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Experimental Study on Hybrid Power System Combining Solar Energy and Animal Energy for Minor Irrigation

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Abstract

In this paper a hybrid power system combining solar energy and animal energy is experimentally studied to supply continuous power to minor irrigation. The solar systems is used as main energy source while the animal system is used as secondary or back-up energy source. This invention provides animal powered mechanical device for prime mover to electric generator. Animal energy in form of high-torque low-speed can be converted into low-torque high-speed through speed increaser to energize the electric generator. A simple and cost effective charge control with dc–dc converters is used for maximum power point tracking and hence maximum power extracting from the both systems. The results show that even when the sun is not available; the system is reliable and available and it can supply high-quality power to the water pump by the animal powered system.

Keywords: Hybrid system, solar system, animal power, speed increaser, electric generation.

1. Introduction

In developing countries like India who depend on agriculture need continuing power supply for different processes like crop dryer, harvesting, paddy dryer, food storage, hot water for germination, suction of wet air, irrigation etc. It is very costly and very difficult to availability of grid power at the remote areas but it is necessary of continuing energy supply. To achieve this goal consists of using renewable energy sources, not only for large-scale energy production, but also for stand-alone systems [4]. Renewable energy technologies are known to be less competitive than traditional

electric energy conversion systems, mainly because of their intermittency and the relatively high maintenance cost. However, renewable energy sources have several advantages, such as the reduction in dependence on fossil fuel resources and the reduction in carbon emissions to the atmosphere. Furthermore, renewable energies avoid the safety problems derived from atomic power [5], which is why, from the social point of view; it has become more desirable to adopt renewable energy power plants [6]. Several authors have evaluated the main renewable energy technologies taking into account sustainability indicators, such as Evans et al. [7] who compared wind power, hydropower, photovoltaic and geothermal energy taking into account the price of generated electricity, greenhouse gas emissions during the full life cycle of the technology, availability of renewable sources, efficiency of energy conversion, land requirements, water consumption and social impacts.

Solar energy is the most abundant, inexhaustible and clean of all the renewable energy resources till date. The power from sun intercepted by the earth is about 1.8×1011 MW, which is many times larger than the present rate of all the energy consumption. Some of the key advantages are: direct use of heat resulting from the absorption of solar radiation, direct conversion of light to electricity through a simple solid-state device, absence of moving parts, ability to function unattended for long periods as evident from space program, modular nature in which desired currents, voltages and power levels can be achieved by simple integration, low maintenance cost, long effective life, high reliability, rapid responses in output to input radiation changes, high power handling capabilities from microwatt to kilowatt and even megawatt, high power to weight ratio, which is more important for space applications than terrestrial (may be favorable for some terrestrial application), amenable to onsite installation, decentralized/dispersed power; thus the problem of power distribution by wires could be eliminated by use of solar cells at the site where the power is required. They can be used with or without sun tracking, making possible a wide range of applications. The major factors that limit the use of solar energy for various applications is that, it is cyclic time dependent energy source. Therefore, solar system requires energy storage to provide energy in the absence of insolation.

Many experts believe that it is not possible for one single alternative renewable energy source to replace the conventional energy source (fossil fuels), but rather a combination of different types of clean energy source will be required instead. Such system is called hybrid system. A hybrid system combines PV with other forms of generation, usually a diesel generator. Biogas is also used. The other forms of generation may be a type able to modulate power output as a function of demand. However, more than one renewable form of energy may be used e.g. wind. The photovoltaic power generation serves to reduce the consumption of non-renewable fuel. Gabler et al. [8] have carried out the simulation study of a wind-solar hybrid electrical supply system. They have also studied the influence of system parameters such as size of different converters, and battery capacity on the renewable fractions and the energy payback time of the whole system. An optimization procedure of a hybrid photovoltaic wind energy system is presented by Habib et al. [9]. Elhadidy in Ref. [10]

has studied the feasibility of using hybrid (wind-solar-diesel) energy conversion systems at Dhahran to meet the energy needs of a group of 20 typical two-bedroom family houses. Author has also addressed the energy generated by the hybrid systems of different component (wind farm capacity, PV area, and storage capacity). The deficit energy to be generated from the back-up diesel generator (in addition to wind plus solar plus battery) and the number of operational hours of the diesel system to meet a specific annual electrical energy demand are also presented. Authors in Ref. [11] have reported the test results on a hybrid solar system, consisting of photovoltaic modules and thermal collectors (hybrid PV/T system).Ai et al. in Ref. [12] have presented a complete set of match calculation methods for optimum sizing of PV/wind hybrid system. In this method, practical mathematical models for characterizing PV module, wind generator, and battery are adopted.

In this paper authors experimentally studied the hybrid power system combining solar energy and animal energy for minor irrigation. In India maximum former depends on natural rain for irrigation. Natural rain water is collected in dams, small ponds and wells. Stored water is used when required by means of human efforts or using diesel water pump where grid power is not available and which are very costly and produces emissions also human cannot work continuously for long period and it is very time consumable. For small former who cannot effort the diesel water pump the solar water pump is best solution, but it has own limitations, so authors combine the solar energy and animal power to minor irrigation system. The force exerted by a working animal is approximately equal to 10-12% of its live weight, and this means for example, that a buffalo has a power output of about 300 W, or 5.4 MJ/day, if it is assumed that the animal works for 5 h per day [2-3]

The methodology of animal power system is very simple. The device called belan pulled by animals comprises of a mechanical link means provided with an extended pipe to transmit animal power in form of high-torque low-speed to a speed increaser; a speed increaser provided with an input shaft mounted with 68 teeth gear and an output shaft mounted with 15 teeth gear for converting animal power received from a mechanical link in the form of a high-torque low-speed to low-torque high-speed in four stages; a belt and pulley system which is connected to the output shaft of the speed increaser for transmitting mechanical energy in form of low -torque high- speed received from the speed increaser to generator; generator to convert mechanical energy into electrical energy; and a storage system. The prime mover is preferably at least one draught animal such as a bullock. More preferably, the prime mover comprises of a pair of bullocks.

2. Experimental Details of Solar System

(i)Solar Power: The solar power of size 1000 Watt which has four solar panels of 250 Watt in series was used in experiment which has been using by author for last two years. Solar panel is manufactured by Sova Power Ltd. It has efficiency of more than 85%.

Module	SS 250P
Rated peak power (Pmax)	250 W
Rated voltage (Vmp)	34.85 V
Rated current (Imp)	7.19 A
Open circuit voltage (Voc)	42.91V
Short circuit current (Isc)	7.85 A

(ii) Battery system: Inverter Tubular Battery of 12V 180 AH is used. The maximum charging current should not exceed 25 Amps. The system cut off voltage shall be at 14.4V and discharge cut off voltage10.8V.

Type: 6SB-180XLTT

12V 180AH @ 10HR. RATE

1.250 SP. GR. @ 27˚C

(iii)Inverter: MRO-TEK's DSP based Sine wave Solar PCU with state of the art technology is used. The key functionalities are when the solar power is available, battery will be charged by solar panel and the load will be powered by solar power. If the load requirement is more than the available solar power then the battery will supply the additional load. Also this inverter work on MPPT (maximum power point tracking) battery charge control system.

Inverter Model	NS 1024S+	MPPT Model	NS 1024S+
Output voltage (VAC)	230±10%	Battery charging current	40 A
Output power (VA/Watt)	1000/1000	Max solar input power	1000 Watt
Output frequency (Hz)	49-51	Peak charge efficiency	95%
Output current (Amps)	15A	Max solar open circuit volt	85
Efficiency (%)	85%		
Battery voltage (V)	24		

(iv)Minor irrigation system: The 0.5 hp/0.37 kwatt centrifugal water pump of RC Energy metering (P) Ltd is used in experiment. The specification of water pump is shown in table:

Drive	0.5HP/0.37KWatt
Voltage (V)	220 ±5%
Frequency (Hz)	50
Suction head (meter)	8 MTRS
Discharge head (meter)	27 MTRS
Discharge (L/min)	33 LPM

3. Experimental Details of Animal Power System

(i) Draught animal: The authors' main object is to use the animal power for generating electricity for domestic and agriculture use. And bullocks are mainly used in Indian agriculture for different purposes. For this experimental study authors use the pair of bullocks. The weights of bullocks are 456 kg and 478 kg. The mechanical link is fitted with a device pulled by pair of bullocks called bellan which is made of wood and has the weight of 105 kg.

(ii) Mechanical link: mechanical link of mild steel material having 52 mm diameter and 230 mm length with extended extra strong GI pipe of 3000 mm length and 4.5 mm wall thickness, capable of transmitting animal power in form of high torque low speed is attached to speed increaser. Mechanical link starts moving in a circular path of 5 meter diameter when bullock drived belan attached to mechanical link with the help of GI wire starts moving. A pair of bullock's moves in a circular path of 5meter diameter With approximate speed of 60 m/min.

(iii) Speed increaser: Speed increaser is a four set of spur gears housed in a frame of mild steel angles having 690 mm × 690 mm at the top and 780 mm × 780 mm at bottom. It is having 4 numbers of stages with gear ratio of 1:4.5. Input shaft of the speed increaser having 50 mm diameter and 600 mm length of mild steel material is in vertical position whereas output shaft having 50 mm diameter and 450 mm length of mild steel material of the same is also in vertical position. The shafts are supported with taper roller bearings at top and bottom. Bearings are fastened on tie-bars which are welded on frame. Speed increaser is specially used for transmitting and converting low-speed high torque to high-speed low–torque.

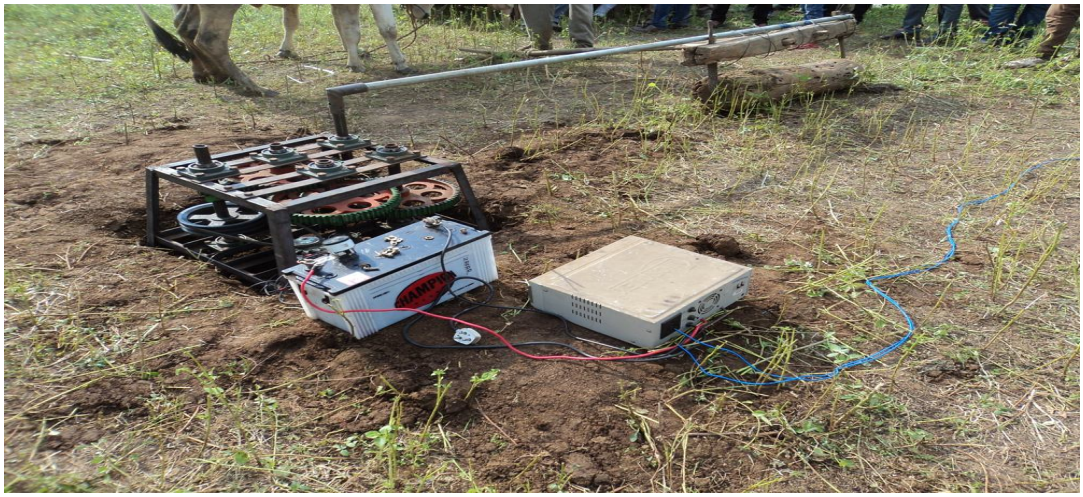


Fig. 1: Integreted Belan, Mechanical link, Speed Icreaser, belt&pulley, alternator and battery.

(iv) Gears: Four sets of spur gears transmits the power among parallel shafts. The spur gears are made of cast iron having module 5 mm. the spur gears has 68 teeth while the spur pinions has 15 teeth. The pressure angle is 20 degree and outside diameters are 350mm and 85mm respectively. The speed ratio of 1:4.5 is obtained in single stage.

Table 2: Material properties spur geare made of cast iron.

Ultimate Tensile Strength(Mpa)	Young's Modulus (N/mm2)	Density (kg/mm3)	Poisson's Ratio	Co-efficient of friction
320-350	1.67e5	7.2e-6	0.25	1.1

Table 3: Shows the geometric detailed and strength calculation for cast iron spur gear.

Geometric details of desired spur gear [1]	Strength calculation for spur gear [1]
• Module (m) = 5 mm, Addendum = 1 module, Dedendum = 1.157*module Pressure angle (α) = 20 degrees Tooth thickness (t) =1.571 * module = 1.571*5 = 7.855mm Whole depth = 2.25 * module • Face width (b) = 5.4 * module = b = 5.4*5 = 27mm. • Fillet radius = 3.9 * module • No of teeth (z) = 68 and 15 Pitch circle diameter (pcd) = z*m = 68*5 = 340mm and 15*5 = 75mm Outside diameter = (z+2)*m = 350mm and 85mm	Using Lewis equation [1] Tangential load F = σb*y*Pc*b Where 'σb' is the allowable stress, 'y' is the Lewis form factor y=0.1034, 'Pc' (Circular pitch) = π * module, 'b' is the face width of the gears, 'd'is the pitch circle diameter of the gear. F = 2*500 = 1000N putting in Lewis equation 1000 = σb*0.1034*(π*5)*27 σb = 22.81N/mm2 σall of Cast iron (high grade) = σut/3 = 320/3 = 106.67 N/mm2 > 22.8 N/mm2

According to [2-3] an animal (bullock) can applied the tangential force of 500N (F=2*500=1000N).

(v) Belt and Pulley transmission unit: The final speed increasing is done by using belt and pulley system. One pulley of 228.6mm (9 inch) was mounted on the output shaft of the speed riser and counter pulley was mounted on car alternator having 76.2mm(3 inch) thereby stepping up the speed in the ratio 1: 3 when connected with toothed belt. According to Indian Standard Code (IS: 2494-1974), the A type of belt is selected which has power ranges 0.7kW – 3.5 Kw.

(vi) Generator: In this experimental study authors select the car alternator to generate electricity. Lucas-TVS car alternator of 12V and 95 Amp is used. Car

alternator needs high rpm to work efficiently. It produces constant voltage but current depends on rpm and produce high as rpm is high. The direction in which the alternator is oriented to spin does not affect its output power. The alternators rotor can be rotated either clockwise or counter clockwise and achieve the same output values. Once the pulley belt is connected between the output gear shaft and alternator head the alternator must be wired to output DC power.

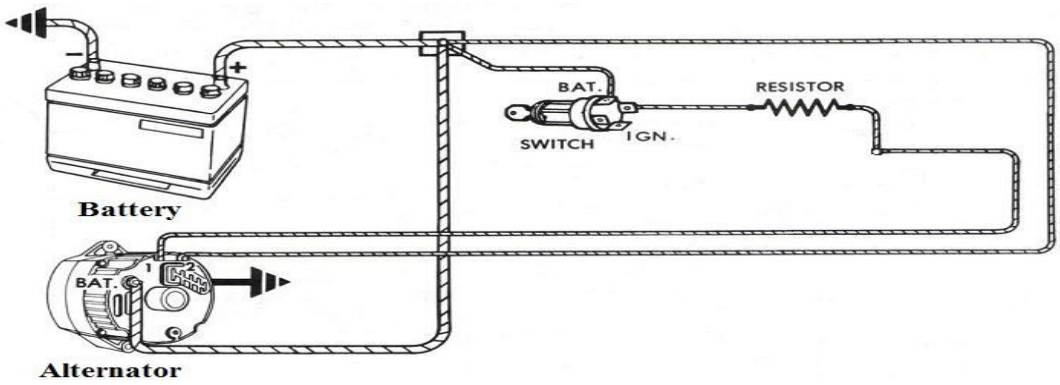


Fig. 2: Standard alternator and battery charging circuit.

(vii) Storage system: A typical 12 V, 150 Ah Lead-acid automotive battery is selected. An automotive battery is a type of rechargeable battery that supplies electric energy to an automobile. It shows 12.6 volt at full charge and at fully discharged: 11.8V. Charging time depends on the capacity of that battery and the resting voltage of that battery when you begin to charge it. If battery is 50% or more full, it takes less time to charge.

4. Fabriction and Procedure

The fabrication of speed increaser was done very carefully because there are five vertical shafts which are supported by taper roller bearing. The bearing covers were fitted with the help of nut and bolt on the mild steel ties, which are welded on the frame at top and bottom. Collars are provided at bottoms of shaft to support the load on bearings. Gears are fitted by means of nuts by driling two holes on the shafts and on gear houges. There are four step gear transmission system. The first gear of 68 teeth was mounted on first shaft at 20mm from the color which meshes with the second gear having 15 teeth mounted on second shaft at 20mm above from the collar. The third having 68 teeth was mounted on second shaft 50mm above the second gear and meshes with the fourth gear having 15 teeth which was mounted on third shaft at the same height. The fifth gear having 68 teeth was monthed on third shaft 50mm above the fourth gear and meshes with the sixth gear having 15 teeth which was mounted on the fourth shaft at the same height. The seventh gear having 68 teeth was mounted on

fourth shaft 50mm above the sixth gear and meshes with the eighth gear having 15 teeth which was mounted on fifth shaft at same height. The pulley of 228.6mm was mounted on fifth shaft at 200mm from the bottom which drive the another pulley of 76.2mm mounted on alternator and alternator was fabricated on the frame with the help of mechanical linkage.

Authors select the car alternator for generating electricity which has the ideal speed of 2000rpm – 6000rpm but effetely work at 3500 rpm. And animal has very low speed (v = 1m/s). If bullock rotates at radial distance (r) of 2.5 m from the main shaft (first gear) then the distance at one revolution is 15.7 m ($2\times \pi \times 2.5$). And the distance cover in one minute by bullock is $1 \times 60 = 60$ m. Hence the initial rpm is 3.82(60/15.7). Due to compactibility and resources available author select the gears used in sugarcane juice machine of speed ratio 4.5. Four stage gear system is used. Output rpm is increased by using pulley and belt which has speed ratio 3. So that the output rpm of alternator if speed of animal is 1m/s.

$$(N_f)_{alt} = 3.82*4.5*4.5*4.5*4.5*4.5*3 \approx 4700 \text{ rpm.}$$

And the speed of output gear according to S S Ratan[13].

$$\frac{N_8}{N_1} = \frac{Z_1}{Z_2} \times \frac{Z_3}{Z_4} \times \frac{Z_5}{Z_6} \times \frac{Z_7}{Z_8} \qquad (1).$$

$$(N_f)_g = 3.82*4.5*4.5*4.5*4.5*4.5 \approx 1567 \text{ rpm.}$$

Before staring the experiment the alternator was connected with battery and ampere meter was jointed in series. The mechanical link GI pipe was fitted with the first shaft of speed increaser by means of elbo and nut-bolt at one end and another end was coupled on belan with the help of GI wire such that the center of belan coincide at 2500mm of mechanical link. The speed increaser was fixed in the pit of 780mm×780mm×300mm. The bullock pair was harnessed with traditional means. The shephered applied the force the bullocks started moving into the circular path and also the belan along with mechanical link rotate the first shaft of the speed increaser. At the starting the rpm was very low hence the alternator was not responding but as well as speed was increasing the alternator start to generating power. Bullocks were need to applied force time to time to maintain average speed. The rpm and generated volt & current were taken after every four minutes.The battery was 50% charged and it took approximate 2 hours to charge fully(multimeter indicate 12.6V). In first two experiments the automotive battery of 12V 150AH was charged with animal power system and the 0.5 hp water pump run using inverter individually. The suction head was 4.7 meter and it took 27 second to deliver 15 litter water. Next two experiment the tubular battery was charged with animal power system and water pump run using same inverter. This time it took 24 second to deliver 15 litter water. Same time the solar system charged the tubular battery using MPPT technology (also dc-dc convertor) and two times water pump run with this tubular battery. Time taken to charge the the

battery is depend on the temperature of atmosphere. The water pump also run during battery charging by means of animal power system and solar power system individually. Finally both charged batteries were connected to the MRO-TEK's DSP based sine wave solar inverter in parallely and 0.5 hp water pump run very efficiently and deliver water continuously for long time and up to 60% discharge. Authors also done combine experiment during charging batteries with animal power and solar power of 250W and found good result.

Fig. 3: Bullocks powered mechanical device for generating electric power.

Fig. 4: Parallel combination of animal power and solar power of 250W.

5. Results and Discussion

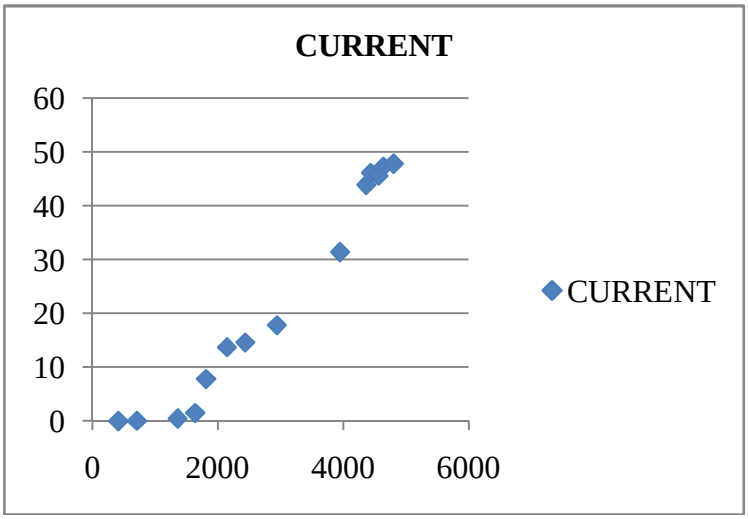
The animals' effort and speed depend on the load subjected and force applied by shepherd. Animal speed is change very quickly and abruptly. It is very difficult to taking speed reading continuously because animals get puzzled. The readings are taken after every four minutes within one hour. Speed vs. Current shows that at low rpm at starting of animal motion it is not generating current by both alternator, but as well as rpm is increasing and reaches to ideal working rang alternators producing high value of currents. Experimental result shows that animals take very little time to get their average speed of 0.8 m/s to 1 m/s. Alternator generates constant voltage of 12V as specified after reaching ideal speed. Fully charged battery shows 12.6V.

The time taken by solar system to charge the battery is depend on atmosphere temperature. Since MPPT technology is used to charge controlle battery get the constant valtage. Normaly 12V 180Amps tubular battery is charged in 7–10 hours because temperatue is vary from morning to evening. But when tubular battery was charged using animal powered alternator of TVS-Lucas 12V 40AH which generate 21 Amps(average) it took 4 hr 35 minute to fully charge. Tubular battery can not be charged using alternator of 12V 95Amps because of high charging current but 12V 150Amps automotive battery took 2 hours to charge.

When 0.5 hp water pump run with automotive battery through inverter it delivers 15 litters in 27 second and worked for 2 hours and 3 minute. So that it delivered 4000 litter of water upto 60% discharge. Same time tubular battery delivers 15 litters in 24 second and worked for 2 hour and 11 minute. So that it delivered 5000 litter of water upto 60% discharge. Finally both charged batteries were connected to the MRO-TEK's DSP based sine wave inverter in parallely and 0.5 hp water pump run very efficiently and delivered water continuously for long time up to 75% discharge. Combine system takes 21 second (average) to deliver 15 litter and worked for 5 hours and 45 minute and delivered 14000 litters of water. Hence solar power and animal power are good combination for minor irrigation system.

Fig. 5: Parallel combination of tubular batteries of 12V 180 AH to the inverter.

Fig. 6: The 0.5 hp water pump powered by hybrid system to deliver water from the small well.



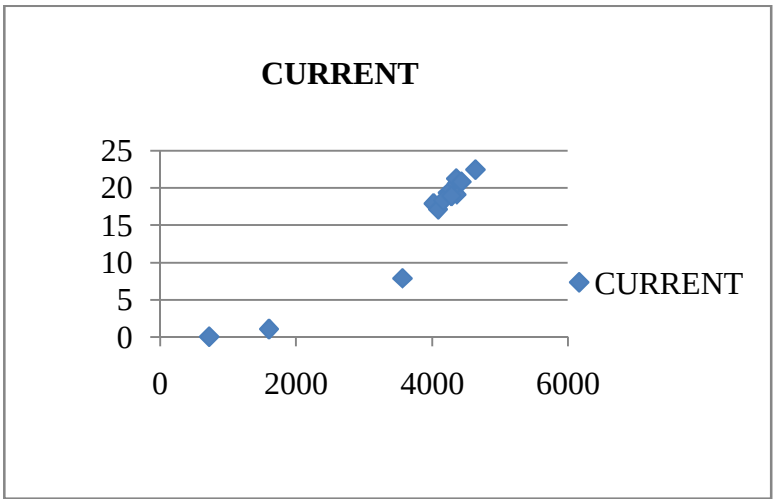


Fig. 7: Alternator (12V 95AH)rpm vs. Current and Alternator(12V 40AH)rpm vs. Current(Amps).

6. Conclusion

The present work provides a system and method for producing electricity for minor irrigation system using the biological energy of the muscles of animals like bullock by means of a mechanical device. The project goal was to combining the solar power and animal power to minor irriation which will work when even sun is not available. This goal had to be met within the constraints of a low production cost and high safety. The project has to offer a durable product with relatively good efficiency and emission free system.This is also concluded that animals are the great energy source for generating power for formers for minor irrigation even having low speed.

7. Acknowledgment

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