Economic Operation and Control of Power System

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Lecture – 35

A very good morning. Welcome you all to this NPTEL course on Economic Operation and Control of Power Systems. Today, we will be solving couple of numerical problems as an application to our previous theoretical understanding. Now, if you, let us consider one example where there are four power systems or four utilities or four different entities and some of them are willing to sell the energy and some of them are ready to buy the energy. So utilities A and B, they are willing to sell their energy and utility C and D, they are willing to buy the energy. From the following table, it is very clear as you could see that A and B are the utilities willing to sell their energy with an incremental price of 25 and 30 rupees or dollar per megawatt and they are willing to also sell a block of 100 megawatt hour and you could easily say that once someone is selling 100 megawatt hour with a cost of 25, so then they are expecting rupees 2500 to be paid if chosen by the pool.

Now similarly for the B, they are expecting rupees or dollar 3000 if their bidding is acceptable by the pool. Now similarly C and D, they are ready to pay the money of actually 1750 as well as 6750 to buy power of 50 and 150 megawatt hour blocks with a cost of actually 35 and 45 rupees or dollar per megawatt. Now, what does it mean? There is a balanced market, there is a market clearing price. So 200 megawatt hour is being sold and 200 megawatt power is being purchased.

So we have picked up the lowest cost energy blocks for selling and we have chosen the costliest energy block for purchase and then we have actually brought them together so that there could be a profit. So when you buy cheaper energy and when you sell it in a costlier rate, so certainly there is expected to be some saving or profit. Now what are those savings? How that need to be calculated? So net pool saving will be 25 into sorry net pool saving will be 35 into 50 plus 45 into 150 minus 25 into 100 plus 30 into 100. So this block, whatever the cost you get, you pay to the energy sellers and the rest will be my profit. And as you could see, there will be at least 3000 rupees or dollar saving due to this mechanism.

So the balancer, the market manager or the pool market will save 3000 rupees or dollar

with respect to the proper arrangement and market clearing. Now one more interesting thing that we can also see. So when you get this 3000, the Broker set up transaction in a different mechanism also. Now this 200 megawatt, we can assume that A sells 100 megawatt hour to D, B sells 50 megawatt hour to D and B sells 50 megawatt hour to C. That means if I go to the previous example, now what you can do, A is selling, what you said? A is selling 100 megawatt hour to D.

That means this gentleman is selling all the 100 megawatt hour to this D. And out of this 100, now you divide it into two blocks, 50 plus 50. One block is coming to my D and the other block is going to my, so the 200 megawatt, there are three different blocks, 100 plus 50 plus 50, 100 and 50 blocks are going to D and rest 50 block is going to my C. That is what the pool has managed. So A is selling 100 megawatt hour to D directly, B is selling 50 megawatt hour to D directly and B is also selling 50 megawatt hour to C directly.

So if you calculate what are the savings because you know the incremental and decremental cost which is available to me. So what is the cost of 100 megawatt power being sold from A to D? Incremental cost or decremental cost of D minus incremental cost of A multiplied by the block. So that means 45, okay, what is this? 45 minus 25 multiplied by 100 will give me rupees 2000. If you repeat this for B and D as well as B and C, you will find 750 as well as 250. So finally you get this 3000 rupees or dollar being the safe, saving amount which is almost same as the previous case.

Now there actually you calculate the saving as a pool but in this case now the saving has also been distributed among the seller and buyer depending upon their transactions. So if they sell directly one to one then you can say okay this gentleman A is now eligible for 2000 rupees and B is eligible for 1000 rupees out of the 3000 rupees which is saved by the pool. So this kind of distribution also can be carried out. Now the rates and total payments are easily computed under the uniform pricing arrangement at the price of the last match that is the highest value. Now we will see one more example.

Now one more example where the price is not necessarily because if you see the previous example this 45, 25, 45, 30, 35, 30 is fine but if I consider no the cost is simply going to be 37.5 for everyone then for each block of 150 and 50 you will get different prices which is 3750, 1875 and 1875 and the net saving is going to be 7500. So if you set the highest incremental cost, rupees or dollar per megawatt hour for each and every transaction then probably you will gain more benefit through this transaction process. So in that case now A is receiving actually 37 dollar rupees, B receives 1875 rupees or dollar from D and C and note that each participant actually clearly benefits. In the previous example everyone is benefiting.

In this case actually everyone is benefiting but it may so happen in the previous example some of them may be having a negative value in a large complex network if these values if 25, 30 is not necessarily to be always less than 45 and 35 because you have a pool of players. So in some of the cases it may so happen that some of the transactions may have to pay negative price if some of the values are going to be kind of less. The selling price is less than or more compared to the purchase price. So that case you will have a negative cost associated. So this model which is very good, very profitable where there is no one is suffering, everyone is gaining benefit because you set a very, very high price.

Now we move to one more example which is very interesting. There are two things here. First of all how do you calculate cost for each transaction? It's very simple. LMPI minus LMPJ multiplied by P megawatt will give you the cost of the transaction. That is known to everyone.

So each transaction cost is known to me but when you do transaction for both generation and load to separate entities then you can calculate cost of each transaction as well as the total amount being saved because you purchase with low price and selling with a high price. So certainly that means saving. Now we are going to address one more problem when there are n number of generating units. Now n number of load units. Now if some of the generating units are scheduled to cater the energy in a particular fashion but due to the real time balancing some of the generating units are being loaded much more what they are supposed to give.

Now because in the real time market what you thought of practically is not going to be the same in real market because A is ready to give 100 megawatt to B. A is ready to give 50 megawatt to C and B is ready to give 100 megawatt to D. So there is an arrangement. But when you go for the real time transactions that 100 maybe 90, 50 maybe 55 because you cannot measure your load exactly. You expect this would be my load, this should be my generation but in real time there could be some mismatch and that mismatch nobody wish to take that pain because you are prepared for that.

But if you take some pain to accommodate in real time so finally the dispatcher will see who are those people did not obey the commitment that they have given earlier and how to recognize those efforts those who could accommodate pain and who are those people actually disturb the system because of not meeting their expectations. So they need to implement. So that is one interesting benefit and then how that benefit will go back to the consumers as well as generation companies in a proper way. So this example will help us to understand more detail on that. The three area are assumed to be members of a centrally dispatched power pool.

The pool's rule for pricing pool interchange are as follows. What are those rules? Each area delivering power and energy to the pool in excess of its own load will receive

compensation for its increase in production cost. Now due to any reason if your area is in excess of its own load so then will receive compensation for its increased production cost because when you give more energy which is not desired due to others then your cost will increase. So that need to be compensated by the pool. The total pool saving will be computed as the difference between the sum of the production cost of the individual areas each computed on the basis that it is supplied its own load and the pool wide production cost.

These savings will be split equally between the suppliers of the pool capacity or energy and the area receiving pool supplied capacity or energy. In each interval where saving are allocated usually a week but in this example only one hour is being considered the cost rate for pricing the interchange will be one half the sum of the total pool saving plus the cost of generating the pool energy divided by the total pool energy. The total pool energy is the sum of these energies in the interval supplied by all the areas each generating energy in excess of its own load. You can I request all the viewers please go through these steps very carefully and when you refer to the next numerical example most of your doubts will be clear. Now consider a case where there are three different areas area number one, area number two and area number three.

Area one which is you know giving a kind of a load of 700 megawatt, 1100 megawatt and 550 megawatt respectively and the production costs are 13677, 18569 and 10042 and total production cost to meet a load of 2350 is 42,288 dollar rupees per hour. Now this is what the standard current operating status. Now we could see some oscillation here. Under the pool dispatch area one and two are dispatched at an incremental cost of 17.149 means area one and two are now dispatching with incremental cost of 17.

149 to generate a total of 1900 megawatt. So initially what was the one and two's capacity was 1800 but now we are saying no, no you have to provide 1900 due to some scenarios with an incremental cost of 17.149. Now what about area three? Area three is limited to supplying of 450 megawatt and with a cost of actually 18.125. Imagine the area load for three is 550 megawatt. Now due to some inevitable circumstances now it is able to meet only 450. So what you have to do? The rest that is the difference between 550 to 450 that is 100 megawatt need to be met by other areas because they are interconnected. So what will happen now? Both area one and two will be loaded with additional 100 megawatt to satisfy the reduction in load in area three and hence there is a mismatch in my costing now. So the previous cost what you have calculated for area one, two, three will now change because you are not respecting 700, 1100 and 550 for which you are prepared for.

Now the generation cost of three areas and the pool under pool dispatch are given by this. So what has happened? Now the third area is now giving actually 450 to 450 from

550 and this instead of 1100 now it become actually 1441. Now the 700 become actually 458. So what has happened? Area one reduced this energy. Area three reduces energy and area two become overloaded by a significant amount. So incremental cost as you know is given actually 17.149 for one and two, 18.125 for the third one. So you can multiply with the megawatt to the cost and you will get actually total cost for each area and that is 41911. Now by doing this what has happened actually? Now the cost got reduced.

It's a wonderful news. So there is a saving for the pool. What is the saving? 42288 minus 41911 is the saving due to rescheduling of energy supply by each one of them that is area one, area two and area three. So the difference between 42288 minus 41911 is going to be 377 rupees or dollar any unit you can use it. Now here area two is supplying 341 extra megawatt instead of 1100. Now it is supplying 1441. So as for the pool rules it has very clearly been said the gentleman who is supplying extra will be given maximum benefit. That means this 341 megawatt hour is being supplied by area two. So the saving that we have created of 377 maximum of this must go to my area two. Now what is the cost of energy supplied to the pool by area two? It is nothing but if you look into this example that is 24232 and it was initially going to be this one but that additional cost we are going to calculate how much cost it will be paid because of the additional 341 being supplied by area two is nothing but the difference between these two cost 24232 minus 180 this that is going to be 5663 plus in addition so this is the cost need to be paid for additional energy plus a benefit half of the benefit of this actually 377 that the pool has gained which is going to be 188.52 and if you add these two you will get actually 581.95. Now the very very interesting part here is that whenever you are going to reschedule any pool market the entity or the area those who have taken extra pay to cater the consumers of the other areas will be paid some benefit okay they are responsible for that and that is coming out of this half of the pool saving will be given. Now what is the cost now the total cost the gentleman area two got it is 5851.95 rupees or dollar for an additional energy of 341.1 so now the interchange price rate for the additional interchange price rate will be 5851.95 upon 341.1 and this is going to be my final cost for that additional energy. So if you see this 1100 megawatt now being supplied as an additional of 1441 so due to this addition a cost will be paid on and above 1800 569 and that cost is going to be 5851 and per unit cost if you calculate which is going to be 17.156. Now the final outcome of each area if you see now the first one actually reduced by 241 third one is reduced by 100 so reduce means we say positive increase means we say negative so first area reduced by 241 last third area reduced by 100 second area increased by 341. So if you calculate similar face in the cost for each one of them so you will get actually this cost this cost this cost so negative if it is increased positive if it is reduced and then you can calculate the production cost and finally you get this cost and the net cost will be now 41911 which is slightly lower compared to the previous cost.

So now it is very clear that who is gaining and who is losing and how the pool benefit can be distributed among different consumers. Note that each areas net production cost are reduced as compared with what they would have been under isolated dispatch. If they do one to one then probably they have to pay more than each area must pay more than what they desire to pay. So the conclusion of today's talk is that when there is a combined effort of selling and buying so that probably everyone benefits. So the re-regulation of electric energy sector has been designed to give benefit to all the consumers and the energy producers.

With this I am stopping at this point of time and thank you once again for your wonderful participation as well as listening to these lectures. Thank you. Bye bye.