TECHNOLOGY UPDATE

April 18, 2012

Coordinator: Good afternoon and thank you for standing by. All lines will be in a listen only mode throughout the duration. This call is being recorded. If you have any objections, you may disconnect at this time. And I would now like to introduce Charles Newcomb with the Department of Energy Wind Powering American program. Mr. Newcomb, you may begin.

Charles Newcomb: Thank you very much. Welcome everyone to today's installment of you monthly Wind Powering America webinar series. I'm very excited about today's - we're excited -- webinars - let me not start there. But, let me say we are particularly and uniquely excited about the technology update.

I think a lot of the audience is familiar with our market barriers and challenges - you know typically those of us who are on the stakeholder side of the world try to think about how do we trim those barriers down - make our market entry smoother. And we forget that there's a driving force on the other side of the equation which is how the technology is changing. At least I do sometimes when I get wrapped up around the market barriers.

So, in that vein we're excited today to bring you three speakers from the National Wind Technology Center. What better place to go for a technology conversation to kind of give us a little bit of an update, starting with wind resource - How thing's changed over the past few year. If anyone was not paying attention or is excited about where we're going.

Also from the technical perspective on the wind turbine side - how the new machine is looking. They've been in the market for a year - year and a half now. These are the class three voters are dramatically changing how we access winds that are higher up and winds that are lower in energy states. And then also on the grid integration side of things. How the new wind turbine controls are interacting with the grid to make it easier for the grid operators and to even provide them benefits that a decade ago we would not have anticipated perhaps.

So with that, I want to introduce my first speaker today. This is Andrew Clifton and actually before I do Andrew I should maybe do the key - a little bit of the housekeeping. Some folks maybe the first time on this Microsoft Office Live Meeting platform and if you are I welcome you to the twenty-first century.

There are a few buttons across the top and the ones that are important to you are the Q&A button. That's your portal passed questions and we'll take questions anytime during any of the presenters. We will generally hold those questions in queue until the final presenter has presented in order to make sure that all presenters get an equal amount of time to present.

They'll be moderated so I'll be reading to the question and paraphrasing them for the speakers and I apologize if I don't get to every question in advance, I'll apologize. And I'll also apologize in advance if I mangle your intent. That just happens sometimes. And so, with that I bring you Andy Clifton.

Andy is on our team at the National Wind Technology Center. You'll notice immediately from his very nice studied accent that he's not from this side of the pond. That's kind of fun for us every once in a while to have somebody with a European perspective who can come into our organization because of you - you probably well know the Europeans are leaders in wind development, technology development and wind deployment in many ways and as we continue to push our technology closer to people, we're beginning to approach a space where the Europeans have been for a decade.

Andy is a PhD so it's going to be a challenge for us to interpret. Hopefully not too much but it's a challenge for Andy to bring it down to our level for sure. He's an expert in resource assessment. He leads the data collection for the tall towers at the National Wind Technology Center. Especially how those - that wind resource interacts with the turbines themselves. And with that Andy I'll give you the floor to take and run.

Andrew Clifton: Thank you Charles. So I've got about ten minutes to talk about how resource assessment and forecasting has been changing pretty much over the last couple of years and how I see it changing in the next couple of years as well. So all of my slides are going to look like this. I have an M which is looking back a couple of years. I put a label on that of 2010. We're talking about now. We're talking about the future and there again I put in 2014 but I'm thinking two to three years.

And these are also the things and the developments if you'd like, that I see. I'd be very interested to see how everybody else actually thinks the wind industry and wind resource assessment has been changing over the last couple of years and where they think it might go. So, looking back, what I see is that two or three years ago we were very much focused on the quantity of wind. And what we were looking at things like what's the wind resource going to be, the annual average wind resource at the up highest.

Part of the challenge though is that we were getting it at - through relatively short towers so we were very often dealing with only fifty or sixty meter towers and then trying to extrapolate that out. And then the next thing to do is we're taking all of that data. We've got almost 9000 hours of data during the course of the year and we've just converted it into a wide world code. So, some kind of a distribution as the wind speeds during the course of the year.

That means you take 9000 hours of worth of data and you convert it into two or three numbers. I think what we've now realized, based on the fact that we have - we've seen historically that we've had a bit of underperformance in the U.S. and actually world wide. And I think what we're realizing now is that we need to move away from just asking the question of what's the quantity of wind to what's the quality of wind. And we need to be much more precise about those measurements as well.

So we're dealing with all the towers. Although putting up an 80 meter or 200 foot tower is potentially a pain in terms of dealing with local regulatory authorities or federal agencies, there's a definite benefit to that. If you go to 80 meters, you reduce your uncertainty in your up high wind speeds.

The other thing that we're doing is we're also looking at seasonal variations and diameter variations, and the day and night cycle. And the question there is how does that fit in - how does that cycle over the season or the day and the night, how does that fit in with other loads that might be sharing the transmission network and how - How can a company - how can a developer monetize that. Basically. I'll talk a little bit more about forecasting later. But really what it means is that you can get more benefit from your wind data up front and you can get a more accurate financial model.

One of the aspects there has been putting up towers like this. This is an 80 meter tower, actually, in Europe. There's quite a lot more effort involved in an eighty meter tower but it - as I say - I think there's a lot of people are finding that it pays for itself.

In the future - In the next couple of years and we've seen this already - I think what's going to be happening is there's going to be pressure form developers and operators to get more information out of the OEMs and the telephone manufacturers up front and there's going to be some very detailed questions that are going to be asked probably through the consultants. And those questions are going to be things like - well tell us how the turbines changed performance as the atmospheric conditions changed.

There has been a lot of talk recently, this is a figure here from a paper by (Judy Lindquist) and (Sonny Walton) at (Lawrence Livermoore) that talks about how turbulence impacts the performance of the turbine. And this is an open access (Lawrence Livermoore) technical report which anybody can access. The number is up there. You can get that from the website.

So people are looking at data like this at field observations and the (sanctoriums) - saying tell me how the turbines are going to change response. So anyway that's one very big thing that we're going to start seeing. And that's going to be partly led by the consultants. It's also going to be led by data that coming out of academic studies and national labs. I think another that we probably will see is a little more work on predicting things like icing. We know that there are areas in the US and obviously in Europe as well icing can be of significant impact on operations and production. Another aspect of that - that I anticipate is what's the impact of climate variability. There is or there were rather recently a couple of studies, one was by Res Americas that talked about how production in Texas was changing with El Nino.

And it's strange this is a climate in fact that's driven by temperatures in the Pacific but it's impacting turbine performance in Texas. So there's going to be a little more work - I think - on things like that. The idea with all of this is we're just going to get a better picture of AEP of turbine performance on a relatively long term scale. But a very useful one.

If anybody has any questions or comments on this there are the - Charles mentioned how you give questions or comments. One of the fun things for me as an engineer is remote sensing. Remote sensing to me in (SODAR) and (LIDAR) faced on the ground measuring the wind fields either complementing or replacing the tall towers.

And if you look back a couple of years, there was not much choice out there. There were probably maybe three or four manufacturers of (SODAR) and (LIDAR) and the systems were relatively young. There was a lot of interest and a lot of demand from the wind energy industry but there wasn't much knowledge about how to do it. (SODAR) was very popular in the US. There were some very well developed systems here in the US but there were also some very popular (LIDAR) systems in Europe.

One of the biggest questions was this idea of bankability. Just how good is the (LIDAR) data or the (SODAR) data and how transferable is it and useful is it. I think we've moved on from that now. I think we've gone past that question of how good is the (LIDAR) data. I think we're kind of accepting that the (LIDAR) data and the (SODAR) data in general are pretty good - pretty comparable. I'm not going to put any numbers on that but the systems are also sold now as complete packages. You can go out and get the remote sensing device. You can get the trailer or the housing for it. You can get the power for it. Somebody will sell you a data management system and the consultants are pretty much ready to do the analysis using that data.

There's less of a national feel now to the systems. The different (LIDAR) and (SODAR) manufacturers have arranged local collaborations to support their systems and I think that it's just going to keep on going in the same direction in the future. I think there's going to be more competition. I think this is going to be very much driven by the market.

The market is going to be pushing towards cheaper systems. Systems that are cheaper to own and cheaper to operate as well. And I think there are going to be some very different business models out there rather than selling direct to companies or to energies, I think the consultants are going to be probably buying more systems and offering it as a joined up service.

I should make the point now - I'm talking about the future but some of these are also being - some of these models are already having - some of these business practices are have - are happily have for a couple of years. There are some people that are further ahead than others.

The last thing I want to talk about is forecasting. I think a couple of years ago on a whole we were relatively young in terms of how we used the forecasting. We were looking for wind events coming through. We knew there were ramp events that might impact performance but it was generally only the larger operators that were using forecasting actively.

Then there was an anchor excel project in Colorado that really looked at how effective forecasting could be and now what we're seeing is as a result of a lot of this kind of background work - we see the larger operators are getting much more involved with forecasting. And really getting a lot of benefit from forecasting.

This image here that I've got up in the top right is from something called the Wind Forecasting Improvement Project which is a DONR project and what has been going on here is in a couple of different areas. So this is a northern area and a southern area of Texas. What's been going on here is there's been an effort to ask the question of if you put more money into forecasting, how much money would you get out. What's the benefit and this is some data that I'm showing here - it may be too small to read - I don't know.

This is some data from (Kerston Ohlrich) at NREL which tries to show what happens when you have more forecasting information. The important thing here is on the top right there are the savings. It's probably the conventional units, the starts and the emissions cuts that are avoided and the reduction in curtailment that are going to be quite interesting for a grid operator or a larger owner/operator.

But one thing that I see is quite interesting on the bottom of that is that the energy and balance cost pay by wind generators - there is a savings there of about one million dollars and I think that just in more money. In terms of the transfer from within the industry - there's quite a savings there. So what will probably happen in the future, we'll probably see more developments like this.

The data that's going to be used in forecasting the surface observations that are going to be used could come from wind farm operators themselves. It can also come from third parties. I wouldn't be that surprised if similarly what's being done W third, we start to see some kind of regional forecasting, groupings or consortia where people are sharing data or rather a forecasting agency is receiving data from lots of different people pushing that into their forecast, using it to refine their own forecasts and then pushing it back to customers. So everybody benefits.

There's in aviation where the data network works in a similar way sharing the observations from aircraft. And I think what this is going to lead to is much more use of forecasting. So at the moment, forecasting is the situational awareness. It's what's happening in the next six to twelve hours and I think in the future, I think what we're going to see, I think this forecasting information is really going to be used to get financial benefit - commercial advantage.

I'm going to stop there. I'm just seeing that I have a question from somebody. What's the advantage of remote sensing? Sorry, I kind of skipped over that. The advantage of remote sensing is that what you can have is you can have a small unit on the ground that means you don't have to put the time and effort and money and headache into putting up a tall tower.

With remote sensing what you can do is you can measure at least to the hub height and possibly higher and you can get information about the wind speed at the hub height and you can get information about the sheer without having to go to a met tower. If you put in a met tower and you have a (LIDAR) or (SODAR), you can take that (LIDAR) or that (SODAR) and you can move it around sight and you can explore how wind conditions vary around sight and compare it back to your reference tower.

There's a third advantage with remote sensoring that's generally very very discreet. So if you just want to go in and have a look somewhere and see what's happening without putting in a tower, you can just go with one of these systems relatively quickly and relatively easily. I hope that answers that question.

Charles Newcomb: Perfectly. Thank you so much Andy and we'll have more questions as we go forward. I'm glad you answered that one real quickly before people kind of did too much head scratching. That's great. Thank you.

Our next speaker is (Owen), known to some of us on the email as Joseph (Owen) Roberts. (Owen) is on our team and does a lot of our project feasibility studies for our federal as well as international clients across a range of issues. (Owen) also has a history in the field as the project developer - construction background. So it's kind of fun to have someone on the team with that spilled some a little bit of dirt on the bottom of his boots, if you look closely enough.

Through that experience (Owen) has maintained the fascination and also a lifeline as to how the technology is changing so that he can accurately conduct these feasibility studies using the newest technology as options for these various clients. So with that (Owen) comes in as a nice speaker on how are things changes, why does it matter, and what people should be looking out for and what is the theme for our wind maps. With that (Owen) if you don't mind taking it away.

(Owen): Thanks, Charles. This presentation is essentially a body of work that was created between Lawrence Berkeley National Lab and NREL and you've probably recognized the names between (Ryan Weiser), (Mark Boeinger) and (Eric Lance), (Maureen Hand). They normally create and distribute the yearly market report for wind for DOE. So these people have a lot of experience with this data set in particular and this data - this presentation just aims to look at the direction that the technology is moving as well as the implications on the levelized cost of energy that wind can deliver to the grid and how that's going to change the market for wind and the national power market in general.

Let's see here. A lower lowerized cost of energy often means lower prices for wind in general and a greater demand for wind energy. Some of the key drivers for this has been the most recently the decreasing turbine cost and we typically use the Ruberg of cost per nameplate kill off rate. The problem with that is that the ratio of the rotor diameter to the nameplate has actually been increasing. So we have larger rotors, smaller nameplates, or proportionately smaller name plates but the cost of the turbine is still decreasing.

And that's counter intuitive. If everything else were equal, you have a larger rotor, you need more material for the blade, you need a better quality control process for a longer blade. You need more steel on the tower because of the extreme loadings on the turbine etc, etc. Theoretically the turbine should be more expensive just for that and then in some cases the generators are proportionately smaller you should see more expense turbines but that's not the case.

The other drivers in the market that the turbine manufacturers have seen this coming in the North American market but also the technology itself has been accelerating. When we look at the constraints such as transmission availability or environmental constraints, or just rural development and sighting turbines closer to people, obviously a lot of the good wind resource areas are not cost effective currently or not accessible anymore.

That drives turbines to be higher output per unit turbine and makes it essentially lower wind speed areas are kind of the focus now and we'll see some examples of that shortly. And also decreases in the proportional balance of plant costs. So the amount of concrete you need per turbine goes up with the larger machine obviously but since you need proportionately fewer machines, it looks like that sensitivity is going to produce a scenario where the cost per unit energy produced will go down on the BOP side.

So we expect the OEM cost to go down per turbines and there's a little bit of information on that as well. So this is a comparison between previously there was kind of a bath tub curb of turbine costs and the bottom of that curb was around 2002 and 2003 and now we've seen a down turn in the cost of turbines curtail a lot. Essentially the two plots, the two boxed plots - I think I skipped a slide actually. I'm sorry.

These are some assumptions that show the basic assumptions that they use in this study. The full study is available online and I have link in this presentation later and obviously all of us are available for questions off line but these are the basic economic assumptions. With the core assumptions which only variable varied capital costs and capacity factor the interesting take away on the plot on the left is that for higher wind speed regimes, the relative cost is very minimal only about a three percent cost reduction. But if you look at our lower wind speed sights, the six meter per second, the top of these bars on the left, you see a twenty percent cost reduction.

Once you include variable such as O&M availability and financing for the current state of the market, you can see that the cost reductions are even higher with a thirty-one percent cost reduction for the lower wind speed sights, with still a proportionately smaller cost reduction for the high wind speed sights.

Obviously one of the points earlier was to look at what this does in terms of breaking down the barriers that were previously problems, or they're still our problems in the wind industry, one of the largest ones being transmission availability and other sighting constraints such as environmental considerations or local impacts on homes or people. And you can see in this plot basically on the X axis, the horizontal axis, has climbed the levelized cost of energy and the Y axis the available land area in North America.

The power price at $55 per mega watt hour, almost 50% more land is developable now than previously thought. I think that actual number is from our 2010 estimates with our 80 meter maps. And so in the past year, the past about year and a half, you see these turbines moving into the market. And these turbines I am referencing are on the order of the GE 1.6 - 100 meter rotor diameter machine - the best is 1.8 - 100 meter rotor diameter machine - the repower 100 meter rotor diameter machine two mega watt - and there's lot more examples of turbines that are under way that we'll look at in an second.

But essentially, we've seen projects that have sprung up in places that we really didn't think would have development. There's really interesting projects in southern New Mexico, in areas that didn't typically have developable resources but they're trying to access the Southern California market. The development is pushing East into lower wind regimes as well and so I guess the take away is with 50% more land developable than was previously thought there is going to be a lot of communities and a lot of states that really weren't expecting a wind regime - a wind industry - to come in to the state or the locale to be present. And we've seen that anecdotally from developers.

Now the question is obviously this study only compares kind of the last generation of machines to the current generation machines that are already being deployed. If you compare the old GE 1.5 axle which was an 82-1/2 meter rotor diameter machine with the new 1.6 - 100, there is approximately fifty percent more swept area for that machine and I've run those power curves through a number of different sites through the Midwest and the western United States and on average it gives about almost 51% more energy at low wind speed sites. And so that's in the six to six and a half meter per second annual hub height wind speed regime.

What that tells us is that proportionally if the rotors get larger, we can see a similar benefit. Obviously it's going to be (unintelligible) in terms of the cost and energy that these large machines can produce but some of the technologies that are being developed in this first column - this first row right here - these are all class 3 turbines with the exception of the (Afeona) turbine. The (Grometia) has a 138 meter rotor diameter on shore four and a half mega watt machine that's currently slated for production in about a year and a half.

Austin has 122 meter rotor diameter machine that I think is actually already prototyped. The (Nordax) 117 is a 2.7 mega watt machine and you can buy those actually right now. There's already been a contract signed in North America for those machines. The (Afeona) 116 repower has a 114 meter rotor diameter machine that they're actually prototype testing. Siemens has a 113 meter rotor diameter and GE has a new 2.7 - 103 meter rotor diameter machine that are all coming to market within a year or year and a half.

The other variable that's really going to change a lot of development is hub height. So there's a lot of indications that - there has been a lot of work in the past decade on looking at taller towers. The real constraint that we see now is crane availability for much larger machines. They only make so many very large cranes and essentially it's going to be very cost ineffective to move these cranes around for anything but the largest wind farms.

GE purchased actually and SBIR Grant recipient from the Department of Energy. GE purchased this company in September 2011 and they are a lattice tower designer that came up with an innovative patent to a kind of self-directing crane if you will. GE is expecting to release a prototype of that sometime this year, they said. Siemens, (Nordax), (Afeona) and others actually already have 140 meter towers.

A lot of these are hybrid towers. Since these towers are meant for the North American markets the transportation benefits of the US roads system are still being exploited. That is to say that the largest diameter base that you can push down the road is about fourteen feet in diameter. The solution is to make either concrete towers for the first thirty or forty meters and then use typically steel power design.

If you put this all together we are seeing developers move in places that we never thought were feasible two years ago. Florida, Louisiana, Mississippi, Alabama, Georgia, South Carolina, North Carolina. In places of Southern California that we previously thought didn't have the wind resource to be available. This is obviously driven by the power market and obviously the resource. The larger variable here is the higher sheer areas such as the southeast. Localized sheer in Mississippi can be in excess of .3 in terms of the sheer exponent and so the benefits as you go higher and higher are more and more.

Other forms of energy are obviously increasing their cost of energy. We've done our work with the larger utilities and know their coal plan. The cost of new coal is significant and much greater than the production that now obviously we have a natural gas - We have a lot of natural gas lying around right now and its really cheap so that's mostly how that bumps the industry.

Essentially, we need to kind of prepare ourselves for development in states that we previously thought the development wasn't going to happen in. Here is the original presentation linked to that if you would like to review all of the assumptions and how they actually broke things down and I think that is is for me.

Charles Newcomb: Thank you (Owen). We're getting a few questions with a reminder that I always forget to mention how you can get the slides after the presentation. The answer to that question is yes the slides are available. Not only are the slides available but there is a transcript of this webinar as well as a recording that are available all via the Wind Powering American website so fear not if some of this might be getting past you and you want to read up about it in greater detail at a later time. You will be able to do that. As well contact information on these slides if you'd like to follow up with any of these speakers, you're welcome to do that as well.

Our next speaker is Kara Clark. Kara is on our team here at the National Wind Technology Center. She came to us from General Electric - from GE - where she was one of their principal contributors on the wind and solar integration studies. She's got the big picture. Grid integration is one of the greater challenges for the wind industry.

You are all aware of the transmission requirements and constraints that we have, but it's also one of the great opportunities and Kara will share a little bit about that. About how coordination in shorter intervals craft which decisions are made. These kinds of relatively inexpensive to implement, hopefully, applications of what we're learning are going to have significant yield as we go forward. So with that Kara I invite you to speak as well.

Kara Clark: Thank you Charles. And let me just contradict you and redirect a little. I'm not so much talking about integration today although I could.

Charles Newcomb: I invite you to on and off, Kara, should you have an opportunity.

Kara Clark: I'm going to specifically look at what you can do with some of the new technology wind turbines. What opportunities which I think is a great word choice of Charles to make the integration easier but with a specific bias towards equipment type capabilities. I am a power systems engineer by training so that's my partiality and my bias is looking at the grid and looking at the integration from the grid perspective, less so about wind speed and solar irradiance but about AC megawatts and how we work with that.

If we - let me figure out how to work this - in the first slide I've made out the four types of wind turbines that most equipment falls into. This is a categorization that was developed - simulated largely any way out of the back Western energy coordinating counsel work on various renewable energy model task forces.

Traditionally, we have the type one production generator wind turbine. We might have some capacitors to address the reactive power consumption to those types of machines but nothing particularly fancy or flexible. Type two gave you a little more capability with a variable rotor resistance - still plenty of those machines out there.

The industry as a whole however, tends to be moving towards the type threes and fours and as Charles said, I came from GE for disclosure on what I know and what I'm going to be talking about today are based on papers from my work at GE and some of those illustrations and examples of performance. But all of the big manufacturers can do something equivalent, similar, better.

The type three wind turbines are commonly called (Double E Fed) so you have a partial conversion between the wind turbine generator and the rest of the system. Say that's roughly a third of the power from the wind turbine goes to that conversion. It has advantages towards speed control and being isolated from the grid. Similarly the type fours are even more isolated from the grid because you have a full conversion between the wind turbine and the electrical grid.

The big advantage of all these converters that power electronic based devices. They have control. That means they are fast, they're flexible. A simple matter of programming to some extent to get them to do great things. Obviously there are equipment constraints, currant voltage etc, but there is a lot that can be done with these new types of wind turbines that were not possible with the older.

And of course you give an engineer capability and they're going to really want to run out and play with it and create some new fancy advance control feature. But the more fundamental question is what benefit can they provide and what needs do they address.

We'll talk a little bit about that in slide three. As everybody knows, there's been a huge growth in the wind industry and now the solar industry. Solar also involves converters so it has some of the similar capabilities. The first integration that I was involved in was in New York and at the time the state had something on the order of a five hundred mega watt limit on the amount of wind in the system and there were 20,000 mega watt systems. A pretty small limit.

And the study looked at integration of up to 10% on the basis of mega watt demand. That is by current perspective extremely conservative. That study was 2005ish. Most of the recent work, we're looking at 20-30% penetration on the basis of energy. New York itself has significantly more regeneration installed than that 500 mega watt limit that we were looking at seven years ago or more and we find that it in areas of the country where we quite high penetration, say Texas.

Here in Colorado some of the instantaneous penetrations are getting to be quite impressive. Excel here in Colorado, Public Service of Colorado, has seen some instantaneously or hourly penetration in the 50% range. Penetration by a daily basis in the 35% range. It becomes important from the perspective of advanced controls that wind plants are getting big and there are so many of them. The grid is no longer infinite.

You're not one wind turbine connected into the rest of the world. You are a wind plant that can have an impact on the power system. Once you can have some impact on the power system, that’s when the questions of some of these improved capabilities really become important. If you look at some of the earlier challenges say five years ago, eight years ago, more than that probably, some of the initial wind plants they were concerned about low voltage ride through. Because historically wind plants, or wind turbines specifically, to distinguish between individual or small groups or turbines and these big 200 mega watts plants or more that we’re talking about.

Some of the early challenges that were based on a perfectly sensible history of wanting wind turbines to trip off when there is a problem. That is no longer an option in a significant part of the generation portfolio. Those questions were addressed satisfactorily, I believe, several years ago and they have found that in many ways some of these earlier challenges have forced wind plants to become more like commercial plants. Being better citizens of the grid. Staying on during faults. Regulating voltage. Contributing bars rather than absorbing bars like the individual induction generators do.

The example picture I have here on the right is measure data from a GE wind plant. The key part of that slide is really in the top half. You can see the wind speed yellow curve bouncing all around. Wind power. Fall speed. Wind plant voltage is the red. That’s moving up a down a little bit. The reason it’s moving up and down is because your objective is to control the voltage at the point of interconnection and that’s the dark blue. And this is a 230 KV system so you can see that you've got quite a flat voltage with a few KV variation, fast variation over the course of this several minute period.

This is a kind of capabilities that are not expected of wind plants because they are such a significant contributor to the grid and it's no longer entirely a question of what the grid can do to the wind plant but what the wind plant can do to the grid.

So that takes us rather nicely I think into the future challenges, future opportunities. I've got two slides on this. One is focused on voltage and reactive power. One on active power. There are a couple of different items in the voltage realm that are front and center.

As I mentioned before for many good reasons when wind was small individual turbines floating around, it was expected that they would be tripped when there was a problem particularly where they're embedded in a distribution system where there is a lot of other customers interconnected. In that situation low voltage tripping is largely not allowed, not applied. Voltage regulation not allowed. Not applied. But changing there's been a directive from (NERC), the IDTF and other work that they reconcile those requirements for distribution plants to trip off versus the larger systemic need for generations to stay on line.

Another voltage related question is on the transmission. Once again a question of bigger plants and more of them means that more plants are located next to each other. Different manufacturers, different capabilities, different control philosophies. How do they all work together. How do you ensure that plant A is not fighting with plant B which is two miles down the road but its electrically closer. There is a body of knowledge in the conventional generation field that can be applied here because there've always been big plants out there coordinated, not fighting each other.

So, there's an attitude related to the growth of the industry. The growing knowledge of the industry and the increasing need, as I mentioned before for the wind plants to step up as they would. The flip side of the voltage question with reacting to power control because it will react power that the person provides you with the ability to control voltage and historically wind turbines absorb reactive power that - and you compensated for that with slow moving devices like mechanically switched capacitors.

Those devices are too slow though to actually respond to something fast or slow. It happens in cycles - milliseconds - type time frames tend to run in milliseconds. To have fast response you might need dynamic reactive power to get you from where you are now to where you're going to be after the fault and converters provide that capability because of their fast control. There are many ways of doing that you can have auxiliary equipment on a plant and still use older styles of wind turbines but eventually again there is a need for some kind of dynamic reactive support to see you through some of these fast faults scenarios.

Some of that is technically very interesting in terms of can you provide reactive power with the converters even when wind is involved and the short answer to that is yes. And that's the fly - the picture on the right shows that. Where the blue line in the beginning is at zero kilowatts, there's no wind blowing there and yet the red line - pink line - which is reactive power out of the equipment. So why would you want to do that?

Essentially it is a question of application specific need. You can easily envision that if it were a solar plant in the middle of the night, no sun, maybe there would be high voltages in your area because relatively less power flowing there would be advantages to the grid to absorb some of that reactive power.

A similar scenario less driven by light and dark with the wind where you can envision that there are certain times of the day, certain times of year, where you might have relatively less wind or no wind and yet there would still be systemic damage to providing dynamic reactive support. Of course the big problem there is there is no market for any one to pay for a virus.

This is an interesting technical capability not one with an obvious immediate need, where need I guess could be defined as what the grid is willing to pay for.

And then the last slide I want to talk about really briefly about active power since I think I've been going on longer than I intended. A couple of things curtailment and ramp rates, that's really a question of what the wind plant could possibly do to the grid. Lots of wind. Lots of wind plants potentially overloading a transmission line. You need to be able to cap the power. Similarly wind coming up quickly that applies stress to the balance of the generation portfolio who then have to respond to that so there might be a need for ramp rate limitations specific to certain applications and to relatively limited times of year.

High stress conditions I think you can make the case that wind plants might need this capability but you might not want to use it very regularly because it does have consequences in terms of curtailed energy production. And then the last item is kind of the latest and greatest frequency response type concerns that have been floating around the industry. (Lawrence Livermoor), (Joe Ido) did some nice work last year, year before on frequency in both the Western interconnection in Texas and about how high penetration can ruin an affect that.

A couple of different levels here of how you might want your wind plants to respond. The key point here is that if you lose another generator, you have got a big mismatch between loaded generation so the remaining generators including the one passed are going to increase the power outputs to hold the frequency and continue to serve loads.

A couple of pictures here that just get at some of the potential capabilities out there. The left picture is frequency, right is power. So I a kind of conventional traditional view, your wind plant would sit there on the right putting out the blue line flat power during the entire event when another big plant is tripped. On the left you can see the corresponding blue line shows the frequency has dropped to fifty nine and a half. With the application of some of these control initial function, you can improve the response.

Take either the pink or the green lines on the left, you've raised the minimum frequency up to 59.6. And you are under frequency load shedding of 59.6 then (unintelligible). So, those are the kind of capabilities that are out there that would make the grid integration easier. And I guess that wraps it up.

Charles Newcomb: Thank you Kara very much. We like to see that. While you're still handy, there is a question about if you could expand just briefly on the notion that you might be concerned about wind plants fighting each other or generation stations more generically needing to be managed so that they don't fight each other. Could you spend just a moment describing what it is, why it is and how do you manage it.

Kara Clark: Sure. Let's dissent whether it's wind or conventional. I'm just going to talk about it generically. If you've got a power plant located at site A. It's a big plant, it's connected to a 230 KV bus. Fifty miles down the road there is another plant also interconnected at 230 KV. Fifty miles sounds like a long distance if you're walking it but electrically it's not particularly far and what you could potentially have is the power plants fighting.

And when I mean fighting I mean they are both trying to control the local voltage on that transmission line to either different value or the same value and it turns out that it becomes just an exchange of reactive power back and forth between the plants to no avail or they could get into some time of ratcheting, cycling behavior where they're going back and forth because of the failure to control.

But that largely happens when they have a specific deterministic objective they are trying to achieve within the controls if they have some kind of slack in that. An integral control from an electrical engineers out there provides that. You get close to your objective but you do not actually have to hit it on the nose. Those are the types of controls that have historically been used by big conventional plants by the grid is coordinated and the reason there is fighting amongst the participants. That type of capability is what is needed with the wind plant. There a most do or can do out of precaution of thinking about it ahead of time and making sure that you have achieved an appropriate level of control to maintain your transmission lines voltage within five percent of normal which is fairly typical requirement for normal operation.

Charles Newcomb: Thank you very much. (Owen) there is a question from somebody about the cost of renewable energy spreadsheet tool. Somebody's trying to hit a number and my advice would be for them to reach out to you directly and I think your information was on the end of your presentation which will again be available for downloading from the Wind Powering America site sometime next week. It obviously doesn't happen immediately. It takes some time to code it all. So that will be there.

Another question for Andy. Can you describe a little bit the - you described about remote sensing and how it has some advantages in that it's discreet, it's quick to deploy, it doesn't require FAA approvals, and that sort of stuff. Can you describe what some of its limitations might be? Is there a smoke limitation? Is there a weather limitation?

Andrew Clifton: Those are all good questions. Those are all very much manufacturer specific actually and I think rather than give a simple yes or no answer, I'd rather that people get in contact with the manufacturers and ask those questions directly. There are work arounds for sure. Slope is generally less of an issue now than it was thought to be at one point in the past. Weather in general, the devices are all pretty much weather proof.

I think it's fair to say that (LIDAR) is generally more successful that (SODAR) in dealing with rain and snow. Other than that, I think they're both fairly weather proof and able to keep an upraising, but again I would say get in contact with one of the manufacturers or the suppliers and put that to them that directly.

Charles Newcomb: Thinking of (LIDAR) is there anything you need for that technology that addresses some of the ice related issues that we see as cups or are you aware of that?

Andrew Clifton: That's another good question. With icing, instruments obviously going to ice up because you get rain or snow accumulating on the devices and then it freezes into place. That's not an issue with (LIDAR). (LIDAR) is - because it's on the ground, it’s a heated unit. It will generally have a wind screen -- or wind screen wiper very similar to what we have in a car -- and that will deal with it pretty easily. So in general, (LIDAR) is not influenced particularly by icing. (SODAR) is also pretty good when it comes to icing. The systems have heaters in the bottom of it so they can shed snow and ice.

And again, I think the thing to do there is to talk amongst the wind industry community and ask the people how they got on with it. Find out what their experiences are. Take their experiences back to the manufacturers and say look how are you dealing with this?

Charles Newcomb: Very good. And then finally, someone mentioned that (Noah) was doing a “shoot off,” looking at the relatively accuracy of (LIDAR), (SODAR) and more traditional means. Are you aware of that shoot off and if you are have you seen any of the results?

Andrew Clifton: I’m not aware of that particular study. I will ask about it. I do know a lot of different people are trying to do - well have done studies in the past with a lot of different results. I think the consensus up to now has been that (LIDAR) and (SODAR) when they're serially produced units and when there is good quality control, they can be quite accurate. It’s always a question of horses to courses though. The accuracy, the question will always be is the accuracy good enough for what you want to do with it?

Charles Newcomb: And you might also acknowledge or would you acknowledge that the technology is continuing to advance so if you had a shoot out three years ago the results of that may not or may have less bearing on today’s technology.

Andrew Clifton: Absolutely and this is one of the things that we’re working on here at the Wind Technology Center is attached to the remote sensoring devices. So if somebody has a device that they want to have a look at a virtual tower, we're working on getting that service out to the industry.

Charles Newcomb: Very good. (Owen) would you mind clarifying if the intent on GE's lattice tower company - is there a goal to make a self-erecting crane or a self-erecting prism?

(Owen): Yes. That's a good question. Basically the technology is if you want to build a 140 meter tower, the smaller pieces the better, the higher you lift them obviously because that reduces the size of the crane acquired. So essentially, the lattice tower can be broken down into very small chunks, if you will and lifted by let's say relatively the same size crane as we use now. The trick is that the rotor and then the cell cannot be broken down into smaller pieces very easily.

The lattice tower manufacturer also came up with what I would call like a hinge crane. It's basically a small lattice structure that sits on top of the tower that can act as the broom of the crane and reach down and lifting the cell and place it on top to the tower while this lattice structure is kind of just a hoop so it can grab the cell and the rotor independently and serve as the lifting device for those large loads.

Charles Newcomb: Excellent and then both you and Andy mentioned sheer a few times in your presentation and sometimes we get folks on the call who just scratch their heads. They've heard of wind sheer and they think about airplanes going down but they really don't - may not have as clear an understanding of what it means with regards to wind. Would you spend a moment just describing that (Owen) and I think you mentioned a sheer factor. And can you just briefly bring that down to earth for some folks that may not be as familiar?

(Owen): Sure. So a sheer exponent is essentially just one mathematical expression that we use within the industry. A typical sheer exponent if you've ever heard of the one seventh power law it kind of some older literature that exists and so very low sheers can be observed in very flat or low roughness trains such as coastal climates.

In the Midwest there is typically sheers of around .2 for a sheer exponent and .3 is very high sheer for an average value for the Southeast. For an average guy in general .2 is very high and that's what a lot of the Southeast has and that's what makes a lot of these taller towers attractive because the wind speeds are much higher than we would have predicted if we used the typical one seventh law.

Charles Newcomb: Got it. Kara if you are still with us, there is an interesting question here that a sort of statement that I think many of us would probably agree with and the notion that there is this floor falling out of the price of natural gas and how that's not helping with wind being competitive. Is the lower cost of gas helpful for integration, the integration of wind and other variable renewables and if you have any thoughts on that.

Kara Clark: Yes it actually could be. All the large integration studies that we send look at a operational simulation of the grid based on production costs. So what that really means is the least cost generators get proactive first to support and provide for the load. In a world where gas is much higher than coal, when wind and solar comes in it displaces gas. And the cost is on the grid.

If gas is relatively less compared to coal when wind and solar comes into the grid it may be more likely to displace coal. The reason that might make integration easier is that in general and let's underline that, in general, typically, representatively, there will be exceptions, gas plants are more flexible than coal. Which means they can respond to the variability of wind and solar that coal plants are frequently base laded.

You've got an hourly, daily schedule, 24/7/365, except for when they're out on maintenance. Gas plants, gas turbines, certainly since they are fired up quickly to meet demand are certainly fast but also the (unintelligible) plants can be pretty good at responding to the uncertainty that you have to address and you have to make some means for.

Charles Newcomb: Okay thank you Kara. We are eleven minutes past the hour by my clock and I think we will wrap it up. As mentioned earlier there is contact information on each of the presentations that you will be able to download at a later date. You can also email us - you can email me if you need to at Charles.Newcomb@nrel.gov. You can also just wait and download the slides and contact the speakers directly if you have follow up questions.

I apologize if I wasn't able to get to every question. I know there are a couple of questions out there. I think they got reasonably well answered even though I haven't asked them exclusively so that's okay. We've got our upcoming webinars. We've got a Careers in Wind Energy in mid-May and we've got some success stories and many of us know these success stories are little pivot points for us to have meaningful conversations with other folks who are interested in wind energy.

Careers in Wind Energy will be covering a little bit of the spectrum and we'll be learning as we dig into this question of who's doing this and how do we get into this better. What do we need in order to get more of the work force up and running. And, I don't think we'll be talking too much about the production tax credit but of course that's on everyone's mind so good thoughts out there to the folks that are fighting that hard battle.

Of course we want to add special thanks to the Department of Energy. There's a few contacts points there. There's my email. (Eon)'s email is a little technical, Technology Deployment Manager. (Jonathan) who is our lead at our Washington Headquarters.

Thank you all for being stellar and staying with us all the way. It's now thirteen minutes past on an hour long webinar. It's fantastic that there are seventy of you, seventy two remaining. Until next week have a safe month and enjoy the coming of spring. We're getting some nice trees doing their thing out here. It's a beautiful seasonal change out here in Colorado. I hope you're enjoying the same where you are. Thanks so much for attending and thanks for the speakers as well, sorry about that guys. All right, take care.

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