Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

PV and SUB-MICRO GRID INTERACTION.

Today is sub micro grids something like our campus something like you are campus small communities there are various types of sources renewal sources and non renewal sources that are connected to the grid and then they need to interact harmoniously so let us have a look at PV and sub micro grid interaction along with various many other sources that are linked into the grid.

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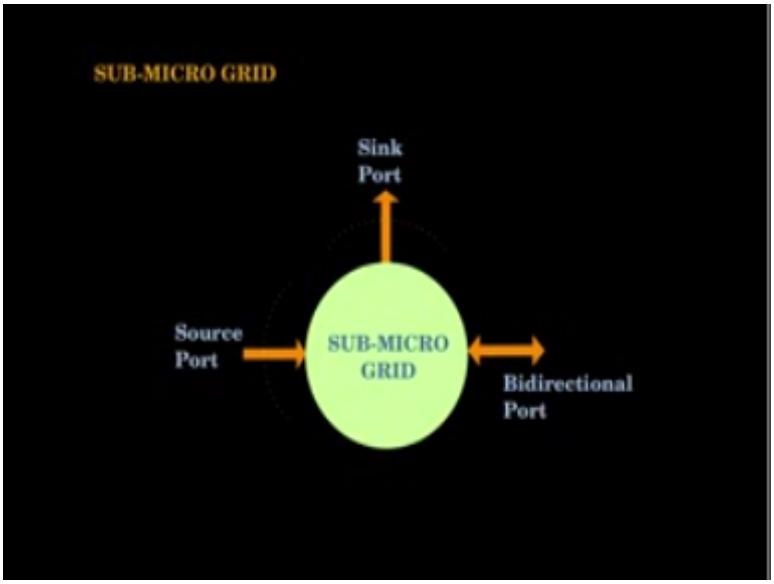

Now what is the sub micro grid now if you take a sub micro grid which could be a large building large community large campus schools, colleges they all come be examples of sub micro grids there is one important port in the sub micro grid the sources port, ports from where power is drawn input to the sub micro grid there is a sink port loads are connected various different loads

are connected to the sub micro grid and that is another important port and then you can also have bi directional ports like the battery where at under some condition it is pumping energy to the grid and under some condition drawing energy from the grid for charging there could be many sources ports and there could be many sink ports.

And the sources and the sinks can be from different energy domains so in sub micro grid today sub micro grid these are some of the challenges that you will see there are different sources before there was a single source coming from the grid well defined but today there can be PV on the building there could be a small hide system that could be wind mill on the roof all this pumping energy into the grid there is a regular means grid also pumping energy into the grid and then the various loads batteries and ups which sometimes give power take power all this are complex systems that are connected to the grid.

So you have multiply sources from sink and sometimes in this cases the bidirectional ports we do not even know which is a source which is a sink at a given point can be source at a given point in time it can be a sink so all theses aspects and still how to maintained quality of the grid can the grid have TSD less than a particular value and it maintain the wave shape can be provide inject power into the grid at unity power factor can we draw power from the grid at unity power factor.

And extensibility of this sub micro grid can if there is not much load requirement in my building let us say a neighboring building needs load can you transfer some amount of power from this building to the other building these are extensibility issues that will come in so the sub micro grid is growing area also linked tightly with the smart grid smart grid area let us look at some of this issues and we will take in this case the help of integrated magnetic for an example case.

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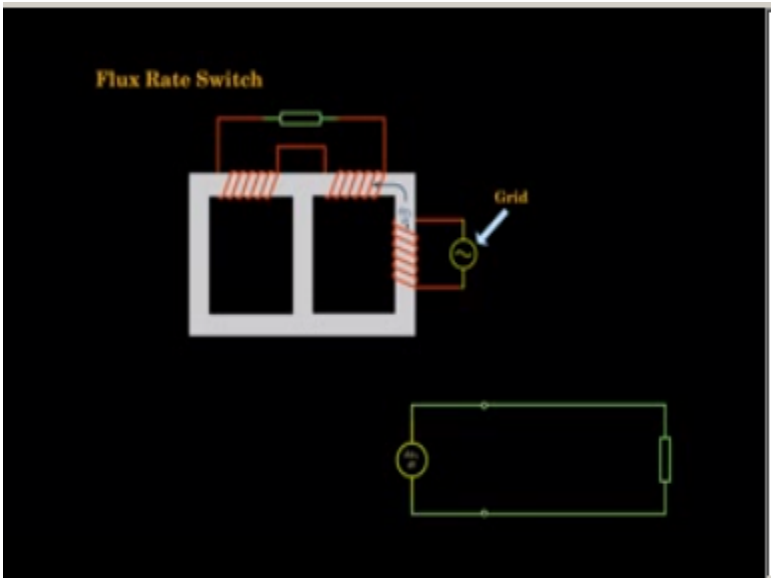

Consider this flux rate switch it is a magnetic switch now let us see what it in an and how does it work now consider at core in the fashion so this is an EE core 2EE core jointed together and let us say I have put some winding on the arc and likewise I am going to put some distributed winding like this across this now across this let us connect the grid so if you connect the grid I am imposing a voltage a fixed voltage it is voltage source across this terminals so magnetically what is happening so this is a magnetic equivalent circuit what I am trying to draw here so inside in the magnetic core magnetically there is a $d\phi/dt$.

So if the voltage is fixed into the magnetic domain by the faradays law $v=nd\phi/dt$ n is been fixed $d\phi/dt$ is directly linked to the voltage so the voltage sources on the electrical side so it is like in the magnetic domain I have a $d\phi1/dt$ source now across this terminals I will connect the load some load some magnetically also it will look as though I have connected a load across here so $d\phi1/dt$ which is the flow, flows through this magnetic circuit through this coil it divides part in this fashion and part in this fashion.

So according there will be a induced EMF here and induced EMF and together the electrical domain they will have an impose on the load now I will induce one more coil on this arc I will introduce another sources here like this which is going to provide $d\phi2/dt$ so equivalently it will look like this for load it is having a voltage here propositional to $d\phi2/dt$ another voltage propositional to $d\phi1/dt$ and they both add up and it is a coming across this sources so that is what is happening here now let us say I include one more winding here can I import one more winding

now here dϕ1/dt is being decided by this voltage sources here I cannot put another voltage source to decide another dϕ1/dt because this is passing well or dϕ1/dt can be decided by only one voltage source this is reflected.

So here I can place a current source and decide only the MMI and NNI,NI across this winding so therefore a current sources something this like can have same dϕ1/dt but it can be decide the NI that comes across this point across this winding so and there by the amount of current that I inject here so this could be like a current source so this can be a voltage current sources voltage controlled source this has to be a current controlled source so this gives us an idea of how we can use this magnetic element here now let us say I field in more current then the here the voltage is fixed the load is damaging power this will provide MMF which will drive power into this load.

And that much less can be taken from the grid so both these units can supply power to the load and in the third component here the voltage controlled source can also supply power to the load so let us see how we can make use of this concept so looking at this equivalent circuit and this voltage control sources is affecting this series sources component so therefore I can say this is a series compensator this will compensate the dϕ2/dt series part this series EMF and this is a stunt compensator this will come into effect on this component here and therefore it can draw more current or give out more current.

And therefore it can behave like this shunt compensator now let me take the case of just only the two source one is the series compensator which is a voltage control sources and there is script now for the moment let us say that the grid is switched off so the grid is not done and let me induce one more winding into the central or here and I will put a switch there direct one simple single pole simple through switch.

Now if you close the switch the voltage across that is 0 v=ndϕ/dt therefore the dϕ/dt here has to be 0 because n is not 0 so once the dϕ/dt is 0 here it is as though this core arm has vanished although it has been switched off so this is the concept of the flux rate switch when I short circuit a winding here the other winding should exist so that there will be transfer of MMF and dϕ/dt to the other arms there should be a path just like inductance previously in that case when you short this dϕ/dt for this arm becomes 0 and this is out of the picture now as though it is only these whole core.

Now the grid is not there this will be supplying the entire dϕ/dt in this single similar to a u type code so this entire core only the voltage equivalent dϕ/dt corresponding to this voltage equivalent will be circulated and also the load is connected directly to this so as though we grid portion is shorted on to that condition let us grid as gone off this source can power the load.

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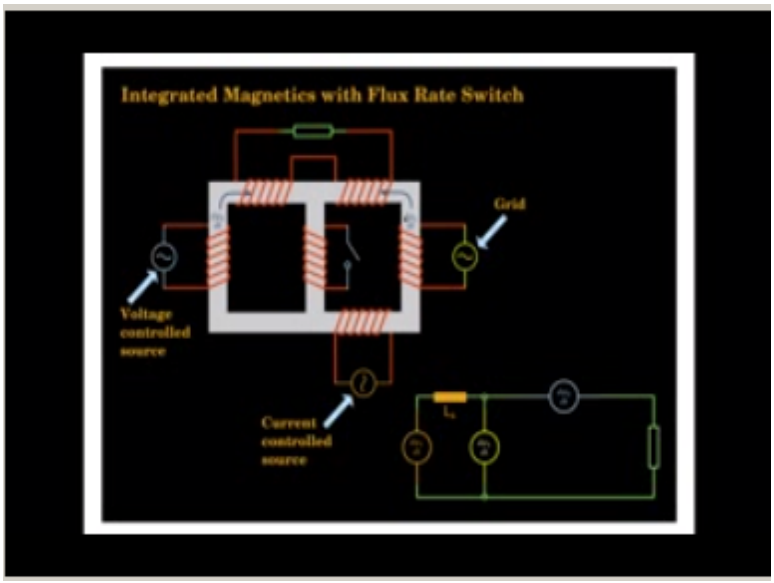

So this is the entire integrated magnetic scheme the basic principle so I can have a current control sources and the grid in one arc and they can share our and put to the put power to the load now suppose the grid goes off then I will use this flux rate switch their remove this arc from the picture then the current control source and the voltage control source can conclude their supply to the load so in this way you can make operate like a UPS when the grid is not there these two will be supplying to the load when the grid is there this will act like a series compensator and make it look like stabilizer and the stunt compensator the current control can be made to look like wall compensator this can current control source can take up all the reactive part of the power and the grid can give only the active part.

So once the current control source takes away the reactive part automatically only that active part is wrong from that grid so you can see that you can do work compensation with this current control source so these are the many uses that one can have in this kind of an integrated magnetic type of symmetric now there is no limit to the number of current control sources that you can put here you can put any number of current control sources here.

So this will be like many multiply sources likewise here also I can have any number of current control sources separately there can be only one voltage control sources the remaining can be current control sources that way one can compensate in the same core the power been generated and transmitted from other renewal energies other distributed energy resources to let us see how this can be used for applying for grid interaction.

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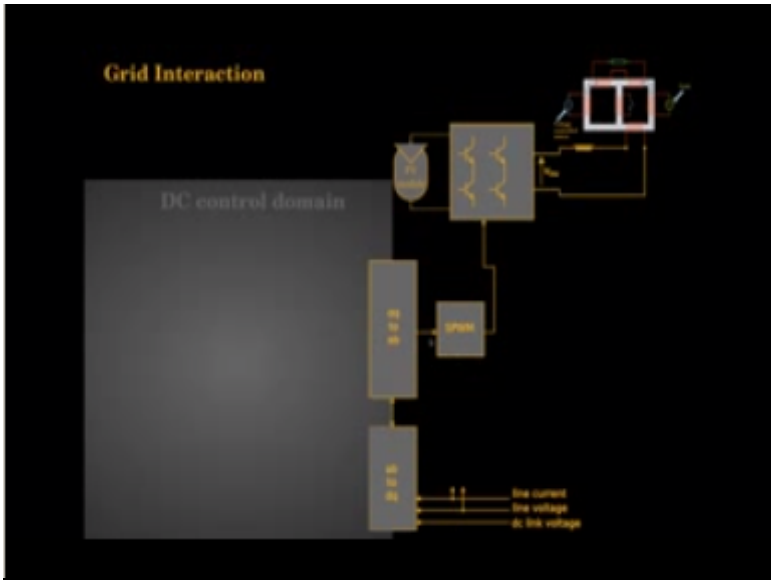

Now consider this integrated magnetic system and I am going to place it here there is grid here and I have a voltage control source and a current control source here and there is a flux rate switch and this is the load and to this current controlled terminal I have a PV module and the inventor and the inventor output through this terminal the control for the inventor is a speed SPP you measure the line current line voltages DC link voltages and then I can shift the AC to the DC we know how to do the transformation ABC to αβ or αβ to DQ and then here we are in the DC control domain thus as we discussed earlier and this sequence angle estimation can be done from the line voltages so I will have ISD,ISQ,VSD,VSQ.

And you could do voltage control or current control so if you have to do voltage control you need to have to extra controllers VS start VSD rape VSD is spread back VSQ rap and VSQ red back and ISD and ISQ the current control by another set of K controllers all these possibilities so

you could do MPPT can do unity power factor by setting ISQ 0 you can also do harmonic cancellation many possibilities for each of these inventors.

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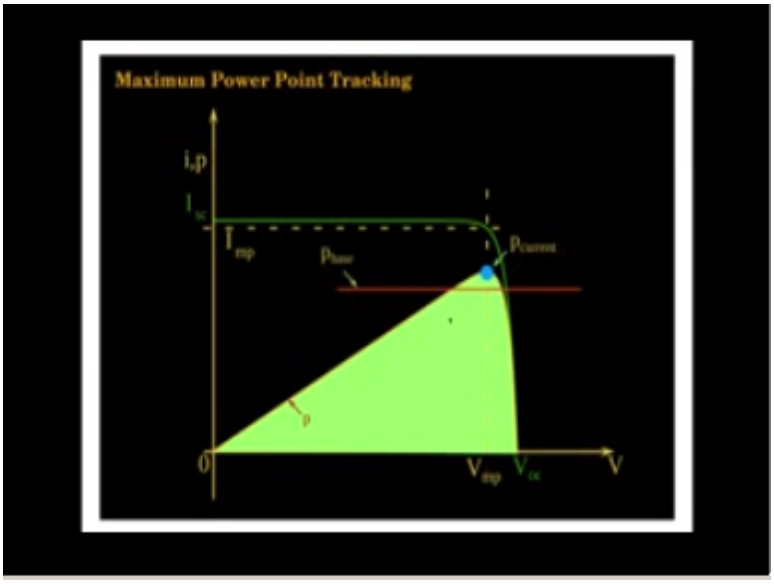

Maximum power point tracking how I induce it let us say we take one of the algorithms remember the hill climbing algorithm where we had a p base.

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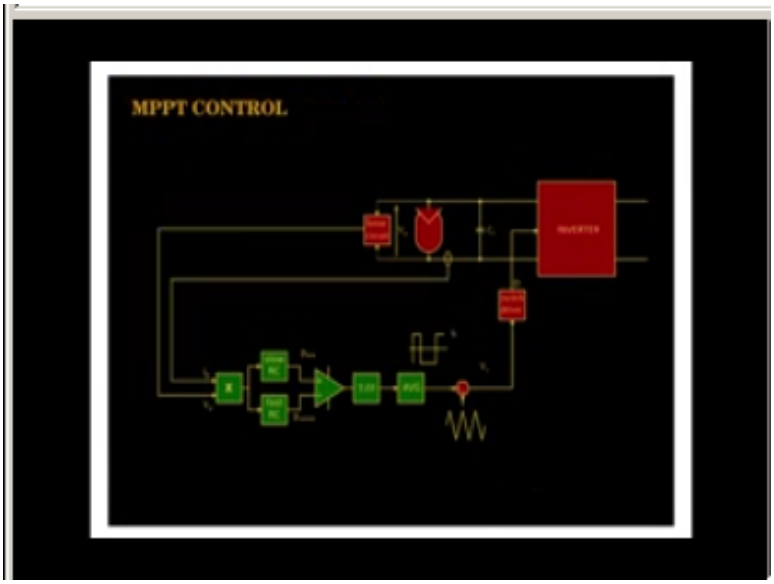

And the current value of P moving up similar algorithm so you sends from the PV sent circuit then you give the PV and IP slope RC pass RC to get the P base P current the past power and the

slow power using through the comparator we know this block diagram a toggle flip-flop averaging circuit comparing it with a carrier and then drive to the switch to the inventor so this is the normal thing but what we can do what we have been doing we cut this position and give this directly to be.

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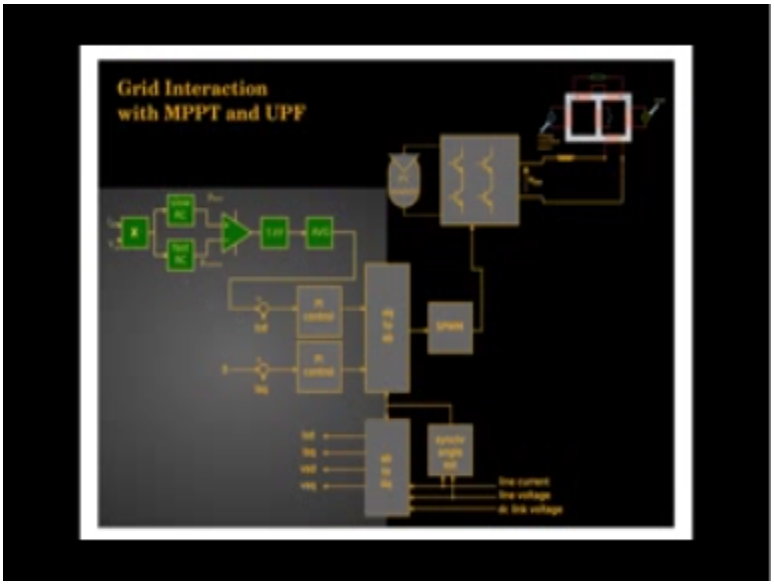

Current references so you see that ISD,VSD and this MPPT algorithm will come in here this is ISD star ort ID star and from this you have you know how to go back from DQ to abc domain DQ TO αβ, αβ TO ABC this goes on power of this inventor.

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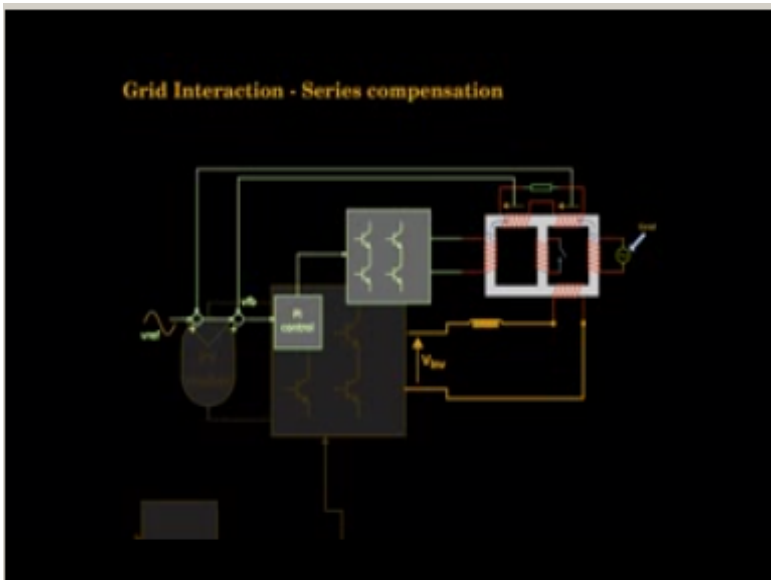

So once the inventor output voltage is according to our reference there is an inductor and then it interfaces at this point so this will be PV current induction so current controlled injection to this wielding there is already voltage defined by the grid so we also could do series compensation so we could have a inventor here and PI controller you can measure from the output and let us say we defined a pure sign like this and then we can take the feedback from the output here so this series compensation operates in this way now let us say the grid is not the full 230 volt.

And then it is probably distracted to now $d\phi 1/dt$ this is $d\phi 1/dt$ this is the portion which is coming directly from the grid reflection so you feed that here so this is the worsted grid representation this is what we want total pure sign wave so this minus this would be by how much the grid has to be repaired or difference by amount of which the grid has to be added in such a way that the voltage across the load will became pure sign wave so this tool for subtraction of pure sign and the distracted sign coming from the grid would be the difference make up that will become the reference here.

So voltage output here is actually coming from this inventor the series compensator this is $d\phi 2/dt$ so this is been fed back here and this will try to ultimately reach whatever this value is

which is actually the difference between the pure sign and the distorted sign coming from the grid so this value here will actually be making up for the difference so this difference which is made up by this plus the distorted grid will make the voltage across the load a pure sign wave in this wave series compensation can be achieved.

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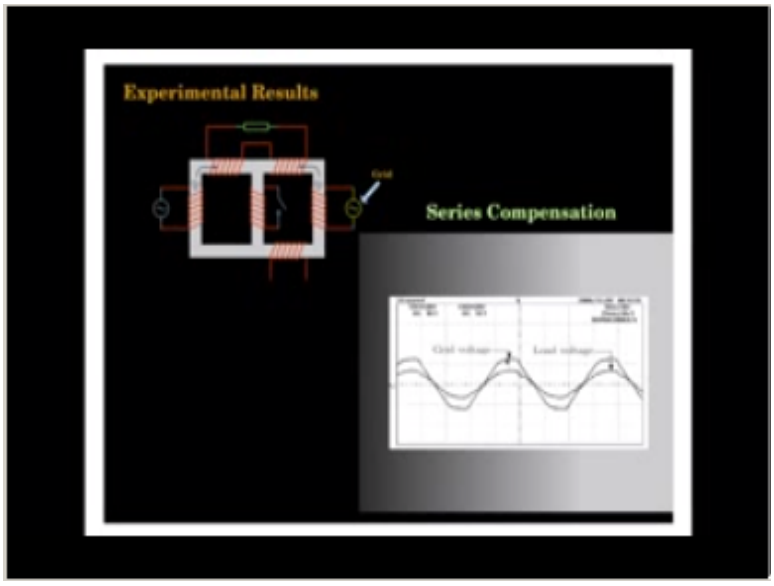

Observe here in the experimental result of this the grid voltage in distorted so the disserted voltage compared to the pure sign and the difference between them is actually used for compensating here and this distorted grid will make people voltage across the load to sign so that is what this voltage down old voltage and the difference between the distorted grid and the pure sign this is what you would see wielding this is across here wielding 4 this is the difference between the distorted and the pure sign so these two when added up will give the pure sign to the grid voltage.

And the load voltage operation of that flux rate switch so let us say up to this point we had the grid voltage than this was a voltage a series compensator was making up for the difference to make the load sign at this point the grid went off now this is taking up the full load because the flux rate switch as operated and removed this R out of the puncture and the whole wielding is coming across this series compensator which is now acting as the single and only source and providing the sign wave voltage to the load observe here that here there was no grid the complete

load was supplied by the series compensator voltage controlled inventor and at this point when the grid came into picture this switch flux rate switch opened out.

And then the grid is pumping power through wielding W3 and the difference power to make a core the distraction in the grid voltage is pumped through W4 and then this going back again to series compensator mode like a stabilizer so this would be Ups mode and this would be the stabilizer mode now stunt compensator effect you can see by having this current controlled inventor so without the compensation you would see that this is the grid voltage and then this is the grid current varies acting and reactive component now once this stunt compensation is enabled you will see that the reactive part is taken over by the stunt compensator and automatically the grid you will draw only the immunity power factor.

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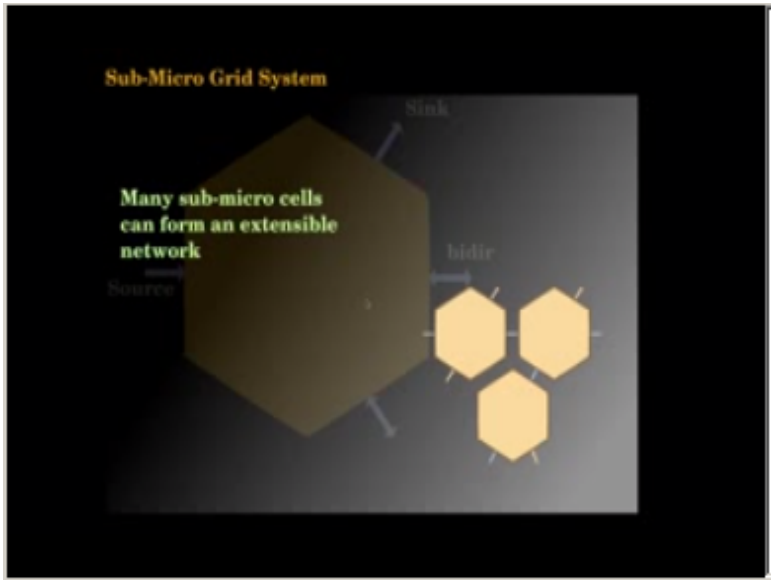

So you see that this integrated magnetic circuit can be a very nice contribution to the sub micro grip system I could have many sources current control sources here current, current sources here coming from different renewal energy resources feeding to the load which are connected here across and this could be the grid port so this could be one unit and then they could be many unit which is sink source by directional units and many such units can be integrated to form an insensible sub micro neck work something like power internet.