International Review of Applied Engineering Research.
ISSN 2248-9967 Volume 4, Number 4 (2014), pp. 355-362

http://www.ripublication.com/iraer.htm

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

S.K. Chandrakar, Sohel Gardia, Nilesh Kumar, Neeraj Ku Diwan, Sushant Ku Gain and Rishab Tiwari

Mechanical Engineering, Shri Shankaracharya Group of Institutions, Bhilai.

Abstract

In this paper a hybrid power system combining solar energy and human energy is experimentally studied to supply continuous power to 0.5 hp water pump-set for irrigation. The solar systems is used as main energy source while the human system is used as secondary or back-up energy source. This invention provides human powered mechanical device for prime mover to electric generator. Human 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 converter 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 irrigation system.

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

1. Introduction

In developing countries like India who depends 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.

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 1.8×10^{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) [1–3]. 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 human power as other forms of hybrid energy system. Peak power output for a fit and healthy adult is about 900W but this can only be sustained for a few seconds. Putting this power output in some context, activities such as hoeing and tree felling require 300-500 W and 600W of gross power respectively [4-5].

The methodology of human power system is very simple. The device called belan pulled by human comprises of a mechanical link means provided with an extended pipe to transmit human 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 human 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 human.

2. Experimental Details of Hybrid 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.

(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.

(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.

(iv)Human power: The group of two person of 56 kg and 61 kg of age 22 year were worked as a energy source. The human pulled the wooden device called belan (dhouri) of 105 kg.

(v)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.

(vi)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.

(vii)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.

(viii) 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.

(ix)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.

3. 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 drilling 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 human has very low speed (v = 1m/s). If human 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 human is 1 × 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 1: 3. So the speed of output gear according to S S Ratan [6]

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

(Nf)g = 3.82*4.5*4.5*4.5*4.5 ≈ 1567 rpm.

Fig. 1: Human and solar powered hybrid system.

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 human 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. The solar system was mounted near the human system which charged the tubular battery of 12V 180 AH. The charged batteries were connected to the MRO-TEK's DSP based sine wave inverter in parallel and 0.5 hp water pump run very efficiently and delivered water continuously for long time up to 75% discharge. Combine system (solar power and human power) took 24 second (average) to deliver 15 litter and worked for 5 hours and 15 minute and delivered 11500 litters of water. After than experiments did during the charging of battery with human power and result found that 0.5 hp pump run very efficiently when battery was charged 75%.

4. Results and Discussion

The humans' effort and speed depend on the load subjected. Human speed is change very quickly and abruptly. The readings were taken after every four minutes within one hour. The time taken by solar system to charge the battery is depend on atmosphere temperature. Since MPPT technology is used to charge control, battery get the constant valtage. Normaly two 12V 180AH tubular battery were charged in 7–10 hours because temperatue is vary from morning to evening.

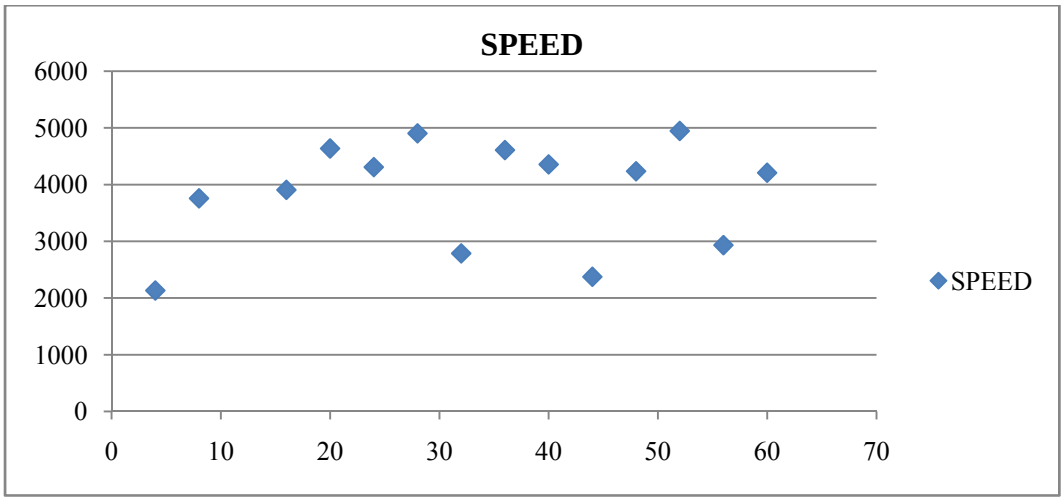

Fig. 2: TIME (in minutes) vs. RPM of alternator.

Speed vs. Time graph shows that average speed of alternator mostly changes, but it is within the ideal working range of alternator. In experiments the automotive battery of 12V 150AH was charged by means of human power system. After 75 % state of charge the 0.5 hp water pump was connected to the battery through 1500VA inverter.

Speed vs. Current shows that at low rpm at starting, it is not generating current, but as well as rpm is increasing and reached alternator producing high value of current. Experimental result shows that it took very little time to get their average speed of 1 m/s. But still alternator is not generating current as expected and specified by company due to very quick and abrupt change in human speed. In experiments alternator generates constant voltage of 12V and average current of 37 AH.

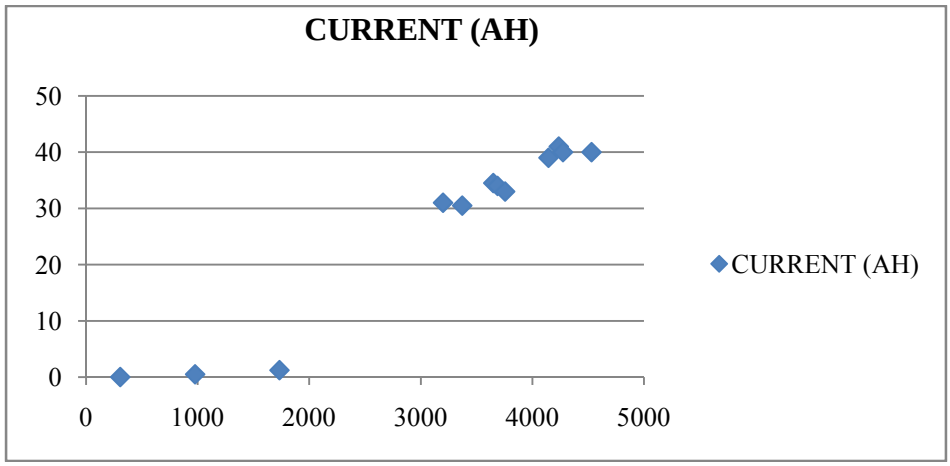

Fig. 3: Current in AH Vs RPM of Alternator.

In traditional manner person pull out the water with help of bucket from the well for minor irrigation which is very hard and time consuming. In this method human effort was reduced as well as irrigation capacity increased. A simple and cost effective charge control with dc–dc converter is used for maximum power point tracking so that maximum power extracting from the solar system. In first four experiments the automotive battery of 12V 150AH was charged with human power system and the 0.5 hp water pump run through inverter. The suction head was 4.7 meter and it took 27 second to deliver 15 litter water and worked for 2 hours and 25 minutes. So that it delivered 4600 litter of water upto 75% discharge. Same time tubular battery delivers 15 litters in 25 second and worked for 2 hour and 50 minutes. So that it delivered 6300 litter of water upto 75% discharge. Hybrid system took 24 second (average) to deliver 15 litter and worked for 5 hours and 15 minute and delivered 11500 litters of water. After than experiments did during the charging of battery with human power and solar power and result found that 0.5 hp pump run very efficiently. Water pump connected to the batteries through inverter when battery was charged 75%. This system works when sun is not available as well as when human power is not available or when people get fatigue.

Fig. 4: The hybrid powered water pump to deliver water from the well.

5. Conclusions

The present work provides a system and method for producing electricity for minor irrigation using the human power by means of a mechanical device. The project goal was to combining the solar power and human power for monor irrigation 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 human is the great energy source for generating power even having low speed.

6. Acknowledgment

Authors would like to thank to the researchers/academicians whose works have been cited directly or indirectly in this paper specialy Mr R J Fuller and Mr Lu Aye and mechanics who helped in this project. Authors also wish to thank to Shri I P Mishra (President SSGI Bhilai), Dr P B Deshmukh (Director SSGI Bhilai), Prof. J K Tiwari (HOD Mechanical SSGI Bhilai).

References

[1] Piegari L, Rizzo. Adaptive perturb and observe algorithm for photovoltaic maximum power point tracking. IET Renewable Power Generation 2010; 4:317 - 28.

[2] Nguyen DD, Lehman B. “Modeling and simulation of solar PV arrays under changing illumination conditions.” In: Proc. IEEE compel workshop. Trou, NY, USA: Rensselaer Polytechnic Institute; July 16e19, 2006. p. 295 - 9.

[3] Salameh Z, Dagher F, Lynch WA. “Step - down maximum power point tracker for photovoltaic system.” Solar Energy 1991; 46: 278 - 82.

[4] Fuller R. J., Aye LU,2012, "Human and animal power – The forgotten renewables" Renewable Energy 48 (2012) 326-332.
[5] Tiwari PS, Gite LP, Pandey MM, Shrivastava AK. Pedal power for occupational activities: effect of power output and pedaling rate on physiological responses. International Journal of industrial Ergonimics. 2011;41(3):261 – 7.
[6] Ratan S S., "Theory of Machines," Tata McGraw-Hill.