**Indian Institute of Science**

**Design of Photovoltaic Systems**

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**NPTEL Online Certification Course**

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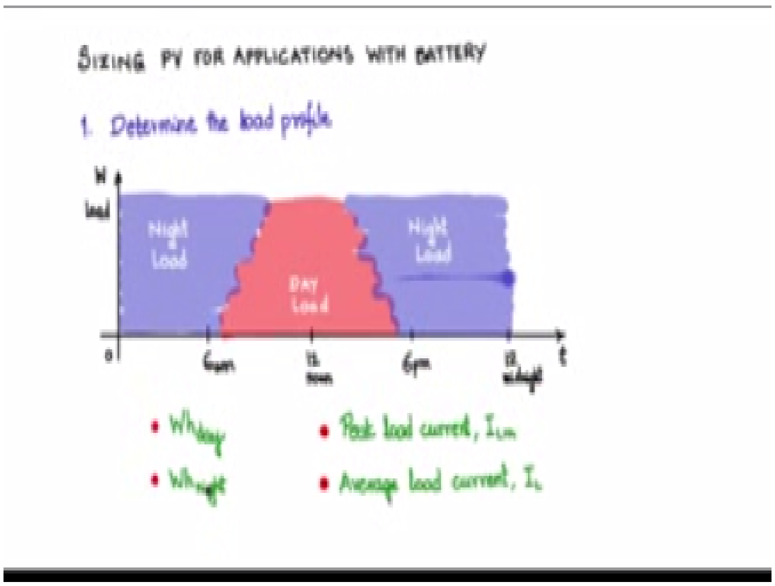


Now let us see how we go about sizing PV for applications with battery, we had already looked at sizing PV for applications without battery, now along with battery what are the modifications and extensions that we need to do in order to select the size of the PV balance. The first step would be to determine the load profile, this is a very important step it in fact will give us an entire picture of the Vltava requirement for sizing the PV and also the battery. By load profile we have to look at what are the types of loads that occur over the entire day and at what times of the day.

So let us draw a graph of on x-axis time in hours from 0 to 24 hours, so we have 6 a.m. we have 12 noon here, 6 p.m. midnight, 12 midnight, so this also will be 12 midnight, so you have 0to 6 a.m. the night then 6 a.m. to 12noon, 12 noon to 6 p.m. and 6 p.m. to 12midnight covers the entire 24 hours of the day and on the y-axis let us have waves of the load so that actually this whole graph should give you the profile of the load or the entire T. We shall split the entire day into two parts one part where the solar PV panel will supplement the load solar PV panel and battery both together will be powering the load.

Either PV panel will be supplementing which will be the battery will be dominating or in high insulation condition, that PV panel will be battery will be supplementing which of the case both the PV panel and the battery are active that we shall call it as a day load and the other type is called the night load. The night load PV is out of the picture there is no insulation PV does not contribute anything the entire load is supported by the battery. So this portion roughly around 7 a.m. to 5 p.m. will be the portion that we can consider as a day load even at 6 a.m. sometimes okay Sun is just rising and what you may not receive significant insulation and even during at this time zone where Sun is setting you may not have significant insulation.

So around 7am to 5 p.m. we can consider as day load all the loads occurring during that time and during the remaining time, we will say this portion from 12:00 midnight to sunrise and from sunset on to 12:00 midnight they all will be considered as times, where night load occurs. So we will write this down as the period where day load happens and here this time duration any load will be considered as night load and here to in this time duration any load will be considered as night load.

After having done the load profile over the entire day for a given application they take away out of this exercise or we need to have got the Vltava of the day as all the loads occurring during this period we need to have got the Vltava of the night the night load, which is all the loads occurring during this period and this period put together, we also need to get what is the peak load current useful for battery design and we will mark it as we will give the symbol ILM I load max we also need to have the average load current during the entire day again helpful in designing the battery, the average load current will just call it as IL.

So this these parameters ILM and IL will be used for designing the battery along with of course the Vltava requirement for the load, Vltava requirement of the day and night we will use for determining the or sizing the PV panels.

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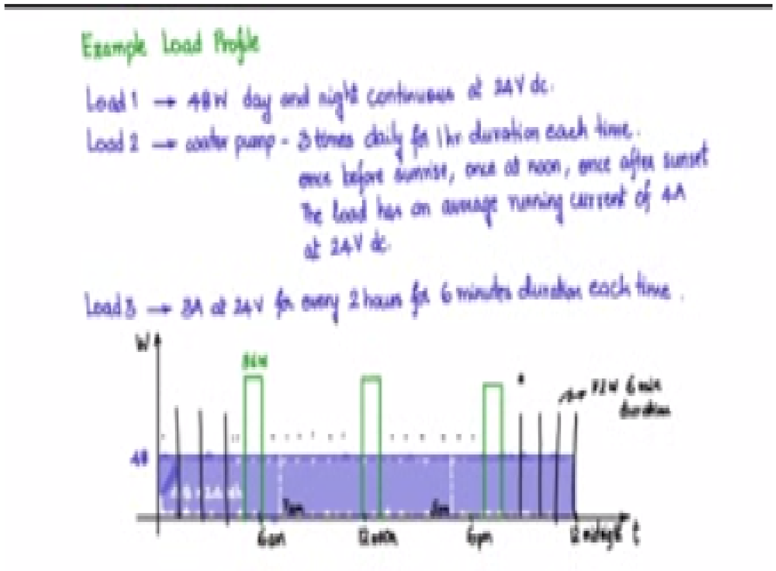


Let us consider an example on determining the load profile, so let us say that there are three loads one of the load one is having this character it is having 48 volts 48 wax and it is a day and night continuous load, it occurs on all times of the day but and it has a fixed set of wax of 48, so this much amount of power 48 back power continuously now load 2, let us say is a water pumping device. So it is it is switched on three times daily for one hour duration each and it is switched on once before sunrise, once at noon and once after sunset.

The load has an average running current of 4amps at 24 volts DC, so this is the character of load to note that load one also is operating at 24 volt DC, so it is having 48 watts day and night continuous load at 24 volt DC let us mark that also at 24 volts DC. So that the voltage is also defined for the load 1 and load to load 3, now let us take the load 3 it is a 3 amp load occurring at 24 volts DC, for every 2 hours that is switched on for a period of 6 minutes only. So 6minutes every time it is switched on but it is switched on at regular intervals of 2 hours throughout the entire day.

Now let us draw the xy coordinates of the load profile, the x is x axis is time in hours of the day let us mark 6 a.m.12:00, noon 6 p.m. and 12:00 midnight they axis of course is rate load words now. First let me mark load, this is 48 whacks the is corresponding to load 1, so this is 48 watts and this entire area 48 watt x 24 hours will be the VAT hours consumed by this particular load one in a day 48 x 24 hours now, let me mark this as the daylight zone or the day load zone. So that is somewhere around 7 a.m. in the morning to5:00 p.m. in the evening so between this time this 10 hour duration let us consider that PV panel is active and participating in delivering energy to the load apart from the battery.

And during this period we say this is night load this is also night load where only the battery is participating. So this is about load 1 now let us see load to what 1 water pump is 3 times daily for 1 hour duration, each time and once before sunrise ones that known and after sunrise, so it is having a running current of 4 amps, so 4 amp into 2496 VAT instantaneous, so let me incorporate that now let us say this is 1 hour duration and that is 96 watts height. Now this is before sunrise like likewise I should have one at noon and one after Sun set so load 2 is taken care by these 3rectangles, height 96 watts and each duration 1 hour duration.

So you have 96 Vltava 96 hours and 96, 5 hours here now load 3 is a 3 amp load for every 2or 6 minutes duration, so it is distributed throughout so you will see spiky lines like okay that is 96 verse you will see spiky lines like this throughout the day I will not part these spiky lines throughout otherwise it will distort the graphs, so each of this line spiky line here represents 72 waxes for 6 minute duration and occurring every two hours throughout the entire day.

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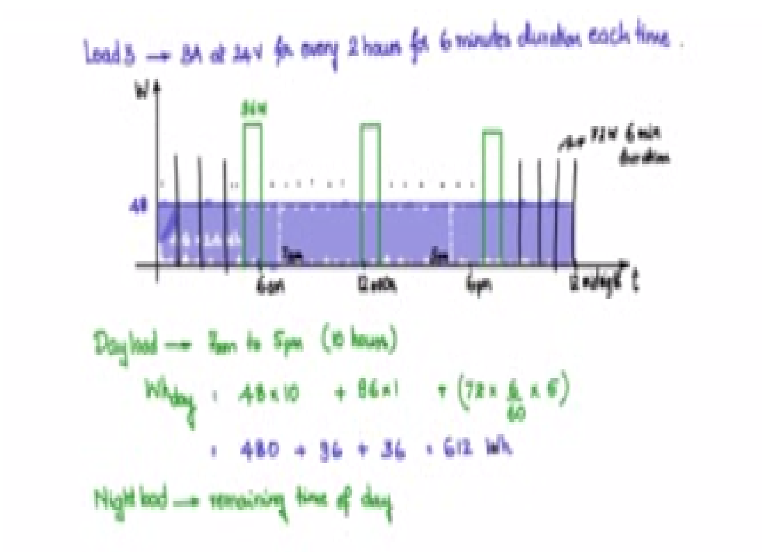

Let me move up the board and now let us calculate what are the day night loads, for the day load now day load we have defined the day to be 7:00 a.m. to 5:00 p.m. of course at different latitudes different places sunrise to sunset can be different, you should appropriately choose that, so we have here a 10 hour period which we consider as day load from here to here. So what are the loads that are occurring during the day time period as we have defined, so what hour day you have 48 x 10, so this 48 workload is occurring constant for a 10 hour period, so this is the idea we need that + this is 96 volt water pumped load 2, so this is 96 x 1.

There is only one rectangle in the day time period + these 72 volt spiky line, 6 minute duration you see between size 7 a.m. and 5 p.m. if I calculate every two hours you will have five such spiky lines here, so 72 x 6 / 60 I have converted minutes to hours to have consistent units x 5, so there are 5 such occurrences of this load here, so when you can play this for 80 volt hours + 96 hours + 36 hours which is 612 Walt hours so 612 at hours of day. Now let us calculate the night load, so the night load is for the remainder of TD and it contains off 24- 10, which is 14 hours for our case here.

Let me move up now let us calculate overnight which is equal to 48 x 14 + 96 x 2 +72 every 6 minutes 7, so totally every 2 hours the spire the 72 at load will occur for 12 times, so 5 is considered in the day load the remaining 7 will be considered in the night load and this when you calculate it 672 hours because192 whatever specifically 0.4, so you have 14.4 Walt hours of night load, this + this together will be whatever's for the entire day.

Let us now calculate the peak load current, the peak load current is now you see that for load one is contributing 48 wax divided by the voltage 24 volts, will be the lower will be load current contribution of that load 96 / 24 volts and 72 / 24volts.

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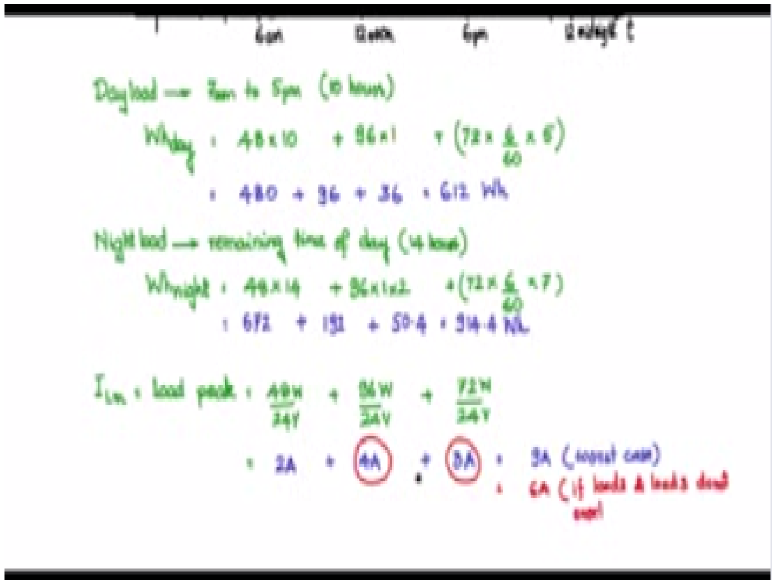

Let me move it up a bit so you have two amps contributed by load 1, 4amps contributed by load 2 and 3 amps contributed by load three which is totally 9 amps this is the worst case where all the loads can overlap, so then the battery needs to supply 2 amps plus 4 hands / 3 and all to this but you see that you can you can manage the loads you can do load management such that some of the loads need not overlap for example load 2 and load 3 need not overlap, you all that is mentioned for the constraint of load 2 is that it should be before sunrise.So you could always see to it that these two do not overlap in which case in which case the maximum worst case would be 6amps the battery has to discharge maximum peak load current of 6 amps under non-overlapping conditions, so if the load 2 and load 3 do not overlap.

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$$I_L = \text{Average load current} = 2A\left(\frac{24}{24}\right) + 4A\left(\frac{3}{24}\right) + 3A\left(\frac{(6/60)\times 12}{24}\right)$$

$$= 2A + 0.5A + 0.15A = 2.65A$$

Now let us calculate the average load current to because this is all the important in calculating ampere hours of the battery, so we will do a duty ratio based on the duty ratio 2 amps is occurring for 24 hours or for the entire day, so 24 / 24 amp the load 2 is occurring 3 times daily 1 hour duration, so 3 hours out of 24 and the 3 amp load is occurring 6 minutes / 60 cannot written into hours this is happening for 12 times, every 2 hours / 24 hours. So this will give you 2amps + 0.5 amps + 0.15 hands and this works out to 0.65 amps as the average battery discharge currents about the entire day, if there is no participation from the PV panel if the battery was even supposed to supply the load to the entire load for the entire day.