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# Experimental Study on Hybrid Power Combining Solar Energy and Animal Energy for Home Cooking System

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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 for cooking food four four person. The solar power is used as main energy source while the animal power 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 the form of high-torque low-speed is 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 so that maximum power extracting from the solar system. 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 cooking system.

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

## 1. Introduction

Over 17% of deforestation is because of cutting wood for cooking food at rural and remort areas. Wood is still used today for cooking in many places, either in a stove or an open fire. As with any fire, burning wood fuel creates numerous by-products, some of which may be useful (heat and steam), and others that are undesirable, irritating or dangerous. Smoke, containing water vapor, carbon dioxide and other chemicals and aerosol particulates, including caustic alkali fly ash, which can be an irritating (and potentially dangerous) by-product of partially burnt wood fuel. The another source using to cooking is a kerosene stove and gas flame which are very costly and harmful

for health and also not available always. Similarlly villagers are using electric heater or induction cooker which need continuou electric power. It is very difficult and very costly to available grid power everywhere specially at remote isolated communities in developing countries 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.

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 $1.8\times10^{11}$ MW, which is many times larger than the present rate of all the energy consumption. Solar photovoltaic generation system offers many advantages such as incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise, among others. The building block of PV arrays is the solar cell, which is basically a p–n semiconductor junction. The current–voltage (I-V) characteristic of a solar photovoltaic is given by Eq. (1) [1–4]. The output characteristics of a solar PV are non-linear and are crucially influenced by the solar radiation, temperature and load condition therefore it must be ensured that it operates at all time to provide maximum power output. In this paper the voltage-based MPPT (dc–dc converter) technique have been used to track the maximum power point of the PV array used.

$$\mathbf{I_{PV} = n_p I_{SC} - n_p I_O\{exp[\frac{q(V_{PV}+R_S I_{PV})}{AkTn_S}] - 1\} - n_p \frac{(V_{PV}+R_S I_{PV})}{n_s R_{sh}}} \quad (1)$$

where $V_{PV}$ and $I_{PV}$ represent the output voltage and current of the solar cell, respectively; $R_s$ and $R_{sh}$ are the series and shunt resistance of the cell; q is the electron charge ($1.6e^{-19}$ C); $I_{SC}$ is the light-generated current; $I_O$ is the reverse saturation current; A is a dimensionless junction material factor; k is the Boltzmann constant ($1.38e^{-23}$ J/K); T is the temperature (K); $n_p$ and $n_s$ are the number of cells connected in parallel and in series, respectively.

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 are used. In this paper authors introducing the animal power and human power as other forms of hybrid energy 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/d, if it is assumed that the animal works for 5 h per day [5-8].

The methodology of animal power system is very simple. The device called belan pulled by animal 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. More preferably, the prime mover comprises of a pair of two animal.

## 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%.

(ii) **Battery system**: Inverter Tubular Battery of 12V 180 AH is used. The maximum charging current should not exceed 40 Amps. The system cut off voltage shall be at 14.4V and discharge cut off voltage10.8V.

(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.

## 3. Experimental Details of Animal Power System

a. **Animal power:** 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.

b. **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 1500 mm length of mild steel material is in vertical position whereas output shaft having 50 mm diameter and 1000 mm length of mild steel material of the same is also in vertical position. The vertical shafts are supported with taper roller bearings at top and bottom.

c. **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 belt. According to Indian Standard Code (IS: 2494-1974), 'A' type of belt is selected which has power ranges 0.7Kw – 3.5 Kw.

d. **Generator:** In this experimental study authors select the car alternator to generate electricity. Lucas-TVS car alternator of 12V 95 AH was used. Car alternator needs high rpm to work efficiently.
e. **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.
f. **Gears:** Four sets of spur gears transmits the power among parallel shafts. The spur gears are made of cast iron ($S_{ut}$ = 320 N/mm$^2$) 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 350 mm and 85 mm respectively. The speed ratio of 1:4.5 is obtained in single stage.

## 4. Fabrication 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 hubs. There are four step gear transmission system. The first gear of 68 teeth was mounted on first shaft at 20mm from the collar 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 (9 inch) was mounted on fifth shaft at 200mm from the bottom which drive the another pulley of 76.2mm(3 inch) 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 animal moves at radial distance (r) of 2.5 m from the main shaft (first gear) then the distance covered at one revolution is 15.7 m (2× π × 2.5). And the distance cover in one minute by animal is 1×60=60m. 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 1: 3. So the speed of output gear according to S S Ratan [9]

$$\frac{N_8}{N_1} = \frac{Z_1}{Z_2} \times \frac{Z_3}{Z_4} \times \frac{Z_5}{Z_6} \times \frac{Z_7}{Z_8} \quad (2)$$

$(N_f)_g$ = 3.82*4.5*4.5*4.5*4.5*4.5 ≈ 1567 rpm.

**Fig. 1**: Animal powered mechanical device.

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 elbow 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 animal 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. The rpm and generated volt & current were taken after every four minutes.The batteries were 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 connected in series to the 1500VA inverter and 1000W induction cooker subjecjected to inverter. Next two experiment the tubular battery of 12V 180AH was charged with animal power system and connected in series to the inverter. Same time the solar system charged the tubular battery using MPPT technology (also dc-dc convertor) and two times 1000W load the connected with this tubular batteries through inverter. Time taken to charge the the battery is depend on the temperature of atmosphere. Finally charged tubular batteries by solar power and animal power were connected in series individually after then connected parallel to the and delivered power to 800W induction cooker continuously up to 75% discharge. The seven experiments done during the battery charging with animal power and solar power. The induction cooker is connected to the batteries through inverter when batteries are charged 75%.

**Fig. 2**: Hybrid power system(solar power and animal power).

## 5. Results and Discussion

The animals' effort and speed depend on the load subjected. Animals speed change very quickly and abruptly. The readings were taken after every four minutes within one hour. Speed vs. Current shows that at low rpm at starting it is not generating current by alternator, but as well as rpm is increasing and reaches to ideal working rang alternators producing high value of currents. Alternator generates constant voltage of 12V as specified. When 800W load subjected with automotive battery through inverter it delivers power very efficiently and worked for 2 hours 15 minutes discharge up to 75%.

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 two 12V 180AH tubular battery are charged in 7–10 hours because temperatue is vary from morning to evening. When 800W load subjected to battery through inverter it delivers power very efficiently and worked for 3 hour 45 minutes upto 75% discharge.

Finally charged tubular batteries by solar power and animal power were connected in series individually after then connected parallel to the inverter and delivered power to 800W load for 6 hrs (average). Experiment also done during charging batteries by animal power and solar power and results found that when induction cooker working at 800W it took 25 minutes (ave) to rice and 35 minutes (ave) to cook vegetable four people. Hence solar power and human power are good combination for home cooking system.

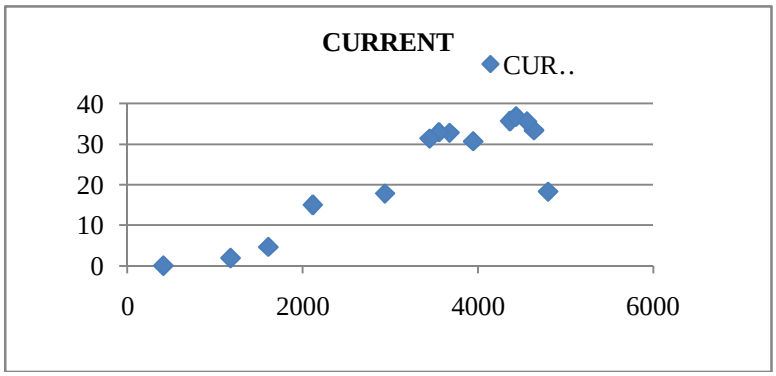


**Fig. 3**: Alternator RPM vs. Current in Amp.(DC).

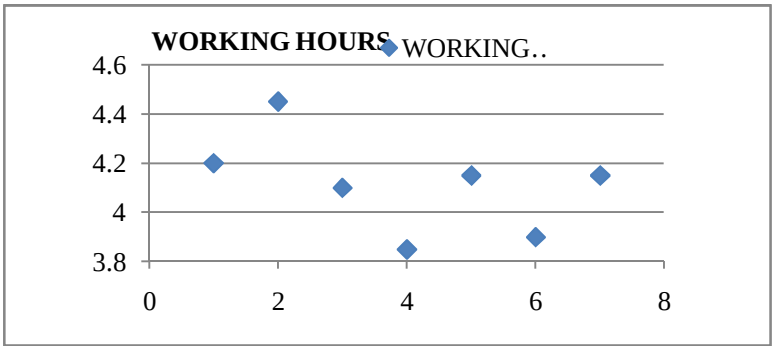


**Fig. 4**: Working hours when 800W induction cooker subjected to system.

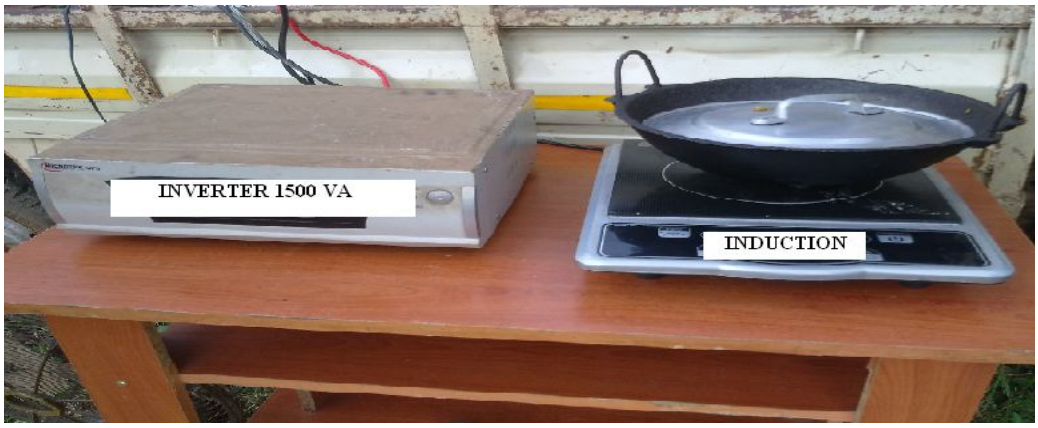


**Fig. 5**: Induction cooker of 1000W subjected to hybrid power system.

## 6. Conclusion

The present work provides a system and method for producing electricity for home cooking using the animal power by means of a mechanical device with car alternator. The project goal was to combining the solar power and animal power for home cooking which will work for minimum time 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 even having low speed.

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