



MALE: So, for the next few minutes we'll be considering the transmission network analysis, how we factor transmission and distribution into the IRRP process, or the integrated resource planning process. And there are several ways to do this. Ideally, you could look at an option in which you sort of co-optimize your generation, transmission, and distribution resources, but that can be very intensive. And so, what you find is that in many cases assumptions are made regarding the transmission system, and then that is incorporated into the overall least-cost modeling, or long-term modeling, that will be done.

So, what we will look at here is the main factors that are considered when you are developing the transmission plan for your resource analysis. Now, in our system planning, the key is to ensure that reliability of a system is maintained under all conditions. And there are two main aspects to reliability. The first is adequacy, or making sure that you have sufficient resources to meet the need. And usually you'd want to include a margin to make sure that if something happens, if you lose



something, you would not have to curtail supply to your resource--to your demand, or your customers, so you include a margin in there.

The second aspect is security. And security deals with ensuring that if something unexpected happens, your system continues to operate reliably. When considering the power system, we know you have to ensure that you match demand and supply at all times from moment to moment. You don't want an imbalance to occur at any time due to loss of generation, due to loss of transmission assets, or anything like that. So, you build that into the security of the system. You do a security analysis to do that.

Now, we've separated adequacy here into two different sessions. The first is resource adequacy, which has to do with the supply, that has been discussed earlier. That has been taken care of already.

Now, when it comes to transmission analysis, also, there is an aspect of adequacy involved, and that is to ensure that you have sufficient transmission



capacity to move your generation to areas where the load is located. To give you an example, in Ghana, for example, they had--for a long time had their generation in two main parts of the country, the east and the west. And there are load centers where the capital, which was, sort of, close to the east but, let's say, almost central. And then also the second-largest city was in the midsection, and there was load to the north as well. So, because you had these generation pockets, and then you had the load in other pockets, you had to make sure you designed the system such that you don't have constraints when you are moving the generation from those pockets to where the load is.

So, in addition to ensuring that you maintain the security of the system, you also have to think in terms of the adequacy of the transmission system. Is the transmission capability sufficient to get the power to where it is needed or where to be consumed?

There is one aspect of adequacy, which we don't consider in the work that we are doing, but I'll



mention it because you may hear of it in other situations. And that has to do with things like the Department of Energy's congestion study. So, what you do is analyze the system and determine if there are certain areas that the transmission capacity may be sufficient, but because of economic usage of the system, you may have congestion in certain areas. So, it may make economic sense to expand the capacity in those areas, so you can use your system more efficiently.

So, you perform those congestion studies. There are models that are used to do those kinds of studies, like the nodal production cost models that do that analysis and help you determine where congestion is today, how that will change over time, and whether you need to make changes to the system.

So, coming down to the transmission network analysis for the work that we are doing, we do it in a number of steps. The first is to assess the capability of the existing system. So, for each of the countries, Ghana, Tanzania, whatever country we are looking at,

first step is to get data that represents the topology of the system. So, we have detailed transmission information, we have location of generators, and then we do our analysis to determine whether the existing system would be able to serve the load reliably.

The first is the transmission security analysis. So, we run the system. We simulate the operation of the system. And, usually, we will look at a period of time when the system is most stressed. So that could be during the peak period. Now, for some systems, you may also look at lightly loaded periods, because those could also introduce challenges.

So, let's say we take the peak period. We simulate the operation of the system at that time. Would the system be able to serve the load without overloading transmission lines, without overloading transformers, without creating situations in which the voltages of the substations are out of the reliable operating range? For substation voltages you don't want them to be too high or too low. There's a bandwidth within



which this should operate. So you check to see whether the system would operate reliably.

And then, the next step after that is to determine what happens if you were to lose some of your components. Let's say there's a unplanned outage of a transmission line. Would your system be able to recover and continue to serve that load, or would it go out of balance? Would you have blackouts, or would you have situations in which now your voltages are going outside the bandwidth?

If problems occur, you then look at potential solutions to those problems. What do you need to do to fix those problems to ensure that your system operates reliably? Now, in the U.S., planners go an extra step above that when they are considering system planning. They actually look at what happens if you lose a second critical facility. Let's say you lose a major transmission line and then another transmission line. What happens? So, you may hear terms like N minus zero, N minus one, and N minus two planning criteria. So, they do that to ensure that



your system will remain reliable regardless what could happen. Some of the foreseeable contingencies that could occur.

In most of our experience with the developing countries, the systems are typically not designed appropriately even for N minus one operation. That is a loss of a single critical element. So, typically, we would not even go to the next step to do the N minus two or the two-element outage. But, basically, that is how you do your analysis to see if your existing system would operate reliably.

Now, related to that, also, is what we call the transfer capability analysis, which is the second bullet on the left-hand--on the box on the left-hand side. And we do this because most of the planning models--the long-term planning models--analyze the system on a zonal basis. They don't have--typically we didn't have the very detailed layout of the transmission system because that can be very resource intensive. So, we aggregate the substations on the transmission system into zones, or into areas or



zones, and then we determine the transfer capability--the transmission transfer capability--between those zones.

Now, when you are grouping substations into zones, it's important that you understand how those substations operate within the system and also understand the impact of changes on the system on those substations. For example, you want to ensure that the impact of congestion on substations in one zone are similar. You don't want to move substations that are impacted differently by congestion on some elements, because you are going to treat them virtually as a single supply point. So, they should behave similarly within the system.

Then once you've done that, look at the existing system, calculate the transfer capabilities within--between your zones, and then determine whether you have sufficient transfer to be able to serve each of your zones. So, using Ghana as an example, I mentioned that the capital is, sort of, let's say centrally located. You have generation to the east



and west. And you have these pipelines that will be serving the capital--the load zone in the capital. Now you have to determine whether the pipeline you have to move the power is sufficient to serve the capital. If it isn't, then there may be periods during your operation when you would have to curtail load within the capital because you can't get sufficient generation in there.

So, we do that, and then determine whether there are improvements that are necessary. First, for the existing system, and then when we move to the middle box, that is looking to the midterm or long term.

So, we know how it's operating today. How would it operate over the next few years, maybe five years, or the next 10 years? And to do that, we include resources that are expected to be placed in service. If there's new transmission that is being planned, if it's under construction or advanced stages of development, we will include them in the, let's say, the five-year model. And then we redo the analysis.



Now this is important because the long-term model is making assumptions about what the transmission system would look like over five, 10, 20, 30 years. So, we need to help the analyst understand how to treat the system as it is today. How that will change over time, so that they can incorporate that into the model.

And then the last box shows how we factor resiliency into our analysis, and Molly touched on that. We typically do scenario analysis. So, after we've done these studies, we then determine how could resiliency change the assumptions we have made. And we'll see, as we go on, examples of some of the factors that we look at. For example, if high temperature would be an issue, would it change the ratings of the transmission lines? And if that's the case, we'll redo our analysis and see whether our conclusion will change, or whether other things need to be changed in the system to accommodate those changes that could occur due to resiliency issues.

If flooding could cause us to lose a substation, we can determine what the impact would be to the grid if that substation is lost. If it's a critical substation, then we will need to take some actions, remedial actions, to ensure that it wouldn't affect the reliability of the system.

So, once we've done all this, we incorporate that information into the least-cost modeling. And there may be some iteration involved when we are doing that analysis. To give you an example, we may decide, based on the information we know, we may have a view of how the transmission system would operate in year five or in year 10. But then when you put that in the long-term planning model, run your analysis, you may come up with a scenario in which generation is built in the fifth year or in the 10th year, that wasn't included in the transmission analysis. In that case, we will redo our analysis with the new inputs from the long-term model and determine whether that would mean additional transmission resources have to be added to the system. So, there may be some iteration involved to ensure that we come to a conclusion, or



we come up with a resource plan that would meet the transmission needs, as well as the long-term planning needs.

Over here, we go into a bit more detail about how we do the transfer capability analysis. I think I've described that, so I wouldn't go into too much detail. But, again, basically, you form your zones, ensure that impact of the system on the various substations you grouped are relatively the same. They operate similarly within the system. You determine the transfer capability between the zones. And we can go into a little more detail about how you do that technically with the power-flow models. We could do that during the Q&A if anyone is interested, as well.

So, looking at Tanzania as a case study. So, in Tanzania our starting point was actually the definition of the system that we received from the utility. So, in their transmission topology, they had included information on how they expected the substations to be aggregated. So, we looked at that, determined whether it was reasonable. I think we

ended up using their definition, which is the four zones that we've shown over there. And so, you'd expect this, on what I've said, that the area 2 and area 12, as an example, would operate similarly within the transmission system since they are grouped into a single zone, zone one.

The areas that are not connected are all off-grid areas. They didn't have any direct ties to the transmission system. So, we did include them to show that there was load in those areas, but they wouldn't be included in our transfer capability analysis for the existing system.

After we did this, we calculated the transfer capabilities between those zones, and then we repeated this for midterm for Tanzania, and, I think, for Ghana as well. We were looking at five-year out. So, we started with the 2014 representation. I think we eventually adjusted to 2015. And then we looked at a 2020 representation. Now, the interesting thing is, by 2020, Tanzania expected to have built a 400-kV transmission backbone. So, when we looked at the 2020



representation of the system, we saw that two more areas, in fact, three areas, about two zones, had been connected--would be connected--to the grid as a result of that transmission line. The first is the area on the top left, Kagera. That would be--sorry if I crucify some of the names. And the second would be the combined areas on the bottom right, Lindi and Mtwara. Those two would be combined as a single zone as well.

So, this means that the 2014 representation of the system in our long-term planning model would be different from the 2020 representation. But that gives us a more realistic view of what the planners think the system would look like during those periods.

We included this to demonstrate the transmission security analysis. This is actually a country that you, I think, you'll all be familiar with. This is the U.S. We did this analysis for the Midwest System--the Midcontinent Interconnection System Operator's



region, MISO. And we were looking at the impact of retirement of some generation on the system.

As system conditions change, would you have to include the system to ensure it continues to upgrade reliably? We did that analysis and we showed--the red lines show the transmission lines that would be overloaded. And in many of these cases, as I mentioned earlier, it wasn't under the normal N minus zero or N minus one. The system was robust enough, but due to their retirement--so you get to the point where you now lose two elements. You start having problems that would have to be addressed. So we saw both line overloads. There are cases where you'd have voltage overloads, voltage--we call them voltage violations because it could go both ways. It could be over voltage or under voltage. And then there were some transformers, also, that were overloaded as a result of the changes in the system.

So, the system planners would have to understand this. And for this, also, I believe we were looking at--it was for either 2020 or 2022. So, we have to

project how demand would change, how the supply would change, generation additions or retirements, and then do the analysis to determine that. We summarized the information, and using this, illustratively, to show the severity of the overloads that would appear.

Now, when you have your transmission lines, you want to ensure that they don't operate beyond their rating. And transmission lines have different ratings. There's the normal rating, which is what you can use for extended periods if everything is operating as it should. And then they have emergency ratings. Emergency rating is usually higher than the normal rating. They allow you to operate the system at--to operate the line--at the higher loading if you are under emergency conditions. If something has happened on the line. That's the emergency rating.

And emergency ratings also can be short term and long term. The long-term rating is what you can use. Let's say you lose a line, and you need to upgrade for a few hours before it comes back in service. You may need to load the line higher than normally, but you



know after a few hours it would come back to that rating. And then there's the short term. That is if something critical happens, and you know you can restore the system within about 30 minutes, you may allow it to go even higher than the long-term rating. Operate it at that point and then do whatever adjustments you need to bring it back within the limit. So, here we were looking at the long-term emergency rating. You don't want to operate at that limit day in, day out. And under the conditions we looked at, there were some lines that would be overloaded 120 percent of their long-term rating. So, it's even much, much higher than the normal rating. So, this shows the severity of the problem and the need to address those problems so your system would continue to operate reliably.

The case study using the Tanzania system. And here we show--I realize we show just transformer and voltage violations. Here we show four transformers that would be overloaded, and I believe this was under the normal conditions. So, we hadn't even got to the point where we had started looking at loss of

elements, transmission lines, or transformers. And we show there will be some violations. Good thing is a few of them are really relatively low, 6 and 7 percent. But there's one that's as high as 41 percent of the rating. So, these are things that need to be addressed on the existing system to ensure reliability.

And then, same thing, but looking at the voltage overloads. And, again, we see there will be some voltage violations under some conditions. This is just a snapshot view. So, typically, as I mentioned, we look at the stressed period, maybe the peak, because if you plan the system to operate well during the time that it's most stressed, then you ensure that during other periods of the day, the system will operate OK.

A final slide for the transmission section. This shows how we factor resiliency into the transmission and distribution analysis. And, as I mentioned, we look at different scenarios. Will there be temperature increases a result of--could be global

warming or other issues that would lead to transmission--to temperature increases. If that's the case, you have to understand how that would affect the system. That can affect ratings of transmission lines. That can affect equipment at substations. You need to factor all that into your analysis and determine how to adjust to that. Will there be extreme events?

We did an analysis, and again, that was the U.S., looking at extreme weather events in New York. And so, for that we have to define the path of hurricanes and determine what assets would be in the path of the hurricane. If you were to lose those assets, what happens to the system?

And things like sea level rise and storm surge also, you have to factor that in. After Hurricane Sandy, one of the things we found out from the utilities was that the flooding wasn't really an issue for them, but it was the saltwater that went into the equipment. So, saltwater goes into the equipment. It starts to rust. There's nothing you can do. You have

to replace the equipment. So, you have to understand all those risks and then determine the measures you would include in your plan.

So, that takes care of the transmission system. For the distribution system you find that it is very similar to transmission system planning because the principles are very, very similar. So, we do something very--virtually--very close to what we do for the transmission system. We look at the system again. Is it able to operate? Look at voltage issues, transmission loading issues, substation issues. We look at that for existing, and then the midterm as well, determine what needs to be done to improve the system.

Now, one of the lessons that we learned from, which I think I mentioned that earlier, also, from the work we are doing, is the importance of including the stakeholders in the discussion. When we are doing the scoping, we need to include them, because it's good to understand what they know today, what they have in



place, and then, also, what they would like to have in their system.

You find, also, that in many cases, the engineers understand--they know the principles, they know the mechanics of doing the analysis that I have described. But the important thing is helping them to understand how to incorporate that into the overall IRP or IRRP process. So, once you know what they know, you'll be able to help them do that.

Now, the box here shows some of the things that we included in the initial scoping for the Tanzania work. That was because of the things that they needed to ensure that their system was working OK. One was to assess development plans for TANESCO and the Rural Electrification Authority, REA. And it was during that process that we came to understand that REA had some plans. They had actually started implementing some rural electrification programs, but they needed help to understand how to expand that to the rest of their system. So, we are going to work with them to determine the optimal means to do that.

Tanzania had also conducted some loss reduction studies, and they wanted to understand how they could implement some of their recommendations. And also whether there were other things they could do to reduce both their technical losses or, Bill mentioned, nontechnical losses, or commercial losses, as some people also put it.

In Ghana we found something similar. In addition to what are all the normal IRRP distribution planning, they were interested in also understanding loss-reduction methods. They had also done a loss-reduction study. In these countries are very high losses, sometimes as much as 30 percent losses, where you combine both the technical and the commercial losses. So, for them, loss reduction is a big issue. It's a huge issue that needs to be addressed. So, they feel like they need help to deal with that.

In Ghana they were also interested in renewable integration studies. We found out that there were in some cases, as happens here, some of the renewable

resources were connecting to the distribution system. So, the transmission utility didn't really ask us about renewable integration studies, but the distribution utility was interested in that. So they asked us about training in renewable integration.

Same with solar generation. They wanted to understand. They had assumptions they were using regarding solar generation profiles. They wanted to know how it's done over here, and how they can do it better over there.

They also asked about other things, operation of competitive markets, probably because the government was looking at converting the local utility into a concession. And a couple of things they also mentioned--distribution of information to help improve reliability of the system. When problems happen, they wanted to be able to automatically reconfigure the distribution system to maintain reliability.



And then the last one was GIS, incorporating GIS data into their planning activities, as well. So, I think that was one of the lessons for us. Involve the stakeholders as we do the scoping, especially for the transmission and distribution systems. So, now I turn our attention to Bill and DSM tools.

MALE: Well thanks, Ken. And just amplifying the last discussion just for a minute, we've seen a few jurisdictions such as the Bonneville Power Administration in the Pacific Northwest, look at nonwires alternatives. So, using demand-side and distributed energy resources to defer or eliminate the need for a new feeder, a new substation expansion. So, that's kind of a little mini version of IRP that doesn't rise to the level of full system IRP, but that work is also interesting.

So, I guess I would subtitle my little section here, and we'll try and pick up the pace a little, is, if it weren't for those pesky customers, it'd be a lot easier to plan and operate a power system. But, nonetheless, we have to understand what's going on,



on the customer side of the meter. We have to understand the physical assets, the consumption patterns, and the trends, and so forth. So, that's what this is about.

It's a four-step process. We have to understand customer loads at an aggregate level and even down to an individual customer type. We have to understand what measures can be applied, design programs to really go after those major savings opportunities. There's estimates of energy and capacity impacts. There's cost-effectiveness, which is really key. And then you have to look at the programs in a wider context. What's really going to be achievable? What's really going to be feasible politically? What's really going to be equitable across customer classes? Are you going to serve low-income customers as well as industrial customers? Things like that.

And then, ideally, you wind up with a suite of program designs that really goes after the biggest opportunities and provides the maximum benefits



across the system, easy four-step process. However, data gets very intensive very quickly.

So, most utilities can give you this kind of data, which is customer class, you know, very low-usage residential, general residential, low-voltage, commercial, industrial, and then the big industrial plants. And what you immediately notice is that 99.7 percent of the customers are small. This is Tanzania data, by the way. But they only account for a little over half the total sales. And then down here you have the really big customers who are, you know, 460 out of 1.3 million customers account for more than a third of the load. So, you need to know those things out of the box. Pretty much every utility can tell you that.

But then you need to understand, well, where is the energy going, refrigeration, lighting, cooling, and so forth for each general customer class? Sometimes you can get that data from analysis of billing information if you have a granular hourly digital metering data. Sometimes utilities will have survey



data. Like, we did a project in Bangladesh a few years ago, and the distribution utilities required customers to fill out a load survey when they applied for service, so the utility would know how many amps to put in the service.

So, we actually had a database accuracy that was standing. Had a database of what devices were going to go into those buildings. We had something to go on.

Ideally, you would go out and visit a sample of customers and do detailed assessments. They have a statistically valid sample. That's expensive. We're proposing to do more of that in Tanzania to get more customer data. One way or the other you have to have some of these basics.

Now, in this case in Tanzania, TANESCO had invested in a fair amount of digital metering capability. So, we were able to go in and sit with their pool of--it was about four people in an office, and they had this database of metering data, and we were able to go in



and get some typical customer data, which showed hourly load shapes. And we were also able to disaggregate through some analysis to find out how much was lighting, cooling, and so on

And this is a very helpful statistic as well. Using regression analysis we're able to plot kilowatt-hour usage against outside air temperature, which helps for predicting, you know, predicting loads and understanding system operation needs, and so forth. So, that when a system operator knows what the temperature is going to be the next day, they have a better way of predicting what kinds of loads.

So, you can see that there's a good regression fit here, and that clearly there's some air conditioning going on in that building. This is a retail store, so it would tend to be air-conditioned.

And then, you know, we looked at different customer types. This is a medium office, a somewhat peakier load shape but also a fairly strong correlation



between usage and outside air temperature. So, there's cooling there.

But then we get to the cement plant, which is a very different load shape. So, for whatever reason, they actually shut off for this period in midday, and then their peak usage was this rather long time-block later in the day. This is not ideal for the utility. The good news is some industries had the ability to defer load scheduling. If they have pumping, if they have ponds or tanks, things like that, they can delay when they run things during the course of the day. So--and obviously there's no air conditioning going on here when you look at the correlation numbers.

So, you have to understand this kind of data. And then we develop a series of efficiency measures that would apply to each customer type and each end use. And I won't go into all of these, but, you know, we try to tease them out for the major residential customer, industrial, commercial, industrial customer classes. So, we have data libraries of measure characterizations from engineering--energy

performance, cost, and so on. We often need to confirm that with local data, especially on the cost side of things. So, we have to build up a lot of end-use measure data.

But when we do that, then we can bundle individual measures into a program. So, for residential water heating there's a lot of potential measures, and here we have five solar thermal water heating--may only be one in some instances, but if there is a shower, that's a very cost-effective, universally applicable device. So you want a mix of measures. So, you'll have some measures you can get installed in almost every customer premise.

I don't really need to go through this whole process. We know we build up measured costs and savings data. We roll them up into programs. We apply a cost-effectiveness screen. We come up with the total program design, and then this aggregates up into a total demand-side potential estimate for the system. And we'll just dive a little deeper here.

So, this is how we would visualize impacts. So, over five years we have a suite of seven programs here, and we're calculating peak-demand impact. So, interestingly, a time-of-use tariff gives you the maximum peak impact, and, you know, down here in refrigerator recycling you're not getting much peak impact. However, in the internet-of-things world, it's possible to envision refrigerators that are internet addressable, where you can defer defrost cycles or compressor operation for hours at a time and no one will notice the temperature difference in the fridge. So, that could change. So, these technologies do change rapidly.

Then we look at energy as well, and the time-of-use rates don't show up at all. There's no energy savings, really, on net, for a lot of the peak-load management programs, but they have a terrific capacity benefit. You do see energy and peak savings for something like refrigerator--you know, you see a lot more energy savings on the refrigerator recycling side, here.



And so, you know, this is a way of visualizing data. We, ultimately, develop what we sometimes call a supply curve, which simply maps the total amount of savings in megawatt hours, and also in tons of carbon equivalent, against the levelized cost or the impacts. And then we, of course, we have to impose a threshold here, which we would term avoided costs. What's the system's average avoided cost? And, of course, this gets much more complicated in different context.

But, what you want to do is find as much as you can underneath this threshold cost. So, we have industrial compressed air and agricultural pumping give us a lot of megawatt hours well below the avoided cost numbers. There's nothing wrong with these programs either, but they're not getting you quite as many megawatt hours in total. So, this helps us sort of pick off points off the supply curve. If for some reason you could make your industrial motors program a little more cost-effective, all of that savings would be in play again. So, this is the helpful way of visualizing the potential.

We also apply qualitative factors. And we've developed this in our energy efficiency opportunities tool. I'll show you a screenshot later. But we also need to look at qualitatively, is this program really going to change the market? Are we going to have to keep offering incentives indefinitely or after five years or 10 years? Will the lighting market or the air conditioning market be changed so that the utility doesn't have to participate anymore? Is it politically feasible? Is it too complicated? Does it offer some environmental benefits? Does it help low-income people as well as big customers? Those kinds of considerations.

We actually use a one to five scale to rate programs on these indicators. So, it gives us a little bit of quantification, but it's basically a qualitative screen. And then once you're done with that, we try to visualize everything in one handy slide. This comes from Kazakhstan. So, what you want is really big circles. The bigger the circle, the greater the savings. And you want very cost-effective programs at

this end of the x-axis, and you want very feasible high-success likelihood programs up on the y-axis. So, upper right-hand quadrant is where you want to be. And we're finding the good news to be there's a lot of programs that load up to that quadrant.

And so, when you do this, the numbers can get quite large. In some countries we've looked at, the impacts run above 20 percent of total kilowatt-hour sales. That's not instantly available. And, you know, it has to be achieved through a continuous presence over a number of years. But, you know, we try to make it simple.

I mean, efficiency is a very distributed resource. If you look at the total efficiency potential, there's actually more money invested in the hardware that uses energy than there is invested in the hardware that generates energy, at least in a country that's developed to any degree. And people don't see that, right, because it's just not visible. When you go out and do the studies, you realize, oh, my God, there's



all this resource out there. The question is how do we get to it cost-effectively?

We spent quite a lot of time trying to figure out how to visualize this data, and it's always still a challenge to fully understand. But it's, you know, we've tried to make it as simple as possible. We've developed a tool for nontechnical folks to minimize the number of input screens. We have a lot of data libraries that will help you look up stuff.

And because we've tested the tool in South Africa, Mozambique, also Uganda, right? India, Kazakhstan, El Salvador, and Mexico. We have default data that applies to some degree within those regions, if not more broadly. So, you don't have to go out and collect every piece of data yourself. There's a fair amount that's been prebanked in there. And, many of us have to rely on default data a lot in these planning processes, because there's just not enough data out there. I did want to stop here at this handy world map. We have a few other countries yet to go, but it's a start.



So, I think that's the end of session two, and Aleisha is going to put us back on track in terms of timing, all that.

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