Micro Irrigation Engineering
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Lecture - 48
Solar Photovoltaic System for Irrigation (Part 1)

Dear participants of micro irrigation engineering subject I invite you to lecture 48. In lecture 46 and 47 we discussed the standard specifications with reference to our Indian coding system. So, the bureau of Indian standards discussed how the different sprinkler as well as drip irrigation system components they can be tested as per the given standards.

In previous lectures we discussed about design of the micro irrigation system. We also discussed about design of the sprinkler irrigation system. In conventional ways of operating these micro irrigation systems or sprinkler irrigation systems we use electricity. We use conventional ways of giving power source supply to operate micro irrigation systems. But this system is not reliable particularly when crops need irrigation to make the system self-reliant and the source of power if it is made available at the field itself.

So, we should find out the alternative and one of the alternatives is using solar photovoltaic systems for irrigation. So, in today's lecture 48 it is on using the solar PV system and we will discuss about the basic fundamentals of the solar PV system. And then we will discuss how a given solar PV system can be integrated with a micro irrigation system in the coming lecture.

So, let us start with the solar PV system. The concept covered in this particular lecture is solar PV system and energy conversion and solar tracking system.

Let us go further deeper on this particular topic. So, we know that energy is a very important component of agriculture and energy for all operations starting from ploughing, starting from seeding, starting from transplanting, irrigation, and there are various other operations till we are

getting the produce in our home. There are various field operations which are carried out and these field operations require energy.

So, energy is a very important component for production of agriculture produce. So, we need a means to operate this one so we have got the conventional source of energy. So, one can use electricity maybe it is a hydropower generated electricity or thermal power. So, you can see here when you are using the thermal power this type of pollution is another problem. So, environmental effects due to using the different fossil fuels generate energy.

Shortage of electricity and especially in the rural area, remote areas where grid supply is not available that is another problem. So, agriculture to get all throughout the year production; so, we need a sustainable source of electricity availability so that all throughout the year cultivation can be done. So, here our main focus is on irrigation parts. So, you are seeing here that whatever the source of energy we are using. We need to operate the pump to make the irrigation water available to the field as and when it is required. So, we call it Agri-voltaic and alliance, an alliance of both agricultural and photovoltaic energy production. So, this is the important component for using the photovoltaic system for irrigation purposes.

Now we know the sun is the source of energy. There are other sources of energy it could be wind, it can be tidal waves, and it could be hydro energy depending on the location available. So, hydropower, biomass, biofuel, coal, oil these are the primary sources of energy. Geothermal is a chemical reaction and radioactive decay inside the earth this also produces the energy. Tidal energy, motion and the gravitational potential of the sun, moon and earth.

That is also you know sun takes the important part and the different position of the moon and earth with respect to the sun accordingly, the tides are moving and then it generates energy for useful purposes. Human induced nuclear reaction. So, nuclear power plants are also available for generation of electricity and this system is available.

Renewable energy obtained from the natural as well as persistent flows of energy occurring in the immediate environment. So, for example we are putting renewable energy. So, the sun is the obvious source of energy. Then there is the wind, wave, tidal. These are the other kinds of energy. So, you can see here this is the natural environment and then there are devices which are used to convert this energy and bring it for use and then the environment sink it is this.

So, the green or alternate source of the energy which is being not affecting the environment. Non-renewable obtained from the static source of energy that remains underground unless released by human interaction. So, examples are nuclear fuel, fossil fuels but it has finite supplies which mean one needs to have enough radioactive material available. But it has got a finite means of limited supply. And then it is a brown energy we say.

We call it also now it has become a conventional source of energy. So, we see here the resources available from the mines. These are also used to generate electricity, generate energy for agriculture purposes.

Now here my talk is mainly focused on solar energy. If you see in our country solar energy is abundantly available and here 68% of the total energy it has a potential that it can be utilized. So, this is the potential 68% of total energy which can be utilized where 68% is solar and it has got a 750 Giga-Watt power. Then next in the order for the renewable source of energy is wind. So, it has got 300 Giga-Watt power and wave that is a tidal wave.

And then another side that is in the range of wave it is 4% that is a 41 Giga-Watt. And tidal energy also there but it is very limited 1% of that so, total energy can be brought. Now my talk is mainly focusing on solar energy. The distribution or availability of solar radiation annual or daily global solar radiation in India which is expressed in kilowatt per square meter per day. So, this varies from 4.4 to I can say 6.6 kilowatt hour per square meter per day. So, the distribution if you see a distribution in the western part of the country is very high which is in the order of about more than 6 kilowatt hour per square meter. And then this part is low because of the cloudy

condition. So, availability of solar energy in the north eastern part is lesser and also the coastal regions are also having this type of problem.

So, we get less but a large part of the energy which can be utilized for our country in a very big way and the government of India is supporting this type of energy.

Now coming to the basic fundamental theory of how photovoltaic energy it converts to electricity. So, photovoltaic systems convert sunlight which is coming from the source. It means this energy is coming from the source of the sun and that is directly converted to electricity and these processes are completely solid state and self-contained. It can withstand severe weather conditions. So, solar insulations which is falling on the solar panel.

So, this is made up of phosphorus-doped N-type the solar system panel consists of these cells and these cells have got phosphorus-doped and boron-doped N-type and then they convert the electricity. When it interacts with this and it converts to the direct current that is DC current. And this DC current if we are directly tagging one can use it for the generation of electricity.

So, there are different classification charts you can see here. So, the classification of solar cell technology has gone considerable development and their lot of development and the efficiency of the system has also improved. And the cost of the system has also gone down. So, this could be you know the solar cell technology is by silicon and then another one is by using the semiconductor compounds or it is by emerging or novel material.

So, silicon could be crystalline, amorphous or crystalline can be a single crystalline or a multi crystalline. Amorphous material it could be hydro generated amorphous silicon. So, this could be like this and then semiconductor compounds can be chalcogenides and compounds of group 3 and 4. Then further if we get into this one then you may find that cadmium, copper zinc, tin sulphide, copper lithium.

So, this is another kind of semiconductor compound which is being used. If you are using other sources, emerging other novel material. So, these are the new materials which have been it is going on. So, the solar energy which is being converted and brought for the irrigation purpose. And the silicon solar cells are made up of monocrystalline cells. Mono crystalline cells have the highest efficiency of about 26%.

When we call it a polycrystalline cell it has got efficiency of converting the energy to 16%. And then amorphous material has got relatively less about 10% of the energy is converted.

So, what we are seeing here when the sun is the source of energy and these are the solar radiations which fall on the solar cell. Now these solar plates or cells could be arranged in a series or parallel. Then it is brought to the controller. Then the controller operates the motor and then this motor is coupled with the pump. And then from the pump water is coming from the source and then supplied to the irrigation system.

This irrigation I am putting here it can be for any other purpose. So, the solar system can be used for supply of water. It can be for drinking water supply or for any other purpose this system can be used. So, PV irrigation is one of the most promising alternatives for rural electrification slowly this work is going on in a bigger way. Idea of using solar energy to meet the water needs of crops began in the 1970s.

So, as early as in 1970 and now almost 50 years it has come and then there is a lot of improvement in the technology as far as the material. So, just now I was telling you there are different materials which are used for making these cells and then there are several novel materials that have come and that is causing the improvement. And not only is the improvement in the efficiency point of view, the cost of the system is also going down.

And the government of India is promoting and you will see that many houses, many government buildings and their roofs are being used for placing these PV panels. And that particular panel is

the power generator being supplied to the grid. So, first PV irrigation system installation was carried down during the 1970s and that was coupled with the pump to direct current motors. The DC motors were connected initially but now improvement has come that it is connected directly with the PV array that used to be there.

Now there is improvement it has been brought that it can convert from DC to AC. Now PV irrigation systems are composed of two primary and highly interrelated subsystems, namely the PV subsystem. And this is responsible for supplying the energy required and the irrigation subsystem which demands energy. So, for the PV irrigation system to perform properly the relationship between these two subsystems has to be established by applying rational and scientifically based methods.

Now when we are talking about solar PV systems in general it has got some advantages. One advantage which is very clear is that it is abundantly available. There is nothing like anyone has to pay for getting solar energy. It is pollution free, it is of low maintenance. The system is absolutely reliable and free from cost. Like we are paying money for diesel, we are paying money for electricity. So, from that point of view it is free.

It is independent from the grid and it has got a long life, about 25 years. This means the system can work and of course when we look from the 25 years whatever expenses we are making in the initial way, but over the year when we are working it will reduce the cost. Now when the pumping part is concerned from an irrigation point of view the PV pumping systems are gaining interest due to their numerous advantages.

They do not depend on the existence of an electricity distribution network which is a common problem in rural areas. The system is highly reliable. It means we can bring the portable electric generator to consume fuels and that is in the case of conventional systems. It means it pollutes the environment. So, those are the limitations of existing conventional ways of generating

electricity. Their design is simple. It does not necessarily require a battery bank. They have a long life or are highly reliable and require minimal maintenance.

Now a PV system or based irrigation system I will say that can be classified in two ways. So, one way of classification is type of power plant. This power plant can be stand-alone plant or this can be a grid-connected plant. So, when we are talking about hybrid system it could be and according to the type of irrigation system you are putting the tank at elevation point and direct pumping. So, here when we are talking about stand-alone plants you can see here that this is the stand-alone.

We have a PV panel then we have got the solar pumping system. The water is being taken with the help of a pump then water is stored and then it is being used for irrigation. So, the stand-alone plants are those that are not connected to the grid and it consists of a PV panel and occasionally a storage system guarantees electricity supply when insolation is low at night time. So, this can also be fed to the grid and then it can be used during night time.

Because PV produces direct current so, inverter is required. This is the important thing that you have to convert direct current DC to AC. So, an inverter is required. Stand-alone plants are advantageous in isolated areas where the electric grid is not near both from the technical and economic point of view. They can efficiently replace the generator set that is being used.

So, grid connected plants can draw power from the grid during the hours when PV generators cannot produce enough energy to satisfy the needs of the consumer. So, this is the advantage of the grid connected plants. On the contrary, when a PV system produces more energy than is required surplus energy which is generated from the solar PV system can be fed to the grid and we can store this energy in the battery also and that can be used. So, that is another advantage.

The different state governments when the particular unit how many units it has been given there it is the users are getting the advantage of the electricity supply or metering chart. Hybrid system

can have both a PV plant as well as the conventional source of energy when the electricity supply is low then the hybrid system can also be used. Both types of system can be utilized.

Pumping to an elevated tank. So, here storing the water in an elevated tank means it is a very simple thing. Then water is taken from the source which is at the lower elevation and then the solar pump. So, a PV operated pump is used to feed water which is at the higher elevation. So, that is the one way and then by using the gravity system the irrigation can be done. Direct pumping that is a stand-alone direct pumping is what you see here.

There is a solar panel and then this pump is connected with the panel and then water is being supplied and then irrigation is given. So, this method needs matching of energy production with irrigation demand. That is a very critical issue and where enough information and data are to be analysed for a place and accordingly the design has to be made.

Now the photovoltaic irrigation system consists of a photovoltaic PV power plant. It has got a power controller, it has got pumping unit, it has got irrigation system. So, the main components of a PV power plant are it has a PV module, solar trackers. So, PV module that you already might have seen, it consists of an array of PV cells and these cells are connected to form a circuit in series or in parallel to increase the output voltage and current up to the desired value. So, main feature of the PV array is to produce direct current between its two terminals when they are illuminated by solar light.

So, several characteristic points are to be distinguished on this curve. So, one is the short circuit current, the current that is obtained from the cell when the voltage at its terminal is 0. That is $V = 0$. Open circuit voltage, the voltage for which current drawn from the cell is 0, $I = 0$ if the device is kept in an open circuit. It will self-polarize with a certain voltage that is the largest. It can withstand the generation region.

So, we can say that it is the voltage to open circuit which we are given by symbol Voc. It is the maximum voltage achieved by a solar cell in silicon cells. Then peak power is another term which is important. This peak power is the power supplied by a direct current motor. The power delivered to the load when P equal to I into V. And there will be operating point where we will get I maximum and V maximum. So, that point is to be taken for a particular solar insolation when we are getting it.

This is I-V performance and when we are plotting the data you can see this is cell current, this is cell voltage and what we are seeing is the maximum power area which is falling and this is the point at which the voltage is also maximum. And then I maximum, this is also maximum at this particular point. So, we select ideal condition for one solar day that is 1000 watt per square meter.

For this particular case this is the case this kind of a thing where I maximum means maximum current and maximum voltage is obtained.

Fill factor that is FF is given by

Voc is the open circuit voltage and Isc is the short circuit current. So, this particular ratio product of this divided by this gives the FF and then sharper the characteristic curve of this cell that gives the higher value of FF and PP. That can be given by

And this gives your PP value. Now energy conversion efficiency is another term which is important for all our calculations. So, this efficiency is given as the ratio between the power delivered and power input. This is your input power. So,

So, I-V curve can be fitted by using the following equation which is given by

Where,

e = the charge of the electron,

m = the diode ideality factor $1 < m < 2$,

k = the Boltzman constant

T = the absolute temperature.

So, this way I-V curve can be obtained by using this expression.

Now photo voltaic modules arrangement. These modules arrangement are arranged into different series-parallel or parallel-series combinations. So, this is what we see here. You can see here the arrangement is in a series order. But when we look at this one this is in the parallel part. So, how the voltage is increasing when they are arranged in the series and the current is increasing when going in, they are arranged in parallel.

So, set of modules with its own connections, framework, this constitutes the PV generator. So, by using this expression which I will not read is available here.

Where,

N_P = no. of module in parallel

N_S = no. of modules in series

V_G = Generator Voltage (V).

So, using this expression one can find out what is the value of I_G. So, number of modules in parallel means we will calculate how many number of modules are in the parallel arrangement, number of modules in the series and then the generated voltage that will also be used to obtain the value of I_G.

So, another important part to get the maximum energy is solar tracking system. Basically, solar tracking system is the system at which maximum solar insolation should fall on the solar panel. So, the mechanism involved is the part of tracking which is responsible for providing the follower with precision in tracking. So, this could be one-axis tracker or it can be two-axis tracker, idea that what type of mechanism it follows can be single-axis or two-axis tracker.

So, here you can see this is a one-axis tracker. So, north-south horizontal axis tracking where this north-south and this c = 90 degree. This is one way and then another one is by taking the polar tracking. So, north-south polar axis tilting is performed. So, rotation is adjusted in such a way that tracker follows the meridian of the earth that containing the sun. So, this way the angular velocity is maintained at 15 degrees per hour this way this will be moved along with the to track the solar intensity it is then both in the northern latitudes and in places near the equator.

So, we can see here east-west horizontal tracking. This is another way of tracking where maximum energy can be generated. So, rotation axis is placed parallel to the ground in east-west direction. And this is done in such a way that it should follow the sun at its altitude angle and then the position of panel every day due to the sun declination. So, this way we follow the east-west tracking.

Azimuthal axis tracking is another way of tracking. So, there are different tracking system which is followed to get this. So, you can see here when we are doing the azimuthal axis tracking. In this system the tilting angle of the surface is constant and equal to the latitude of the place. So, this way the azimuthal axis tracking.

Two-axis tracking.
In this case of two axis tracking, we can see here the maximum energy collection can be achieved because due to its total freedom of movement. So, this type of tracking also it is also known as dual axis tracking.

Driving motor is another component. Here the most common driving mechanism is an electric motor because it allows simpler and precise control of the movement. So, alternative current motors are mostly used than the DC ones. Now DC ones are normally converted to the AC motors. For one-axis tracker only one motor is required or when we have got two axes, tracker and then two motors are required.

So, solar tracking control and this could be a feedback type of control where the sensors are placed to detect the energy depending on the particular type of insolation condition, cloudy conditions. So, based on the photovoltaic sensors which are used are giving feedback accordingly.

Open loop controller is another kind of device. Here this control technique uses microprocessor but it does not need any sensors to determine the position of sun. So, movement of the sun can be predicted by astronomic equations. Those equations are utilized to get the position accordingly this open loop gives the input information.

Then there are other ways to install the system. So, one side of greenhouses can be used to collect the electricity and the greenhouses become self-sufficient to operate. There are different units inside the greenhouse for irrigation purpose, for operating forgers and other devices.

You can see these are the roof of the bigger greenhouses where this greenhouse's roof can be used. Now such type of installations these are available in plenty in the rooftop as well as bridges, tunnels, canals are also being covered by using the solar panels.

So, we have discussed these topics in detail. And then for more details you are advised to refer these references to go into detail about the solar PV system.

So, in order to summarize the whole lecture, we discussed about the importance of solar energy. We discussed about the different energy sources which are used for irrigation purpose. Solar PV system, its concept, and how does it work, and then classification and components of solar PV system. We discussed about the different types of tracking system and controller. Now in forthcoming lecture we will discuss how to integrate solar PV systems with irrigation. So, this will be in the next lecture. Thank you very much.