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Experimental Study on Animal Powered Mechanical Device for Home Lighting System

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Abstract

In this paper authors experimentally studied the animal powered electric generation system for home lighting. Although animals have been using for domestic works at rural and remote areas, but the electricity generation by Animal power is a novel technology. This invention provides animal powered mechanical device for home lighting system. It has unique features of using animal power as prime mover for 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. The electricity generated is stored in the battery and used when lighting is required either for DC light or AC light using inverter. This equipment is emission free, low cost and has long life. Also this equipment needs less maintenance and any person can run either skilled or unskilled.

Keywords: Animal power, speed increaser, electric generation.

1. Introduction

Over 1.5 billion people rely on kerosene for light. Lack of suitable home lighting is directly linked to illiteracy, poverty and health problems. The current widespread burning of kerosene also results in environmental pollution. It is very difficult and very costly to available grid power everywhere specially at remote isolated communities in developing countries. There are many renewable power sources like solar power, wind power, hydropower, bio-energy, geo-thermal power, tidal energy etc, but all have their limitations. Although from beginning of mankind animals have been using for

domestic works at rural and remote areas, but the electricity generation by Animal power is a novel technology[4-6].

According to FAO [7], animal power is still “persistent and widespread in Asia and Latin America” and its use in even “expanding in Africa”. In terms of numbers of working animals, estimates vary. Wilson [8] estimates there to be at least 300 million drought animals, although acknowledges that other estimates are much higher. FAOSTAT [9] indicates that there are 110 million equines alone. In terms of net efficiency, animals are comparable with the tractor with efficiencies above 30%, but walking and maintenance reduces their efficiency significantly to approximately 10% [10]. The input-output model of animal illustrates the multiple function of a working animal [11]. While this presentation indicates the generic inputs, outputs and waste products of an animal viewed as an energy conversion device, the reality is much more complex. To ‘operate’ an animal may require human inputs for task such as herding, cleaning stalls or pens, milking, harnessing and guiding.

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[2-3]. Table shows the weights, speed and output powers of different animals. However, many factors can reduce this output significantly. These include stress, malnutrition, a poor fitting harness, difficult ground etc. The impact of poor nutrition is significant because thin, underfed or sick animals will not be able o work efficiently. Output can decline as much as 50% in oxen and buffalo, according to Pearson [10].

Table 1: Sustainable power of individual animals in good condition [2-3].

Animal	Typical weight kN (kgf)	Pull-weight ratio	Typical pull N (kgf)	Typical working speed m/s	Power output W	Working hours per day	Energy output per day MJ
Ox(Bullock)	4.5(450)	0.11	500(50)	0.9	450	6	10
Buffalo	5.5 (50)	0.12	650 (65)	0.8	520	5	9.5
Horse	4.0 (400)	0.13	500 (50)	1.0	500	10	18
Donkey	1.5 (150)	0.13	200 (20)	1.0	200	4	3
Mule	3.0 (300)	0.13	400 (40)	1.0	400	6	8.5
Camel	5.0 (500)	0.13	650 (65)	1.0	650	6	14

In many countries in Asia and Africa, and in Madagascar, the crop is threshed by being trodden underfoot (by humans or animals) in India (Chhattisgarh) it calls “Dhouri” The same method, but using a vehicle (tractor or lorry) is also commonly applied. The vehicle is driven in circles over the paddy bunches as these are thrown on to the threshing area (5m to 10m in diameter around the stack) in India (Chhattisgarh) it calls “Bellan”. In this study authors select use the animal pulled bellan.

The device called belan 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.

This paper explores the proposition that there are opportunities to reduce the drudgery, improve incomes and health, and raise skill levels by introducing new power technology in many remote isolated communities in developing countries. At the same time, the paper makes the case that animal power is seen as renewable sources of energy and this technology are equally recognized as part of the 'renewable' family. The authors recognise that it is a dangerous to use animal energy for non-domestic technology and making request that this technology must be use only for domestic and agriculture use.

2. Experimental Details

(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 (Dhauri) 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 5 meter diameter With approximate speed of 60 meter/min. Input shaft of the speed increaser coupled to mechanical link rotates at 3.8 rpm when a pair of bullocks completes one round of 5 meter dia. circular path in one minute.

(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 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. Bearings are fastened on tie-bars which are welded on frame. Speed increaser is specially designed for transmitting and converting low-speed high torque to high- speed low –torque.

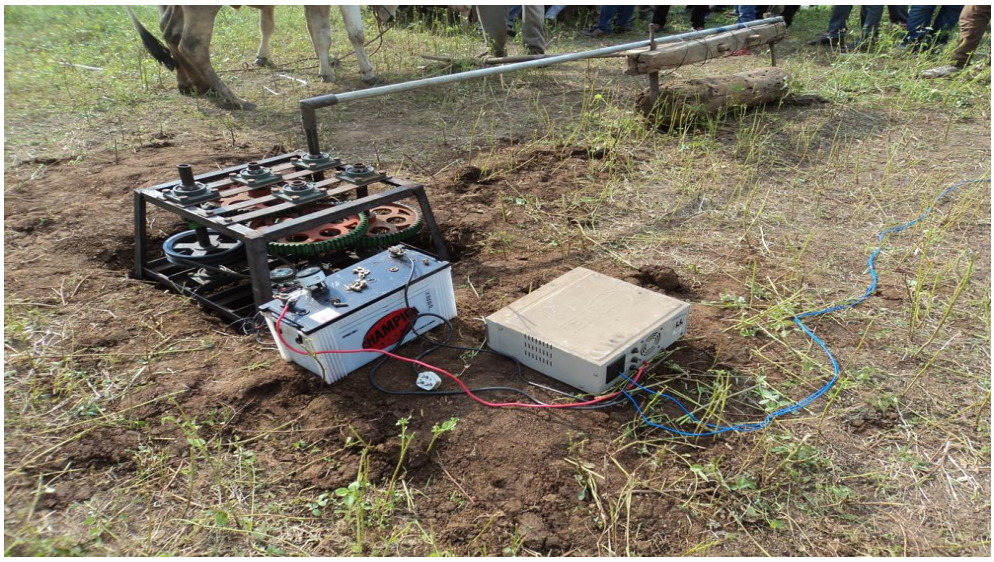

Fig. 1: Integreted Belan, Mechanical link, Speed Icreaser, belt & pulley, alternator and battery.

(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[1].

Ultimate Tensile Strength(Mpa)	**Young's Modulus (N/mm^2)**	**Density (kg/mm^3)**	**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/mm^2 σ_{all} of Cast iron (high grade) = σ_{ut}/3 = 320/3 = 106.67 N/mm^2 > 22.8 N/mm^2

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. The alternator and battery circuit is shown in figure.

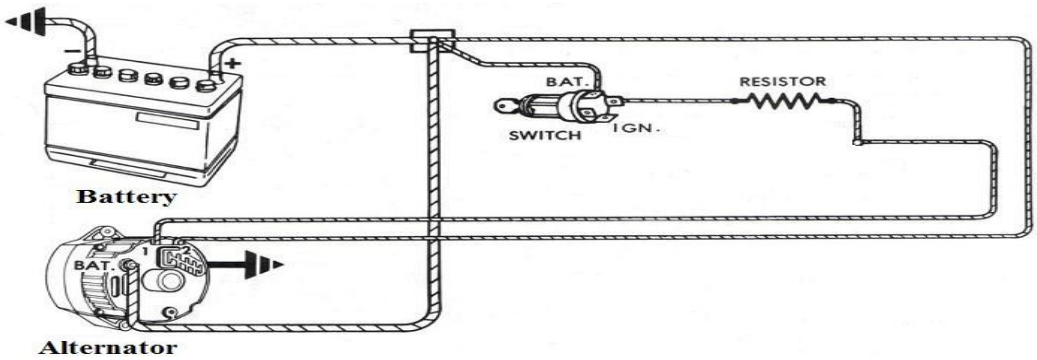

Fig. 2: Standard alternator and battery charging circuit[12].

(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.

(viii) Home lighting system: This inventions main object is to produce power for home lighting at rural and isolated remote areas where population rely on kerosene for lighting. This system consist the six CFL bulbs of 25 watt (25*6=150 watt) for AC use and six DC bulbs of 60 watt (6*60 = 360 watt). The Microtek inverter of 750VA, 230 Volt at 50 Hz is used for converting DC to AC power.

3. 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 (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 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 SS Ratan [13]

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

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

The system was tested by means of human power for three times and it was recognized that the initial force (torque) to rotate alternator at idle speed was very low, it can easily operated by using single hand. 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 into the pit of 780mm×780mm×300mm. The bullock pair was harnessed with traditional means. When shephered applied 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. First time the battery was 50% discharge i.e. 12V 75AH(approx as indicated by hydrometer) and it took approximate 4 hours to charge fully(hydrometer indicate 12.6V). Second time battery was 45% discharge and it took four hour and some minutes. The experiment done at 60%, 65%, 70%, 75%, 80% and 85% state of charge and time taken to charge fully had taken. Parallely the time required to discharge the battery at different percentage when 150 watt AC load was subjected to battery through inverter had taken.The experiment had done 9 times using same bullocks and animal had taken care regularly. At single time 360Watt DC load was subjected to fully charge battery and time taken to discharge it 50% was two hours and 7 minutes.

Fig. 3: Animal powered mechanical device for home lighting system.

4. 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 got puzzled. The readings are taken after every four minutes within one hour and results are shown in graphs. Speed vs. Time graph shows that average speed of alternator is mostly changes, but it is within the ideal working range of alternator. Speed vs. Current shows that at low rpm at starting of animal motion it is not generating current, but as well as rpm is increasing and reaches to ideal working rang alternator producing high value of current. Experimental result shows that animals take very little time to get their average speed of 0.8 m/s to 1 m/s. But still alternator is not generating current as expected and specified by company due to very quick and abrupt changes in animal speed. Voltage vs. RPM proves to be completely unchanging as expected and alternator generates constant voltage of 12V as specified after reaching ideal speed. State of Charge vs. Charging Time shows that battery takes more time to charge as less as state of charging is low for charging same amount. Fully charged battery shows 12.6V. Fully charged battery takes the approximately 2 hours and 7 minute to discharge 50% when 6 bulb of 60Watt DC is loaded. Since alternator takes initial current to energise the battery must not be discharge completely. Lighting Time of 6 CFL bulb of 25W AC for different state of discharge is shown in graph. Results shown that battery and inverter have more than 80% efficiency as expected. Finally result was found that at least 4 hrs (6pm – 10pm) the home will be lighted using that system.

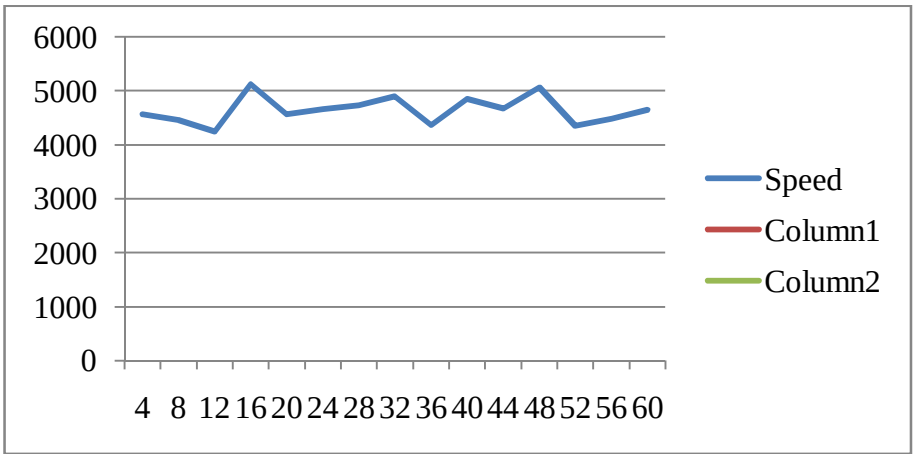

Fig. 4: Time (in minutes) vs. RPM of alternator.

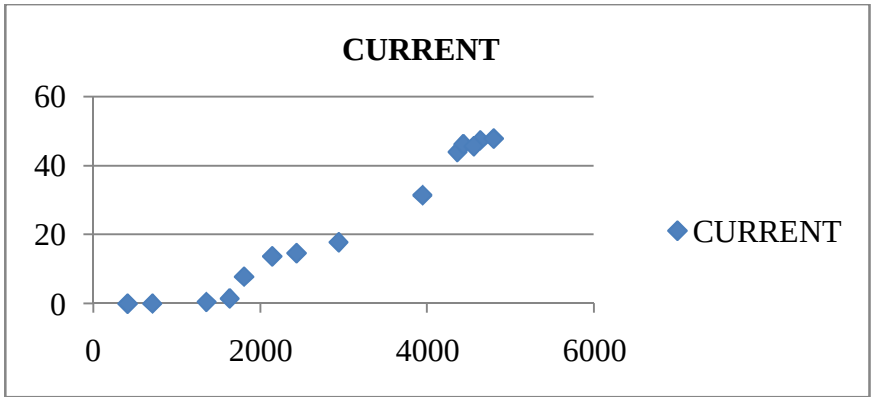

Fig. 5: Alternator RPM vs. Current in Amp.(DC)

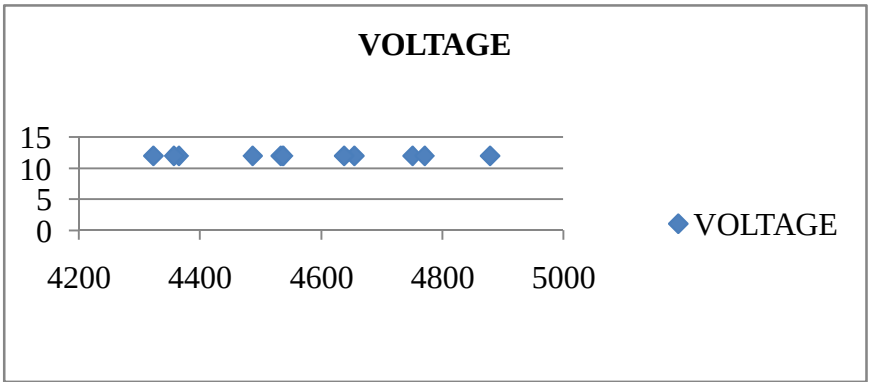

Fig. 6: Alternator RPM vs. Voltage in Volt (DC).

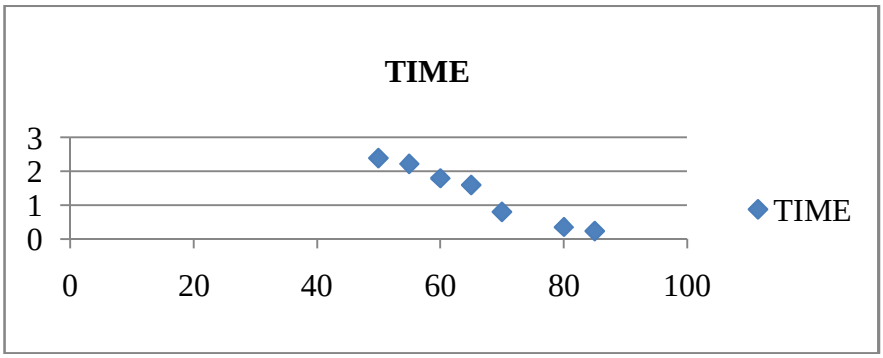

Fig 7: State of Charge vs. Time to fully Charge in hours.

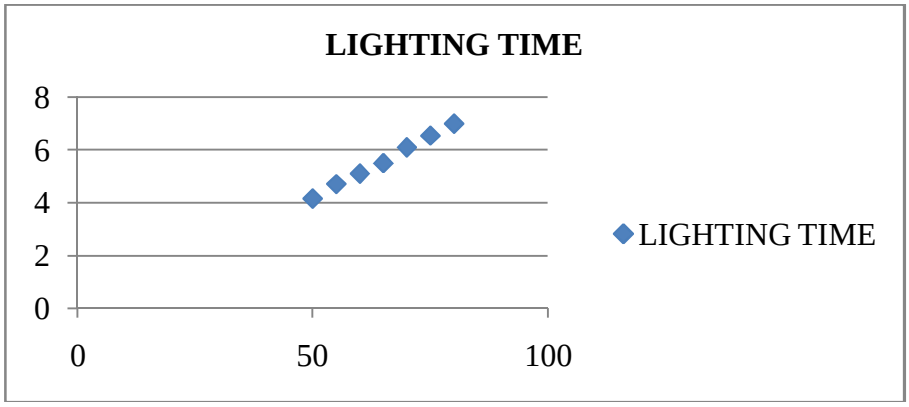

Fig 8: State of Charge vs. Lighting time in hours.

5. Conclusion

The present work provides a system and method for producing electricity for home lighting using the biological energy of the muscles of animals like bullock by means of a mechanical device. The project goal was to supply a battery array with a 12 volt DC output for1.5 billion people who rely on kerosene for light. 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. Authors believe authors accomplished this goal. The project results were conclusive with the animal as a prime mover for alternator as an electricity generator. This is also concluded that Animals are the great energy source for generating power even running at low speed at least for 6pm – 10pm at night for rural and isolated areas.

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