Design of Farm Machinery

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Lecture 60 : Solar energy operated thresher

Hello everyone, this is Professor H Raheman. I welcome you all to this SWAYAM NPTEL course on Design of Farm Machinery. This is lecture number 60, where I will try to cover the design of a solar energy-operated thresher. The concepts which will be covered include power requirement and peripheral speed of the threshing drum to carry out threshing, then development of a standalone solar energy-based powering system for carrying out threshing, then performance of the developed solar energy-operated paddy thresher.

In today's scenario, we have to get rid of fossil fuels, that is, the drive everywhere. So, how to get rid of fossil fuels in farming? The answer is : we have to look for renewable energy-operated machinery. So, renewable energy, we can use solar energy, we can use wind power, we can use fuels, but not related to fossil. Not fossil fuel, some other fuels we can use. So, with that attempt, we try to develop a solar energy-operated thresher. Solar energy can be utilized for different farming operations, starting from, say, spraying, threshing, and nowadays, solar energy-operated, battery-operated tractors are available. So, what we have to do is we have to find out how to utilize, how to utilize the solar energy.

So, threshing is a very important operation which is to be done in a particular place, you can say either you can do it in your farmyard or you can do it directly in the field. So, for that, we require a power source. So, the most commonly used thresher for carrying out paddy threshing is the pedal-operated, since it involves human beings to operate the cylinder because in a thresher, the main components are cylinder and concave; the cylinder has to be rotated. So, a human being is used to rotate the cylinder. Because of the shortage of labor, now you have to get rid of those human laborers in the farm. So, we want more mechanization. We want to get rid of fossil fuels, and we want to get rid of human beings, that means, because of the scarcity of labor. So, this is an attempt to develop a solar energy-operated thresher.

So, now, the thresher, as I said, is the most commonly used threshing equipment for threshing paddy crops. So, we have selected that thresher, which is called a wire-loop type pressure. The mechanism is: the person has to hold the crop bundle and expose that bundle against the rotation of the cylinder. So, when he exposes that bundle to the rotary motion of the cylinder, that cylinder has a number of wire-loops which will try to strip off the grains present in the straw. So, that is the concept. So, the specifications of that thresher are: it has a drum diameter of 500 millimeters, a drum width of 650 millimeters, an effective width of 550 millimeters, and 20 bars on which the wire loops are provided, with 16 wire loops in each bar. The height of the wire loop is 15 millimeters, and the thickness of the wire loop is 3 mm. These are the specifications, and since a human being is operating this one. So, now, the question arises: what will be the power requirement? If you assume that the power consumption is less than 0.5 hp. So, that way, you cannot design. So, what exactly we did is, we tried to first measure how much power and torque are required to carry out threshing in this type of thresher. So, that is the first attempt we tried to measure. So, for measuring the torque and power requirement, we fixed a torque meter here - a torque transducer. So, that is coupled to the shaft - the main part of the threshing drum. So, when threshing is carried out at different feed rates, we tried to measure how much torque is required and what is the corresponding power requirement? So, to utilize this torque transducer, we need to calibrate it. So, we calibrated it, and this is the calibration curve. Then we tried to rotate it with the help of an AC motor, meaning the power supplied to the threshing drum is by an AC motor. So, the thresher was rotated by an AC motor with a speed controller using a belt and pulley transmission, and then we measured torque at different feed rates. I will show you.

These are the performance results when the thresher is operated at different RPMs. You can say the speed of the thresher drum is varied, and the peripheral speed is also varied. Because the speed is varying, the peripheral speed is varying, and then the feed rate is also varied. We measured the output of grains, the corresponding torque, and the corresponding power requirement. And the most important thing is this efficiency because the Bureau of Indian Standards (BIS) says the efficiency should not be less than 95 per cent. The 5 per cent loss which is given - within that loss, the percentage of broken grains should not be more than 2 per cent. So, this exercise has been carried out for a grain moisture content of 13.38 per cent and a straw-to-grain ratio of 1.1:1. Under that condition, we tried to evaluate the thresher. Our aim was to find out how much the power requirement would be and what the output would be in terms of grain output, feed rate, and efficiency. We considered these three parameters and then tried to decide the best combination of operating parameters to get the maximum output, minimum power requirement, and maximum threshing efficiency. Now, if you look at this table, the efficiency side, there is not much difference in efficiency. The only thing is they are around 95 per cent. So, there is not much difference whether you increase the speed or the feed rate from, say, 240 to 292 kg per hour. Now, the other thing is the torque requirement. So, if you look at the torque requirement, this red row which I have indicated is the best combination by which you are getting the output and the efficiency.

So, the combination is the rpm of the shaft is to be kept at 310, then the peripheral speed corresponds to 7.3 meter per second and the feed rate that means, amount of crop it is going to handle is 260 kg per hour and the output is 127.83 kg per hour and the torque requirement is the minimum and the power requirement obviously, it will be minimum because power is nothing but T into omega and the omega is minimum torque is minimum. So, that is why you are getting minimum power requirement. So, this operating conditions we maintained that means, we wanted to operate this drum shaft at 310 rpm and we tried to keep the feed rate around 260 kg per hectare that is our target. So, then our torque requirement is this one.

So, when you try to convert this thresher into a solar energy operated thresher, then the first thing we need to know is what is the torque requirement, so that we can provide a motor which is suitable to supply this much of torque. Then we will find out what is the rpm of the motor which supplies this much of torque. If rpm does not match with our requirement like 310, then we have to think of a speed reduction or increase in speed that part we have to look into. Now, after knowing the torque requirement then we selected this is the motor which is available in the market which is closer to to our requirement. So, the DC motor was of 350 Watt capacity and the voltage is 24 Volt, the idle current requirement is 3.1, then the actual speed which is 300 rpm. So, that means, it matches with the requirement directly we do not have to make any transmission ratios. Then you need to know, then we have to have a motor charge controller to control the speed. So, the control specification is given to 960 Watt, then operating voltage is 10 to 50, peak current is 40 Ampere, then adjustable speed range is 5 to 100 per cent, operating temperature is minus 20 to 40 degree centigrade. So, after deciding the DC motor, then next is how to power this DC motor. The best way is : you utilize a battery, but battery you cannot use for a longer period of time. It has some power limitations. So, if you want to use this solar energy for a longer period we have to have a power source by which you can run it throughout the day maybe 6 hours - 7 hours like that.

So, we thought of providing a battery as the storage unit and the battery is to be charged from the solar panel. So, the concept is we will utilize the solar panel and solar panel will provide the required current and voltage that will be utilized to charge the battery and from the battery we will take power to run the DC motor and the DC motor will run the threshing cylinder. So, that is the concept. So, if you look at the chart flow chart, one side there is a solar panel, the other side there is a battery and in between there is a device called MPPT - maximum power point tracker. The purpose of providing MPPT is to maximize the output, output of the solar panel. So, that it adjusts how much will be the current and voltage that should be supplied to the battery and how to extract maximum power from the solar panel. So, that is the job of MPPT. Now, it will extract maximum power then supply to the battery depending on whether the battery charged or not. Then depending on the load, it will allow the voltage and current to go from the battery or if excess power is available, it can directly supply that voltage and current to the DC motor. Then you have a motor controller to regulate the speed and then DC motor and wire-loop type paddy thresher. So, the thresher which we are utilizing is at the end and these are the components which are required for the stand alone power generating system.

So, the component wise : we have to have a solar panel, then we have to have a maximum power point tracker, we have to have the battery may be a group of batteries depending on the voltage and current requirement, then we have to have a motor, motor controller and the thresher. So, according to the power requirement that is current and voltage required for DC motor for carrying out threshing, the battery size was decided which could operate the thresher for nearly 2 hours. So, that means, this timing you have to fix otherwise you know, the battery capacity will increase. So the timing which we maintain is, if you do not charge the battery then the battery is in a position to run the equipment for that is, run the thresher for 2 hours. So, there is a time gap of 2 hours and if you charge it simultaneously that means, charging and loading then we can run it throughout the day.

Then the solar panel capacity was decided based on the current voltage requirement, requirement of DC motor and the average solar radiation which is available in that area during the harvesting period. And a maximum power point tracker was integrated into the system to maximize the output from the solar panel. So, to design the size, that means, to decide the size of the battery, we need to know what the power is, the maximum power required, how much duration we want to utilize, then the degree of autonomy - in how many hours or in how many days we want to recharge it, then what is the percentage of battery which you want - which we will allow to discharge and the battery capacity. So, our requirement, which we calculated, is 277 watts. So, we have taken 280 watts, and then the duration we have taken is 6 hours in a day, and the degree of autonomy - that means every 2-hour interval we need to charge it. So, that way, this becomes 2; the degree of autonomy becomes 2 by 24, and the battery discharge rate we allow is only 60 per cent - there is a maximum discharge from the battery and then the battery size means 24 Volts; that volt you have to decide, current has to be calculated.

So, for deciding the battery size, if you put these values in this equation, the current requirement comes to be that ampere-hour: 9.72 ampere-hours. So, we have to now think about what size of battery - these batteries are available in the market so that this can meet this requirement. So, we looked into the market, and there we found that 12-Volt, 12-ampere-hour batteries are available. So, we selected 2 such batteries and then connected them in series. So, that we will get the desired voltage of 24 Volts. So, 12-Volt, 12-ampere. So, they will be connected in series. So, that they will provide 24 Volts and 12 amperes. Whereas, we require only 9.72 ampere-hours. So, that way, the battery sizes are alright.

Then the next question is: what is the solar intensity or the solar radiation that is available throughout the year? We carried out an exercise, for the last 5 years to determine the solar radiation available in Kharagpur, where we have designed this equipment, which is placed at 22.35 degrees North and 87.23 degrees East. In that place, how much solar radiation is available throughout the year? Now, if you look at this graph, we may not require this data for the entire year because the harvesting period is fixed. So, weeding time, harvesting time, weeding time, harvesting time. So, I have indicated for the rabi crop and for the kharif crop. So, in December, late November to December, even up to January to some extent, harvesting continues. This is for the kharif crop, and for the rabi crop, the harvesting is from the beginning of April to the end of May or June. So, this is the period when threshing is required or carried out. So, during that period, we tried to measure the intensity of solar radiation available, and what we observed is : this is the total beam radiation; this is the diffuse radiation, and the total radiation is 1004.61 watts per square meter. In the months of March and April, it is more than 1000; in November and December, you can see it is below 1000 watts per square meter. So, the design is done for the minimum available insolation - that is another thing. So, if you design for the maximum intensity available or the solar radiation available, it will be difficult to manage in the lean period. So, we considered the minimum value, then considering the conversion efficiency of the solar panel, a very minimum one we have taken. Nowadays, conversion efficiency has increased to 17 per cent. So, but we have taken the minimum one 12 per cent, then that way we required this much of watt per meter square. That means, the solar panel if it receives this much of intensity then it will produce only 95 Watt. So, around 100 watt it will produce per meter square. Then considering the motor efficiency as 80 per cent, the power consumed is 350 Watt and then the required size of solar panel will be 337.5 divided by 95.57. So, that way this much area of solar panels is required. Now, the solar panel size is calculated based on the energy consumption per day, then the peak sunshine hours which are available. So, that way 280 into suppose you are running it for 3 hours continuously or 3 hours a day. So, 280 into 3 divided by a peak sun shine hours that means, where you are getting 1000 Watt per meter square. So, that way you are getting this is the Watt peak value of solar panel that means, when the radiation is 1000 it will produce 311 Watt that is the concept.

So, the solar panel was selected taking into consideration the current requirement of the motor to provide desired torque to carry out threshing and the current required by the discharged battery to fully recharge that is another requirement in the duration of 2 hour because we said within 2 hours it has to be charged. So, within that the discharged battery should be charged that is before the time required to complete discharge. Then taking these two factors, current requirement and the time required to charge the battery we decided a solar panel size of 325-Watt peak. And the detail specifications are given like optimum current, optimum voltage, then open circuit voltage, short circuit current and conversion efficiency we can say 16.8 percent.

Now, these are specification of solar panel as well as the battery. So, detailed specifications are given. Then we tried to incorporate the power operating system to a thresher, wire-loop type thresher and that thresher is given to the farmers, farmers for verifying its performance. So, I will show you the video. So, the advantage here is they do not have to do anything only hold the bundles of crop against the rotation. It is rotating continuously. So, what they are doing, they are cooking when they are free the ladies will come and do the exercise of threshing that is another advantage. So, you require less hired laborers. So, the family members they can utilize their hours and carry out threshing. So, the mechanism if you look at - the cylinder is rotated. This is the cylinder and is rotated by the motor which is mounted here. The motor is mounted at the base. From the motor with the help of chain and sprocket, power is transmitted to the central shaft with the help of a motor controller and in the top, there is a solar panel. And the battery set is there in the back side of the motor. So, solar panel is charging the battery with the help of a MPPT. It is also fixed in the back side and the power is taken from the battery to run the motor that is the concept.

And panel is provided at the top and there is a provision also provided in the panel, so that you can change the orientation. Depending on the direction of sun rays, you can change the orientation, so that you can get maximum output. We have also developed another set of threshers which is run by solar energy so you can see. So, the cylinder is running and the bundles of crops are exposed to the cylinder. The threshing is carried out. You can see in the top - there are two solar panels in fact, we provided 160, 160 Watt peak solar panels. So, that way 320 Watt peak solar panels and then we tried to carry out the threshing operation. So, power is transmitted from the motor, motor is powered. This is the MPPT which will indicate how much voltage we are getting from the solar panel, what is the current and then how much it is charging to the battery. So, all those information will be available in that MPPT (maximum power point tracker). So, let us now see the performance, performance of the solar energy operated thresher. If you look at the graph which is shown here, the x axis is the time, y axis is the power requirement, power requirement to carry out threshing, power taken from the battery and the power available from the solar energy. The red one indicates the power available from the solar radiation. The solar panel output is your - the top one is the solar panel output and the battery power is this one, the black one and the threshing power requirement is the bar chart. So, threshing started at 9 am it continued up to 4 pm in the afternoon and during that period we tried to measure the voltage, current and the total power requirement for the source that is battery and the what is available from the solar panels that we have done. And if you look at this one, the power requirement is nearly, nearly constant you can say around 100, maximum is 170 Watt because the load given is less that is why. The load means kg of crop which is handled is less that is why the power requirement is 170 watt. Now, if you look at this, I have divided this total duration into two regions one is denoted as B the other one is denoted as A. B is the region where the solar panels are not sufficient to charge the battery or run the thresher. So, we have taken we have taken power from the battery. So, that is why you can see this is power this is the power taken from the battery. Now, requirement is this one red one shows the solar radiation data. Solar radiation data and blue indicates the power which is available from the solar panel. So, the requirement - in this region requirement is not made by solar radiation. So, we need to extract power from the battery. So, that is why it is showing the negative value. Power is taken from the battery. So, it is showing the negative value. So, this extra power which is required is supplemented from the battery. Now, from this region to this point that means, from 10:30 onwards, 10 o'clock onwards up to, say, 12, the solar panels are giving excess power. So, where will that power go? The excess power will go to the load - the power will go to the load, and the excess power will go to charge the battery. So, that is why the battery charge is increased - you can see the increase. Now, from 12 onwards, the solar radiation is going down again - you can see that the solar radiation is going down. So, the output from the solar panel is reduced. So, but the battery power is taken away that is why it is going down. Now, from 1 o'clock onwards, if you look at the solar radiation, the solar radiation is going down, and the output from the solar panel is also going down. So, this is the area where you require power, and this power is met from the battery - you can see the battery power is extracted. So, it goes down. So, from this, what you can conclude is: yes, the system which we developed is. The only thing is we need to have higher insolation; then only you can supplement otherwise. The battery size which is selected is sufficient for the total duration - you can run it because we have not discharged the battery to more than 50 per cent or more than 60 per cent. So, battery size is alright, it runs the thresher, but in combination. It does not run directly from the solar panel output. So, solar panel output is only in this region. If you do not have a battery also the thresher will run, but in the morning hours in the afternoon hours we need the support from battery. So, we have to charge the battery before hand so that it supplements. In short, we can say the developed solar photovoltaic system for powering the thresher continuously supplied power to run the thresher for 2 hours without charging.

If you charge it and carry out threshing simultaneously then we can run it throughout the day. And the threshing capacity of the developed thresher is 260 kg per hour with a threshing efficiency is more than 97 per cent and the labour requirement that is the main thing which is reduced. So, labour requirement is reduced because we do not have to operate the thresher. So, only the operator will expose the bundles to the rotating cylinder. So, that way man hour requirement is reduced and the cost of threshing if you compare you can see is only 1400 around 1500 rupees, whereas, if you are using pedal operated the cost is around 1925 rupees

So, that means, there is a saving in cost and that is what a farmer needs and we have our design has sufficient to run the machine. So, similar such machines are required to be developed if you really want to mechanize the farming operations without fossil fuels. So, these are some of the references and in short, I can say we discussed about the design of a solar energy operated wire-loop type thresher and discussed how to select the panel size, how to select the battery size and then the performance of the developed machine is also discussed.

Thank you.