PCA Case No. 2023-01

IN THE MATTER OF AN ARBITRATION

-before-

THE COURT OF ARBITRATION CONSTITUTED
IN ACCORDANCE WITH THE INDUS WATERS TREATY 1960

-between-

THE ISLAMIC REPUBLIC OF PAKISTAN

-and-

THE REPUBLIC OF INDIA

CERTIFIED TRANSCRIPT
(SITE VISIT)

COURT OF ARBITRATION:

Professor Sean D. Murphy (Chairman)
Professor Wouter Buytaert
Mr. Jeffrey P. Minear
Judge Awn Shawkat Al-Khasawneh
Dr. Donald Blackmore

SECRETARIAT:

The Permanent Court of Arbitration

ON BEHALF OF THE COURT OF ARBITRATION:

CERTIFIED PURSUANT
TO
PARAGRAPH 19 OF ANNEXURE G

27 April 2024

Sean D. Murphy

Professor Sean D. Murphy
Chairman

Arbitration pursuant to Article IX and Annexure G
of the Indus Waters Treaty 1960

NJHEP Powerhouse Site
Pakistan-administered
Jammu and Kashmir Region

Day 5 Saturday, 27th April 2024
Site Visit

Before:

PROFESSOR SEAN D MURPHY
PROFESSOR WOUTER BUYTAERT
MR JEFFREY P MINEAR
DR DON BLACKMORE
MR STEPHEN POMPER, NEUTRAL OBSERVER

BETWEEN:

THE ISLAMIC REPUBLIC OF PAKISTAN
-and-
THE REPUBLIC OF INDIA

Transcript produced by Trevor McGowan, Lisa Gulland,
Anne-Marie Stallard and Georgina Vaughn

APPEARANCES

FOR THE ISLAMIC REPUBLIC OF PAKISTAN

MR RAJA NAEEM AKBAR, Ministry of Law and Justice
MR SYED ALI MURTAZA, Ministry of Water Resources
MR SYED MUHAMMAD MEHAR ALI SHAH, Commissioner for Indus Waters
Mr ILYAS MEHMOOD NIZAMI, Ministry of Foreign Affairs
MR SOMEIR SIRAJ, Office of the Attorney General for Pakistan
MS ZAINAB MALIK, Office of the Secretary of Law and Justice
SIR DANIEL BETHLEHEM KC, Twenty Essex, London
PROFESSOR PHILIPPA WEBB, Twenty Essex, London
DR CAMERON MILES, 3 Verulam Buildings, London
DR GREGORY L MORRIS, Technical Advisor
MR PETER J RAE, Technical Advisor

THE REPUBLIC OF INDIA WAS NOT REPRESENTED

SITE EXPERTS

MR MUHAMMAD AZAM JOYA, Pakistan Water and Power Development Authority (WAPDA)
MR USMAN-E-GHANI, Additional Commissioner for Indus Waters
DR TAHIR MAHMOOD HAYAT, Diamer Basha Consultants Group
MR MUHAMMAD ARFAN MIANA, Neelum Jhelum Hydropower Company (NJHPC)
MR MUHAMMAD AYUB MALIK, NJHPC
MR NAYYAR ALAUDDIN, NJHPC
MR MUHAMMAD UMAR FAROOQ, National Engineering Services Pakistan (NESPAK)
MR FIAZ HANIF SENDHU, Tarbela 5th Extension Project
MR ARSHAD MALIK, WAPDA
DR YASIR ABBAS, NESPAK
MR MUHAMMAD TARIQ, Tarbela 4th Extension Project
MR HAMEEDULLAH KHAN, Warsak Hydro-Electric Project

FOR THE PERMANENT COURT OF ARBITRATION

MR GARTH SCHOFIELD, Deputy Secretary General
MR BRYCE WILLIAMS, Legal Counsel
MR SEBASTIAN KING, Assistant Legal Counsel
MR DAAN NIEUWLAND, Videographer

Saturday, 27 April 2024

THE CHAIRMAN: Okay, I think we are ready to begin. Thank you, Mr Miana, for hosting us here at the powerhouse, and we look forward to hearing your presentation No. 8.

Presentation 8: Powerhouse Orientation

MR MIANA: Mr Chairman, members of the Court of Arbitration, a very good morning once again, sir.

You already know me, but again I'm Muhammad Arfan Miana, the chief executive officer of the Neelum-Jhelum Hydropower Company. Sir, I am very delighted to receive you at the Neelum-Jhelum powerhouse site, and to give you a brief site orientation, combined with a safety briefing.

At the moment, sir, we are in the office of the project director of Neelum-Jhelum Hydroelectric Project, who is also joining us, sitting behind. So you can raise your hand.

And for today's schedule, we'll have presentation No. 8 first, then we'll have the coffee break, then followed by the presentation nos. 9 and 10. Then we'll have the lunch break. And after that, we'll go for the site visit of the powerhouse, starting from the control room inside the powerhouse. So I will feel pleasure to guide you as well in the powerhouse, as I already guided you at the dam site twice, yesterday and day before

yesterday, sir.

Sir, at the outset of the presentation, one of the questions that was asked during the presentation No. 3 by -- I remember one of the Court members, Professor Wouter, regarding the regulation. Sir, yes, we have the regulatory authority, which is called National Electrical Power Regulatory Authority in Pakistan, which controls all these regulations for the power industry.

Slide 2, please. Sir, in my presentation I will present an overview of the powerhouse site, covering the main features. These will be developed further by my colleagues in presentation nos. 9 and 10. So we have three presentations, which are connected with each other. And since yesterday, sir, we were discussing about more dams and spillways, all the civil structure, from now onward we are in the powerhouse, so mostly we are discussing about the power generation and electromechanical equipment.

Slide 3. So we have already, sir, seen this photograph yesterday, and let me give you some brief explanation about it. Sir, this is a small stream coming from this side, on the very right side of us, indeed through. And we'll see it when we'll go to the powerhouse, this small stream.

And this is the River Jhelum, the lower limb of River Jhelum, and the powerhouse is located over here. Powerhouse is almost 22 kilometres from Muzaffarabad city, and it's about 100 kilometres from Islamabad.

The headrace is coming from the dam site and carrying the water for the power generation up to this one. And after generating the power, the water is released to the Jhelum River again.

Beside the powerhouse, we have surface switchyard over there. Rest of the powerhouse is underground. So we have this one. And this is outlet of the tailrace you have already seen when you were coming from Islamabad. So this is an overview of our Neelum-Jhelum powerhouse site.

Slide 4, please. Sir, regarding the powerhouse generations, the construction was started back in 2008 and it was completed in 2018. We commissioned all the four units during the year 2018 to get the 969 MW power. The expected annual generation, depending upon availability or hydrology, is 4.66 billion units. And the total energy generated as of today is about 19.56 billion units. So total earning up till now is about PKR 178 billion, which comes about US$640 million, converting as of today's exchange rate.

We can move to slide 5. Sir, this is the expected

energy generation from the powerhouse as per estimation. So starting from January in the calendar year, January, February and March are the less flow season, where we have less water available for power generation. Similarly, after August -- in September, October, November and December -- there is also very less power for generation. Rest are the five months available where we have the maximum available power from where we can generate the maximum electricity.

Most of the electricity -- about 70% of the estimated energy generation -- is in these five months. And the rest, 30%, is generated in these seven months. So these five months are very crucial for the power generation.

Almost 700 GWh we can generate in each month during the high-flow season. And if we look at the 1 GWh of the power, that can provide enough energy for about 700,000 homes in an area.

Slide 6. I've already mentioned about that today: we'll be discussing more about the electromechanical parts instead of the civil works. So this is a view of inside the powerhouse during the construction. This is the powerhouse cavern. Beside it is the transformer cavern. We have already seen many drawings and photographs about that one.

So we can see here the installation and construction/fabrication of the powerhouse, the generator rotors.

Generator basically consists of two parts. One is a stationary part and one is the rotating parts. The stationary part is called the "stator", while the roting part is called the "rotor", as per its name.

The construction starts from the rotor hub. Then steel plates are installed over here, and at the outset of those steel plates we install the poles. The poles are then excited with the DC current. And with that excitation we can generate the electricity, and that electricity is collected at the stator, which is transported to the switchyard and to the national grid.

So this is the phenomenon of the powerhouse, this one. So the cavern width is about 25 metres. And starting from top of generator hall up to the lowest part we have 54 metres height over there. So today we'll have chance to go all these floors when we'll have the powerhouse visit over there.

THE CHAIRMAN: Mr Miana, can I just ask: I realise this is a photograph of the construction. Am I recalling correctly that there's ultimately four of these generators, and we're looking at basically two of them here, one of which is more constructed than the other?

MR MIANA: Yes, this is the sequence, because we have to construct the power units one by one. And the construction is done outside their unit place. You can see 1, 2, 3 and 4, but the construction is outside of that unit. So we have to construct it. And this is the heaviest part that we have to install inside.

To lift this one, sir, we have two cranes over there. The capacity of two cranes, about 550 tonnes. Whereas the maximum capacity of one rotor is about 450 or 460 tonnes. So we will have to go with the tandem operation of the two cranes. The two cranes are coupled together, and they are operated by one operator. So he has to lift the rotor with both cranes simultaneously and put it in the specified place in the generator.

So the construction of the rotor is outside their unit place, it's not inside.

Can we move to slide 7. Sir, this is the view. As you mentioned the four units over there, sir, this is units 1, 2, 3 and 4. This is a finished product of the powerhouse when all the units and their auxiliary were installed over there. And after their installation, we can now recognise all these four units very well over there.

The numbering starts from this side, and it comes up to the distance. So when we'll go around this side,

we'll see further unit 4 over there; and then 3, 2 and then 1.

The capacity for each generating unit is 242 MW. It's 242.25 MW, more precisely. And it takes 70 cumecs of water to generate that electricity, because the head is quite high, about 420 metres, so the less water is required for generation of 242.25 MW by each unit. So adding all four units, we can get 969 MW of electricity, if the water is available for the generation, sir.

Can we move to slide 8, please. Sir, this is the complex diagram of the tunnelling system, because all our facilities are underground except the switchyard and the control building for that one. So I will briefly explain about this thing, sir.

So this is the headrace tunnel coming from the dam site, showing in green. And this is the surge shaft that we have seen, that we were comparing with the Eiffel Tower, 353 [metres]. So this is the surge shaft over there.

And then we have four penstocks over here. And with that penstock, all the four units are connected, 1, 2, 3 and 4, with each one.

And this is the generator hall that I was just showing in the previous slide about this one. So everything is encompassed underground in the powerhouse.

To access the powerhouse, we have this tunnel 5 -- we call it adit A5. So we'll also go from this tunnel over there, and then we'll reach the powerhouse. With this tunnel we have also access to the headrace tunnel where we have one plug over there for the one headrace, and we have some drainage gallery and the monitoring instrument over here. So we can have access from this one tunnel to the powerhouse, the monitoring gallery, as well as to the upstream of the penstock over there.

We can also access the powerhouse from this purple line, which we call adit A6. We call it the cable gallery as well, or cable tunnel as well. We can go over to the powerhouse directly to this one. Or if we want, we can go to the transformer.

From the transformer, sir, we have the power evacuation through the XLP cable. So instead of conductor, we have the XLP cable coming from the powerhouse, and that are connected to the switchyard that is outside the tunnel.

And these four --

THE CHAIRMAN: So Mr Miana -- no, no, it's fine. So these tunnels that you just pointed to, these are actually tunnels that physically humans would go into to access these areas?

MR MIANA: Yes, these are for the physical humans as well as transportation and the vehicles. We'll see -- we'll go in these tunnels today.

THE CHAIRMAN: Oh.

MR MIANA: We can also go in this tunnel as well!

THE CHAIRMAN: Okay!

MR MIANA: So these are the four outlets. These are draft tubes. After the draft tube -- the water comes out the draft tube. And then 1, 2, 3 and 4, they are combined over here. And then from this point we have the tailrace tunnel starts over here.

The issue of tailrace tunnel was explained by Mr Nayyar yesterday briefly about the collapse. That happened somewhere over here. So I will be describing something more about it with the photographs in this presentation.

We will also, sir, access this downstream surge tunnel because it was quite a big one to cover in photograph so we had to cut it overhead for the presentation. So we can go around this one and then come to this point.

Usually during the inspection of the TRT, we have two exits. One is exit near the outlet that we have seen over there. And the second, going from this purple line that goes here, combines over here, and then we can walk through and come back to this one. So these are

quite big tunnels, but this is small tunnel, so a small vehicle can go inside, instead of a big one.

So this is all about the complex system. And this -- we have the transformer cabin, and all this is -- everything is underground. So today we'll have the chance to see all these components physically.

Please move to slide 9. Sir, this is again the slide showing the four units over there. This is looking from top down. It is photo of a wall and not the floor.

So we have the downstream wall over here. Four units, 4, 3, 2 and 1, over here. Just to show you that we have a scroll case, a spiral case, along with all the -- in all the units. That is before entering the water into the turbine system.

You can recognise that shape is not a constant shape, it's a spiral shape like this one. Because the number of blades are more, but the energy required at each entrance of the blade should be the same. If it's not the same then it may cause vibration. So keeping energy the same at all the inlet points, we just can work the pressure into kinetic energy by reducing the dial of spiral casing.

So the water entering the larger dial from this one, and then it has a reducing dial over there, and it ends

very small over there. Since all these are underwater, we cannot see this one at the moment. But this is the phenomenon of having the same energy at the inlet of each turbine.

To this, we are connected with MIV. I will explain more about MIV in my next slide. So this is all about the spiral case and the installation process of the turbine and the associated parts during the construction.

One more important thing, sir: you can recognise the water is coming in this direction, really in this one. But when it passes through the turbine, it is along the axis of the shaft over there. The water is also changing its rotation during the power generation.

Slide 10, please. Sirs, this is the cross-section of turbine engine rotor. So let's start from this side. So this we call the upstream side of the main inlet valve; it is over here. And this is connected with the penstock, and the penstock is connected with the headrace tunnel. So this is the scheme over there.

The main inlet valve is provided just to shut down the unit or isolate the unit in case we need maintenance inside the particular unit.

The operation of the MIV, the main inlet valve, is such that it is operated with counterweights. So

advantage of counterweight is that in case of failure of electricity, and in emergency, the counterweight can automatically close the main inlet valve to avoid any damages to the turbine parts.

After that main inlet valve, the spiral case or the scroll case starts. You can recognise the small dial and then the big dial there. This is just before the entrance of the water to the "stay rings", we call it, it's named the "stay rings", that guide the water directly to the blades of the turbine or the runner.

And after giving the rotation to the turbine, the water releases from here to the draft tube, and from the draft tube it goes to the tailrace tunnel. And I already described very in detail in my previous diagram.

With this -- there are many different other parts I will explain one by one. With this runner we have a shaft over there, and that shaft is connected with the generator.

So this is the generator. In purple, it is shown the rotor of this one. Whereas this one is -- this is the stator of this one. So when the turbine rotates, the runner rotates, it also rotates the rotor of the generator. And with this rotation, the electricity is produced and collected at the stator.

To excite and to give the continuous supply for the generation of electricity, we have the excitation system at the top of that rotor -- generator.

So altogether they function in a very systematic way, and with all protective instruments over there, because change of any one parameter can impact on the other parameter as well. So all these are covered with the protection system, instrumentation system and electrical and mechanical protection system over there.

There are a number of protection systems, starting from the mechanical to the electrical and electrical to the protection system. A number of protections are available just to avoid any damage to the plant. And from this one, the tailrace, we have then going outside this one. The grey structure is all the steelwork structure where all these have been embedded in.

And this one, we can recognise these are some bearing supports over there, turbine guide bearing, the generator guide bearing, the thrust bearing. So many kinds of the equipment, very small and tiny equipment. These are small, but they are very important with respect to the smooth operation of the plant.

Slide 11.

THE CHAIRMAN: Mr Miana, before you leave this slide, can I ask: you have not yet had to replace any of the

turbines or generators; is that correct?

MR MIANA: No, not yet, sir.

THE CHAIRMAN: And if you did have to replace, let's say, the turbine because of a problem from sediment or anything else, do you have to remove the generator before you can get to the turbine, or is there a different way of ...

MR MIANA: It's a different way. We have, sir, opening over here at the bottom. So we have to take it out, lower down the runner from here and take the runner outside, put the new runner on the rails and put it inside, hanging up with the shaft, and put back the start of -- we call this the drafted cone -- so put back the cone inside over there. So in this way we can convert months into weeks for the replacement of a runner.

THE CHAIRMAN: And I assume you regularly inspect the turbines to see their condition. How do they look now that it's six years after your start?

MR MIANA: Since all was submerged in the water, we inspect annually, because approaching the turbine is a lengthy process, because first we have to put -- close the inlet valve, put the bonneted gate at the outlet over there, then dewater the system, open the very big holes (inspection window) -- so we'll see the holes open there -- and then go inside.

So we do all this activity during the annual maintenance of each unit. So far we feel that the turbines are not in a very good -- in a good condition over there. So they can be operated next few years over there.

THE CHAIRMAN: And so based on their current condition, you think that you would not need to replace them for another five years, maybe even ten years? Or: no, there's a pretty clear point at which you may need to replace them?

MR MIANA: Not five/ten -- we cannot specify the number of years. But maybe next few years, maybe two/three years or four years we can operate easily. But that also depends on the sediment load coming to the turbine side. So if more sediments are coming, they will have this one.

And we also -- another thing, thank you very much, that I can mention over here: the turbine and the runners. They are already coated with a high-velocity oxygen fuel, so we have a protective film on the runners, so that protects the parent material of the runner.

THE CHAIRMAN: Thank you.

MR MIANA: Slide 11, please. So I briefly said about the tailrace collapse and that repair we did. Mr Nayyar

already explained very briefly about this one yesterday. So I will go and show you more photographs, and what we did with this collapse, and how we get out of this collapse, in how much time.

Next, slide, number 12, please. Sir, this is a photograph showing the collapse area. We had a collapse just 250 metres below the powerhouse, and that was chainage 0+251 over there. And that collapsed lasted up to 0+293 over there. These are photographs of August 2022, sir.

One thing we can recognise over here: that we can see that these are small pebbles or small stones over here; whereas at the outlet side we have big boulders like this. So this indicates the complex geology inside the TRT that was explained by Mr Fiaz during his presentation, that all along the part of the HRT and the TRT we have very complex geology changing from the sandstone, siltstone and mudstone over there. So this is an indication of that as well.

So we have a collapse of 42 metres, but that was full collapse since it closed the tunnel, so we are forced to shut down our plant, and to repair this one and to handle this situation.

I will explain on next slide, 13. Sir, since when there is a collapse inside the tunnel, the most important thing: how to take that rubble from the collapse area. Because it is not just to excavate that and go inside as we do not know about the cavity above that collapse, we do not know about the geology, what is going on there, and we do not know how big is that cavity.

The most important as per the advice of the consultant: we have to use the forepoling method. Forepoling is a common method used in the collapse system for the recovery of that part. This is the start from the downstream side, sir, as you look 0+293. So we have to move up, sir, to the powerhouse side.

First protection was provision of the lattice girder over there. And this protection was just to hold the ceiling of the area before the collapse. With this, we have to put forepoles over there, all along this periphery. And after putting that, perforated metallic pipes were there and then they were grouted with high-pressure grout. That created some kind of false ceiling above that one.

The length of each forepole was 7-8 metres. So 8 metre area of the false ceiling was, you can say, temporary ceiling was provided over there. Once that was provided, then it was easy to excavate this 1 metre by 1 metre. So we have to excavate this one say

3-4 metres, and then we have to again overlap the previous forepole with the new forepole.

So in this way, sir, we succeeded to safely cross and have the breakthrough for this collapsed area.

And the most important thing is that during that collapse there was no accident over there, and with very much safety. All the precautions related to the excavation were taken to prevent any kind of accident.

Slide 13. Having the time for this one, we also inspected the remaining tunnel instead of the 42 metres, and wherever we find some weak points, so we addressed them with the different methods.

One of the methods was that we also used the RRS. RRS is the reinforcement rebars support. There are two kinds. We have already seen on a previous slide the lattice girder over there, and in this we can see steel bars over there, a juncture of six steel bars over there, which were put in the tunnel with rock bores over there. And after putting the rock bores, it was shotcreted just to give the support.

So these are different kinds of methods applied as per the requirement of the damages and the weaknesses. So this was the area about 1+585 metres to 1+700 metres.

THE CHAIRMAN: Mr Miana, looking at this picture, I think I'm now maybe realising something I didn't understand.

So the water is flowing through the pipe, not through the tunnel as a whole, is that correct?

MR MIANA: No, in fact this is an air duct.

THE CHAIRMAN: It's an air duct.

MR MIANA: This is repair method.

THE CHAIRMAN: So that's just for the repair process?

MR MIANA: Yes.

THE CHAIRMAN: Once you've finished, you take that air duct out and the water flows through the entire tunnel; is that correct?

MR MIANA: The entire tunnel, sir.

THE CHAIRMAN: Okay.

MR MIANA: So we'll see that photograph next, that we have done with the 42 metre collapse area. So that will give the clear picture of the tunnel over there. In the next slide we are going there.

So for the 42-metre collapse area, reinforcement was provided over there, two layers of reinforcement provided over there for getting more strength in that area. And then the concrete was put in in that area.

So next slide will be slide 16. So this is the finished product of that 42-metre collapse area. That is starting from 0+251, and going up to 0+293 metres. However, we extended -- we started from 0+248, 3 metres ahead of that one, and we went up to 0+308. So

60 metres of that portion was properly strengthened with the method I have just shown in the previous slide: the reinforcement bar, then the concreting properly.

Proper drainage system has been provided just to provide drains for release of water; and after the concrete, even, we also put the concrete grouting, to give further strength in case of any -- in future if something happens. So this concrete is sufficiently supported and strengthened to avoid any kind of -- such like of incident in this portion of the tunnel.

Can we move to slide 17.

THE CHAIRMAN: Just one question before you do the safety briefing. At the moment when the collapse occurred, did it block water completely from going through the tunnel, or was there still water able to go through the tunnel, it's just you knew there was a collapse?

MR MIANA: It's a very good question, sir. It was completely blocked because I have already shown on slide 12, so you can see that this was completely blocked. This is the crown of the tunnel, and this is the lower part of the tunnel; "invert", we call it. And so tunnel was completely blocked. And we recognised that whenever we were operating the plant for one or two days or just to observe this thing, as soon as the water flows, the pressure inside, beside this one, started rising over there. So that was indication that either water was not or less flowing in this one.

So there was no other way, just to tackle this one and take this rubble outside and give the clearance to the whole of the tunnel for a smooth operation. And since last August, TRT is in operation, and we are operating safely, sir, without any problem.

THE CHAIRMAN: And at the moment of the collapse, was there any harm to the turbines or the generator from the sudden stoppage of the water, or was the system able to handle the sudden blockage?

MR MIANA: As soon as we recognised the increase in pressure, we already started slowing down the output, so that avoided any kind of damage to plant -- so there was no incident or accident or damage to mechanical parts. It was only the tunnel that we have to repair.

THE CHAIRMAN: Thank you.

MR MIANA: (Slide 17) Sir, about the safety briefing, this is similar to that one we had, except with a few additions because the power plant is in operation, and all the electrical panels are energised. The control panels are also energised, so we have to take a little bit of extra care when we are walking through the powerhouse site.

So slide 18. We all are using rubber soles so it is

very excellent that we are using that one. In the dry air powerhouse we'll also be wearing helmets, hi-vis vest, and we'll also have the hand gloves if we want to touch any equipment which is dirty and we want to have some discussion on that one. We'll also be using the safety goggles inside, if someone would like, because it's better to, when you go inside, we should have the safety goggles over there.

And rest, we should avoid the electrical equipment, which is energised. We'll go in group, and will not be scattering everywhere over there, so that we have sufficient distance from the energised panel. And I think -- I believe we are going first to the machine hall, the generator hall, and then going all around the powerhouse, and ensuring this will be a very safe visit over there.

Next slide (19). So, sir, this is all about from my side. I will conclude my presentation for this one, and thank you very much for your kind attention and the questions. I hope we'll have a successful visit of the powerhouse in the afternoon. So if you have, sir, any questions, I'm available to answer.

THE CHAIRMAN: Any questions? We have no further questions, Mr Miana, so thank you very much.

MR MIANA: Professor Wouter has one?

THE CHAIRMAN: Oh, sorry, please.

PROFESSOR BUYTAERT: Two days ago we discussed the wicket gates, or the "coaster gates", I think my colleague calls them. Would you be able to indicate where they sit in the configuration?

MR MIANA: Okay. So wicket gates are configured over here, just upstream of the runner. This is a runner in the red, and yellow is the wicket gate over there.

PROFESSOR BUYTAERT: Great. Thank you.

THE CHAIRMAN: Okay, I think now we are done. So if I understand correctly, maybe we take a tea break now, and then we'll come back for the next presentation.

MR MIANA: Thank you very much.

(Pause)

THE CHAIRMAN: I think we are now ready to hear from Dr Hayat on presentation no. 9. Please proceed whenever you are ready.

Presentation 9: Dam -- Powerhouse Basics

DR HAYAT: Thank you, sir. Mr Chairman and members of the Court of Arbitration, it's a pleasure to address you again, sir. Alongside me is my fellow presenter -- the presentation will be shared by Mr Muhammad Tariq -- can you raise your hand, please; thank you -- who is the chief engineer at Tarbela 4th Extension.

Already you have been given a general orientation of

the powerhouse with Mr Miana, Arfan Miana. So this presentation is an overview of the powerhouse design, construction and operation, turbine design, with some brief comments on generation and transmission, which will be further developed in the next presentation.

First, I will cover the role of tunnels in the powerhouse, and features of construction. Second, Mr Tariq will focus on turbines, their operation and different types, and how to ensure their longevity. And third, I will come back again to explain the role of different elements needed for power generation and transmission.

Slide number 2, please. I start with a cross-section of the powerhouse, which was excavated underground. You are already familiar with this. This is a cutaway view that gives you the configuration of the main equipment and major equipment within the cross-section of the underground excavation. Notice also the human that has been placed there just to give you an idea of the scale.

You will notice that there is considerable height above the main generator floor. So I would also like to point out towards the rails that have been placed, and this is for the cranes that are installed here to lift heavy equipment. And already Mr Miana has also shown you some pictures of that.

So notice that generally -- generally -- it is necessary to remove the generator and then the shaft, and then you can go to the Francis turbine. And that is the general situation.

However, in the case of Neelum-Jhelum, as I think previously mentioned also in one of the presentations, arrangements have been made to remove part of the spiral casing, and have possibility of removing the Francis turbine from the bottom, which saves a lot of time and hassle basically.

While I'm talking about taking out the turbine, which is necessary after a few years for maintenance purposes, because of the abrasion that you have, I will make a small clarification in matter of the abrasion-resistant runner coating.

On slide 33 of presentation no. 6, we showed you a photo of a turbine runner from Neelum-Jhelum with coated and uncoated portions, showing abrasion on the uncoated portion. The coating on the runner is only applied on the leading edge of the turbine blade, which showed no abrasion after four years of use.

This photograph -- or that photograph, actually -- therefore not only demonstrates the effectiveness of the coating, but also the effectiveness of the desander at

the Neelum-Jhelum Project.

Beyond that, let me walk through the major features of the facility. So as previously shown also, this is the generator hall. It is 25 metres in width, 53 metres in height, and 137 metres long, along the axes of the paper, perpendicular to the paper.

Within the generator hall you can see the control room also. However, the real complexity is below this floor level. You only see this part when you walk into the generator hall, but actually the complexity is below this. So this extends exactly four floor actually below: 1, 2, 3, 4.

So starting from the generator which is shown in greenish colour here, we have the shaft, and below this is the turbine. So the shaft connects the turbine to the generator. So if you strip the machinery from all of this, just to give you an idea of the scale of this, from the bottom to the top you can fit in a 12-storey apartment building in this space. And this is all underground. So that gives you an idea of the complexity of the underground construction and its actual size.

So on the right you can see a blue arrow, and this is from where the water comes in, and this connects to the penstock, which is not shown here. And this of

course drives the turbines. And after that the water exits through the draft tube into the tailrace tunnel.

Slide number 3, please.

THE CHAIRMAN: If I can just ask one question. The entire structure is underground.

DR HAYAT: Sir.

THE CHAIRMAN: Is that because the angle with which the water is coming into the facility requires it to be underground, or are there benefits in having the structure underground separate from that?

DR HAYAT: Very good question, sir. I think both ways, sir. You maximise the head as you are underground. In fact, sometimes when you calculate, even a centimetre of height difference will make, over a period of the lifetime of the project, a lot of difference in the energy that is generated. That is number 1.

Number 2: in terms of -- because the Himalayan region is also quite seismic-prone area. Having a structure inside actually is less prone to any damage or acceleration. So the acceleration or the forces that are generated on underground structures are much, much less than if they were to be overground.

So these are one of the two main reasons that we have this thing.

Next slide (3), please. Now I will explain on

tunnelling construction and tunnelling in the context of the powerhouse.

So can we go to slide number 4, please. Tunnelling is one of the most challenging parts of the hydropower construction in the Himalayas. We need tunnels because we have to convey water from the dam through the headrace, so that's the tunnel. Plus there are plenty of other tunnels, as you must have seen in many of the sketches and photos that have been shown.

This is because (a) the geology is complex, so you have different types of rocks coming in. You have minor and major faults, which means these rocks are crushed. So they are not at the best of their strength. There are high rock stresses. Sometimes the rock cover is quite high. So then you have these squeezing ground conditions and you've got rock burst. These are technical terms, basically. Which means that at a given height, you will have rock actually bursting into your tunnel. And presence of water, which is always present there, almost.

So all these things combined, they make tunnelling really challenging in these environments. And I'll explain a little bit.

Many plants, you know, they use pressurised tunnels, headrace tunnels, to convey water over many kilometres.

So the headrace -- and again, this pressure itself has to be managed, because it will go into the rock. And it may cause problems, especially (a) when you are energising and (b) sometimes then you have to empty the tunnels, and it has to be done gradually because otherwise all the pressure that has gone into the rock, when it starts coming back and you do it quickly, it can damage your tunnel.

So the other tunnelling works will include, of course, the surge tunnel and the tailrace tunnels, plus the excavation adits, the conveyance adits. Adits are basically tunnels but smaller diameter. When I say "smaller diameter", it doesn't mean like very small, but they are still like 4 or 5 metres. So we call them "adits" and the others are basically tunnels. So they are not small per se, but we call them "adits". Because we look at very large tunnels; the smaller ones, we say "adits".

So there are basically two methods that you can use to excavate the tunnels. And factors that will control are, again, the geology, the tectonic setup, the strength of rock, hydrogeological conditions, water, as I said, and geometry of the tunnel. Tunnel geometry could be totally circular, it could be a horseshoe, it could be a D-shape. So there are various types of

sections that you can choose from for a tunnel, depending on your use and the geology.

So conventionally, tunnels are drilled by what we call a "drill and blast" method. So you have a -- let's say you have a full face of the tunnel, and in concentric circles you drill holes and you charge them with dynamite. Tonnes of dynamite -- hundreds and sometimes thousands of tonnes of dynamite is used in a typical construction.

So these concentric circles of holes are made and filled with explosive. So with certain delays. Delays are in milliseconds. So what you do is: the first -- the innermost circle is blasted first. So that creates a space. And then the outer circle and then the outermost circle is blasted. So it all falls in, and then what we call is the mucking operation. So that is loaded into a truck or on a conveyor belt, and it is taken out of the tunnel.

Normally, because you have to drill and then you have to charge, so the length of the drilling is normally kept at about 3-3.5 metres. So this -- each cycle: drilling, charging, blasting, clearing out. And after that of course you have to put in the first support, which is normally shotcrete. So it's with a high-pressure nozzle. It's concrete that is flowable,

so you spray it on the face.

And you have seen -- you see even it here. So this is shotcrete, basically. So it is quick-setting, it just sort of sticks onto the surface, and it gives it that initial strength.

So normally in a day you do only one blast and muck at one phase. Therefore, if you have a long tunnel, progress is very slow. So how to overcome that problem: you have multiple faces that you attack. So you go from one side, you go from the other side, so now you have two faces. So now your progress from 3 plus 3, or you get to about 6-7 metres.

Then you also sometimes put in an adit in between. So now you have one, two, three, four faces that you can attack on. So then your daily progress goes to about 15 metres a day.

So these are some of the techniques that you use when you are going for drill and blast.

And often we use specialised machinery which is called the tunnel boring machine, TBMs. And TBMs also come in various forms: there are open gripper, there are shield tunnels, there are earth pressure balance machines. And all these depend on the type of geology and stratigraphy that you have.

Here is a photograph of the cutter head of the

tunnelling breaking through, basically. So this is basically a TBM in Albania. So here we also use two TBMs in Neelum-Jhelum Project. So it's a giant cutter head at the front. And the energy requirement to run these TBMs is in megawatts. And you need a specialised plant actually to feed these TBMs.

And so these cutter heads, they move in a rotating fashion, and they cut the rock, and while it has been thrusted forward by pistons. That's the basic sort of mechanism with these TBMs work. And they normally take about 15 -- you can do 15 metres a day, on average. Some of the good TBMs have done 20, 30 metres even, in a day. So compared to one face, 3.5 metres with drill and blast, and you have to have multiple faces, here with one TBM you can do 15 metres, on average.

So as previously mentioned also, the tunnel network at this project is 68 kilometres through very difficult geology. Both drill and blast and tunnel boring machines were used in different parts.

Slide number 5, please. So I think Mr Arfan Miana has already explained the various tunnels that we have, and you have already seen this sketch a few times. But just as a recap, this is the main transformer hall -- main generator hall, the transformer hall. These are the access tunnels/adits. This is the headrace tunnel.

The headrace, manifold, penstocks. And because the pressure is high, these are steel-lined.

There's a drainage gallery in here. And through this drainage gallery, we drill holes in all directions so that, if there is any water -- because the pressure is very high, some water will find its way through the rock joints towards the powerhouse. And we don't want any water coming because we have sensitive instruments and things and we don't want any water.

So in addition to a lot of grouting and sealing those joints, we have this drainage gallery with all the drain holes, so any water that comes in, it is taken into this gallery and taken out, so it doesn't go towards the powerhouse.

Then also, as Mr Arfan Miana and many others said, the size related to the Eiffel Tower and, you know, the surge shaft, you have seen that. So there is a lot of tunnels in this area. So we will look more closely at some of these features later on. So just a recap.

Slide number 6, please. This is the headrace which conveys the water from the dam towards the powerhouse. In Neelum-Jhelum Project, this is about 28.6 kilometres, and it is made of single and twin circular and horseshoe-shaped tunnels. The tailrace tunnel removes water from the turbines back to the river. It's

3.5 kilometres.

So the project also consists of ten access adits. You know this, like adit this and adit that. This is the entrance and this is the cable adit. And total length is about 11 kilometres for all these adits.

So between the headrace tunnel and the turbines, as I pointed out, we have the penstocks.

THE CHAIRMAN: Just a question, I think, from Mr Blackmore.

DR HAYAT: Sir.

DR BLACKMORE: Just on the headrace, yesterday I understood that the headrace has three different sorts of tunnel lining: it has shotcrete, concrete, and down underneath the river I think it was steel-lined. Could you just give me an idea of what length each of those linings was, please?

DR HAYAT: I will refer that question to Mr Ayub Malik, who will have a better answer on exact numbers. Can you answer that question, please, for me? I want to be precise.

MR MALIK: The twin tunnels are 19 kilometres in length. Out of that, 10 kilometres is shotcrete-lined; it was excavated by the TBMs. Remaining is: 9 kilometres of the twin tunnel is concrete-lined, 8 kilometres of single tunnel is concrete-lined. And then we have got around 732 metres under Jhelum crossing which is

steel-lined. This is the lining in the tunnels.

DR BLACKMORE: How much under Jhelum?

MR MALIK: 732 metres, twin tunnels.

DR HAYAT: Can you go slowly? Can you come in front here, please, and do this thing, so that everybody can see you and hear you better. (Pause) Slowly, one by one.

MR MALIK: Okay. Single tunnel, 8 kilometres -- more than 8 kilometres is concrete-lined. Twin tunnels, around 9 kilometres is concrete-lined. And twin tunnel, 732 metres under Jhelum crossing, steel-lined. And twin tunnel, 10 kilometres average is shotcrete-lined, which was excavated -- it's circular and excavated with a TBM.

DR BLACKMORE: And the 10 kilometres is closest to the dam?

MR MALIK: Yes, it starts 4.5 kilometres downstream of the dam.

DR BLACKMORE: So the first 4.5 kilometres are unlined?

MR MALIK: It's concrete-lined. First 4.5 is concrete-lined.

DR BLACKMORE: Okay.

MR MALIK: Which was excavated with a drill and blast.

DR BLACKMORE: Yes.

MR MALIK: And then we have the TBM tunnels.

DR BLACKMORE: Yes.

MR MALIK: They are then 10 kilometres which is shotcrete-lined.

DR BLACKMORE: Okay. Has the headrace tunnel been inspected?

DR HAYAT: Not -- I mean, after being energised and after being full of water?

DR BLACKMORE: Yes.

MR MALIK: No, sir, but I think the plans are there now. Because you know better than I believe anybody else in the room that you have to do it slowly, and then that means losing generation for that amount of time, sir.

Now they are planning that there are specialised firms with an ROV that go into the tunnels, and you can have inspection while the tunnel is running with water: you can put that submersible into the tunnel. So they are planning, and I think hopefully in the next few months they will have an inspection with that method.

DR BLACKMORE: That was my next question, whether you are using some form of remote sensing, so well done. I think it's important, that's all.

DR HAYAT: Thank you, sir.

Slide number 7, please. So these are some of the photos of the tunnel excavation. I think you have seen this one before also. This is the start of the headrace tunnel. This is during construction. This is the collecting canal while it was being constructed. You can also see some formwork and reinforcement for the desander area that we were at. So this is during construction.

Of course a lot of this hill had to be cut through, and this was basically conglomerate, this was not rock. And that is why you also saw that roller-compacted concrete on the upstream side to stabilise this area.

You can imagine the excavating tunnel in this type of geology -- and this Murree formation especially, with its soft shales, silt stones, clay stones and sandstone inter-bedded -- it's a huge undertaking. I think it's one of the monumental projects in such a geology, to be building such a large and long headrace tunnel with such a high pressure. And we of course also encountered faults and falls, and one was very near Jhelum.

Actually, when you are driving back to Islamabad, I would like you to have a look at both sides of the river, and you will see that the rocks here also are different on both -- like you saw on the dam site, here also the rocks are different on both sides of the River Jhelum. On one side you have the Murree formation, which are maroon-ish or reddish shales and sandstone, where the road is, on the left bank of the river. And on the right side, when you look, it is Hazara formation, which are shales and schists. And actually the river is running along the fault.

So it took almost ten years to complete the Neelum-Jhelum Hydropower Project. The initial design for excavation was actually to use the conventional drill and blast method. But for a significant length, as Mr Ayub Malik also just told you, we used two tunnel boring machines, to increase the pace of work basically.

The total length of the headrace tunnel is 28.5 kilometres, just to repeat. Out of this, 20 kilometres are twin tunnels, and that is 20 plus 20, so this means actually the tunnelling was 40 kilometres. The length is 20 kilometres, but you have 20 kilometres and 20 kilometres, so it makes a total of 40 kilometres. Out of this 40 kilometres, 20 kilometres was excavated by the two TBMs.

Slide number 8, please.

Now, this slide shows the cross-section of the penstock and inlet. So this is coming from the manifold or the part of the headrace, and this is the penstock. This is all steel-lined, very thick steel, and it is also grouted and encased in concrete.

And here (indicating) you have the -- this is the main powerhouse or the generator hall. You have the main inlet valve, or "MIV", as we call it in short terms. And of course this is the turbine, the shaft and the generator (indicating). So just a cross-section of

that.

So design of the penstock must include not only basic hydraulics, like (inaudible), but also consider the high pressure, and the presence of pressure spikes caused by closing. So of course for that we have the safety mechanism of the third shaft, to take care of the effect of increased pressure.

So these inlet valves actually act -- there are four inlet valves, because you have four units. So you can isolate any one of the units at any given time, not that you have to shut the whole plant.

Slide number 9, please.

DR BLACKMORE: Sorry, I'm just wondering: did you need to put any expansion joints in any of those penstocks?

DR HAYAT: In this penstock, sir?

DR BLACKMORE: Yes. I can see you --

DR HAYAT: Not to my knowledge.

DR BLACKMORE: I think you've got --

DR HAYAT: But again, because Mr Ayub has been here: any expansion joint in any of these penstocks?

DR BLACKMORE: I can see you've got thrust collars, I think, if I can read it correctly.

MR MALIK: There is a small expansion joint between the MIV and the spiral case.

DR BLACKMORE: Yes. Okay.

MR MALIK: To cater for any movement in the powerhouse or in the MIV. Very small, I think it's in millimetres.

DR BLACKMORE: Oh, is it?

MR MALIK: That's all you require.

DR BLACKMORE: Yes, yes. No, there's not much temperature change, so yes. Alright. Thank you.

DR HAYAT: Thank you.

Next one (slide 9), please.

This is the inlet valve. I'm sure today you will -- here you can't judge the scale maybe, and the 20-tonne counterweight that you have, but I'm sure you will be looking at it today when you are on a visit to the powerhouse, and it's a sight to see.

So basically it's an on/off valve. During operations, the flow of water is controlled by the wicket gates along the periphery, which has been explained by Mr Arfan Miana in his presentation.

So unless you have any questions for me at this stage, I will hand over to Mr Tariq.

THE CHAIRMAN: Any questions?

No, we have no questions, Dr Hayat. I take it we will see you again a little later in the presentation.

DR HAYAT: A little later, sir.

THE CHAIRMAN: Very good.

DR HAYAT: I will take over from slide 25 later on, sir.
THE CHAIRMAN: Okay. We look forward to having you back.
MR TARIQ: Mr Chairman and members of the Court of Arbitration, I am very pleased to address you for the first time. My name is Mohammed Tariq and I am chief engineer at WAPDA ...
THE CHAIRMAN: Let me just interrupt you for a moment.

Is the audio okay on this?

Okay, please proceed.
MR TARIQ: Thank you.

... responsible for the operation and maintenance of Tarbela 4th Extension Hydropower Station.

The next fundamental component of powerhouse structure is turbine. Turbine is rotating in a mechanical device that extracts the kinetic energy of moving fluid, which in our case is water, and converts it into the rotational energy, which is transferred to electrical generator by means of a coupled shaft to convert it into electrical energy.

Before the invention of waterwheel, the water cycle was the same as it is today: rivers were flowing from glaciers to the sea, irrigating land in between. The kinetic energy of water was utterly wasted, contributing only to the erosion of land.

After the invention of waterwheel, a small fraction

of the kinetic energy was utilised for different purposes, including milling grains and powering machinery. Later on, after Industrial Revolution and invention of AC generator in the 19th century, the output of waterwheel was not sufficient. This led to the development of initial turbines, which were not very efficient, but much better than waterwheels.

They were preferred, due to their various shapes and design, for the use in the regions where the waterwheel could not be installed. Later on, they were customised for different locations, water flow and landscape, resulting in birth of modern turbines.

Slide 11, please. This short video will describe operation of turbine in hydroelectric power plant. Please play.

(Video played)

Now we will play it again, and I will explain. Please pause. Please pause.

Water flows from reservoir, passing through the penstock, and enters the spiral casing, where turbine is housed, and exits through draft tube into the tailrace.

Please play.

The coupled shaft imparts rotational energy to the electrical generator, resulting in production of cheap and environmentally friendly electrical energy, which

can be transmitted to national grid through 500 kV, 220 kV or 132 kV transmission lines. Hydroelectric power plants have the ability to quickly ramp up or down, therefore they are playing a crucial role in grid stability.

Slide 12, please.

This slide is a detailed view of internal cross-section of Francis turbine installed at Neelum-Jhelum and its associated structure for conversion of the kinetic energy of the water into electrical energy, which has already been explained in detail by Mr Arfan Miana in presentation 8, and its working in principle will be explained in upcoming slide number 15.

Slide 13, please.

We know that turbines are not one-size-fits-all. That is why we classify them on multiple design factors to meet our specific requirements. Some key design factors are: energy at inlet, direction of flow, head and revolutions per minute.

There are two types of turbine, based on energy at inlet. These are impulse turbine and reaction turbine. They have already been explained in detail by Mr Ayub Malik in presentation no. 2.

However, impulse turbine operates by converting the

kinetic energy of high-velocity jet of water into mechanical energy. Pelton wheel turbine falls in this category.

However, in a reaction turbine, reaction turbine uses both potential energy of the water stored in the reservoir and the kinetic energy of the high-speed flowing water. Francis and Kaplan turbines fall in this category.

We classify turbines in four categories with respect to the direction of flow. In tangential flow turbines, water flows tangentially to the turbines' runner blades. In radial flow turbines, water enters directly and exits tangentially. Pelton turbine falls in this category. In axial flow turbines, flow of water remains parallel to the axis of rotation. Francis and Kaplan turbines fall in this category. In cross-flow turbines, water passes across the turbine blades.

There are three types of turbine with respect to the water head: high, medium and low. 300 metres and above is considered as high head. Pelton wheel turbines are installed to utilise this head. Head ranging from 30 to 300 metres is called medium head, and Francis turbine falls in this category. However, in modern studies, medium head is defined up to 500 metres. Head below 30 metres is considered as low head, and Kaplan turbines fall in this category.

There are three types of turbine with respect to the revolutions per minute: high, medium and low, for Pelton, Francis and Kaplan respectively.

Slide 14, please.

Let's discuss prominent types of the turbine. Their selection criteria depend upon head, flow rate and site conditions, which have already been explained by Mr Ayub Malik in presentation 2.

Francis turbine is a type of a reaction turbine in which water enters in spiral casing and flows both axially and radially through turbine runner blades, changing direction and velocity. This change in momentum creates a reaction force that pushes the blade, causing a rotation. These turbines are suitable for medium head and variable flow rates.

Francis turbines are used and are in operation in WAPDA. Pakistan's largest hydroelectric power plant, located at Tarbela on the River Indus, features 17 Francis turbines with a rated installed capacity of 4,888 MW. In WAPDA, Francis turbines are also used in many other hydroelectric power plants, like Mangla, Neelum-Jhelum, Ghazi Barotha and Warsak.

Pelton turbine is a type of impulse turbine which uses kinetic energy of high-velocity water jet fired

from nozzles at specific angles. These type of turbines are also in operation in WAPDA at high-head power plants, located at Duber Khwar, Allai Khwar and Khan Khwar power stations.

Kaplan turbine is also a type of reaction turbine. These turbines are suitable for low head and large water volumes. These turbines are also in operation in WAPDA at small hydropower stations located at Rasul, Shadiwal, Nandipur and Chichoki.

Slide 15, please.

Now we will have a short video demonstrating fundamental working principles of Francis turbine in 3D. Please play.

(Video played)

(Indicating) Penstock. Transmission lines. Switchyard. Hydroelectric power plant. Machine hall of the power plant. Guide vanes, regulating rings. Runner. Guide vanes. Guide vanes. Turbine shaft. Spiral casing. Fixed vanes. Guide vanes. Runner with spiral casing -- draft tube.

In this video we have seen penstock is a conduit to transport water from intake structure to turbine. Inlet wall is positioned at the entrance of the spiral casing. Spiral casing directs pressurised water from inlet wall to the turbines runner blades. Its gradually decreasing

dial accelerates the water flow for efficient energy transfer. Guide vanes regulate the flow of the water. Volume of the water can be controlled by adjusting the angle of the guide vanes.

The runner is the heart of the turbine and directly interfaces with the water flow, capturing its kinetic energy and transmitting it to the turbine shaft.

Bearing supports turbine shaft within the turbine housing and ensures proper alignment of the shaft to avoid wear and tear.

Draft tube is located beneath the turbine runner and it provides the exit passage to the water for discharge into the tailrace. Its gradually increasing cross-section area acts as a diffuser.

Slide 16.

The performance and longevity of the turbine depends upon many factors, including head, flow rate and sedimentation. Head or height difference between the water source and the turbine directly affects the pressure and speed of the water entering the turbine. Similarly, flow rate or volume of the water passing through the turbine per unit time affects the output of the turbine. Therefore, matching of turbine type with site condition is crucial for determination of performance. That is why Pelton turbines are suitable

for high heads and Kaplan turbines are suitable for low heads.

Sedimentation is the deposition of particles carried by water. It has significant impact on performance and longevity of turbines. Accumulation of sediments can cause erosion, abrasion and damage to turbine blades over time. This phenomenon and its management strategies have [been] discussed in detail by Dr Abbas in presentation 6.

This slide shows a close-up image of turbine abrasion on turbine blade profile. Rate of abrasion on the turbine increases with increase in head and size of grain. Sand particles larger than 0.2 to 0.4 millimetres are particularly abrasive.

Slide 17, please.

Protective measures are essential for turbines to ensure their reliable operation, longevity and efficiency. These measures are necessary to mitigate various risk and threats that turbines may encounter during their operation.

Protective measures include: inlet screens and trash rack; desander; surge tank; pressure relief valve; runner coating; and mechanical protection. In the following slides, I will quickly go through the measures which have already been explained by Dr Abbas in presentation 6.

Slide 18. Inlet screens and trash racks are installed at the intake of turbine to prevent entry of debris, rocks and branches, to mitigate the risk of blockage, abrasion, erosion and mechanical damage to turbine components, therefore prolonging lifespan of turbines.

Slide 19, please. Desanders. Desanders are designed to remove sediments and abrasive particles from water before it enters the turbine. They help to reduce wear and tear on turbine components and prolong the operational life of the turbine.

Slide 20. Surge tanks are installed between penstock and turbine to absorb pressure surges caused by sudden changes in water flow. They protect turbines from water hammer effect.

Slide 21. Pressure relief valves are safety devices installed in turbine hydraulic system to release excess pressure and also to prevent pressure-related damages to turbine during abnormal conditions in the power plant.

Slide 22. Runner coatings are applied to turbine runners to enhance their resistance against abrasion, corrosion and cavitation damages. These coatings provide a protective barrier between turbine blades and the abrasive elements to reduce wear and tear on turbine

blades, therefore extend operational lifespan of turbines.

Slide 23. Mechanical protection. Various sensors and monitoring systems are installed to detect mechanical faults, such as: bearing oil level monitoring; turbine overspeed protection; regular inspection of inlet valve and pressure relief valve to ensure their proper operation; vibration monitoring to avoid wear and tear on the turbine shaft components; shaft seal, to ensure as minimum as possible water leakage between the turbine shaft and the head cover; monitoring of bearing pad temperature, to avoid any damage to the plant components with respect to the turbine.

Alarm and automatic shutdown mechanisms are triggered in response to abnormal conditions to prevent the damage to the turbine components.

Thank you very much for your attention. Now Dr Tahir Hayat will continue the remaining portion of the presentation.

THE CHAIRMAN: Any questions? No.

MR TARIQ: Thank you, sirs.

THE CHAIRMAN: Okay, we have no questions for you Mr Tariq. That was very clear. Thank you very much.

MR TARIQ: Thank you, sirs.

DR HAYAT: A pleasure to be back, sir. I'll talk a little bit now about generation and transmission.

Slide 25, please.

So this shows the photo of the generators inside the powerhouse, 1, 2, 3, 4, in Neelum-Jhelum. As you know, and as has been explained by Mr Tariq also and others, the generators convert the mechanical energy produced by the turbines into electrical energy, which is then readied for transmission via the transformer hall and the switchyard.

So the Neelum-Jhelum generator hall includes four generators, each rated at 242 MW and expected to run at 300 RPM, revolutions per minute.

The vertical arrangement seen in this photo, the generator is mounted on top of the turbines. You have also seen other illustrations and videos. This is the characteristic of large plants, while in smaller plants the generators and the turbines could be in a horizontal direction. So here they are vertical, and one vertical, and in smaller plants there could be a horizontal arrangement also.

As is in here, a hydroelectric plant would usually have multiple generating units because this would allow individual units to be removed from operation while the others are kept running. So that is a desired design

feature that we have, that we have more than one unit.

So multiple units also allow for power production to track variations in available flows of water or changing power demands during the day. So if you have less than peak demand, so you can only run two generators, and as the demand rises, then you can add on, or subtract as the demand goes down.

For any turbine or generator, the energy conversion efficiency is achieved by running a single unit at its design optimal operating point, rather than running multiple units at lower flow rates. So it is better to be within the sweet spot, I would say, of the turbines and generators, 50%, 70%, 80%, 90% efficiency, rather than having all at 40%, 30% efficiency. So given that the largest generating units produced by most of the manufacturers are approximately 750 MW, larger plants will need multiple such units to meet the plants' design capacity.

Slide number 26, please.

Next, this is the transformer, photo of a transformer, this one, and this is also a step-up substation in the powerhouse. And it is located, in the case of Neelum-Jhelum, underground also, and you will see it today, only a few metres away from the generation hall.

The voltage that is produced at the generator in Neelum-Jhelum is 15.75 kV. As it is taken to the transformer, it is stepped up to 525 kV, and this is for efficient transmission.

So a transformer, a step-up transformer -- there are two types of transformer, step-up and step-down. This is a step-up transformer: it increases from 15.75 to 525. This is because this will allow generation of transmission of high voltage with less energy loss.

So sometimes the transmission lines could be hundreds of kilometres. It's very normal, because they have to take these to a central grid station. In the case of Pakistan, it is distributed all over the country: it becomes part of the whole big basket of energy that you have.

So modern turbines can convert about 94% of the potential energy theoretically available from water into mechanical energy, and generators can convert about 98.5% of that mechanical energy into electricity, and about 1% will be lost in the process of transforming the low voltage of the generator. So at the transformer level there's 1% loss.

So at the optimal operating point, over 90% -- to combine all the efficiencies and the losses, so from the total energy available in water we can produce

electricity which is about 90% of that. This 10% is various losses that we have in the system.

Next to the switchyard, please. Yes, 27.

So this is a place where once the voltage has been stepped up, it is directed to the transmission line, and this plays a major role in the security of the power, or the security of the system. So it comprises a series of switches, breakers and other protective devices which can be either manually or remotely opened and controlled to energise or de-energise specific transmission circuits leaving the plant.

To disconnect a transmission line leaving the plant, the breakers are opened, and to connect, they are again closed. So these are the breakers that we have, large ones. And basically to protect, if there are any surges or there are other problems, then you have these breakers to isolate the system, or multiple systems. So the Neelum-Jhelum switchyard is rated at 575 kV.

Can we go to slide 28, please.

So the transmission lines deliver the plant's electricity into electrical power grid at the designated point of connection. So that point has sufficient transmission capacity to accept the energy being produced at the plant and then to deliver it into lines serving the users, basically.

So getting the hydropower to homes and businesses, it takes very careful planning, as transmission lines can carry the amount of electricity that will be consumed. To keep the right amount of power flowing, computers calculate how much electricity should be sent, when and where across the system, and power generation of various plants feeding the grid will be adjusted.

So this is at the master control level. So all the plants, you know, they are at a master control level. They have a control which then decides which plant produces what and at what time, and where it has to be sent. So during the course of the day it will be adjusted so the correct amount of energy is flowing into the grid, and that will be used over the next whatever period it is required.

Number 29, please. Okay.

So beyond the transformer, there are multiple other types of substations in the power systems.

There are step-down substations, which decrease the voltage for local distribution. Because the voltage that comes into your lines, for those living in America it is 110, for those living in this part of the world it is 220. So it has to be stepped down from that higher level to the distribution point for the ... So this is where we have the step-down substations.

There are also distribution substations that supply electricity direct to the consumer, and switching substations. So multiple lines come into the switching substation, and if there's a problem with one, or there's less need, so that will decide -- these are the switches where you go from one place to the other place.

So basically, switching stations can isolate, just like your main inlet valve or other safety devices: that's also another sort of a safety protection. If you need maintenance on one line, you will switch it off. If you need more energy in some, then you can give it to that.

So next is, I think, the thank you. 30. Yes.

So I'm at the end of my presentation. If you have, sir, any questions, I will be glad to take those, myself and Mr Tariq.

Yes?

THE CHAIRMAN: Mr Buytaert.

PROFESSOR BUYTAERT: Would you know what is the percentage contribution of the Neelum-Jhelum plant compared to the total hydropower production in Pakistan? What share does the plant provide?

DR HAYAT: So I would say it is about -- roughly 1 over 26, because the total -- please. To be precise.

MR MIANA: For the hydropower station, we have about

9,400 MW installation capacity. Out of that, 969 is the -- so almost 10%.

DR HAYAT: But what about the total big -- that is 25,000?

MR MIANA: Yes, they asked for the hydel.

DR HAYAT: You're only asking about hydel?

PROFESSOR BUYTAERT: Yes.

DR HAYAT: Or total mix in the Pakistan ...

PROFESSOR BUYTAERT: No, the percentage. So the 10% of the total hydropower energy --

DR HAYAT: Total hydropower.

PROFESSOR BUYTAERT: Yes. While we're at it, what is the percentage contribution of hydropower in general to the total electricity consumption; would you know?

MR MIANA: About 25-30%.

PROFESSOR BUYTAERT: Okay, yes. Thank you. And the rest? Would you happen to know the percentages of the other types of hydropower?

MR MIANA: This is the nuclear, the thermal, and the way it --

DR HAYAT: I think it will come in the next presentation.

PROFESSOR BUYTAERT: Okay, perfect. No, no, I'll be happy to wait.

DR HAYAT: So that will be answered in precise terms in the next presentation.

PROFESSOR BUYTAERT: Great. Thank you.

DR HAYAT: If that's okay with you.

PROFESSOR BUYTAERT: Absolutely.

DR HAYAT: Thank you.

THE CHAIRMAN: Just one question from me, Dr Hayat. You mentioned that there would be a sort of master person or place that would decide where the energy needs to go at what time. Is that located somewhere in Pakistan, and you receive instructions from them here as to where to send the energy? Is that how it works?

DR HAYAT: That is how it works, sir. I think if I am not wrong, it is called NTDC, National ... NPCC.

THE CHAIRMAN: NBCC?

DR HAYAT: NPCC, National ...

THE CHAIRMAN: NPCC.

DR HAYAT: National Power Control Centre.

THE CHAIRMAN: National Power Control Centre. Okay.

DR HAYAT: So what happens is -- so he will also be talking about that in the next presentation, to give you more details. But I think there is a daily exchange of data between all the power plants. So it's a data coming out, so they will tell them what is the capacity that is available with them on a particular day, and they will tell them how to dispatch and what to do. But he will tell you more about it, sir.

THE CHAIRMAN: Okay. Very good.

So I think then we have no further questions. So that concludes this presentation.

If I understand correctly, Dr Hayat, you may need to leave at this point. Let me just, on behalf of the Court, say how much we appreciate all that you've done during the course of this visit. It's been very helpful to hear from you.

DR HAYAT: It has been a pleasure, sir, to address you, and give you as much information as I could, sir. Thank you very much, sir, for listening to me.

THE CHAIRMAN: Thank you very much.

So I understand now is our lunch break, and then after that we'll resume with the next presentation. Is that correct?

MR MIANA: We have now the next presentation, and after that we have the lunch break.

THE CHAIRMAN: Okay. Next presentation and then lunch.

(Pause)

I think we are ready now for presentation no. 10.

Presentation 10: Power Production

MR KHAN: Honourable Mr Chairman, members of the Court, good afternoon.

I am Hameedullah Khan. I am from WAPDA. I have a 31-year service length in WAPDA, mainly working as operation and maintenance engineer for powerhouses.

Currently I am chief engineer, Warsak powerhouse.

I have spent quite a time of my service at Tarbela Power Station, serving the first power station, the second power station and also the T4, where now my colleague Mr Tariq is chief engineer. I have spent more than 20 years out there.

Currently I am looking [after] the north region powerhouses in the country, six of them, relatively small powerhouses. I am also looking after the rehabilitation work of Warsak powerhouse, which is one of the oldest powerhouses in the country, in fact the powerhouse which was commissioned back in 1960. It has a 242 MW installed capacity.

So in our presentation -- along with me Mr Arshad Malik, co-presenter: he is also chief engineer in WAPDA -- we will be talking to you about the power systems. You have heard a lot about the hydropower, how the energy produced, and I consider that you are now the hydro experts, along with me. So it will be easy talking to you about the power production and the power systems now.

We will be first discussing power system in general, then we will go to a simple power system, then we will be discussing it in more detail. Finally we will be discussing the role of Neelum-Jhelum, which my colleague will be presenting to you, in the current country's power system: how it fits and what is its contribution in the power system.

Slide number 2, please. Hydropower.

A lot has been said about the hydropower. It is the power extracted from the water, either from the falling water or the running water. And from the falling water we get the potential energy; from the running water, we get the kinetic energy. So either of them, or the combined effect of them, can generate a lot of mechanical power.

Anciently, this mechanical power was used for mechanical purposes, like signboard or textiles, or maybe for grinding grains. After 1833, a modern hydro turbine was developed, and then this hydropower was started to be used as a source of electrical energy.

As we know, water is about 800 times more dense than air. It has a density of 1,000 kg per metre cubed. In contrast, air has only 1.293 kg. So a little bit of water flowing with a smaller head can generate electricity. It is an equilibrium which we have to hit, where we stand or where we design our powerhouse, regarding the flow and the head.

So, as I have told you, Mr Benoît Fourneyron was considered as the founder of the modern turbine in 1833.

Then in 1882, as the slide suggests here, on River Fox in Wisconsin we have the first formal hydropower unit in the USA.

The story doesn't stop over here regarding evolution of the turbines. In 1897, the first HEP was set up in Asia, at West Bengal, and it has an output of almost 130 kW. Although it was a smaller one, as we are looking out to our powerhouses of the day, like Neelum-Jhelum is 969 MW.

Slide number 3, please.

Hydropower. Hydropower has three major advantages: it is clean, cheap and reliable. And by "clean" I mean that it doesn't generate any industrial waste: it doesn't have any chemical reactions going on while we are generating the hydropower. And it is environmentally friendly, in a broad spectrum.

By "cheap" I mean that maybe the initial cost is very high for a hydropower station, but the running cost is minimal. It is almost perpetual, a perpetual machine having a generating efficiency of 98%. In fact, the tariff of the system is controlled by this cheap characteristic of hydropower.

Then we have the reliability factor in it. As you know, the hydropower consumes water as its fuel. In contrast, if there is a nuclear power [plant], it will

require some uranium or some fuel; for fossil fuel plants, it will require coal or some furnace oil, et cetera. But here the fuel is water.

Water as known as the white gold. It doesn't generate any flue gases. In a hydropower station, you will not experience the extra high thermal losses because the temperatures are very low. And as these are built on the rivers, and the river has a flow around the year -- maybe it's less or high, maybe in wet season they are getting more water and in dry season they are getting less water, but the flow doesn't cease. It is not the case in the rivers, certainly, which are located in this part of the country, in the Himalayan region.

So you have a minimum flow. And these hydel generators or hydropower plant can run in any part of the year. The production may vary. In wet season, they will be running as a baseload plant -- what is baseload? I will explain it in detail later -- or they may be used for peaking. But they will be kept running, owing to the property of the river, which doesn't cease: the minimum flow is there.

Then the other advantage is: easy to maintain. And for this, we have to make the comparison. We have to make the comparison between the hydropower plant and a steam turbine.

So the auxiliary equipment are the essential equipment in a powerhouse to run main equipment, i.e. generator and turbine. Turbines give you the mechanical energy; generator converts to the electrical energy, which is the theme over here.

So the balance of the plant equipment which are essential for running these two major equipments is known as the auxiliary of the power plant. And this auxiliary in a hydropower plant is minimum as compared to a thermal power plant. Maybe a thermal power plant has so much auxiliary for one 600 MW unit, which is sufficient for a 2,000 or 3,000 MW hydro turbine.

Less auxiliary means less maintenance, there is more reliability, and it's more economical also.

The system doesn't run on the same load pattern throughout the day or throughout the season, so it must have a powerhouse, which can vary with the system requirements. And this property is mostly and reliably found in a hydropower unit.

It can start up very quickly. Our turbines at Tarbela -- because I have worked a long time at Tarbela -- they can start in a matter of 3 minutes only, from zero to their rated speed of 136 RPM, and they can be synchronised in next 2 minutes. And the ramping of these turbines are so quick they can take a load of

100 MW in a matter of few seconds: maybe 60 to 70 seconds and they are running at 100 MW.

So you see how they adapt to the changing load and how flexible they are. So for the reliability of a system, you cannot ignore the role of a hydropower plant.

Ramping, as I have already explained, it is the ability of the turbine or a generator to go up quickly and to go down quickly in terms of loading, depending on the system requirement. So this ability has to be there if we are requiring a reliable system or if we want a system to be more reliable.

Hydro turbines are also used as frequency regulators: they are put on auto mode and they will automatically regulate the frequency. The standard frequency in Pakistan is 50 Hz; as you already know, in America, it is 60 Hz. So due to quick ramping, they are used as frequency stabilisers.

Slide 4, please.

Sir, this is the map of Pakistan, showing the hydro potential of the country. All of these powerhouses which are shown over here are not operational. Some of them are operational; some of them are under construction; some of them are in feasibility stage, study stage.

So you can see the legend over here. And the powerhouses in green colour are in operation. The powerhouses in magenta colour, some of these are operational, some of these are under construction, but they are operated by a private owner and are controlled by PPIB, Private Power & Infrastructure Board. They are working under the umbrella of PPIB.

Right now, sir, if I can show you, we are here (indicating), Neelum-Jhelum. You can see this is Neelum-Jhelum; this is a reservoir, and it is Mangla. So this Neelum-Jhelum, as you know, is a run-of-river plant. But what's coming to this reservoir is stored, and Mangla can operate as a reservoir-based plant throughout the year.

If you are interested where I am working and coming here to brief you, I am working, sir, here (indicating). This is River Kabul and Warsak powerhouse. Right now I am performing my duty over here.

Where I have spent a lot of time, 20 years, this is Tarbela (indicating). Tarbela 1, 1,750 MW; Tarbela 2, 1,728 MW; Tarbela 4, where Mr Tariq is working, 1,410 MW. And now we are in a process of developing another powerhouse, which is known as Tarbela 5, and it will be completed in a span of a few years.

So we have a lot of other projects, sir, which are

under construction or feasibility in the northern side of the country. Generally, the heads available are as per topography or terrain which Pakistan has. The north and west portion of the country has the heads, has the rivers. So all of the hydro generation is concentrated over here, in the north. In the south and in the central portion of the country, we have plain terrain, so thermal units, wind units and solar units are there.

Next slide, please, slide number 5. Sir, now we will be talking about the power production and the power systems. So I will be explaining you first a simple power system.

Next slide, please, slide number 6. Sir, this is a simple power system, and it is just for the sake of understanding, sir.

So as you can see over here, sir, in the red we have the generation. We (indistinct) belong to this portion. Then we have the transmission, which is shown here as blue. Then we have distribution system, which is shown here as green. And then we have black, the essential part of a system: customers, from where we get the money.

So, sir, explaining my portion first: the generating stations. These are designated as red. This generation station may be a hydel, in a power system -- and now

I am talking about a power system, sir. So this may be a hydel, it may be a nuclear power plant or it may be a thermal power plant, or wind or anything. So it is the first part of a power system.

Then we have this generator step-up transformer. This is very important, sir. Because in powerhouses, whether it is a hydro or a thermal, the generation voltage, as Mr Hayat also explained, for Neelum-Jhelum it is 15.75 kV. But to transmit the power at this voltage level will ultimately result in a lot of losses, because -- as a simple technical discussion -- the losses depend on the amount of current.

So the power we generate over here, 242 MW, and we have a 15 kV voltage at the generation. So the current will be obviously in kiloamperes. And for the losses you have to make square of the I and then multiply it with the resistance of the transmission line, and the result will be so much high losses.

So to control these losses, we need a power transformer to step up the voltage to a level which is suitable for the transmission.

So, as per engineering standards, the designer has suggested these levels, starting from 138 kV to extra-high voltage level of 765 kV. And the choice depends on: the distance you will be covering to the load centre; the topology of terrain of the area which you will be crossing during the transmission lines; the wind pressures, if the area gets snow, any snow loading, everything. There are so many factors. The designer knows about it.

So, sir, here we will step up the voltage levels to the appropriate voltage level to reduce the current and control the losses. And then we will reach to a substation, which is the first step of the distribution network. So here we will reduce the voltage level again, and will bring it to an acceptable voltage level so that we can easily distribute the power which we have generated in a power station to the load consumers.

So there are so many types of the load consumers. We have divided, for simple power system consumers over here, in three categories.

First is the substation, consumers who like to buy the power in bulk. They will directly buy the power from you at a relatively high voltage level and they will distribute it in their system at their own will. So these are the first category. They purchase the power in bulk at a high voltage level.

Then we have a primary customer, who needs the power at, in our country, only 11 kV, and just step down it to

240 workable voltage and distribute it. These are the second: we call them primary customers.

And then there are so many customers, like domestic, like markets, like hospitals, like railway stations, and so many customers who require the ready-made product, the finished product. So the finished product in our country is sold as 240 V; in America it is 120, I believe.

So, sir, this is the simple power system. And now I will be moving, in slide number 7, to a little bit complex power system. Sir, this is the same power system, but here it is a little bit -- more things are added in it.

These are again the consumers: rural consumers, then more denser city consumers; a farmhouse; distribution network; windmills; solar farms; small powerhouses located near the load centre, just to give the voltage boost and to control the peaking hours.

Then we have the industrial consumers. These may be the sugar industry. They have their own powerhouses. So they will generate the energy, generate the power, consume it for their machinery, for their use; and which is surplus, they will give it to the distribution network. And if they have a fault on their generators, they can [do it] the other way round: they can take it

from the distribution network. This is called a concept of net metering. If you have a surplus, you give it to the system; if you have scarcity, you take it back.

This is the first layer of the powerhouses, where we have the medium size. And these are at a little distance from the cities. So it may range from 150 MW to 350 MW. Most of the small thermals are designed like this.

Then we have the main stabilisers of the system. The junk of the power is supplied from here (indicating). These are the large hydro and thermal power plants. So it can be as large as 22,500 MW like Three Gorges. In our country, it is Tarbela, 4,888 MW. It could be a coal plant, it could be a nuclear. We have one nuclear, 2,300 MW, at KANUPP.

So this is the concept of an integrated power system, where the large power plants are available, the medium-sized power plants are available, relatively smaller power plants are available, windmills, solars are available, and the most important, consumers are available.

Next slide, please, slide number 8.

So now coming to the Pakistan power system, how the power is distributed. This is the map of Pakistan and these are the transmission lines, the hard lines are

actual transmission lines which exist in the country. The dotted transmission lines are the future transmission lines: their feasibility is complete and they are in a construction phase now, sir.

Sir, for better understanding, I will request you to just concentrate on this legend. The red lines, all the red lines, these indicate 500 kV transmission lines. The green lines, these indicate 220 kV transmission lines. This magenta colour, this is the new addition in our system, the DC transmission lines. So far we have only one, starting from Matiari and ending at Lahore.

Then for future, we are considering another DC line over here (indicating), to import power from Tajikistan in future. This is under consideration, sir.

We have the powerhouses over here (indicating) also, sir. You can see these rectangles with a straight line: these show you the hydro powerhouses which are running in the system. And the rectangles with this cross, with this diagonal line, these show the thermal powerhouses.

So, sir, for a wet season, when we have ample amount of water, the power flow in Pakistan is from north to south. And during the dry season, when the water is less in the rivers, to meet the country demand, the power flow is from south to the north, and most of the thermal units are running at that period of time.

So it's quite a hectic planning. And as my earlier colleague Mr Hayat said, the NPCC, National Power Control Centre, is the system operator. They have the complete data and they are responsible for this planning. They will tell you when to start your unit. As an operator of this power plant where we are sitting right now, Neelum-Jhelum, its operator cannot start it, Mr Miana cannot start the unit at his own will. He will get the information and the instructions from NPCC, sir. So NPCC is the planner of the system.

The transmission lines are controlled, maintained and erected by another company, sir, which is known as NTDC, National Transmission & Distribution Company, sir. This was once WAPDA: we were all brothers. But then we were disintegrated in 1998, obviously to improve the efficiencies. And WAPDA was given the mandate of developing and running the hydropower, and NTDC is looking after all the transmission lines, the grid systems, and developing the new transmission lines and studying the new transmission lines.

Next slide, please, slide number 9.

Sir, now coming to the energy mix of the country. Sir, this is the data from June 2023 and it will give you the idea what is the Pakistan total installed capacity and how it is generated, what is the energy

mix.

Sir, the country, as of last year, has an installed capacity of 46,035 MW. Out of this 46,035 MW, almost 52-55% is generated through thermal powerhouses. Then we have the hydel. And its share is now shown over here as 23%, but as of now, in January 2024, it has risen up to almost 26%.

Then we have nuclear, renewables and Karachi Electric. It is running independently from the rest of the system. It is obviously interconnected, but it is operating independently. This is an independent company responsible for supplying energy to Karachi, the mega-city of Pakistan.

Next slide, slide number 10, please.

THE CHAIRMAN: Before you move past this slide, just to clarify: the hydro component is which parts of the pie slice?

MR KHAN: Sir, this is "WAPDA Hydel", the hydel powerhouses controlled by WAPDA. But as I explained in the previous slide, there are certain powerhouses which are run under the umbrella of PPIB, private power producers. So they are here, in yellow. Collectively, hydel is -- here it is shown as 23%, but as of today it is almost 26-27%, sir.

THE CHAIRMAN: Okay, very good. Thank you.

MR KHAN: Next slide, slide number 10.

Sir, this is how we are utilising the powerhouses in our system. We have installed capacity of 46,035, as I have already told you, in megawatts. But it is not possible to run all these powerhouses on their full capacity all the time. Maybe the water is not available for a hydropower station, or maybe a nuclear power plant has some issues, or maybe the thermal power plant is under maintenance. So the planner has to decide how to use it most economically, in the economic merit order.

So this is how, in previous year, 2022/23, we have utilised our thermal nuclear hydel/IPPs. This chart shows the energy in gigawatt hours, and this is the contribution of each power plant.

So as from the previous slide, the thermal is almost more than 50%, sir. So if you can see over here, the contribution of the thermal in the power system is also around 50%, sir.

And just in fact, sir, the nuclear is less in percentage [than] the energy mix we have seen in the last slide, and the hydro is more in the energy mix, in terms of percentage. But you can see over here there is very little difference between the energies of the hydel and the nuclear.

It is because the hydel is seasonal: it depends on

the flow of water. In dry, you have minimum water, so you cannot run Neelum-Jhelum at 969 MW all the time. But a nuclear will only require fuel -- if you have the fuel for the plant, you can run it 24/7, round the clock, throughout the year.

The system operator and the planner have to consider these points as well while they are planning how to run the power plants.

Next slide, please, slide 11.

Sir, now we will be talking about how the HEPs, the hydropower plants and the power system, how they are interlinked, how a HEP fits in a power system.

So next slide, slide number 12, sir.

A lot has been said about this slide, sir, in previous presentations. And this is the HEP, and how HEP can be designed run-of-river with pondage and run-of-river without pondage, a reservoir or a pump storage. So I will not talk much about this. Then, as Mr Tariq explains, the turbines have low head, medium head and high head. This is the choice.

So these two are the design parameters. And once the powerhouse is established, then the operator has to look to it from the load perspective.

Now he has to decide, for an HEP, whether to operate it as a baseload plant, intermediate-load plant or a peaking-load plant. And what are these terms? I will be explaining to you in the next slides, sir.

Next slide, 13.

Sir, before going to that, a very simple formula, just for understanding how the P, the watts, the power, which factors it depends [on].

So obviously it depends on the quantity of water and the head of water. You already know I consider you, sir, as hydro experts now.

So the other things are: the gravity, acceleration due to gravity, a fixed quantity, 9.8 metres per second squared.

This is the density of water, 1,000 kg per metre cubed.

This is, sir, the efficiency of a turbine. The efficiency of a turbine theoretically can vary from 0 to 100, but for a modern turbine, it is always above 90%. So even if we considered it as 0.9, which is 90%, we can easily calculate the watts from a given quantity and head of water.

This is how the HEP output is derived, and this is the main theme in the minds of the planners during the wet and dry season.

Next slide, please, slide 14.

Sir, now this is the daily plant loading. I was

talking to you about the baseload, intermediate load and peak load. So let us first understand what I mean by baseload, intermediate load and peak load, sir.

Sir, obviously this load requirement is from humans. Humans are pretty predictable: all of them sleep during the night. After midnight, everybody feels sleepy and they sleep.

So if you can see over here, this is the time starting from midnight up to 12.00 [noon], and this is the power requirement or the load requirement.

So you can see the minimum requirement is around 12.00 midnight. All of us are sleeping. We don't require any lights in our rooms, we don't require TV, we are not interested in going to the restaurants, so the power requirement is minimum. So this point, we are achieving this point, sir, indicating lowest point.

Sir, then when the people are rising in the morning, around 6.00 am, they are switching [on] the lights; the industrial load is about to come. So we get a minor peak over here, and this is called the morning peak of the system. This is for a relatively smaller duration, maybe 2 hours. And then when the people settle down in their offices and their workplaces, then the demand goes down a little bit, but it doesn't touch here because we are not sleeping; we are still working.

Then during the evening, when most of the people return to their homes, they are cooking, they are doing their works, markets are on, everything, then we get another peak. Lighting load is there. And this peak, as you can see, is a little bit prolonged. In our country, this lasts 4 to 5 hours. Morning peak lasts from 1.5 hours to 2 hours. So in general, in 24 hours you get 8 hours of the peaking, or maybe less than this.

Then, sir, concentrate on this portion (indicating). This is the amount of power -- in this graph, almost 12 MW -- which is consistently required, which has a straight line, which is consistently required from midnight until 12.00 [noon]. And then the power or the load which is consistently required by the system is known as the "baseload" for that system.

So if I am talking of -- if I have a multiplier of 1,000 over here for a system of 25,000 MW, so it means that I will require 12,000 MW as a baseload. And now I have a data to give it to the planner, or the planner has a data to think about how they will use plants in this baseload, the plants which are most reliable and cheaper in their production.

The varying load of the system, sir, but which doesn't vary much, is called the "intermediate load". It lasts some 14/15 hours a day in 24 hours, or maybe

18 hours. And the peaks, which are the abnormal high load requirements, last about 8 hours.

So if we multiply this time with these megawatts, we will get the energy, the base energy required, the intermediate energy required and the peak energy required. And now we have arrived to a point where the planner can, in terms of gigawatt hours, can decide which plant is best for baseload and which plant is best for the peak load.

Next slide, please, slide 15.

Sir, again the same: baseload is 24 hours a day; intermediate load, [8] to 14 hours, depending on the power system; and peak load, less than 8 hours a day.

Next slide, please, 16.

Sir, this is another view, another way of looking to the power system. Now we are moving ahead. I have explained you the daily load curve. Now I will be talking in broader spectrum: weekly load curve. We can make this as monthly load curve; we can make it for a full year load curve. And then we can effectively plan our power system and the power plants which we have available to adjust in this system.

So, sir, looking at this graph, now it is days of the week, starting from Saturday and ending on Sunday. So you can see peaks are there, everywhere. But on the weekends it is relatively less because people are not working, and on the other days these are quite high.

So this we can get from our daily load curve. And then we can multiply the time with this load, and we will be representing it in the percentage of time and the load requirement, and we will arrive to a graph which in our power system is called as the "load duration curve". So now we have arrived to a point where the planner can easily decide, sir.

This is 100% of the time, sir. This is the baseload of this power system. Then this (indicating) is the time where the load requirement is quite high, but it is quite less in time; and this (indicating) is the peak of this power system. And the rest is the intermediate load.

So, slide number 17, sir.

Sir, now in Pakistan we have more than 150 power plants, different: coal, nuclear, hydel, wind. And now the system operator has to decide, having this load curve and the choice of the available power plants, how he will use to run this power system most reliably and most economically.

So I will start from the right. This is, sir, my interest portion, because it is for wet season, where hydro is baseload. As I am from hydro, I will explain starting from here.

Sir, we have a lot of water in the wet season. So a big hydro like Tarbela, even the Neelum-Jhelum, can run on baseload. Because a large amount of water is available, and it is better to operate the power plant at its optimum level. Variability will be less because there will be no changing in the load. And obviously we will get good energy from this power plant, which is cheap and reliable, sir.

Then nuclear power plants, which are less in ramping, and which have hazards if they are changing loads abruptly because of this nuclear uranium present and variations presented there. So they are preferred, globally preferred, as a baseload. So nuclear will be the second choice in this load duration curve.

Then the big coal, the steam power plants. Steam has a low ramping, sir. If you compare it with a normal hydro, it has 100 times lower ramping. So it will be again preferred as a baseload where no major variation is required.

Then we have the gas turbines, which is quick in ramping, in the thermal family.

Then the peak, we have -- we may have the combustion turbines. They are put over here because they are expensive. They have low efficiency, sir.

Finally on top the reserve capacity; and by "reserve capacity", I mean for make up the deficiency, sir. All these power plants are machinery-based and they can develop faults. So if one of the power plants develops a fault and reduces its load, so this reserve capacity must be there to cover it. Hot reserve capacity must be there to cater [for] this. This is essential for the stabilising, stability of the power system, sir.

We can look at the other scenario, sir, which is the dry season for hydro. You see hydro is missing over here base, and it is here. The run-of-river plants can no longer now run as a baseload. It will be used as a peaking load. But by using it as a peaking load, we will avoid the combustion turbines, and now we have a cheaper energy at the top. So we have the advantage. And the others are in the same economic order as I have already explained, and the reserve is still from the combustion chambers.

So that's all, sir, from my side. Now for Neelum-Jhelum in the power system, this will be explained and presented to you by Mr Malik, my co-presenter, chief engineer in WAPDA.

So, thanking you, sir. I am waiting, sir.

THE CHAIRMAN: Thank you very much, Mr Khan. Let me just check to be sure we don't have any questions. No. It was very helpful, Mr Khan.

MR KHAN: Thank you.

THE CHAIRMAN: We appreciate you coming all the way from across the country to be with us for this.

MR KHAN: My pleasure, sir. Thank you.

THE CHAIRMAN: Thank you very much.

MR KHAN: Thank you, sir.

(Pause)

THE CHAIRMAN: Okay, Mr Malik, we're ready.

MR MALIK: Thank you. Honourable Mr Chairman and Honourable members of the Arbitration Court, I'm Arshad Malik, presently working as chief engineer, hydel operation in head office, Lahore. I have got 31 years of experience working at different positions of WAPDA, thermal and hydro projects, and a major part of my service is at Ghazi Barotha Project, another run-of-river project on the downstream of Tarbela.

I will be elaborating the concepts given by Mr Hameedullah in a very good presentation, and will explain the things, particularly by taking the example of Neelum-Jhelum Hydro Project, where we are sitting: how it fits in Pakistan's power system.

So please go to slide 19. Now definitely you are becoming somewhat expert, and know well that Neelum-Jhelum Hydro Project is a 969 MW run-of-river project, having a small pondage.

And in the region where it's operating, there are three other projects, hydro run-of-river projects: for Patrind, having a capacity of 150 MW; and another hydro project of Karot that is 720 MW; while there is also the Mangla Project at the River Jhelum, which is a storage project having a capacity of 1,000 MW.

These projects, as we can expect from the hydro projects, that in the dry season they're operating as the combination of the baseload and the peaking load, depending upon the water and the head available; whereas the Neelum-Jhelum project specifically, in the wet season also it is working, like the other conventional hydro run-of-river projects, as a baseload plant. This we expect from this plant.

On the left side, this is the switchyard of this Neelum-Jhelum Project, from where two 500 kV lines are efficiently transporting the power at the voltage level of 525 kV to a distance of 285 kilometres in total.

And another interesting thing is that at the distance of about 80 kilometres, another powerhouse has been added and connected to these lines. That is the Karot power station.

Slide 20. Now, this slide, this gives then the overall view of the power system expansion in the region

where the Neelum-Jhelum Project is lying. In this slide, you are seeing triangles of different colours. And to understand these, you can see the legend, please.

The green ones, these are the projects which are in operation. And number 2, this is our Neelum-Jhelum Project. In its vicinity, number 4, is the Patrind Project. While coming down, it's the Karot Project at the River Jhelum. And this is the Mangla Power Project in the green colour.

While the red colour triangles, these are the plants which are under construction. And these violet-coloured triangles, these are showing the plants which are in the planning phase, and they are going through that.

All these plants are planned in such a manner, including the Neelum-Jhelum Project, not to [only] serve the present needs of the country and the system, but also the future requirements. So availability of these plants gives the system operator the flexibility to harness the benefits of cheap hydroelectricity which is available, as well as it can fit well to the system requirements, especially in the role of adapting to the load changes and coping with emergencies.

Slide 21, please. Now come to see this slide. This shows the generation curve of the whole system, and how the Neelum-Jhelum and the WAPDA hydro projects as well

as the total system generation fit with each other. It has been made on 31 July 2023, which is, you can see, the peak of the wet season. We expect that water flow is maximum in this part of the year, and therefore you can see Neelum-Jhelum is running almost flat throughout the day, 24 hours, on the baseload of 969 MW.

Same pattern is reflected, with small variations, with the other hydro projects of WAPDA. You can see that they are almost running flat, serving the baseload requirements with some little variations, delivering about 7,500 MW.

And the big portion you can see, the thermal, it has -- the total system generation, not only thermal -- this is the total system generation. It has available peaks which are significantly changing because of the thermal mix, because in this period of the year we are having the maximum hydro potential, so we run them as the baseload, and thermals are just to, you can say, meet the remaining requirements and serving the peaks in addition with the hydro systems.

In this part of the year, we are also having the maximum load requirement; see this figure. In the coming slides this will be important to see. You see that the maximum load for the system generation is about 20,000 MW in this period of the year. This is natural

because in July we are having hard temperatures, so the loads like air conditioners and similar things, these are definitely in extensive use. So that's why the generation required is also maximum in this period of the year.

Slide 22, please. Now, this is the other side of the picture. Look at this date. This is almost the peak of the dry season: 23 December 2023 this generation graph has been taken. It reflects also the Neelum-Jhelum, the WAPDA hydro and the total system generation.

Look to interesting behaviour of Neelum-Jhelum in this period on this day specifically. You see that it's operating very below its peak for about 10 hours, when it is switched off then so that some water is stored. And later on in the peak time, it started again to feed the peak load, but definitely at very low capacity beyond its installed capacity.

Why it is so? It's already explained that all the hydro projects are highly dependent on two variables which are in the hydro generation. One is the available flow; and the other one, the available head. If these are available, definitely system operators prefer them to operate. And if it is normal, then these sources, they are to be utilised.

You can see now the behaviour of the other hydros. It's quite different from the Neelum. They are running from these hours to drop up to these hours also up to the base, and observing some peaks, some peak time from here and here. But they're running almost throughout the day and run at the base and peak combination, and fitting in the overall generation of the system with the available hydro capacity.

The interesting thing which I have pointed out before, look here: that the total demand is below 12,000 MW in this period of the year, which was above or near about 20,000 MW in the summer seasons; naturally, because the temperature is low, so the big load of air conditioners and similar items is shut off.

Please go to slide 23. Now, this is the period of the intermediate generation which is reflected. And you can see this is March 2024 this year.

Neelum-Jhelum is an early riser: water comes early. And because of the arrival of the water, you see the behaviour in the operation of Neelum-Jhelum in this brown colour; it has also changed. It is now running throughout the day for 24 hours, with the combination of the base and peak loads as per availability of the water in the head, and the system fitting into the system requirements along with the other hydro plants of WAPDA,

which are following always the same pattern for the baseload, the peaks, and fitting into overall generation pattern depending upon the availability and the system requirements.

And also see that with this change in the season and the temperature or the weather, the generation demand is also changing: from 12,000, it has reached almost to 14,000. So this is a scenario which is reflecting that how the behaviour of the system, the load demands and the operations of the plants, they are changing with the passage of time; and how the system operator makes the decision depending upon the available powerhouses, the storage capacity and things like that. He makes the decision keeping in view all these things.

Let's go to, please, slide 24. This is taking only for isolated behaviour of Neelum-Jhelum Project in the month of February. And the whole month of February is covered here. Water has started coming, and with the increase in the water flow, there is also gradual load rise with some spikes increase in the generation of the Neelum-Jhelum. This is the baseload and this is the peak load, only for Neelum-Jhelum. As you can see, after some flat period it is gradually increasing, some spikes, and then increasing.

And ultimately it goes to near flat in the baseload,

up to near 400 MW; whereas, correspondingly, the peaking load is also, with some spikes and with increase in the water flow, it also has a similar trend in gradually increasing. And ultimately it goes up to near 700 MW during the month of February.

So this is the period of the intermediate generation, where we have both the baseload and the peak loads because of, you can say, the feature of the early riser of Neelum-Jhelum, which gets the water earlier than Tarbela.

Slide 25, please. This slide, here we have taken the turbine discharge in this brown colour, and the corresponding power generation in this colour, the red one. You can see starting from July, which is the peak period, or we can say the wet season, where we have the maximum flow.

In this period of time, the required discharge for Neelum-Jhelum to have the maximum generation is available throughout: nearly you can say 280 cumecs are required for running four units on full load. We had almost the maximum generation in this period of time, running them at the baseload, as I have already described.

Then when the water inflow reduces, correspondingly the turbine discharge, which is used for the generation

reduces, and the power generation also reduces. And where we come here, you can see in the period here of December and January, you can see the generation is almost stopped, and it's zero. And in these months' period if time we have only the environmental discharge, there's no generation.

This behaviour then continues till the water arrives. And with that arrival, there's some little generation, which continues to increase with the increase in the water, you can say the inflow, accordingly the discharge, and then the power generation.

Ultimately, in March we are able to have the maximum installed capacity generation of 969 MW, which then continues. And the best periods of the generation are here from almost up till, let's say, September we are having the maximum generation in that period of time.

Slide 26, please. Now, here comes the interesting slide, the production plans. How the operator plans his generations, these are based on the requirements of the system as well as the capacity of the hydro plant. But capacity means both the machines are available, because particularly the machines are also shut down and some maintenance work has to be done, it depends on that; how the plant planned that. And sometimes the machines are having a preventive maintenance; they are usually done over a period of a year. But depending upon conditions the system operator decides when to give the shutdown to any machine, and when to make off: the system operator makes these decisions.

However, if the plant is unconstrained, even then, depending upon its own particular conditions it will operate in a different manner. So this is very important to describe here. Although the Neelum-Jhelum and Ghazi Barotha Projects are fundamentally having the same design, but they are operating in a different manner.

The actual reason for this difference of operation of Neelum-Jhelum and Ghazi Barotha is that for Neelum-Jhelum we are not having a big storage otherwise, unlike Ghazi Barotha, which has, on its upstream, Tarbela. Tarbela has a large storage, and Ghazi Barotha is immediately downstream of this Tarbela power project.

The other thing which makes the difference in the operation for Neelum-Jhelum and Ghazi Barotha is that Ghazi Barotha has got some more pondage at site itself Barotha station is lying, as well as at barrage. And whereas Neelum-Jhelum has got a little pondage, only of itself, which you have seen during your visit at C1 site.

So accordingly, Ghazi Barotha is used more aggressively during the peaking hours in the dry season because of the reason which I have already told you, that it has a big reservoir only upstream, in the form of Tarbela, and there is some pondage. So this makes the big difference in the operation of Neelum-Jhelum and Ghazi Barotha: Neelum-Jhelum is totally dependent upon the water inflows.

Next slide, please, slide 27. So the concept which I've already given is reflected in these slides and the coming slide. The Ghazi Barotha project off-peak production is reflected here over a period of a year. This in red colour shows the off-peak generation of the Ghazi Barotha, whereas this green colour is reflecting the generation from the Neelum-Jhelum. And for the reason which I have described, you can see behaviour in this off-peak production from Ghazi Barotha, as well as the peak you will see later on.

Here, you will see that both are following the same pattern till here, and both are operating at the maximum load, supplying the grid you can say from this period onwards, the peak season for the water inflow, and the period of the months of July and August. And then there's a steep decline gradually in the production from the Neelum-Jhelum for these off-peak hours, subject to

the water availability; whereas the Ghazi Barotha, it drops and follows the pattern of the Neelum-Jhelum by December for a short period of time only.

And then later on, the Ghazi Barotha again rises and gives much more generation than the Neelum-Jhelum because of the factors that I have explained whereas Neelum-Jhelum starts performing and generating more near its capacity by March, which is when it is able to generate at its installed capacity, already described.

Okay?

THE CHAIRMAN: A question for you, Mr Malik. So looking at the comparison of these two hydroelectric plants, it does seem that there's great value in having a larger pondage so that you can generate power throughout the year. Why would it be that at Neelum-Jhelum the dam wasn't designed perhaps to have a higher dam so that you could have more pondage to achieve a comparable result of what you got at Ghazi Barotha? Is it a cost issue or is it other issues?

MR MALIK: These things have been explained by my friends also. And what I remember -- tell if I'm wrong, I will take help from Mr Ayub -- you can say that before it has been explained that the geological conditions, they have prevented to make a big reservoir there. The excavations in that dam area were difficult.

And the other thing was that what advantage has been taken, that having this tunnelling of 28 kilometres, the high head has been depleted by covering in terms of distance. And through that, we have been enabled to use, with very small quantity of water, the generation near to Ghazi Barotha. One unit of Ghazi Barotha, it generates 290 MW. But for that 290 MW, it requires 468 cumecs of water because the head there is only 69 metres. Whereas for this project, the head is 420 metres, and that's why it requires only 70 cumecs instead of 468 cumecs.

So these are different things which have been in the minds of the designers.

THE CHAIRMAN: Okay, thank you.

MR MALIK: Slide 28, please. Now, this is the behaviour of the Ghazi Barotha project for the peak production. You can see that it is aggressively used almost throughout the year, as compared to the Neelum which is in the green colour. And only for a small period of time the peak production is less, and which restores much earlier than the Neelum-Jhelum. And it follows almost then the pattern after the months December, January, from February onwards, the Neelum-Jhelum, whenever it starts, from March onwards, to serve the peaks at par with the Ghazi Barotha station.

So these are the things and the concepts I think I have been able to clear you. And if there are still any questions, you are welcome, please.

THE CHAIRMAN: Thank you, Mr Malik. Let me just check to see if we have a question. Professor Wouter.

PROFESSOR BUYTAERT: Yes, thank you.

Would you be able to go back to slide 25, please. Two questions on that slide.

First, a quick technical question. You see those big drop-downs during the wet season, where I assume the turbines were switched off. Is that because of maintenance? So you see during the wet season, occasional peaks down to zero. Is that because of maintenance or is that because of a lack of need to produce electricity?

MR MALIK: Yes, what I remember: that in this period of time we were having some maintenance activities.

PROFESSOR BUYTAERT: Maintenance, okay.

MR MALIK: Yes.

PROFESSOR BUYTAERT: Thank you.

And then looking curve this is of course for 2021-2022 and looking at about the time of year we are now, the end of April, at least in this year it seems to be already at maximum capacity and high flows, which seems to be much higher than what we have at the moment.

Does that mean that we are currently in relatively dry conditions, or is that just an impression?

MR MALIK: I have already described that all these decisions regarding the running and loading, these are to be made by the system operator. How he fits the things in his system primarily depends on him.

And if the summer works are to be done by the local plant operator locally, then they make their requests to have some works to be done, and accordingly it's registered. So it's a matter of the decision merely because of the system operator, how he fits any plant in the generation plan. It depends mainly on him.

PROFESSOR BUYTAERT: Yes, okay, thank you.

THE CHAIRMAN: Okay, Mr Malik, I think we have no further questions, but thank you very much for your presentation. It was quite helpful.

MR MALIK: Thank you. My pleasure.

Presentation 11: Powerhouse Inspection

MR MIANA: Mr Chairman and members of the Court, good afternoon and welcome to the powerhouse site. We are at the entrance to the control building for the powerhouse.

First of all, I would like to introduce my operation and maintenance team.

THE CHAIRMAN: Very good.

MR MIANA: So that is headed by the chief engineer of operation and maintenance.

THE CHAIRMAN: Sean Murphy. Nice to meet you.

MR MIANA: This is project director for the Neelum-Jhelum Project.

THE CHAIRMAN: Good to see you again.

MR MIANA: He's the resident engineer, mechanical.

THE CHAIRMAN: Nice to meet you. Sean Murphy.

MR MIANA: The resident engineer, electrical.

THE CHAIRMAN: A pleasure.

MR MIANA: He's the senior engineer, operation.

THE CHAIRMAN: Nice to meet you.

MR MIANA: And the senior engineer, electrical.

THE CHAIRMAN: Wonderful. Nice to meet you, sir.

MR MIANA: So we'll start with looking at the switchyard because we have the opportunity that there's no rain over there.

THE CHAIRMAN: Okay.

MR MIANA: So it's fine, we can take that opportunity.

So at the left-hand side is the powerhouse which we have already seen is on the ground side. So here is the power coming from the inside. We have the two adits over there. We call it adit A5 -- tunnel A5 and tunnel A6. So this tunnel is going that we have shown in the pink and the green colour in our slides, over there.

So the power coming from the A6 side, which is

a cable tunnel as well, and that cable is terminating in the switchyard over here.

THE CHAIRMAN: I see.

MR MIANA: And from this switchyard, we have the transmission line going outside, we can see over there. This one. The tower at the top is taking the power evacuation from this powerhouse.

THE CHAIRMAN: Can we walk over a little bit?

MR MIANA: Sure, sure. (Pause)

So this switchyard consists of all the equipment, like the equipment which isolate and circuit-breakers: the current transformer, the protection transformer for metering, for instrumentation and for the protection system and for the electrical instrumentation. So everything is in there.

Now, at the moment they are taking power to the national grid over there. This is a double busbar one-and-a-half-breaker scheme. One-and-a-half-breaker scheme has the advantage that it takes less space, but it works like a double-breaker scheme. So at the moment, two units are -- one going outline and one unit can be put in one-and-a-half-breaker scheme. So if one breaker is under maintenance, so we will not have any problem for the operation of the power.

THE CHAIRMAN: All of the power is going out through those

lines up there?
MR MIANA: These are the lines to the national grid over there.
THE CHAIRMAN: So you're not taking us into the ...?
MR MIANA: No, we can, we can.
THE CHAIRMAN: No, no, no.
MR MIANA: That's providing the (indistinct), because there is the corona effect, you can hear the noise. This is the corona effect.
THE CHAIRMAN: Ah, okay.
MR MIANA: This is the high tension, the high voltage is there. So that creates the ionisation of the air, and that creates that noise over there.
THE CHAIRMAN: Interesting.
MR MINEAR: What is the current electric production at this moment?
MR MIANA: Actually production power or electricity? We explain in the -- we are going there, okay.
MR MINEAR: Okay, great.
THE CHAIRMAN: Good. Wonderful, thank you. (Pause)
MR MIANA: So the same safety rules are mostly given already. We will come down over here after visiting there. Maybe we have to check Professor Wouter over there, just the height, the head.
So here comes the main control room for the power

transmission, everything. These are the two shift engineers -- please take your seats and do your work. These are the shift engineers responsible for the smooth operation of the powerhouse. And in case of any fault or any indication coming, so they have to take action immediately. So all the time, 24-hour, their shifts are there to be covered in the shifts, and they are responsible for all these things.
I will explain over there, starting from the switchyard from there. I can go there, just to give you more information.
So here we have the four generator units: 1, 2 3 and 4. And I have already explained the double busbar. We have two busbars over here, and one-and-a-half-breaker scheme. We call one-and-a-half-breaker scheme because we have three breakers over there: 1, 2 and 3.
So these three breakers are for the dual operation. Like, in this bay we have one transmission line and one generator is coming. So in case of fault or maintenance of any of the circuit-breakers, we'll be able to have connection with both of these busbars.
So this is our generation side. And at the moment we are operating all four units, but with restricted load of 530 MW. The water is available, but during the first week of April we find the pressure fluctuation in

the HRT, so we have restricted the load to 530 MW with the consultation with the consultants.
We are working on that one, first to have the ROV inspection and then to see what has happened inside. Why 530; why not 500 or why not 600? We have calculated the velocity, and this velocity is within the permissible limit of the velocity within the HRT. So we are working on that limit.
At the moment, all four units are in operation. The unit no. 4 is generating 125 MW; unit no. 3 is generating 150 MW; third one, unit no. 2, is generating 130 MW; and unit no. 1 is generating 124 MW. So altogether -- can we switch it to the other picture?
So this indicates the electrical parameters. So the green lines are showing the active power, the megawatt generation from each of the units. You can see it. And there are all the parameters, starting from the megawatts: megawatts, generation voltage, generation of electricity, the frequency, and the available head over there, and the servo motor position. This is the wicket gate position that we have been talking about.
So you can see this is at 51% and this is 49%, because load is 125 on that one, and there the load is 130, so slightly above that one. Similarly, the load at unit no. 3 is 150. So it's 55% opening. So as soon as

we open the wicket gates, the generation exceeds this one. So this is what happens. And altogether we have 530 MW over here, generating this one.
DR BLACKMORE: So who's controlling the wicket gates? Are they controlled from here, or is that automatic?
MR MIANA: At the moment they are automatically controlled with the frequency and the output that we have given as a set point to the generators. But if the system operator asks to reduce the load due to any outage at this one, then our shift are responsible to adjust the load.
THE CHAIRMAN: Does the step-up get recorded here?
MR MIANA: Step-up is not ... (Confers in Urdu)
This diagram. So our generation at this one here, we are generating at this one at 15.5, 15.75, and we are stepping up from this transformer to the 525. So these are actually the common nomenclature and the identification for presenting in their drawings for the step-up and step-down for this one.
So we already also have the CCTV all around the powerhouse. We can see all these three screens are showing the different locations inside the powerhouse and outside the powerhouse.
That's this control room. But if you have any questions about the control room or this one; otherwise

we will proceed.
THE CHAIRMAN: So when you receive the instructions from the National Power ...
MR MIANA: Control Centre.
THE CHAIRMAN: ... Control Centre, do they come to this room, and you then adjust to provide them with the power that they seek?
MR MIANA: Yes. This is a communication through the telecom system.
DR BLACKMORE: Are those communications verbal or over the computer?
MR MIANA: Both.
DR BLACKMORE: Both?
MR MIANA: If it is the immediate action, it's verbal --
DR BLACKMORE: Yes.
MR MIANA: -- but that would also be documented.
DR BLACKMORE: Okay.
MR MIANA: And also our shift operator -- let me show you one thing. (Confers in Urdu) He records every event in this one. (Confers in Urdu)
So then the shift in charge takes over the shift. Then the shift changes. So they record the shift charge taken over by these engineers, and then they start writing every event over there. You can see the time: 9.30, then 10.04, and even 10.21 and 11.40. Every event

is recorded on this one. So it's a permanent document over there.
At the end of this, the shift engineer also signs and dates it over there, just to make that he has returned all these things.
THE CHAIRMAN: Is there any particular communication between the powerhouse and the dam site?
MR MIANA: Yes, we have three kinds of the communication with the powerhouse and dam site. (Confers in Urdu)
So we have this one data coming from the dam site to the satellite, and then we have the communication through Thuraya satellite telephone, and the third one is the local communication system.
DR BLACKMORE: Okay. All three are closed?
MR MIANA: All three are closed, yes.
We are also getting that inflow data. (Confers in Urdu) This one. So now we can see the intake level is this one. It's coming from that one. And this is the TRT pressure over there, and this is the HRT pressure that we are observing. We are putting the yellow colour different, just for observation. And these are megawatts and this is frequency. So we are getting online data, this one.
THE CHAIRMAN: Would you say that the instructions as to where to place the gates and so on comes from here, or

is it taken up there?
MR MIANA: That person responsible for the inflows and the safety of the dam.
THE CHAIRMAN: Yes.
MR MIANA: So altogether, when he changes the inflow, the outflow regulates. So he immediately informs that, he gives the message. They also give the message in case of the increasing flow to the local administration downstream, so that everybody should be ready for the increase in flow.
THE CHAIRMAN: Very good. Questions?
PROFESSOR BUYTAERT: I saw that on the previous screen you also had the other two power plants on there.
MR MIANA: (Confers in Urdu)
PROFESSOR BUYTAERT: So at the top you've got (indistinct) power plants?
MR MIANA: No, these are not the power plants; these are the outgoing lines.
PROFESSOR BUYTAERT: Okay.
MR MIANA: One is going to the Karot hydropower plant and the other is going to the Ghakkar grid station.
PROFESSOR BUYTAERT: Okay, yes. And from there then they go on to the national grid?
MR MIANA: Basically -- you already know about that -- we have downstream the Karot hydropower.

PROFESSOR BUYTAERT: Ah, okay. That's the --
MR MIANA: So one circuit goes, terminates there, and then out from there.
PROFESSOR BUYTAERT: Yes. So --
MR MIANA: So one is directly going to this one, the Ghakkar grid station 2.
PROFESSOR BUYTAERT: Yes. So from here you've got two lines going --
MR MIANA: Two lines and one pole.
PROFESSOR BUYTAERT: Okay.
MR MIANA: Each side. Double circuit.
PROFESSOR BUYTAERT: Thank you.
THE CHAIRMAN: Very good. Very interesting. Thank you.
MR MIANA: So we'll move to the downstairs again. (Pause)
So I will show you some instrumentation and switchgear installed there.
THE CHAIRMAN: Very good.
MR MIANA: So here we have the --
THE CHAIRMAN: Let's wait for the ...
MR MIANA: Sorry, sorry. But it's already going here.
THE CHAIRMAN: I know. But I like to have the other members here so they can see you pointing.
MR MIANA: Okay. Sure, sure.
So this is with the busbar protection schemes for the switchyard. I already mentioned busbar 1 and

busbar 2. So there are two busbars over there, different breakers: middle breaker, side breaker and the other breaker. So everything is coming over here and switching from there. They are controlling and protecting all these things from this one.

THE CHAIRMAN: So this is taking the power that's coming out of the turbines and moving it into the switch --

MR MIANA: Yard.

THE CHAIRMAN: Before it gets stepped up, or has it already been stepped up?

MR MIANA: Already stepped up.

THE CHAIRMAN: Okay.

MR MIANA: The step-up is inside the powerhouse.

THE CHAIRMAN: Ah.

MR MIANA: Yes. We will see the transformer inside.

THE CHAIRMAN: Okay.

MR MIANA: We will go to where the transformer is.

Actually this is only the protection system. So there everything -- we cannot work all that well there, just to have an indication of any fault, taking some reading. Metering, all instrumentation, everything is done from this panel.

MR MINEAR: These are basically your circuit-breakers, you said?

MR MIANA: Circuit-breakers and all the other -- all equipment. So we have data up there coming.

This is our private exchange used for the local control over there. This is the administrator for private exchange for the communication between the control building and with the powerhouse, and even with the (indistinct) meters. So this is a private exchange, with automatic exchange installed over there.

THE CHAIRMAN: Very good. (Pause)

MR MIANA: So this is the battery room. So we have two sets of the battery level: one is a 48V, the other is a 220V. The 48 is also sometimes stepped down for the different protection relays and the metering. And each cell is 2V. And these are the 220V batteries over here. Just in case of the emergency, everything is switched off, the battery will take the load to the -- for the essential load and for the emergency loads.

PROFESSOR BUYTAERT: Are those lead acid batteries?

MR MIANA: Sorry?

PROFESSOR BUYTAERT: Are those lead acid batteries?

MR MIANA: Lead acid batteries.

DR BLACKMORE: These are exactly the same batteries I have for my solar!

MR MIANA: But these are dry batteries. They are dry batteries.

THE CHAIRMAN: Very interesting.

MR MIANA: Thank you. (Pause)

So now we'll move to the powerhouse inside the tunnel. So I think they have to close this one, or I don't know whether they will continue with this one.

(Pause)

MR MIANA: So welcome to the powerhouse. We are at the entrance gate of the Neelum-Jhelum Hydroelectric Project, 969 MW. We will go in a small group, so that I can communicate with you more clearly.

I will also request, as I mentioned in my briefing, that all the panels are energised, so try not to touch them. And I would also request all the guests who are travelling with us inside the room, they should take all the safety PPEs, personal protective equipment, and please do not touch anything. If you want to have some clarification, you can ask the operation people, they can clarify to [you].

Okay, so just moving inside.

THE CHAIRMAN: Thank you. (Pause)

MR MIANA: If you like, you can also have the earmuffs. If you like the earmuffs, it will feel more nice your ears. It will feel more nice over there. (Pause)

So let me start with the two cranes that I have mentioned in most of our presentations over there. We have two cranes, 275 tonnes each, so altogether we have 550 tonnes capacity for the lifting of the heaviest part in this powerhouse.

The heaviest part is the rotor, as I mentioned in my presentation number 8. The heaviest part is the rotor, which is about 450-460 tonnes. So the tandem operation with (inaudible) the crane and electrically it is operated by one operator. So that is called the tandem operation.

THE CHAIRMAN: And these can go down the galley to the location they're needed?

MR MIANA: Yes, they can go up to this one, along all this rail over there they will travel to.

So we'll just go to this one, and we'll see the other things over there. (Pause)

We have already seen this when we were on the dam site from the upstairs. The same photograph there, just for the presentation, when some delegates come, we present them directly on this floor.

With this we have the tunnelling system over here, we have already seen this one, and at the moment we are here in this powerhouse site.

If we look at the salient features, we have the composite dam, gravity plus rockfill, and its length is 160 metres. The rest is the earth-filled dam, 65-70 metres. This is the length of single tunnel, length of TRT, the total head for this one, the total discharge for the operation of all four units, and this is the output of the four units over there.

This is the annual energy generation of 4.6 billion. And this is the (indistinct) of the powerhouse plant that we have [been] involved in construction of this one.

This is the installed data of this one. And up till now, we have generation up to -- they have put down the latest figure, 19.9. I only show at 19.6 in my presentation, but that was a couple of days ago. So now they put today this figure over there.

THE CHAIRMAN: Very good.

MR MIANA: So at the moment we are just here, inside this one (indicating).

This is the cavern, the powerhouse cavern or the big cavern. We'll also go to the other side in the transformer room, where the small cavern, we'll see over that. Before going to that, we'll just go around this powerhouse and I will try to explain over there.

Here is the unit number 4 in front of us and this is the excitation system for that one. I already mentioned during the presentation that the exciter gives the DC current to the poles, and then when the pole generates the electricity, which is collected at the rotor. So this is the excitation system; beneath this one is the generator.

So let's have a look on this one downstairs. There we can see the main inlet power over there. That's what we're talking about. Just upstream of this one, this one is the penstock, and downstream to this one is the spiral case. And inside the spiral case we have the stationary vanes, then the wicket gates and then the runner. So we'll go there; that's just to describe from here.

THE CHAIRMAN: And that is the counterweight there?

MR MIANA: These are the counterweights. They are holding MIV in balance (inaudible). And the other one is there in case of emergency, power failure of the complete powerhouse, then they can move by their weight, close the unit to avoid any damage.

MR MINEAR: How do you actuate the counterweights?

MR MIANA: How?

MR MINEAR: How do you begin them? What do you do to trigger them?

MR MIANA: We have the hydraulic system to operate them. We will see that hydraulic system when we go down there. (Pause)

So this is the online monitoring panel number 4, for unit number 4. Here we can see the picture of the generator. The inside is red, is the rotation rotor, and outside yellow is the stationary parts. So these are all parameters. We can see from here the maximum upper limit air gap is coming over there, round the variation to all the parameters (inaudible) which been installed and other protection and the effective operation of the plant.

Then we can see the similar -- the upgrade, this one. This is the generator. From there we are generating 15.75 kV. At the moment it's 15.78 over there, we can see on the top of this one. And from this one, we can also see the unit speed, 99.9. It means 300 RPM is 100%; slight variation because of the frequency changes.

And then the servo motor, the wicket gate opening over there, 48%. And the flow at the moment is 36 cumecs over there. And the field voltage for the excitation, 159 V, and the field current is 1,026.

So do we have generation? The power is okay, but do we have the generation connection for this one?

Okay, sir. So then we have there breakers, earth switch, and here is the transformer with this one. There we'll step up the transformer. Just before reaching the 525 kV switchyard that is showing on the top one.

THE CHAIRMAN: And this is just for this turbine?

MR MIANA: Yes, panel number 4. So each unit has a separate control panel over there. So we'll go around there.

These are different switches: the generator construction panel, overall unit control panel, and this is extra (indistinct). This you can supply over there.

So here we can see the unit number 3 in operation. The red light indicates that unit is in operation. When the unit is shut down, this light will not be glowing; it will be switched off. (Pause)

Here we will see the whole picture and the cross-section of the Francis turbine. The lower part is showing the runner and the wicket gate and the spiral case, the middle is to the shaft over there, and this is the generator over there. So we have all the parameters which are required, which has been given the instrumentation it's displaying over there.

Similarly, this one, number 3, is generating power 149-150 MW at the moment. (Pause)

Just for the record, just to show you, this is our turbine operator over here. They also work in the shifts. And they take all the parameters which are displaying overhead just for the record. You can see the parameters that are displaying on those panels, they also record hourly readings over there, and we have that record for the years.

So since the start of 2018 we have all the records, all these are available with us. So whenever we want to analyse some fault at this one and we want to compare the old parameters, so we can just take the sheets out and we can compare it.

Similarly, this is the unit number 2 over there.

And finally, the unit number 1 over here. And the same panel also installed for these units. So all the units have their separate operational panel and their instrumentation panel, so they are operating separately, independently.

THE CHAIRMAN: And right now all four are operating?

MR MIANA: Four are operational, yes. Because all the red lights are on.

DR BLACKMORE: I notice that the chamber is very dry. So just looking at your drainage, you have a lot of drainage around to keep it dry?

MR MIANA: Yes, we already mentioned that there is upstream drainage gallery over there.

DR BLACKMORE: Yes, it's on that side. Okay.

THE CHAIRMAN: And the reason for the cavern to be so high is so the cranes can operate?

MR MIANA: Yes, because we have to take the lower part and this height maximise, and then the height of the shaft.

THE CHAIRMAN: Okay. So how far down are we underneath the mountain?

MR MIANA: At this place, I think about 300 metres. I will check, but it's around 300 metres.

THE CHAIRMAN: Okay.

MR MIANA: But that varies from the C one to this one, starting from 200 metres and the maximum that we have are 2,000 metres. So maybe here 300, plus/minus. Maybe I have to check the exact figure. But it's around 300-350 over there.

MR MALIK: This is 600. Overburden is about 300-plus, 300 metres-plus.

MR MIANA: We will go down, then come up.

THE CHAIRMAN: Perhaps we'll do a group photo of the Court on this side.

MR MIANA: Okay. Okay, you can take now, because we have plans to go down as well.

THE CHAIRMAN: We could do one down there too.

MR MIANA: Yes, yes.

THE CHAIRMAN: But this is a wonderful space, so ...

MR MIANA: I think better if you stand with the unit number 4, then the whole picture is shown there.

THE CHAIRMAN: Okay, perfect.

MR MIANA: We have that place for the photographs.

THE CHAIRMAN: Okay. (Pause)

MR MIANA: So by standing over here, you can (inaudible) over here. (Pause)

So we'll go by stair. I will come to the elevator. (Pause)

So we are at the basement number 1 of (inaudible) this one, and the elevation at this point is 594. The elevation at generator floor was 600 metres. And also I forgot to mention that from the portal of the tunnel to the generator, we were 14 metres lower than that one. So that outlet is 614 metres. So at the moment we are 594 over here.

So these are the different panels, we can look at this one, the production and the instrumentation panel. This is the circuit-breaker inside the powerhouse for different equipment, like the motor and the compressor and everything. So all these panels have different readings.

We have also some spare over here. In case of the faulty breaker overhead, we can change the (inaudible).

So here we can see the panel indoor lighting. This is for the lighting system. Similarly we can see the main transformer on this one, main transformer. So main transformer means that supply to the main transformer, not the main transformer load.

And similarly, these are all the switchgear, the

400 V switchgear for the different electricity supplies. (Pause)

Here we can also see this is the bonneted gate, we call it, and this is at the outlet of the draft tube. So whenever we want to have the maintenance inside the unit, we have to shut down the main inlet valve and close this one, then we can dewater the unit up to the draft.

And this is the crane for the maintenance of this draft.

We will go up to there, just to show around the upstairs. (Pause)

These are different switchgear and the panels. I will not go into detail because they are a similar kind of panel.

So this is the output from the generator, going to the transformer, the main transformer. Here the voltage is 15.75 kV, but the current is in thousands.

I will check with -- what is the total current?

10,800 is the total ampere generated from there. With the step-up transformer, we enhance the voltage but lower the current. Advantage is there because the current has to be transported on the outer conductor. So if we have thousands of ampere, we cannot have the big cable like this one. So reducing the size of the

cable will increase the voltage level.
THE CHAIRMAN: I see.
PROFESSOR BUYTAERT: So inside these pipes are the electric cables?
MR MIANA: Yes.
PROFESSOR BUYTAERT: What diameter? (Pause)
MR MIANA: We will check diameter.
But these are basically insulated. If they are not insulated, we cannot stand here!
PROFESSOR BUYTAERT: We would be fried here, yes!
MR MIANA: If the outer diameter is, say, 1 metre, it will be around 0.4 metre.
PROFESSOR BUYTAERT: Yes, something like that.
MR MINEAR: Is it copper cable?
MR MIANA: Yes, copper, all of it.
Similarly the other unit monitor gauge over here, as we've seen for the first one.
We can look round from this, the opposite side.
So this is the main inlet valve. We are getting closer to the main inlet valve. The main inlet valve, over here.
And this is bank of CO2 cylinders for the generator protection in case of fire.
DR BLACKMORE: CO2, ah. (Pause)
MR MIANA: So that ends the powerhouse system. And we have

also the fire alarm system over there. If there's a fire, it will generate the signal and the operator will know about the location of the fire in this one.
And this is the CCTV network that I showed you in the control room.
THE CHAIRMAN: Yes.
MR MIANA: The signal is coming all around us from these panels. (Pause)
So here we can see inside. (Pause)
So here we have the transformer oil used for this one, and we have a spare. So for the transformer oil bank we have a separate protection system with the CO2 in case of fire.
THE CHAIRMAN: So the step-up occurs through this transformer?
MR MIANA: No, no, no, the transformer oil only. This is the oil being used in the transformer. We will go [to the] transformer, we will see, we will touch that.
THE CHAIRMAN: I'm not sure I want to touch it, but ...!
MR MIANA: No, we will touch it, because we have a spare without generation.
THE CHAIRMAN: Okay.
MR MIANA: And this is used for cleaning of the transformer oil. (Pause)
So please, please take care. We have another one as

well downstairs. These are okay, but downstairs one step more we have another one.
So here we have the air system for the brake system, for the braking of the generator, the air brake, and the station supply for the different purposes. So we have two different systems over there: small for the braking system, and these bigger for other systems of powerhouse. (Pause)
THE CHAIRMAN: So we've seen these on several levels. So are these to be removed when you need to ...?
MR MIANA: Yes, when we need to lower the material downstairs, we cannot take down through the stairs.
THE CHAIRMAN: Yes.
MR MIANA: So we have to take it out, and then lower the material and then place it back. This side and the other side as well, on both sides of the powerhouse.
So here is again battery power system, battery system. So we have four banks of 220 V over there, for the station supply in case of emergency: bank 1, bank 2, bank 3 and bank 4.
THE CHAIRMAN: That's a lot of batteries!
MR MIANA: Yes. It's essential, because the tripping is a common phenomenon that can happen any time. So if there's no supply, then the batteries take electrical load, and the powerhouse also is underground, so more

dangerous for this one. So there are a lot of batteries over there, just to make it more safe.
THE CHAIRMAN: And why don't you use a generator, a gas generator?
MR MIANA: I'm sorry, I forgot to show you. When we go back, I will show you that we have in the beginning. But starting a generator takes some time. These generators are just like (indistinct) power supply.
DR BLACKMORE: How long do you expect the battery to last?
MR MIANA: I think they have not yet replaced any of the batteries, this one. Not replaced yet any of these ones.
Similar to that on the dam site with the control building we have the generator, and similar to that control building we have another generator over here. So that capacity, this is sufficient to operate the first unit. (Pause)
So here, different cooling waters. You see closed-loop cooling water system for the cooling of the different equipment over there. So this inlet has the open-loop and we also have a closed-loop output. So normally in the old power station we have only the open-loop cooling water system, but in the modern one that has been changed and we have both the open loop and the closed loop.

Advantage is that because the heads are high, and if we are using the open loop then we have to take the water from upstream of the inlet valve, main inlet valve. So if you take the water from upstream of the main inlet valve, the pressure is too high. We will normally use the pressure-reducing valve over there. But in case of rupture of any pressure this side, it will flood the powerhouse.

So the concept has been changed. Instead of one cooling, there are two cooling systems, but the water is taken from the downstream instead of taking from the upstream. So the more waters they are coming, but the danger of the flooding has been mitigated.

DR BLACKMORE: Yes, that's a very sensible move.

MR MIANA: Yes. (Pause)

For each unit, a separate system. (Pause)

So here is the closed loop.

So we can see we are very much near to this one again. So the (inaudible). We are getting closer to this point.

THE CHAIRMAN: Yes, we certainly are! (Pause)

MR MIANA: Similarly, we close and open for the last. And these are the heat exchangers, so they're -- not the heat exchangers; these are the cleaners. So they take mud over there, they rotate and take the mud inside, and

the oil is then taken out for the cleaning purposes. A very different (inaudible). These are the control panels for this one.

THE CHAIRMAN: So it cleans the oil?

MR MIANA: Yes.

THE CHAIRMAN: Wow.

MR MIANA: Yes, basically this is the heat exchanger for the closed loop and the open loop. So the heat exchanger is this one. These are channel plates, like different plates over one, then the other.

THE CHAIRMAN: I see.

MR MIANA: So move to the lower one. (Pause)

So again, please take ... Be careful, please. And this one is the most dangerous. It's the most dangerous. The rest is comfortable. (Pause)

So this is the (inaudible) system, the hydraulic system for operation of the wicket gates. So we then want to operate the wicket gates because they're under the pressure, and hydraulic pressure is required for that. I think -- how much is the total pressure?

350 bar is the pressure for this one to operate that we can gauge inside the running water.

We'll have the chance to see the rotating shaft over there. We will not go inside, but then we will see it from the outside.

THE CHAIRMAN: Okay.

MR MIANA: Here we have the shaft, the shaft over here, 300 RPM. 300 RPM. And wicket gates are outside this one.

And you can see over there the shaft. Going up to the generator. (Pause)

THE CHAIRMAN: That's the generator up there. (Pause)

MR MIANA: So here we can bend the water at the gate. So we need this one here.

So when we want to operate it, we have the separate hydraulic system for the operation of this one. We just lower (inaudible) inside that cylinder and they've got the operation over there. We can have the isolation from the downstream side, the other side, and the isolation from the HRT, upstream side, is (inaudible).

DR BLACKMORE: Did you have to activate these when you had the tunnel cave in? Were these gates activated when you had your tunnel cave in and you had to --

MR MIANA: We just opened this one because that's for air ventilation --

DR BLACKMORE: Ah, you let it go through. Okay. That'll work. (Pause)

MR MIANA: So these are the pipes. Damaged pipes, if we have the water from the pump, due to the rain or anything, the water comes down over here. As we can

see, very small water is coming. (Pause)

We are going there just to see a valve which is used for the dewatering of HRT. We have not yet used that one, but we're just showing there.

So you can see over here, the similar one over here. When we want to put the things down this one, we have to take it out and put it over there. But not up to the (inaudible) maybe this is only for the -- maybe this is only for this floor and the down floor.

So this is the MIV. We have reached the MIV over here. We can now see the counterweights over there.

This is the needle valve. When the unit is shut down, this valve is closed. So when the valve is closed, there is always leakage in the wicket gates, small leakage. So spiral casing gets empty to some extent. So in the beginning we just open this one, this automatic system, and the water is filled from the upstream side to downstream side. And when the pressure is balanced, then we can open this one. If the upstream and downstream pressure are not balanced, we cannot open MIV.

And this is our HRT, headrace dewatering, this one. If we want to dewater the headrace tunnel, then we have to operate this one.

THE CHAIRMAN: The penstock comes in here?

MR MIANA: Yes, the penstock starts from here.
THE CHAIRMAN: Right there?
MR MIANA: Yes, going there. This is the end of the MIV, this big bolt over there. And the penstock you can see is on the pedestal, and this was it.
DR BLACKMORE: Where is the expansion valve?
MR MIANA: I was expecting this question! I will ask Ayub Malik. (Pause)
MR MALIK: We'll invite them, because I was not there at that time. So we can ask the consultant who is the oldest person over there. 16 years (inaudible) over here.
THE CHAIRMAN: Okay.
MR MALIK: So 32 years is half of it. (Pause)
So this is the expansion valve.
DR BLACKMORE: What's the expansion valve packed with? What's inside of it?
MR MIANA: What is the inside? Inside is rubber. What is the inside in the expansion valve?
DR BLACKMORE: What's it packed with inside?
UNIDENTIFEID WORKER: Inside, rubber (inaudible).
DR BLACKMORE: Ah, okay.
THE CHAIRMAN: And that's the hydraulic that operates the counterweight?
MR MIANA: Yes. Yes, this is hydraulic, and they have

separate system for this one. This is the hydraulic system for the MIV.
THE CHAIRMAN: Okay, very good. Wow.
MR MIANA: And all these are the metering pipes, metering and some other things. The pressure and the different -- there are different locations over there.
And this is the air vent valve. Whenever you want to -- I mean, after the annual maintenance, when we are filling this one, the air has to take out from that area, because the air has to be taken from this one. Air vent valve. (Pause)
So we will go in parts, because the elevator is small: maybe 6/7 persons can go at a time.
So in the first instance, with us the cameraman and we can go, and Mr Pomper can also join us. Please, join us. Come in, come in. 13 persons. (Pause)
We have the opening over there just to lower the weights, the heavy equipment down there.
DR BLACKMORE: Okay. Where do you bring the runners up to this level?
MR MIANA: I think this is the place. We can even take them from there.
DR BLACKMORE: Oh, okay, move away.
MR MIANA: Because the runner position is over there.
DR BLACKMORE: Okay. So you slide it that way and bring it

up?
MR MIANA: They slide it and they take it out, yes. Because the runner is small in diameter. It's weighing about 40 tonnes. 40 tonnes is not a big weight.
THE CHAIRMAN: Any other questions?
MR MIANA: Then we'll move to the transformer room, cavern.
THE CHAIRMAN: Sure, yes. (Pause)
MR MIANA: So this is a big cavern, and now we are moving to a small cavern.
So here we have entered the transformer cavern. We have seen two caverns on each drawing and photograph. So earlier we were in the big cavern; now it's the small cavern over there.
These are the pipes taking the current and the voltage from the generation side.
We'll just go to see the transformer, which is energised, and then we'll come back to one which is not energised.
Yes, please come in, gentlemen.
So this is the power, the transformer is energised. They step up 15.75 kV to the 525 kV. These are different equipment, the protection system, everything, installed for the transformer.
THE CHAIRMAN: Is the power coming in from ...?
MR MIANA: This side.

THE CHAIRMAN: Up there?
MR MIANA: Yes.
THE CHAIRMAN: Oh, okay.
MR MIANA: You have seen that --
THE CHAIRMAN: We saw the tubes, yes.
MR MIANA: We saw the tubes from outside.
THE CHAIRMAN: Okay. Wow.
MR MIANA: This we can touch. This we can touch.
THE CHAIRMAN: Because it's --
MR MIANA: Because it is not energised.
THE CHAIRMAN: -- it's not working right now?
MR MIANA: No, it's spare. In case of failure of any other transformer, we have to take it out. The rails have already been provided over there just to drag it out. And first drag out the faulty one, take it outside, and then drag it out this one and then place there, it is required.
THE CHAIRMAN: Spare transformer?
MR MIANA: Yes, spare transformer. Because without the transformer, we cannot generate the unit.
THE CHAIRMAN: Yes.
MR MIANA: There is always one spare at every power station.
THE CHAIRMAN: And is the single transformer for all four?
MR MIANA: No.
THE CHAIRMAN: There's --

MR MIANA: Each unit has three transformers.

THE CHAIRMAN: Three transformers?

MR MIANA: Yes. So this one is 13 number. For the four units we have 12, and this is the spare one. So the power is 242, so divided by three will give the power for this one.

THE CHAIRMAN: It's unlucky to have 13!

MR MIANA: So 98.7 kVA (sic) is the transformer capacity of each one.

DR BLACKMORE: Very good. Seems like a very nice place to be on a hot day!

THE CHAIRMAN: Good. Okay. (Pause)

MR MIANA: Maybe they want to see.

THE CHAIRMAN: We were looking at the spare transformer.

MR MIANA: We were just looking at the second cavern there. That was the big cavern we have seen in the sheets and the slides. So this is the small cavern for the transformer.

DR BLACKMORE: They have 13, [12] plus a spare.

MR MIANA: Total transformers are 13, 12 for the four units. Each unit required three transformers and one is spare.

And the capacity of one transformer is 98.7 MVA.

THE CHAIRMAN: And those big tubes are bringing the power in from the generator ...

MR MIANA: Yes, from the generator to the transformer.

THE CHAIRMAN: ... to the transformers.

Good.

MR MIANA: Good. Sorry, one thing remaining.

Above this, we have also the GIS system over there, gas insulated switchgear over there, inside the powerhouse. And we have some connection of this powerhouse with the other tunnel which we have seen outside there, which was closed. We'll just see, go over there. So we have that connection as well over there.

So please, take water.

THE CHAIRMAN: Thank you. (Pause)

MR MIANA: We'll leave all these PPEs over here, inside, and then we'll go back to that same place.

THE CHAIRMAN: Okay.

MR MIANA: But before going there, I will show you the transformer, the diesel generator room outside.

THE CHAIRMAN: On the outside.

MR MIANA: Yes.

THE CHAIRMAN: Okay. Where would you like us to put these?

MR MIANA: Over here. (Pause)

Let's go. Everybody outside.

So if you have any question or clarification. I think I have explained in a very detailed [way], so that you should become familiarised with all the

electromechanical equipment over there.

THE CHAIRMAN: Any questions?

No, this has been a very interesting walkaround for us. We saw them in pictures before; now we see the real thing. So thank you very much. That's wonderful.

MR MIANA: You are welcome.

So now we are going back to the same welcome building in the (inaudible). Okay?

THE CHAIRMAN: Very good.

MR MIANA: So in the back we can see that there are two generators over there. We can see the outlet pipes are (inaudible). So in case of the power failure from the public or from the powerhouse, we can immediately operate the diesel set, in addition to the batteries.

So now we are at the entrance of our A6 tunnel, which we call the cable tunnel as well. And on both sides of this tunnel we have the cables coming out from the four units. Each side contains the cable for the two units over there. So there are six cables in each one: red, yellow, blue. Red, yellow, blue, unit 1, unit 2, unit 3 and unit 4. And this is going out, this one, and also that is going to the TRT. We have shown you this is going to downstream-side tunnel over there. So these are different cables for the lighting system, the instrumentation and everything over there.

THE CHAIRMAN: So on each of these, there are cables?

MR MIANA: Yes, these are cables we can see over here.

THE CHAIRMAN: Yes.

MR MIANA: Different -- the CCTV cables, the power cables.

And also we have a connection from -- when we go downstairs, we can see the connection going into the powerhouse. So we also use this as a second route for when we are rehabilitating the TRT over there.

So these pipes, you can see we've just left these pipes over here. We use these pipes to dewater the tunnel from the upstream side. It's a mechanical system that we have to dewater from the upstream side from these pipes.

THE CHAIRMAN: And you can stop and have a snack too!

MR MIANA: These are for the security people. They can sit over here.

PROFESSOR BUYTAERT: When the downstream tunnel collapsed, did the water pass through or filter through by itself, or did you have to evacuate the water from the upstream part of the collapse?

MR MIANA: So I already mentioned collapse started from 251 to 293.

PROFESSOR BUYTAERT: Yes.

MR MIANA: So downstream of 293, it was dewatered through the pumps that we installed permanently inside the TRT.

Upstream, we could not do that. So we put these pipes specially for dewatering on the upstream side.

PROFESSOR BUYTAERT: Okay. Yes, that was then ... okay.

MR MIANA: And we have one bulkhead at the end of this tunnel, before entering to the downstream-side tunnel.

PROFESSOR BUYTAERT: Okay.

MR MIANA: But that is permanent -- that is closed, and when required we open that one.

PROFESSOR BUYTAERT: Okay. Thank you.

(Pause)

Final Remarks

THE CHAIRMAN: Well, I think I will stand up here, so that I'm not looking at a blank wall.

So the court has met and discussed whether there are any follow-on questions that we have, and we really don't have many. But we do have one, and it's actually a question we asked you, Mr Miana, during the power station visit, which you answered, but some of us did not hear the answer, and so we were hoping you could just answer it again.

The question was: to the extent that the turbines, generators, are not doing full power today, what was the reason for that?

MR MIANA: I explained that there was some pressure fluctuation in the headrace tunnel that we observed

during the first week of April this year. So we have reduced the generation to the extent that the velocity inside the HRT is within the permissible limit.

THE CHAIRMAN: I see.

MR MIANA: So as and when the matter is resolved, then we go for the 969.

THE CHAIRMAN: Okay, yes.

Okay, very good. So we have no further questions for you today, and we don't expect to have any, say, tomorrow morning or anything, so I think basically we are done. We don't need to return to the dam site or to the power station site.

The reason why we don't need to do those things is that we've been relatively active in asking our questions throughout the site visit and feel that we've received the answers that we need to understand as best as possible the information that you've been providing to us. And I think that's in part because you've had a wonderful number of slides that you've been providing to us, even a video today, some hands-on materials with the rocks and the sediments. So we really feel we received quite a bit of information that was extremely helpful for us in understanding the issues that are before us.

I also want to note how the Court felt that you

brought an enormous number of talent to this site visit, an extraordinary breadth of individuals who are experts in different areas, some coming from here, some coming from afar, and we're really very grateful for that. It allowed us to understand the situation as the water is approaching the dam and as the electricity is arriving at the customers, all the way through that life-cycle. So we're very grateful for that.

I do want to reiterate what I said at the outset, which is that I do regret that representatives from India were not here for this site visit. I think we would have benefited from any observations they may have wished to make with respect to the information we were receiving. And of course also it would have been of great benefit to do a site visit in India as well, so that we could see their facilities and hear from their experts. In any event, we do welcome the possibility of India joining in this proceeding at some point, so that we could benefit from them.

Maybe in this regard I will just note that because of India's absence, we've tried to maintain a pretty sharp division between us and all of you who have been presenting to us. That has felt awkward at times, but it was something we felt we had to do in order to ensure the integrity of the visit as best we could.

So just a few thanks at the end of the visit here. Mr Miana, I particularly want to thank you. I understood and I said yesterday that you were the boss. I found out today that there's a thing called the NPCC which is the real boss standing behind you! But of course I joke. We are all very grateful for your assistance throughout this visit, to you and your staff. You've really allowed us to not only hear from people we needed to hear from, but this ability to walk through the various facilities was extremely helpful.

I mentioned yesterday that the dam site was your home. I now see you have a second home here at the power station, and you were very generous to allow us to come and see it.

I also want to thank, of course, the Government of Pakistan generally. I won't list out the various ministries that I did on the first day, but the Court is well aware that this was a project that required individuals from across the government to assist.

External counsel, of course; experts assisting external counsel. The Court imagines that all of you were deeply involved in helping to make the site visit move forward, and we're very grateful for that.

I would be remiss in not also saying thanks to the Permanent Court of Arbitration, which also was instrumental in making this possible, and our videographer, who did yeoman's work in chasing us around and being sure that we recorded everything that happened here.

Let me just finish by saying that we do have next steps in our process, which I won't go into any detail, but we will be contacting the deputy agent and external counsel in relatively short order to discuss where things go from here.

So with that, I think I'll bring to a close our site visit. Again, tremendous thanks to all those involved. You've made us feel very comfortable here; you've educated us on the issues we wanted to learn about. And from all of you here in the room and all of those outside the room -- the security staff, the transportation people -- it's really been a remarkable opportunity for us that you made very seamless, so we're very grateful for it. Thank you very much.

MR MIANA: I would like to say a few words.

Mr Chairman and the Court of the members, I really feel pleasure and honour that your stay at the Neelum-Jhelum was quite comfortable, that you mentioned over there. And I'm also thankful to you for your keen interest during all the presentations; and not only the interest, but you are aware of asking the questions that

encourage all the presenters to respond very effectively throughout this one.

I'm also thankful to all my presenters who were joining with me in the whole visit starting from the presentation no. 1 till the presentation no. 11. They have all done very well. And I'm especially thankful to all of them that are coming from very far away from this site.

I hope that this visit, the presentations that we tried to make were very informative, knowledgeable for you people to understand the operation, maintenance, design, and almost starting from the pre-feasibility study of a run-of-the-river HEP. I'm again thankful to all of you, and wish you a very safe journey back to your homes. So thank you very much.

THE CHAIRMAN: Thank you very much, Mr Miana.

(The site visit concluded)