Indian Institute of Science

Design of Photovoltaic Systems

Prof. L. Umanand
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

NPTEL Online Certification Course

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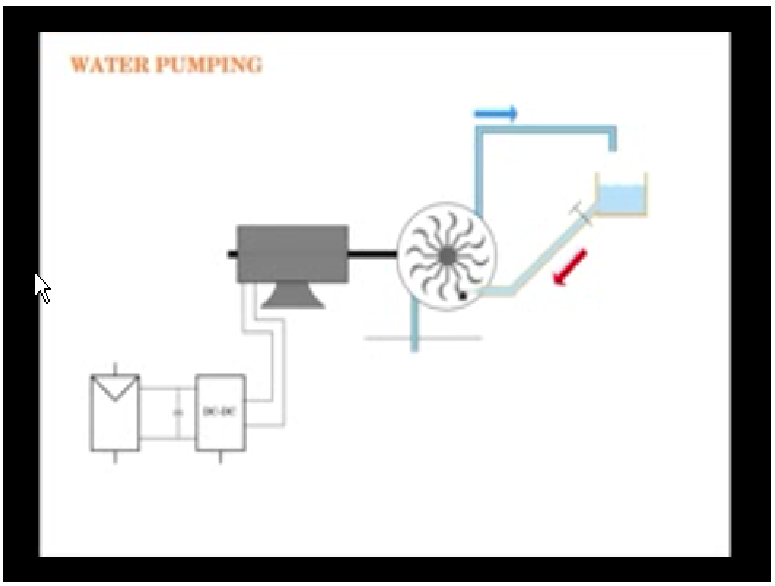

Another application of water pumping is in energy storage, recall in week 5 that we had discussed other forms of energy storage or pumped hydro was one of it. Here you lift water from the lower level to a higher level and store the energy in the form of potential energy, they lifted up potential energy of the water. And when you need it, you would like to convert that potential energy into kinetic energy may be simple as rotate.

And then the shaft of the motor which is rotating, the motor will now act like a generator which will transfer the mechanical energy into electrical energy. So in this way we will get out the electrical energy which can be used for covering up the loads. So to do that we place a bike in this fashion, this is called a pen stock and at the end of it there is a jet by controlling this valve you can control the jet here which will make the impellers to rotate.

And thereby get the mechanical power which will get converted to electrical when this machine now acts like a generator. In this system the pumped portion and the hydra portion both use the same machine pump configuration when it is pumping up, this is a motor and this will be a pump, a centrifugal pump let us say. And when you are generating the electrical power output, this will become a turbine and this will become a generator.

So here if you are using a DC motor and you will get a DC output. Alternately if you would like to get an AC output at different power levels, so the pumping power could be at one rating, the power at which you will take out the power, retrieve the energy can be at higher power.

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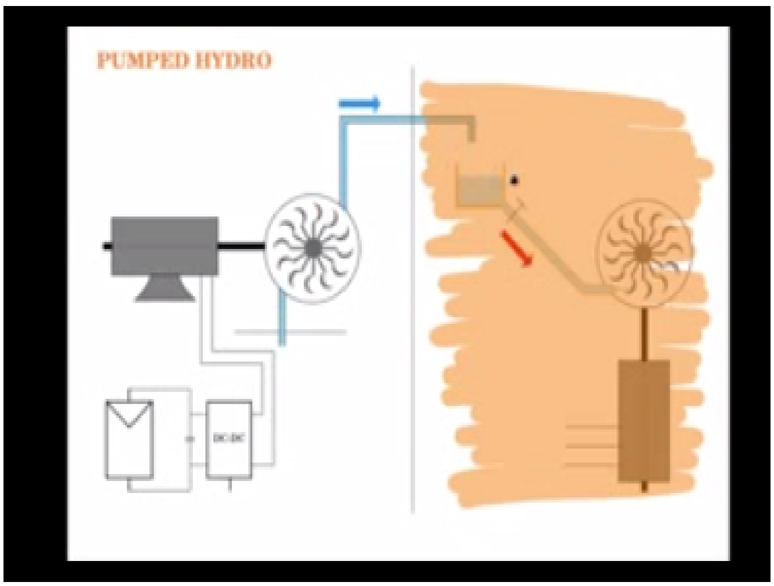

So a decoupled system like that will be something like this. So you have the PV panel pumping using the DC motor and a centrifugal pump in this fashion here to pump up the water from the lower level to an over at tank a reservoir what we could say. And then from this over at tank I use a pen stock and then use it to run another turbine and the shaft of the turbine is connected to a generator and the output of the generator is a DC output or it could be a 3 phase AC output depending up on whether you want to have DC generator or a AC generator so another advantage with this is that you can pump up the water at a lower power you can speared it over the whole day the water can be accumulated over the whole day.

So the power the hydraulic power needed will be low and then you may need the electrical output during the night time let us say for a shorter period let us say you pump up in 4 hours and then you would like utilize this electrical energy which is stored in 1 hour then this rating can be higher the power rating of this can be higher and you could probably have the output in AC you will pump up using a DC motor and then you will take out the power in the form of an AC using an AC generator and alternator.

And this AC can directly been used powering up many loads so if you d couple it you will see that it is much more advantages but only thing is that you will have to pay for an extra turbine and generator so this also another scenario we have discussed at length about this part pumping up water from a lower level to a higher level we have discussed about how to calculate the hydraulic energy for this part let me briefly discuss about this part.

Now for this particular application of pumped hydro the right side position which is shaded is called a hidey system and depending up on the power rating is it could be called hidey a min hidey a micro hidey or a peek hidey the ratings are the order of 5 kg volts micro hidey of the order of 50 volts, so let me discuss a simple peek Cho hidey system for small homes and community usage kind of a thing and let us just look at briefly the important equations.

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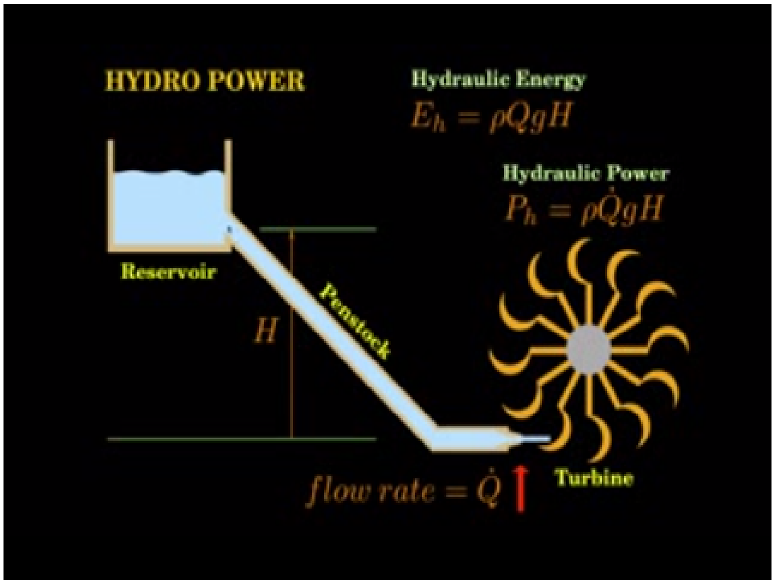

Consider a reservoir and from the reservoir a pen stock and at the end of the one stock there is a jet and the jet of water is in pinching on the blades of the impeller and this act as the turbine which converts the kinetic energy of the water in this jet to the mechanical shaped energy and we know this height here, now I will give a symbol upper case h because lower case h we have used for total dynamic hacked in the case of water pumping so this for retrieving energy I will use this upper cases h and this point here at the jet we will say Q. is the flow rate of the discharge rate.

We know the hydraulic energy E_h which is ρQgh and we also know the hydraulic power ρQ.gh only difference note that the height is different this is the height up to the center of this access of the jet.

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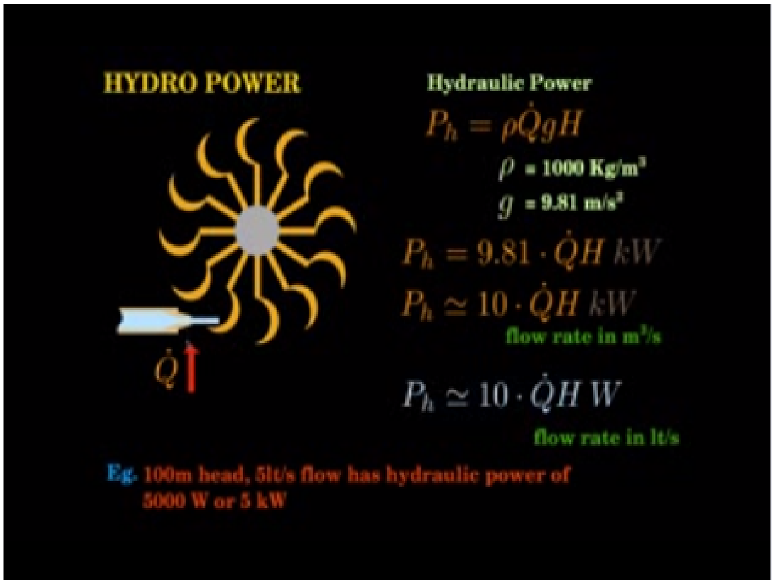

Consider this turbine this pelton wheel and where the jet at the end of the penstock that is imp inching on the Pelton wheel and converting the kinetic energy do mechanical energy and this is Q. the flow rate the hydraulic power ρQ.gh ρ is $1000 kg/m^3$ as before $9.81\ m/s^2$ is g and we have the hydraulic power that this point and we can take it has approximately 10 Q.hkw flow rate is an m^3/s and if you take flow rate in lt/ s then it will become 10 Q.H W that flow rate is liters per second, so how this remain the same except the value of h so there is an example 100m head 5lt/s flow as hydraulic power of 5000W of 5 kW at this point.

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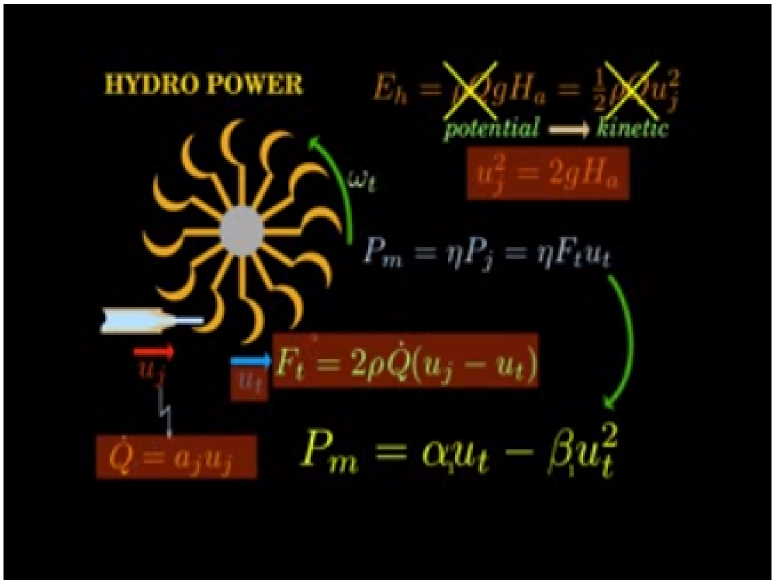

Now let me define that this is the fluid velocity at his jet, jet velocity U_j now the turbine velocity is u_t the angular speed of the turbine ωt this is the tangential velocity, now Ft the force tangential force on the turbine is given by 2ρ Q.u_j – ut u_j is jet velocity u_t is the turbine tangential velocity, uj-ut having a unit of m/sec, $\dot{Q}$ having the unit of m^3/sec and ρ having unit of kg/m^3 so you have overall kgm/sec^2 as the overall unit, so m/sec^2 having the acceleration units and you have kg so mass and the acceleration so this is having the unit of force, so this can be derived.

So tangential force is this much we also know that the hydraulic energy ρQgHa I will say Ha is the actual measured physical height from the center of the jet to the center of the outlet of the reservoir, so this potential energy is converted to the kinetic energy as 1/2ρQuj^2 this is with the form 1/2nv^2ρQ mass uj^2 jet velocity. Now ρQ and ρQ I can remove so you will have 2gHa=uj^2, so now at this fluid velocity I know the cross jet cross section is aj let us say, aj x uj will be $\dot{Q}$.

So I have these three relationships from these three relationships let us say a $\dot{Q}$ can be expressed in terms of uj, uj itself can be expressed as 2gHa, so when you replace $\dot{Q}$ and uj here so you will have ft as a function of only ut, ut is the only variable the tangential velocity everything else. So you say the power the mechanical power is efficiency times jet power which is the hydraulic power here which is efficiency times ft x ut, ft x ut is the jet power.

Now this because this whole ft itself is a function of ut x ut so you will have ut^2 term and a ut term so I will in general put it as Pm=α1ut-β1ut^2. So $\dot{Q}$ and Uj replace it in here and ft you replace it here you will get the mechanical power in terms of μ_t that is the tangential z velocity.

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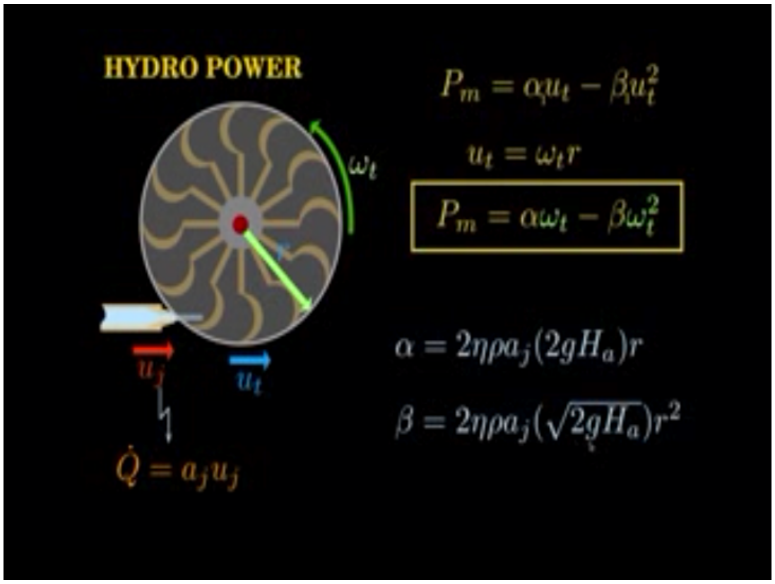

Now µt itself can be expressed in terms of the angular velocity so I have the radius r so µt is equal to ωt*r which is the radius of your inhaler now Pm can be expressed as α ωt-β ωt^2 now this would be the power equation the mechanical power at available at the shaft there α and β are given this one this can be as I said you substitute you will get this relationship.

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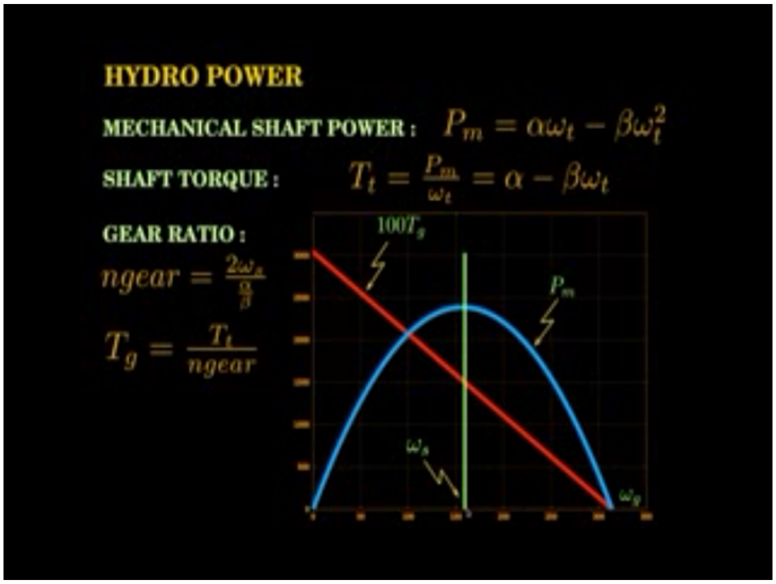

Now using that power equation the mechanical shaft power Pm which is equal to $\alpha\ \omega t$-$\beta\ \omega t^2$ see that torque and power are related torque into ω is power so therefore torque the shaft torque can be obtained as power divided by ωt angular velocity which is equal to α-$\beta\ \omega t$ so this is the falling this is linear and falling slope now when t is 0 when the shaft torque is 0 you will see that ωt is α/β.

Now that should correspond to see if you are using it for generating an generating 50 heads, 50 heads is the sinking frequency so that should correspond to two times the synchronous frequency I will tell you why therefore you need a gear ratio so that two times is synchronous frequency and α/β correspond and at the output after the gear box it will be Tt/gear ratio.

Now let us just plot and see what I mean this line red line is the torque line consider this you will see here α-$\beta\ \omega t$ so one ω is equal to ωt is 0 you will have the some value of torque and that value of torque keeps on increasing here it becomes 0 at some point when t is equal to α/β now power here is as square term this is parabolic so you get a parabolic where the maximum power is here.

So when you have the maximum power there would like my ωs when I am using it as generator my AC motor alternator or induction generator should have a frequency corresponding to ωs, corresponding to my 50 heads component here. Then this should correspond to 2 ωs, so that is why we used ωs should correspond to α/β when the torques becomes 0, so that is how this gear ratio is calculated. So at this point the shaft torque which becomes 0 is α/β from this equation.

But we want the value to be 2ωs from the frequency of the alternator then finally should be given to the user loan, so using that we get this clear ration 2 ωs = α/β and have your operating point somewhere close here where you can get the peak power.

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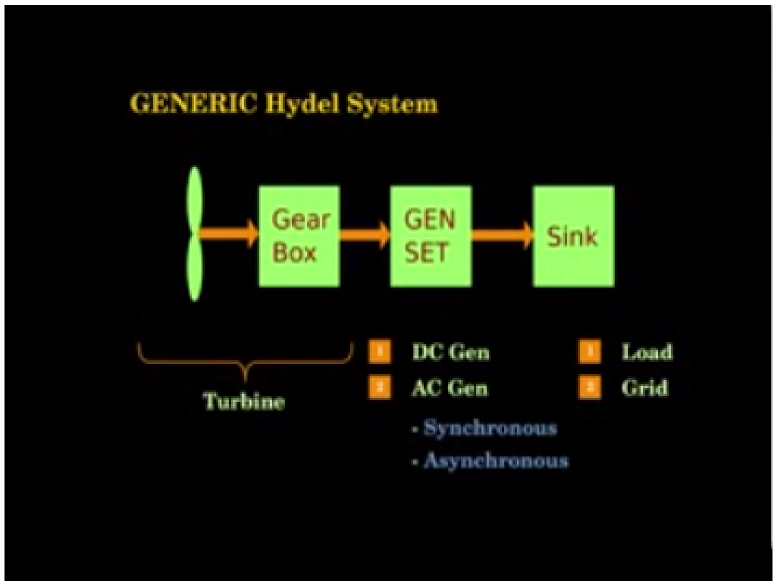

At generic hydel system consist of a turbine a gear box, gen set and sink will be load any type of load. So this portion we turbine with the gear box with the turbine portion the generator gen set can be a DC generator or AC generator, could be a induction generator or alternator in the Ac case, so synchronous and you can have the sink as the load or you can pump back into mains grade also, so these are the different application which are there.

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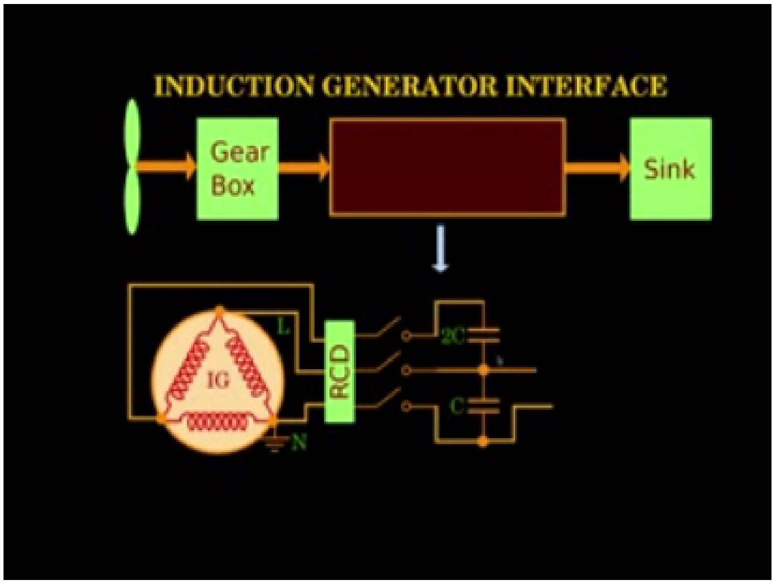

Let us see a very common popular hydro mechanism where the induction generator is used to interface the turbine with a sink; the sink could be the main grid or even standard. So typically what is done is, so you have a induction generator it is Δ winding there is a neutral and this is line, wring is done in this way from each of phase of it, it is brought out to this RCD. The residential current you have an MCB circuit breaker switch and follow it up with the capacitor C to C connected in the same fashion and make sure it is C to C.

This will form open Δ you do not need 3 capacitors, just use 2 capacitors if it is the open Δ configuration it will be able to give slightly less power than complete full Δ configuration but it is much less expensive then I can draw out a single phase line across this capacitance C and that goes to an IGC, IGC is nothing but an induction genitive controller it is basically something that will see to it that load which is presented here is more or else constant so what is done is this while keep switching between blasting and the actually load so there will be blast and then there will be the actual user load.

So this will say that if this load decreases the actual user load decreases it will increase the balsas load so that the load presented here is always same if there is no load the full balsas load is applied here and then same amount of power is drawn and when this is full load this balsa load is cut off and still the same load will be presented to this terminals the reason that is done is the induction generator the frequency swings widely with variations in the load so therefore it is always ensured that how most constant the load is presented to the terminal fear.

So that the frequency of the induction generator does not change so that is function of the IGC that is the induction generator controller it basically tries to see that between the balsas load and the actually load it is appropriately switched and presents almost constant load across the terminals of the generator system so in this way hide micro or a peak hide system works and this is the very simple configuration idea of pumped hydro.

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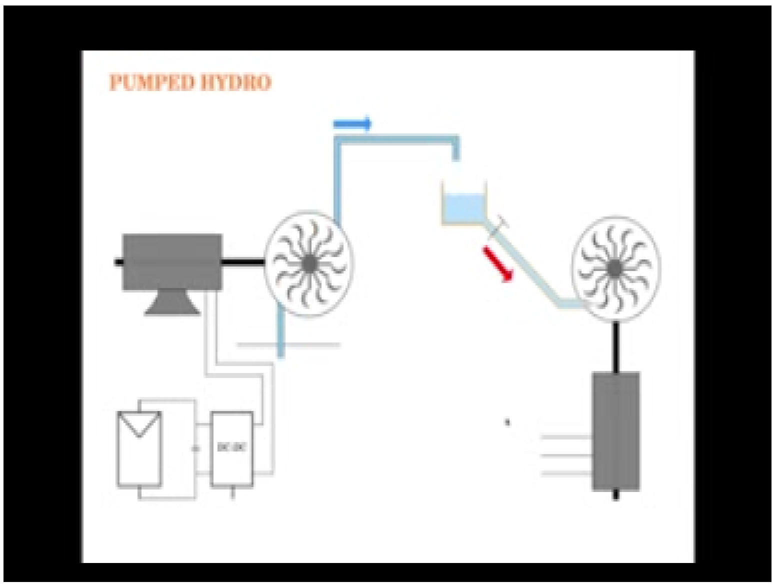

Where water pumping is one half of the part of the hydro application where the PV is used for pumping water at any particular rate to a reservoir and the other part of the application is from the reservoir the stored potential energy is converted and made available in an electrical form compare table to particular loads so this is the pumped hydro concept.