Indian Institute of Science

Design of Photovoltaic Systems

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When one things of storage batteries or the component that comes to mind of course batteries are the most popular and efficacious and is sold in almost all the electronic gadgets and energy systems where energy storage is used, however in large energy storage systems energy systems you will find people have used other mechanisms for storage too, it is good to be aware of what other people have used for storing energy or systems that can act as energy buffers apart from battery type of systems.

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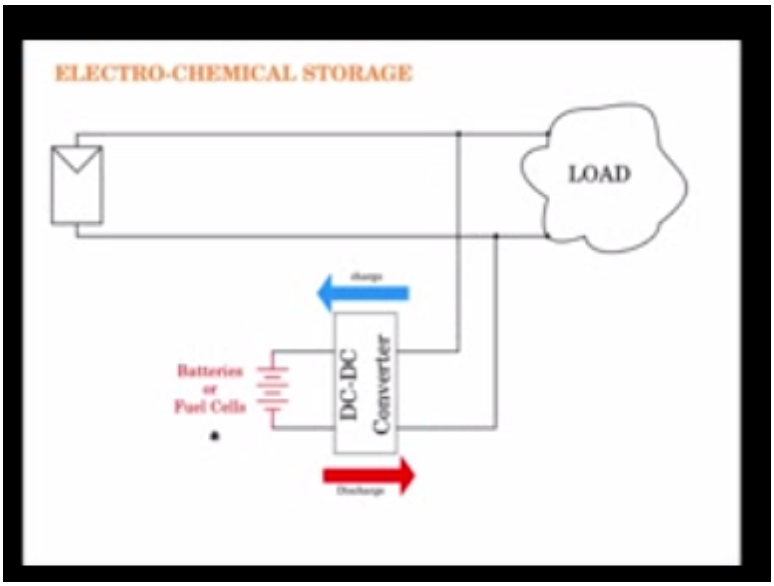

So generally in the case of a PV system we have a PV panel like this and that is connected to some load, energy is flowing from the PV panel to the load however we know that due to varying insulation the energy output of the PV panel is not constant throughout the day it keeps

fluctuating varying and therefore the energy that is received to the load is a fluctuating energy and therefore we need to have some kind of a buffering mechanism.

Where when the insulation is high the energy excess energy can be stored somewhere and when the insulation is low the energy which is stored in the buffer will supplement the PV panel and see to it the load gets a fixed amount of energy, therefore we connect an energy buffer at this point the point at which it can supplement along with the PV panel so the energy buffers in general will have an interface block here and this interface block will connect with the actual energy storing device.

And we will call that one as the energy buffer and this would be called as the our interface, so generally this power interface has to be my directional in both power and the energy flow so it should be able to charge so whenever there is excess energy available from the PV panel during high insulation conditions and low load conditions the excess energy has to flow through the power interface into the buffer and that is called the charging mode.

And during the discharge mode that is when the insulation here is low the energy is not sufficient to be able to handle the load the excess energy should come from the buffer to discharge the buffer should discharge and then deliver that to the load so that that supplements the energy coming from the PV panel so that the load gets its quota of power and energy, so in the case of batteries the energy buffer here is a battery.

And for the battery to interface to this here you have DC and the battery is also DC the interface will be a DC- DC converter a bi-directional DC -DC converter so we will have a battery here and it may be a battery or even fuel cells so the energy is actually stored in the chemical form so you have the electrical energy here gets scaled and then the electrical energy is stored within the battery in the chemical form.

And then when you want to bring the energy out when you want to discharge the batteries the chemical stored energy is check converted to electrical within the battery and the electrical energy discharges into the load is an electrical power so this is the electrochemical storage mechanism which we are familiar with which we have seen, let us now see a few other mechanisms which follow a similar kind of generic topology.

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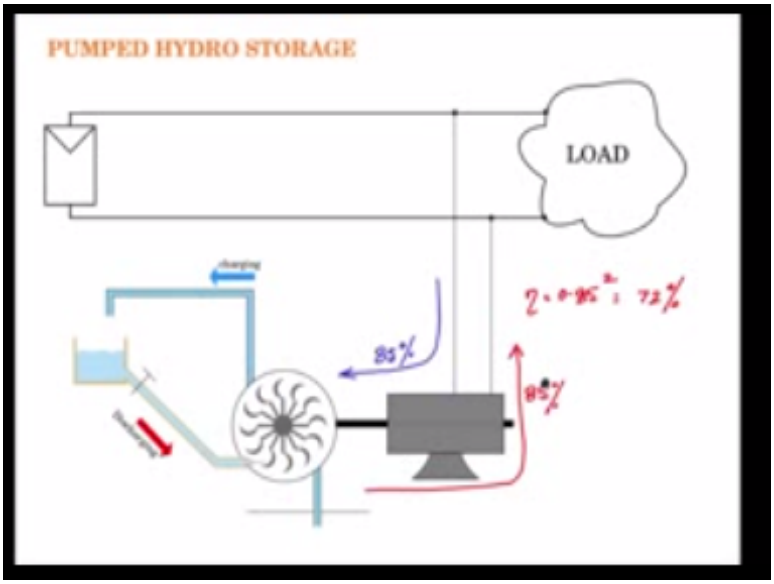

Another energy storage mechanism is called the pump hydro here the energy is stored by virtue of lifting water to a height and storing it as potential energy, so let me now show you the components that come within the system and then we will see the various modes that the charging mode and the charging mode this is a motor the electric power here will drive the motor and convert the electric power to mechanical power.

And this motor is connected to a pump so I have just indicated this pump here a peloton wheel based pump but it could be a centrifugal pump or reciprocating compound depending upon the application, so this pump will lift the water which is down below in a sump let us say, so this water will flow into the pump and then out of the pump here into an over a tack, so what this pump has done is taken water from below the ground the sump and then lifted the water and then put into the over a tack.

So it could be lifted from a well as well and then put into a reservoir which is at a height so in general we are trying to lift the water and put it at a higher potential so that the water stores the energy in the form of potential energy, let me mark the base level from which water is to be lifted and let me indicate that by H variable H then if there is a mass of water which is getting lifted from the suction pipe and through the delivery pipe into the over a tank MGH is the amount of energy that has been given into this water as potential energy to be stored.

Now this MGH amount of water which is lifted up and stored there is coming from this pump which is getting driven by this motor and this motor is getting driven from this DC bus which is getting the energy from the PV panel, so the excess energy from the PV panel is driving the motor and then the pump which is acting as an instrument to lift water give it the potential energy and store it here as MGH.

And this mode is called the charging mode, this mod is called the charging mode now let us look at the other mode also when the power is needed by the load and then we need to discharge the energy through this mechanism into the load, during the time when we need to discharge energy MGH energy stored here into the load here we need to have a pen stock a pen stock like this so you open the valve this valve can be electronically controlled depending upon the load requirement.

When we when the power delivered by the PV panel is low the load will have to draw from here at pitch time electronically automatically this valve gets operated and released and what will flow through the pen stock and in the form of a check will fall on this tendon wheels and this will now act as a turbine and this turbine will rotate the shaft of this machine this what was supposed to be the motor and this motor will now act as a generator and pump energy into the bus and thereby to the load.

So you can discharge the energy that was stored hereinto the load in this fashion, this is called the discharging mode. So this pump will now be here as a water turbine in the discharging mode this will act like a water turbine and the discharging mode the motor will now behave as a generator so it will generate as a DC generator generates it and puts energy into the DC bus during the charging mode there will be some loss in the motor there are also be some loss in the pump and also in the suction on the delivery heads.

So you will see that about 85% efficiency is the practical value likewise again during the discharging process there will be some loss in the turbine and there will be some loss in the generator before pumping the energy into the while pumping the energy into the DC bus so another 85 percent would be a practical value so the overall efficiency of the charge and discharge cycle of the energy buffer system is 0.85 square which is around point72% 0.72 or 72 percent. So you saw that even in the case of the battery buffer the efficiency of the battery electrochemical storage system is around 70 percent here also it is around 70 percent.

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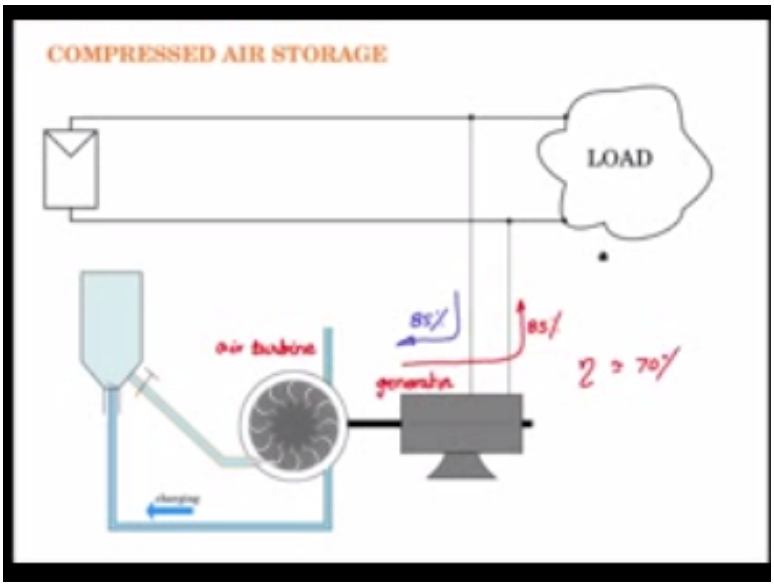

Another energy buffering mechanism is the compressed air storage mechanism, here the energy is stored the excess energy from the PV panel is stored in compressed air by virtue of the increase pressure, here again we shall use a motor which converts electrical energy into mechanical energy at the shaft and the shaft of the motor is connected to an air compressor the in compressor takes in the ambient here atmospheric air compresses it and puts it into a container through a non-return valve.

So it will push the compressed air into this container and the pressure within the container keeps increasing at a constant volume and you store the pressure in the form of P into Q pressure into the research volume, so in this way you can charge up this compressor by taking the energy the electrical energy excess energy from the PV panel acid through the water converted into mechanical and from the mechanical to hydraulic pressure and push it into this container and this is the charging process or energy storage process.

So the energy stored layer 2 of the pressure and the discharge volume Q and the instantaneous power can be controlled by the discharge rate so P Q dot will be the power P Q dot means P QDQ/ DT note that during the charging mode this device is acting as a motor converts electrical energy to mechanical energy this device acts as an air compressor converts mechanical energy into hydraulic energy and stores the energy by virtue of the increased pressure of the air.

In order to discharge the stored energy into the load we need to have an outlet an electronically controlled valve here and the Discharge rate of the exit is controlled by a nozzle and an air turbine is used to convert this energy in the compressed air to mechanical energy in the mechanical energy to the electrical energy through the machine which now acts as a generator, so that would be the discharge mode.

So compressed air here by means of this electronically controlled valve will operate an air turbine and the air turbine converts hydraulic mechanical energy the mechanical energies convert electrical energy through a generator here also there is loss of energy while charging putting the energy into the hydraulic form there is around 85% efficiency there is loss in the motor and also in the compressor.

And while discharging also there is around 85% efficiency there will be loss in the air turbine and also in the generator while transforming the hydraulic pressure into the electrical form, so the overall efficiency here again will be around 70%.

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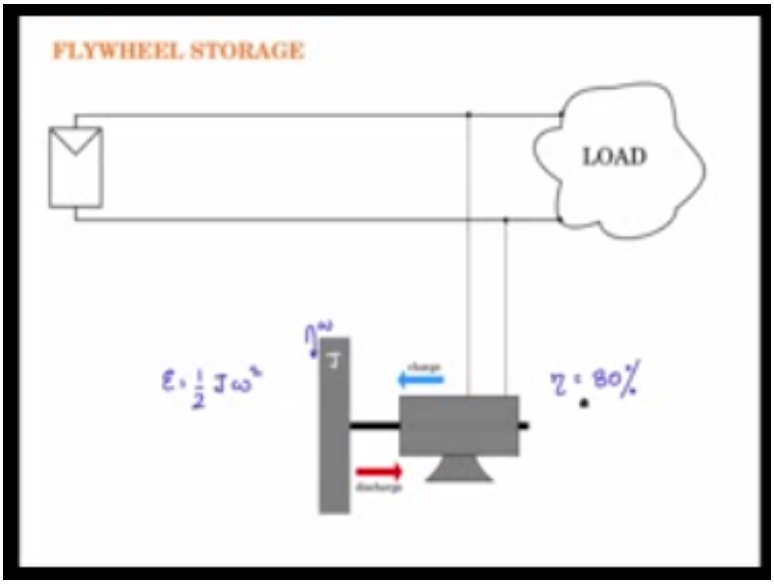

Another storage mechanism is called the flywheel storage mechanism it is becoming a very popular method for storing energy of buffering energy the principle is very simple it stores the excess energy from the photovoltaic panel by virtue of the kinetic energy of the flywheel which

is rotating at a speed Ω, so let us use a motor like this which converts the electrical energy into the mechanical energy and to the shaft of the electric motor let us connect a fly wheel of some particular inertia.

So while we charge that is energy from the PV panel goes through the motor into the mechanical shaft and stores here by virtue of increased rotation the flywheel kinetic energy is increased and you will see that that is charged up by having increased rotational angular speed and then while discharging the energy stored in the flywheel the inertial energy that is stored in the flywheel is passed on to this machine now which will act as a generator and puts it into the load.

So the flywheel is having an inertia J and rotational speed Omega in radians per second then the energy contained within the flywheel is given by ½ J ω^2 so if the motor shaft speed increases then the flywheel speed Omega will also increase and thereby its kinetic energy will increase by Omega squared the differential omega square and that is how the energy is stored within the flywheel and when you want to discharge into the load the ½ J ω^2 the flywheel speed will decrease and release that energy into the motor which will release it into the load.

So this is how the final storage mechanism operates and here again you will see that there is the efficiency of the motor that comes into the picture so this will have an efficiency of around 80 percent so this system allows overall efficiency in that order because it is just one component that will come in to the picture here which is the motor and directly to the shaft of the motor the flywheel is fixed so you can expect practical efficiencies of around 80 percent in this system.