a maximum of 18 foggers (Table 1). Specification of selected fogger), each of which has a discharge rate of 12 l h^{-1}. The solar power assisted cooling system was equipped with a DC pump coupled to a motor of 84 W (12 V & 7 A) and an operating pressure of 4.1 kg cm^{-2}. The system was provided with 2 solar panels of 37 W each. The cooling system comprises a digital timer, a 22 -meter LLDPE lateral, and a 250-liter water tank (flow chart of the cooling system ~~fig~~Fig.1). A pump capacity of 84 W (12 V & 7 A) with 4.1 kg cm^{-2} operating pressure and discharge rate of 4.1 l min^{-1} was selected on the basis of the maximum discharge rate and operating pressure of the cooling system and it was found that the maximum discharge of the cooling system was 3.2 l min^{-1} at 4.1 kg cm^{-2}.

The panel capacity was decided based on the power requirement by the selected pump. The maximum power required the pump to discharge the desired flow rate at maximum operating pressure was found to be 60 W. Thus, two solar panels of 37 W each were selected and installed on the roof of the animal house supported with mild steel square bars (Table 1. ~~specification of solar panel~~).

The system was provided with 12 V & 22 Ah lead acid dry type battery and a solar charge controller. When completely charged, the selected battery had a backup capacity of up to 6 hours. Additionally, a provision was made to charge the battery using grid electricity to handle cloudy days when the sunshine was insufficient to generate the necessary power to run the developed cooling system. The pump was mounted to the rigid H beam with the help of a binding wire. The battery, timer, charge controller and pump were mounted to the H beam under the roof in series. A frame made of mild steel bars that was supported by two mild steel angle bars holds the battery in place by connecting it to the H beam.

The digital timer and charge controller were fitted to a wooden panel that was mounted to a rigid H beam of the housing structure through bending wire. The PVC water tank was set on a platform of a 6 foot water tank stand, which was constructed of mild steel angle bars. A 6 m × 3 m rectangular frame composed of square stainless-steel bars was used as support to place the lateral pipe within the house. The lateral pipe was fitted with the foggers, which were spaced equally apart.

Fig 8. Solar power-assisted cooling system in an animal housing structure

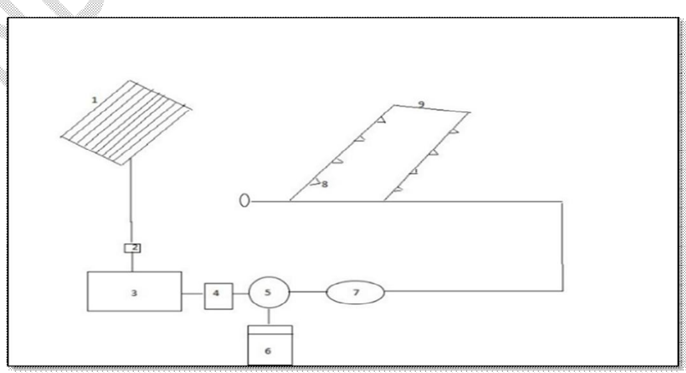

Fig 9. Schematic diagram of the cooling system

1. Solar panel
2. Charge controller
3. Battery
4. Timer switch
5. DC motor coupled with pump
6. Water tank
7. Pressure gauge
8. Fogger assembly
9. Pipe

3. RESULTS AND DISCUSSION

The solar power assisted cooling system was developed by considering the total area to be cooled and maximum power requirement by the system at maximum discharge of foggers. The parameters considered in the development of the cooling system are discussed under the subheadings.

3.1 Pump and solar panels

As discussed in section 1 capacity of the pump and solar panels are selected based on the application rate and power requirement. A 12 V ~~dc~~ DC motor coupled with a pump has been selected to give a maximum discharge of 4.1 l m^{-1} at 4.1 kg cm^{-2} pressure.

Solar power through solar panels acts as the main power source for the cooling system which was explained in section 1 and the capacity of the selected panels were 37 W each. The specifications of the panels were explained in Table 1. The required capacity to run the pump and available capacity were matched with the proper selection of the solar panels.

3.2 Analytical calculation of current produced by the panel, charging and discharging time of the battery

As discussed in section 4.1 the current produced by the solar panel found out to be 6.16 A. The time required to charge the battery was found out to be 3 hours and 57 minutes. The discharging ~~characteristics of the battery was~~characteristics of the battery were tested and discharge time of 4 hours and 50 minutes was obtained during the experimental period.

4. CONCLUSION

The result of the present investigation indicates that the solar powered cooling system was developed with a 12 V ~~dc~~ DC motor coupled with a pump has been selected to give a maximum discharge of 4.1 l m^{-1} at 4.1 kg cm^{-2} pressure. The capacity of the selected panels were 37 W each which was the power source for the cooling system. Further, the cooling system developed will be evaluated for significantly managing the heat stress in cows to create optimum environmental conditions.

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