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Performance analysis of solar energy operated crop cutting machine

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The research aims to analyse the performance of solar energy operated crop cutting machine (SEOCCM). During the cutting of crops, farmers face harsh climatic conditions such as summer (for cutting crops of wheat, sugarcane, corn, mustard, etc.), and winter (for cutting crops of rice, sunflower, herbs, etc.). It is a general observation that to avoid such harsh conditions of weather, the farmer used to cut the crop during the night (in summer especially) and sometimes face accidents such as snake-bite, insect bite, or wild animal's attacks which lead to the death of several farmers. As manual cutting (i.e. utilising by man-power) takes several hours, sometimes a farmer loses his crop due to a sudden change in weather such as rain. There are various machines available such as harvester which consumes either conventional fuel (Diesel) or electricity which leads to air pollution. Hence, there is a requirement of a machine which consumes no conventional energy, saves both time and cost. To get rid of all, SEOCCM is conceptualized for providing a solution to the farmer who cut the crop manually or using a conventional source of energy. It is fabricated using a PV module (165 W_p), DC motor (250 W, 12 V, 4.2 A, 1500 rpm), cutter (diameter of 250 mm, tips of Tungsten Carbide), charge controller, battery (80 Ah) and iron frame. SEOCCM saves a conventional source of energy (e.g. fuel, or electricity) as it works on solar energy which is a renewable form of energy. The other features of SEOCCM include: (i) provisions for water bottle, (ii) meal, (iii) umbrella, (iv) LED light, (v) Insect rappeler (by ultrasonic sound waves).

In the performance analysis of SEOCCM, various climatic (solar radiation (global, diffuse and 'on tilted surface'), temperature (ambient, PV module surfaces), load i.e. DC Motor) and operational parameters (output parameters such as voltages and currents of PV, Battery and load) are observed in the summer (June 2019) condition of Prayagraj (Old Name: Allahabad, Latitude $25^\circ 27'$, Longitude $81^\circ 44'$), Uttar Pradesh, India.

It is found that average solar radiation in the month of June in Prayagraj is 850 W/m^2 which generates the voltage from PV (mounted with an inclination of 25°) of 14 V and gives the power of 76 W at surface temperatures on top and bottom ranges from 47°C to 50°C and 55°C to 58°C respectively, average wind speed of 3.5 m/s and the maximum ambient temperature of 48.9°C. And load consumes on average 60 W.

Keywords: Crop cutting, solar energy, photovoltaic module, temperature, solar radiation, performance analysis.

Introduction

"Energy - demand" is one of the major threats for India as well as the world. Finding solutions to meet the "Energy - demand" is the great global challenge for a social scientist, engineers, entrepreneurs and industrialists. According to them, applications of non-conventional energy is the only alternate solution for conventional energy demand. Nowadays the concept and technology employing non-conventional sources of energy become very popular for all kinds of development activities. One of the major areas, which finds a number of applications are in the agriculture sector. Solar energy plays an important role in drying agriculture products and irrigation purposes for pumping the well water in remote villages without electricity. The technology working on solar energy can be extended for cutting an agricultural plant are sugarcane, mulberry plants and paddy hence it is a hand-held solar cutter. India has the largest paddy output in the world and is also the fourth largest exporter of rice in the world. Paddy is cultivated at least twice in a year in most parts of India, the two seasons being known as Rabi and Kharif respectively. Presently in India, fuel-based cutting machines and old harvesting methods are commonly used to cut paddy. Paddy is the staple food for Indian people. The growth of paddy decreases day-by-day because of the shortage of labour and increasing the cost of fuel. Fuel based harvesting cost represents a significant portion of the total paddy production cost. Harvesting cost per acre land influenced by many factors including harvesting performance rate per acre, input costs like running and labour cost and other. Hence, there is a need for the solar-powered hand-held cutter. Several researchers have developed crop cutting machines and studied for their performances.

Harvesting

It is the process of gathering a ripe crop from the fields. Reaping is another term which is a part of the harvesting process itself. It refers to cutting of grain or pulse for harvest typically by using a scythe, sickle or reaper. In small farms for poor farmers, harvesting is the most-labour intensive activity of the growing season and requires large effort and time to get the crop harvested. In large mechanized farms, on the other hand, harvesting utilizes the most expensive and sophisticated form of machinery, such as combine harvesters. Specialized harvesting equipment utilizing convey or belts to mimic gentle gripping and mass transport has replaced the manual task of removing each seeding by hand. The completion of harvesting mark ends of the growing season or growing cycle for some crops. Getting their crops harvested successfully is sort of a celebration thing for farmers and its social importance makes it the focus of many seasonal celebrations such as harvest festivals in many religions. The following is the classification of harvesting:

Traditional harvesting method:

Early harvesting methods included, and still do in some fields, the cutting of stalks with machete-type knives, also known as a cutlass. This method was very labour-intensive, and cutters were subjected to stooping to cut the lower length. Fig. 1 shows the grass cutting machine operated by electricity which cannot be used for crop cutting.

Fig. 1. Mechanical grass cutting machine in MNNIT Allahabad.

Mechanical harvesting method:

Machines are also available for harvesting rice. The machine cuts the paddy stubble, sugarcane stem and mulberry pruner and lays down in the field. Later, the harvested rice stem should be bundled and stacked in a dry place if not threshed immediately.

Equipment used for harvesting:

Manual harvesting/reaping: Poor and low scale farmers having a little amount of land for cultivation use this type of harvesting equipment. This method involves deploying of labourers in the farm with sharp hand-held cutting tools such as a small axe, sickles etc. To get the crop cut and paying them wages in turn for the work. Generally, manual crop cutting involves slicing and tearing action that results in plant structure failure due to compression, tension or shear. This manual crop cutting practice is followed by the majority of farmers because of social-economical and Agro-technological reasons. Different types of sickle are used in a different part of the country. The instruments which are handheld and are operated manually to cut the crops are quite sharp and any handling mistake or even carelessness may and often leads to major injuries.

Harvesters and different crop cutters: Farms with large farms use harvester combine machines to harvest the crops. Poor farmers are also using such machines because of lack of labours and high cost of manual harvesting.

Problems

Problems associated with manual crop cutting in fields by deploying labours and family members by poor farmers are quite concerning with health as well as economical point of perspective. Further, they have to cope with the climate changes, soil erosion and biodiversity loss. They have to satisfy consumer's expectations and their changing tastes. They are somewhere part of balancing the supply and demand chain which fluctuates volatility. Currently, they have problems with adopting and learning new technologies. They have to invest in their farm productivity which sometimes keeps themselves into financial debts.

Farming is a business: While large-scale farmers may be able to afford to invest, small holders don't always have access to an affordable source of credit. And then farmers must learn how to best use these technologies to improve their business. Farmers are not aware much about the use of affordable technologies which can make their business easy.

There are villages which don't have harvesters in the whole village or even in the villages which are nearby. So, the farmers are left with no option than to employ manual forces to get their crops cut. Labour costs around Rs. 300 per day working for 7 to 8 h a day maximum and on an average 5 such labours are required to cut some 10000 square feet of paddy or similar crop. The poorest of farmers having 35000 to 40000 square feet of cultivated land will have to invest at least Rs. 6000 to Rs 7000 in cutting for one season. Also, there are numerous villages not having any electricity supply to date. Such farmers will benefit from the Solar power-based crop cutter as it does not have any electricity requirements. Apart from the problems faced by farmers, the emissions from farming which generates 12% of greenhouse gas emissions every year can be lower up to some extent by using this SEOCCM.

Hazards

The following are the various hazards associated with manual crop cutting:

(i) Chances of attack from various wild animals, bites from poisonous reptiles as snakes etc. to labours and people working in fields.

(ii) People work in fields during night-time based on season,

(a) especially in summers because of the loo, high solar intensity, increase labour charges and labour shortage,

(b) to get their crop cut in the required time span to have a good yield of the crop both in terms of quality and amount as sudden changes in weather condition may spoil their hard work spent in growing the crop.

Experimental setup

The SEOCCM (Fig. 2) was fabricated (similar to grasscutter shown in Fig. 1 but for crop cutting purpose) by cast-iron frame (alternatively aluminium/fibre-metal body can be used as lighter material) which is the external skeleton of the machine and it supports all the sub-assemblies such as DC motor coupled with steel cutter, battery, solar panel and charge controller with the help of different joining methods.

Fig. 2. Solar energy operated crop cutting machine.

The blade used in this machine is a stainless-steel cutter blade having a diameter of 250 mm and a bore of 25.4 mm. It has tips of Tungsten Carbide which may be treated as an insert. The blade (which can be changed according to the type of crop) is mounted directly on the output shaft of the DC motor without any reduction mechanism such as gears. The PV module can be adjusted according to the altitude angle of the sun. SEOCCM also has provisions for carrying a water bottle and food, handle, LED bulb for night time illumination and operation, and insect repellent device.

(i) Advantages of SEOCCM: The following are the advantages of SEOCCM:

(a) Low initial costs.

Table 1. Instruments used with specifications and uncertainties

Sl. No.	Measurement characteristics	Instrument specifications and make	Uncertainty
1.	Solar radiation	Solarimeter Model: AMPROBE SOLAR-100, Make: Amprobe, Everett, WA accuracy: +-5%, range: 0–1999 W/m^2, resolution: 0.1 W/m^2	±1.4
2.	Surface temperature	IR thermometer Model: FLUKE 62 MAX, Make: Fluke Corporation, Everett, WA range: -30–500C, resolution: 0.1°C	± 0.14
3.	Wind velocity and ambient temperature	Anemometer Model: BTH401 (New Delhi, India), accuracy: (a) velocity: +-2% of reading; (b) temperature: +-2% of reading, range: (a) velocity: 0.4–20 m/s; (b) temperature: -10–50°C, resolution: (a) velocity: 0.1 m/s; (b) temperature: 0.1°C	± 0.14
4.	PV Module Specifications	Maximum power (P_{max}): 165 W_p, Voltage at max. power (V_{mp}): 18.65 W, Current at Max. Power (I_{mp}): 8.85 A, Open Circuit Voltage (V_{oc}): 22.84 V, Short Circuit Current (I_{sc}): 9.55 A, Tolerance: +-3%, Maximum System Voltage: 600 V, Specifications are at STC: 1000 W/M^2, Irradiance, AM 1.5, Cell Temperature 25°C, Make: Luminous	–
5.	Battery	Tubular Plates Capacity: 80 Ah @ CIO, Sp. Gr. – 1.240 +- 0.005 (27°C), Make: Luminous	–

(b) Affordable by Indian farmers.

(c) Use of non-conventional source of energy which makes this technology clean and environmentally friendly.

(d) Conservation of fossil fuels, no cost of fuels.

(e) Low operational cost, low maintenance requirement.

(f) Reduce time for harvesting the crops.

(g) Easy to handle makes it user friendly.

(h) It is safe to use.

(i) The system is non-programmable. Can be operated by an unskilled person.

(j) Purchase and operating costs are very less. It does not require a high maintenance cost.

(ii) Limitations of SEOCCM: The following are the limitations of SEOCCM:

(a) The battery is most important as it has less life.

(b) Battery weight makes the machine a little heavy.

(c) Lightweight crops (grass) not cut properly.

(d) Charging through the solar panel will be affected by atmospheric conditions.

(iii) Applications of SEOCCM: The following are the applications of SEOCCM:

(a) It can be used to harvest the agricultural field.

(b) It can be used to remove unwanted crops or grass.

(c) It can be used in small farms where productivity requirements are more.

(d) It can be used in farms where there is no availability of labour.

(e) It can be used also as an alternative to the shortage of electricity.

(f) Charged battery can be used for small appliances at night.

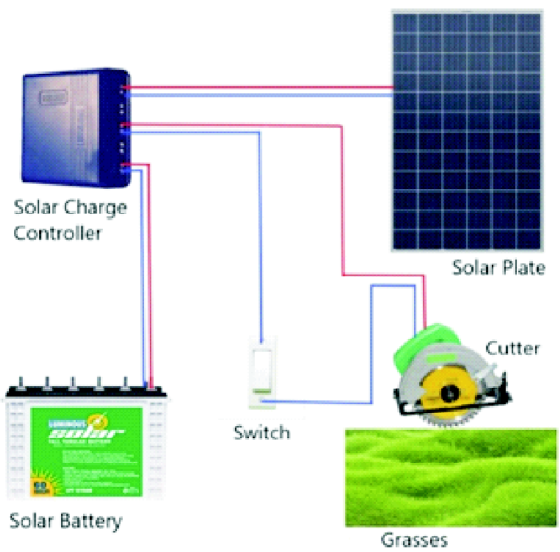

Fig. 3. Diagram of SEOCCM.

Results and discussion

The climate data for typical days in the month of June 2019 at Prayagraj, have been obtained from the experimen-

Table 2. Observations taken for SEOCCM under non-cutting mode on date 06/06/2019

Time	Solar radiation (W/m²)			Temperature (°C)				Wind speed	Voltage (V)			Current (Amp)		
(h)	Global	Diffused	Titled	Ambient	Solar cell (Top)	Solar cell (Bottom)	DC motor	(m/s)	PV	Battery	Load	PV	Battery	Load
9:00	782	285	581	38.5	45	51	41	3.0	13.8	13.7	13.6	6.2	3	4.2
10:00	815	320	612	39.3	47	52	42	2.5	14	13.9	13.8	6.3	3.1	4.3
11:00	889	309	870	42.4	50	58.5	44.5	2	16.2	14.2	14.1	5.4	2.5	4.2
12:00	918	300	884	43.5	52.5	61	46	1.7	16.6	14.5	14.3	5.7	2.7	4.3
13:00	830	312	793	45.5	52	60	46.5	2.5	16.3	14.4	14.3	5.7	2.6	4.2
14:00	814	260	653	45.8	51.2	56	46.6	3.5	15.3	14.4	14.3	6.7	3.5	4.1
15:00	810	241	631	45.3	51	57	46.7	3.8	15.2	14.3	14.2	6.6	3.5	4.1
16:00	658	198	300	45.3	46	50	46.6	2.2	13	12.8	12.8	3.2	2.3	4
17:00	539	171	209	44.2	42	48	46.5	2.8	12.4	12.4	12.4	3	2.2	4

Table 3. Observations taken for SEOCCM under non-cutting mode on date 20/06/2019

Time	Solar radiation (W/m²)			Temperature (°C)				Wind speed	Voltage (V)			Current (Amp)		
(h)	Global	Diffused	Titled	Ambient	Solar cell (Top)	Solar cell (Bottom)	DC motor	(m/s)	PV	Battery	Load	PV	Battery	Load
9:00	100	40	90	32.5	38.0	40.0	35.8	0.1	13.4	13.4	13.4	4.8	4.5	1.0
10:00	160	115	130	34.3	47.6	49.9	37.3	0.1	13.4	13.4	13.4	5	4.8	1.1
11:00	878	237	838	34.4	53.5	56.5	38.6	0.4	14.2	14.1	14.1	7.9	7.9	1.1
12:00	936	240	311	34.8	54.3	56.3	41.6	0.5	19.7	14.4	14.3	2.3	2.2	1.1
13:00	920	264	878	35.3	50.2	53.8	41.1	0.8	19.6	14.4	14.3	2.3	2.3	1.1
14:00	808	300	690	35.5	56.3	61.7	43.3	0	18.8	14.4	14.3	2	2.1	1.1
15:00	153	110	151	35.7	54.6	61.3	43	0	13.5	13.4	13.4	3.2	3.1	1.1
16:00	425	198	335	35	41.5	43.7	40	0.1	19.5	13.7	13.7	1.3	1.3	1.1
17:00	212	109	132	35	40.9	42	40	0.3	13.4	13.4	13.4	3	3.3	1.1

tal observations. The global, diffuse radiation and intensity of solar radiations on the horizontal surface is measured to know the condition of the day (weather clear, hazy or fully cloudy). These radiations are measured using a solarimeter (solar power meter). The wind velocity, ambient temperature and relative humidity were measured using a digital anemometer. A mercury-in-glass thermometer was also placed to measure the ambient temperature. The surface temperature of the solar cell (top and bottom), DC motor were measured using an infrared thermometer. Voltage (V) and current (Amp) of PV, battery and load (DC motor) were measured using clamp meter and the revolution per minute of DC motor was measured using Tachometer. The following are observations for typical days as shown in Tables 2 and 3.

It is found that average solar radiation in the month of June in Prayagraj is 850 W/m^2 which generates the voltage from PV (when mounted with an inclination of 25°) of 14 V and gives the power of 76 W at surface temperatures on top and bottom ranges from 47°C to 50°C and 55°C to 58°C respectively, average wind speed of 3.5 m/s and the maximum ambient temperature of 48.9°C. And load consumes on average 60 W. It is also observed that the experimental setup ran for more than 50 h under non-cutting mode. It is also found that SEOCCM is able to cut the hard stems of the plants. During the non-cutting season, the SEOCCM can generate electricity which can be used for illumination at home too.

Conclusions

The following are the various conclusions of the present study:

(i) SEOCCM was studied for its performance in the month of June 2019 at Prayagraj, Uttar Pradesh, India.

(ii) It is found that the SEOCCM is able to cut the hard stems of the plants. Dry stalks have a perfect cut.

(iii) The problems of farmers who were previously described met with their solutions.

(iv) The experimental setup ran for more than 50 h under non-cutting mode.

(v) During the non-cutting season, the SEOCCM can generate electricity which can be used for illumination at home too.

Improvements

(i) The fabrication of the machine is completed with irons which may cause erosion from water. Choose appropriate material which is erosion-resistant, e.g. plastics, fibres.

(ii) Proper placement of battery location (centre of gravity) where the feeling of the net weight of the machine can be minimized.

(iii) Rubber wheels may be replaced with plastic or steel so that the friction and stickiness of rubber can be reduced.

(iv) Proper design of wheels: back wheel size should be bigger in size should be taken into consideration.

(v) A battery of larger capacity can be chosen, sometimes extra electricity generated by the PV panel may not get wasted.

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Comparison with published papers

In the following paper compared:

1. C. J. Mnajunatha, K. Manjunath, A. Kumar and M. Natraja, Study and fabrication of solar powered multiple crop cutter, *Int. J. Innovative Research in Sci. Engg. and Tech.*, 2018, **7(7)**, 1-4, ISSN (online) 2319-8753.

(i) The numerical performance analysis of solar-powered multiple crop cutter has not been performed rather than described only part of theoretical portion.

(ii) The equipment used in their machine is very less in number.

(iii) No actual real work photos have shown.

(iv) No solar radiation, temperature and wind analysis for a particular region has not done.

(v) Problems associated with harvesting and how practically a machine can solve the problems are not described.

2. T. N. Pathak, T. R. Vidhate, S. S. Jadhav, S. D. Thakur, A. P. Vadnere and V. E. Kothawade, A review on development of solar-powered multi-crop cutter for harvesting, *Int. J. Research in Mech. and Civil Engg.*, 2017, **3(4)**, 60-64, ISSN 2208.

(i) In performance summary part only advantages, limitations, and applications are described rather than their performance analysis.

(ii) Specifications of the components and performance analysis tools used has not been described.

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