Micro Irrigation Engineering
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Lecture - 49
Solar Photovoltaic System for Irrigation (Part 2)

Hello participants, I invite you to lecture 49. This lecture is in continuation to my previous lecture on solar PV system for irrigation. This is part two. Here we will emphasize how to integrate solar PV system with micro irrigation. So, in this particular lecture we will discuss about controller, we will discuss about pumping unit, we will discuss about the how to match and properly integrate solar PV system with micro irrigation system.

So, a controller consists of a maximum power point tracking, inverter and variable frequency drive VFD, in short form we say VFD. The MPPT that is a maximum power point tracking maintain system operation at or near maximum available power.

The power which we are getting from the solar panel, in this particular place which you are seeing that the power which is coming from the solar panel. This power which we get, this power is DC that DC is supposed to be converted to AC in order to operate the submersible pump. So, when we want this particular unit it goes there so here, we have got a VFD. A VFD regulated motor speed by varying the motor input frequency and inverter converts direct current into alternate current that is AC current according to the type of load.

So, finally the energy is supplied from the solar system to the pump. The pumping system usually consists of pump. These pumps could be placed at the surface so surface centrifugal pump or submersible pump means it is placed below the ground level and then the water is being withdrawn when the there is a deeper depth of water available.

So, variable speed pumps are powered by a synchronous motor or an electronic frequency converter that allows the pump to work under different angular velocities. And frequency converted can be considered as an inverter which is able to modulate the output signal to desired frequency and amplitude. Because what happened that power supplied by the PV array is variable means during day time. You may find that in the morning solar insulation is low and it increases. So, it increases means your solar insulation when it increases so energy available is also increase. So, it is varying due to that is another part. Also, another one is that it may vary due to cloud. So such type of variability will happen depending on the incoming radiation. So, power required by the pump can be modified by modifying the angular speed of the pump to match the incoming power.

So, it is very important thing that matching of the pump required as per the demand and then how much power it is available that is coming from the solar PV system. So, this matching is a very crucial and important.

So, to select the most appropriate capacity of the pump for a particular application, the performance curve, already we discussed in the pump class and previous lecture there is a discharge-head-efficiency curve and this curve is established between these parameters of the pump and provided by the manufacturer. So, pump manufacturer supplies this information. This relationship is governed by the affinity laws that relate the shaft power, this is given here, this will relate with the shaft power, it will relate with the available head, it will relate with the discharge and also with the rotation speed.

So, according to the affinity law the pump discharge that is ratio of original discharge to the pump discharge at a desired speed can be given by

Where,

Q_2 = pump discharge at desired speed N (Ls^{-1})

Q_1 = original pump discharge at speed N_1 (Ls^{-1})

N_2 = new pump speed desired (rpm)

N_1 = original pump speed at which the characteristics are known (rpm)

H_2 = head at desired speed N_2 and discharge Q_2

H_1 = original head at speed N_1

P_2 = power at desired speed N_2 (kW)

P_1 = original power at speed N_1 (kW)

So, this is explained using the affinity law.

This relationship it is giving us valuable information while we are selecting the pump. This is another important characteristic curve which you can see here that how the head and discharge it varies for the pump. When the power it is supplied at different frequencies and when the pump is operating at different, it has got different efficiency so you can see the typical curve which is available. This is the curve giving us say 74.37% is the efficiency when let us say that a pump is delivering discharge it is delivering discharge of 4 litter per second. And it has a 100 meter head what is the appropriate efficiency. So, if I need a pump of this particular efficiency accordingly what will be the power frequency requirement of the motor that can be decided?

Then on farm irrigation network to select the operating point, that is the point which will be available from the curve we will get. And then that is a discharge head that curve which I was telling you from that on this type of curve of the PV irrigation system it is a function of power supplied by the PV plant not only the simply taking the head discharge of the pump but also one has to see the network system curve, irrigation network system curve.

Now two different cases can be distinguished depending on the type of irrigation system which we are using. Say case one which when we are telling when pump is operated to fill the tank which is at some certain elevation. So, here one can find out what is the total head? So, total head H will be means from the curve we will be getting total head will be given by

where

z = the elevation difference between the groundwater level in the well and the water level in the elevated tank

h_f = the friction head losses throughout the discharge pipe system.

So, this elevation difference one has to find out that when the pump is being used and how much head it will be required to fill the tank which is at some certain elevation.

The other case is, it is directly supplying water to the irrigation network which is used in drip irrigation or sprinkler irrigation system. In case of drip irrigation system, it can be elevated case where gravity system after the water is filled in then gravity system is used to operate the drip system which is of low head drip system. But for larger system when the means where irrigation is to begin for a very large area then it is directly the means irrigation system is directly connected with the pump. So, for a sprinkler it requires normally a larger pressure so pump is needed. So, the system curve can be calculated by using the following relationship

where

h_o = the head required to operate irrigation network (includes emitter operating head, friction losses in pipelines and other components).

Where drippers are there or sprinklers or micro sprinklers or the overhead sprinklers are there so how much pressure it requires to operate plus frictional loss in the pipeline and all that take care of by hf.

So, there are other design parameters which needs to be considered while we are designing the system. These are the following design steps one has to follow for sizing the PV system and pumping system. So, first is to determine the water production goal. Water production goal means it is simply water requirement of the crop.

So, we studied in the water requirement of crop a particular in the previous lectures. If you remember how to estimate the evapotranspiration requirement of the crop by using different methods I discussed. So, pan evaporation method is one method but here it is given highest water need. So, suppose we have got the crop which is grown it is a perennial crop or it is a crop which is to be grown during summer month.

So, water requirement during summer month when it is during the peak period that has to be taken into consideration. So, if the same crop is grown for last few years so those data are to be analysed say and then one can take 5 years recurrence interval what is the maximum water or evapotranspiration needed by the crop during peak period means when it is in the high demand period. That is to be taken in the design side then another part is considering that what time of the day and what is the wattage available at that time. So, use the design month insulation that is 1 sun means the hours at 1 sun. Hours at one sun is for the design purpose it is taken as 1000 watt per square meter for 1 solar hour. So, that is the value which is considered for the design purpose.

So, this we are calculating Q that is the design discharge will be daily demand divided by insulation multiplied by 60.

So, this we will get the value of Q now find the value of Q that is the dynamic head versus discharge at particular discharge. So, this we will get this particular relationship what is the value of H. So, we will find out the capacity of the desired head and for a given flow rate.

So, we will get the value of how many number of modules it is needed and these modules when as I discussed told you that they are given in series and parallel to get the maximum powers. So, number of modules in series can be calculated by

When we are interest to find out the PV strings in parallel, this can be given by

So, these values are available how much it is there so we one can find out the how much is the value which is for the you know in the parallel and this so that one can find out the number of strings in parallel.

And then power input in kilowatt it can be given by this also expression

So, once the PV capacity is known suitable controller of equal or greater size than pump rating can be selected. And also, according to the maximum current and voltage of PV system and pump the cable and switches depending on the field requirement they can be selected.

Now there are other expressions which are important when we are computing. So, solar PV system power calculation is made so we are calculating for the maximum power by using this expression which is given by

So, this particular equation it is developed for the set condition at 25 degree Celsius the operating cell temperature can be estimated by using this expression.

Where,

P_n = nominal capacity of PV system (kW)

γ = temperature coefficient of drop in power

T_{cell} = operating cell temperature (^oC)

T_{amb} = ambient temperature (^oC)

NOCT = nominal operating cell temperature (^oC)

G = solar irradiance (W m^{-2})

NOCT is provided by the manufacturer and so we will work out this value. So, we will work out this value and this is for a particular time of the day. So, this we will work out and G is the solar irradiance this also for a particular time of the day. So, one can work out what is the P max available at the particular period.

Now here we are integrating the system with the solar PV system with the micro irrigation system. So, this integration it involve that you can see here this one is this source of energy it is supplying the solar energy and then with this particular solar energy it is generating energy and that is in DC. So, we need to convert by using the VFD that is a variable frequency. So, we are converting it. If the generated energy, which we are generating more, then this can be feedback to the grid supply. If it is more than the desired value then it can be also stored separately. And then again when it is needed during night time or any other time this can be supplied or when there is a problem if there is a raining or some cloud condition exist at that time this can be done.

Now by using the VFD, we are supplying the power to the motor and then the pump is supplying water to the irrigation system. So, pump is discharging, the interesting part here it is that the power generated from the sun it is a variable and it is not fixed for the whole day period. So, during daytime, diurnal period itself you can see it is going peak and initially it will be going slow and then it will go to peak again then again it will go down.

So, the science involved or the main part it is involved is not simply direct coupling, one has to know that how the discharge means power available or discharge available from the pump which will generate the pressure that pressure matches with the requirement of the pressure at which when we are operating or connecting with the drip irrigation system or micro sprinkler system or sprinkler irrigation system it will depend. So this is where an important aspect is involved how to use the available power or head pressure for operating the system. Because the discharge from a drip emitter, discharge from a sprinkler system, it is a function of operating pressure. So, discharge will increase or decrease depending on the pressure available.

We have installed SPV based micro irrigation system this particular system is supported by Ministry of Agriculture and Farmers Welfare, GoI. Now there are 16 panels each panel is of 320 watt capacity vision and then this system is standalone system it is a single axis sun tracking with grid storage arrangement. The total system it converts total energy is of the order of 5.12 kilowatt power which is being used to operate 5 horsepower submersible pump which is located at 30 meters below the ground level. The pump capacity as well as; we have an arrangement for the data logging which is being used by using the GPRS where the data logging for the solar radiation, temperature, and flow rate at every 3 minute interval is being monitored. The system this particular system was installed in December 2017.

Now strategies for integrating solar PV and micro irrigation system to regulate system and to optimize use of generated energy for irrigating the crop is to design more than one irrigation unit in the field. Means we need to see that the whether we need to supply water for at one unit or more than one unit. So, whole farm can be divided into number of unit so, that the available system can be effectively utilized.

And then whole energy which is available from the field it can be used for irrigation and then cost of the system can be also reduced. So, when farm is divided into the number of subunit greater than one. The discharge and power needed to irrigate each unit can be obtained by dividing the maximum discharge and the maximum power by the number of sub-unit and according to the power availability the units can be irrigated.

So, in this case system can start irrigating with the shaft power that is the ns and time lower than when the only one subunit is considered. Two different strategies can be utilized one strategy to irrigate with only one irrigation subunit in operation or to irrigate with multiple irrigation subunits. Subunits in operation that is operated simultaneously. This is a typical you can see how the solar insulation during a day time in different season it varies. So, you can see here this is the total sunshine hour we are putting it say from 6:30 means some places this it goes till late 7:30 or so in the evening time but you can see the maximum power available is between 12'o clock to 1'o clock. So, this particular curve it is for winter where the minimum energy is available.

And then solar energy is available and then this red curve which you see that is for the maximum. So, this is during summer month and then the autumn and spring they are falling in between winter and during summer. So, this is a variable so solar insulation it varies so power availability will be also vary pump discharge will vary that is where the important part is how to match this varying solar intensity with the pump part.

So, this is the one layout it has been shown here there is field where the pump is located. And then from the pump the main line and then from the main sub-main line is there. And then there are the sub-main manifold that some main is connected with the manifold. And then from the manifold the laterals are attached. So, this is one layout which is given here. So, from these 2 C main pipeline from C to B there is a sub main pipeline and from B to A there is a manifold and on these manifold laterals are attached. The other strategy means your sub mains are laid in this way and on which the sub main and laterals are attached this is another strategy or layout is given that from the pump.

The main pipeline is attached that these 2 C is brought here and then this is your main. Sub main pipeline and then sub main manifold it is the length of the manifold is reduced and then the length of lateral is increased. So, this could be the; another way and one has to find out the really economics and amount of the power it is being generated. So, this can be another strategy. The third study layout it can be made that pump is you know this will source of well it is located somewhere in the middle. Then from there the main line is connected and from main the sub main and manifold, sub main manifold it is there. And from there the laterals are connected so there can be another strategy. So, there can be the different layout. And strategy it can be made depending on the field requirement.

Only thing that one has to see in all the unit that head loss due to friction is minimum and we are saving energy. So, that we can select the minimum number of panels and we can economize the cost and the pump will be also of lesser capacity lesser horsepower. So, it will be also economical so, there are several ways one can work out the economics part.

A solar irrigation pump system method needs to take account of the fact that demand for irrigation system water will vary throughout the year this is what you have seen from the graph which I was showing. That the demand will increase because the power supply will be also changed so peak demand during the irrigation system is often more than the twice the average demand. Yes, it is correct this will depend upon the of course at what time of the season we are considering and then at what growth stage we are considering. At the initial stage it is too low and when it is in the peak demand stage when it is a fully developed crop maturity stage the demand will increase. This means that the solar pumps for irrigation are underutilized for most of the time in a year.

This is correct that initial part it is less but so attention should be paid to the system of irrigation water distribution and application to the crops. We need to see that here if the demand is less then we need to supply the power to the partly to the grid. The layout of the micro irrigation system consisting of number of subunits will play the key role in optimally selecting the operating PV energy. Irrigation pumps should minimize water losses. It should minimize water loss and power losses. So, this should be without imposing significant additional head on the irrigation pumping system and it should be of low cost it should be economical this is our aim. So, to get more detail about this particular topic, how to integrate solar PV system with micro irrigation system please refer these books these particular books these are useful for your study.

So, in this particular lecture we discussed about power controller, we discussed about selection of the pump, we discussed about how to integrate micro irrigation system there could be different strategy, there could be different layout of the system. So, this way and in the fourth coming lecture, we have studied several formulae there are several equations.

So, means we will have the practical experience and while we will calculate those values in the forthcoming lecture that is tutorial 10. So, thank you very much.