CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

Greening the Grid: Best Practices for Grid Codes for Renewable Energy Generators

—Transcript of a webinar offered by the Clean Energy Solutions Center on 4 October 2018—
For more information, see the clean energy policy trainings offered by the Solutions Center.

Webinar Panelists

Adarsh Nagarajan National Renewable Energy Laboratory (NREL)
Jennifer Leisch United States Agency for International Development (USAID)

This Transcript Because this transcript was created using transcription software, the content it contains might not precisely represent the audio content of the webinar. If you have questions about the content of the transcript, please contact us or refer to the actual webinar recording.

Katie Contos

Hello everyone. I'm Katie Cantos and welcome to today's webinar, which is hosted by the Clean Energy Solutions Center in partnership with USAID. Today's webinar is focused on Greening the Grid: Best practices for Grid Codes for Renewable Energy Generators.

Before we begin, I'll quickly go over some of the webinar features. For audio you have two options: you may either listen through your computer or over the telephone. If you choose to listen through your computer please select the mic and speakers option in the audio pane. Doing so will eliminate the possibility of feedback and echo. If you choose to dial in by phone please select the telephone option and a box on the right side will display the telephone number and audio PIN you should use to dial in. If anyone's having any technical difficulties with the webinar you may contact the GoToWebinar's help desk at 888-259-3826 for assistance.

If you'd like to ask a question, we ask that you use the questions pane where you may type it in. If you're having technical difficulties viewing the materials for the webinar portal, you'll find PDF copies of the presentations at cleanenergysolutions.org/training. And you may follow along as the speaker presents. Also, the audio recording and presentations will be posted to the Solutions Center training page within a few days of the broadcast and will be added to the Solutions Center YouTube channel, where you'll find other webinars as well as video interviews with thought leaders on clean energy policy topics.

Finally, one important note to mention before we begin our presentation is that the Clean Energy Solutions Center does not endorse or recommend specific products or services. Information provided in this webinar is featured in the Solutions Center resource library as one of many best practices, resources reviewed and selected by technical experts.

Today's webinar agenda is centered around the presentation from our guest panelist Adarsh Nagarajan, who has joined us to discuss an introduction to the key concepts for understanding renewable energy grid codes and review how grid codes has developed in the U.S. and internationally. Before we jump into the presentation, I'll provide a quick overview of the Clean Energy Solutions Center. Then following the presentation we'll have a question and answer session where the speaker will address questions submitted by the audience. At the end of this webinar you will be automatically prompted to fill out a brief survey as well. So, thank you in advance for taking a moment to respond.

The Solutions Center was launched in 2011 under the Clean Energy Ministerial. The Clean Energy Ministerial is a high-level global forum to promote policies and programs that advance clean energy technology to share lessons learned and best practices and to encourage the transition to a global clean energy economy. Twenty-four countries and the European Commission are members, contributing 90 percent of clean energy and responsibility for 75 percent of the global greenhouse gas emissions.

This webinar is provided by the Clean Energy Solutions Center, which focuses on helping government policy makers design and adopt policies and programs that support the deployment of clean energy technologies. This is accomplished with the support in crafting and implementing policies related to energy access, no-cost expert policy assistance, and peer-to-peer learning and training tools such as this webinar. The Clean Energy Solutions Center is co-sponsored by the governments of Australia, Sweden and the United States, with in-kind support from the government of Chile.

The Solutions Center provides several clean energy policy programs and services, including a team of over 60 global experts that can provide remote and in-person technical assistant to governments and government-supported institutions, no-cost virtual webinar trainings on a variety of clean energy topics, partnership building with development agencies and regional and global organizations to deliver support, and an online library containing over 5,500 clean energy policy-related publications, tools, videos and other resources. Our primary audience is made up of energy policy makers and analysts from governments and technical organizations in all countries, but we also strive to engage with private sectors, NGOs and civil society.

The Solutions Center is an international initiative that works with more than 35 international partners across a suite of different programs. Several of the partners are listed above and include research organizations like IRENA and IEA and programs like SEforALL and regional focus entities such as ECOWAS, Center for Renewable Energy and Energy Efficiency.

A marquis feature that the Solutions Center provides is a no-cost expert policy assistance known as Ask an Expert. The Ask an Expert service matches policy makers with more than 60 global experts selected as authoritative leaders on specific clean energy finance and policy topics. For example, in the area of grid integration we are very pleased to have Hugo Lucas, head of energy department EF Factor serving as one of our experts.

If you have a need for policy assistance in grid integration or any other clean energy sector, we encourage you to use this valuable service. Again, this assistance is provided free of charge. If you have a question for our experts, please submit it to our simple online form at cleanenergysolutions.org/expert. We also invite you to spread the word about this service to those in your networks and organizations.

Today's webinar is co-moderated by Jennifer Leisch, who manages the USAID-NREL partnership, overseeing a portfolio of clean energy integration projects. Jennifer leads the USAID Greening the Grid and directs the agency's work to account for greenhouse gas emissions reductions as well as USAID clean energy programs.

And now I'd like to provide a brief introduction for today's speaker. Adarsh Nagarajan is a research engineer in the Power Systems Design and Studies group at NREL, with a focus in distribution systems analysis relating to clean energy systems. And with that very brief introduction I'm very pleased to welcome Adarsh to the webinar.

Adarsh Thanks, Katie. Thank you all for attending the webinar. This webinar will present necessary background for understanding renewable energy grid codes and review how grid codes are developed in the United States and internationally.

Grid codes are key mechanisms that state entities, utilities, nations use to ensure safe and reliable interconnection processes when connecting new resources. It may be PV, solar, wind, storage, anything that shows up.

Recent development in inverter interface energy technologies poses new challenges to the design and implementation of grid codes. In this webinar we will talk about some of the most recent inclusions to the grid codes such as right-throughs, which means what should these new technologies do when there is an event on the system; voltage regulation, which means what should these devices do when there is no issues on the system for inverter interface energy technologies.

Grid codes have been evolving in its ability to support and organize a lot of ideas surrounding new technologies. Legacy grids involve centralized generation and consumption typically far away from the point of generation. The legacy system included three categories: one is generation, second is transmission, third is distribution. However, increased generation in the low-voltage or medium-voltage area is causing disruption in the legacy system practices and posing a need for advancing grid codes.

Our system is evolving in numerous ways in parallel. There are new technologies that are showing up frequently, and there is increased penetration from these new technologies. And all these devices are expected to be smart and be able to communicate with each other and with the grid in general. Along with all this there is significant growth in electrification of transportation.

With all this the system needs more flexibility, which can be achieved by enabling or leveraging these new technologies the right way. This grid code webinar will mostly speak about the most recent 1547-2018, which is dedicated vertically for distributed energy resources, which I will caveat in the next few slides, while what do I mean by IEEE 1547 standards for DER?

For the next few slides I would like to point out how the new technologies are evolving in the last 10-15 years, and I'll be referring in particular to solar energy just to make the point.

Before 2014-2015 timeframe all the all-over USA and some parts of the world saw a significant increase in solar energy. That installation could be for -- at that emission level could be the distribution level at different voltage levels, but there was significant increase.

After 2015 there was no indication of using these devices for providing any controls, which means all these devices were used only to generate active bar and were not dispatchable or flexible in no way. Even if there were older issues or any issues in the system these devices here would just keep generating unless there was an event, like a fault.

After 2014-2015 is when the grid code started looking at all these things and started understanding what if these technologies can be curtailed or regulated in a particular way to make sure the grid doesn't get affected.

2017 onwards there's a significant increase in energy storage, along with solar, which is a photo app solar fresh storage, which makes solar so much more dispatchable, and there is not even any reduction in active power option for all generation from all this technologies.

The same analogy also applies to wind, if you look back, wind or [inaudible] power but now wind can do numerous things -- wind is so much more dispatchable as of course a few years back. The rule of inverter in phase technologies are involving. IEEE 1547 has been a major voluntary standard that's evolving with time. This is a footprint of how the 1547 standard evolved in the past 15 years.

Just a caveat: 1547 standards very good for all resources that get connected to distribution resources, however but the evolution has been signification in 1547. Before 2003 all the inverter interface technologies such as solar systems, energy storage that got connected to residential level could not do anything except generate active power. If there was any abnormal conditions the system had to pick. However, in 2014 IEEE came out and amended the old standard and said, "If at all a particular facility or region or state wants to use this technology to perform some voltage regulation, when you provide write-through frequency response they might start trying. There is nothing wrong about trying. But it's not a standard yet.

In the meanwhile, specifically California and Hawaii, along with a few other states, started trying pilot studies, which means they started using this freedom of trying, or leveraging these devices to provide better services. And that led to a significant upgrade in 2018, which led to the most different standards.

Now, all these DER that get connected shall be capable of actively regulating voltage; it should provide support during abnormal voltage frequency conditions and should be capable of frequency response. And now it may provide inertial response. Maybe this might become a shell in the next few years.

Just to get into a little bit of detail of how individual state utilities led to a significant growth on the understanding of all these new technologies. The reason why I'm pointing out those two states is because—just to give a context. NREL was significantly involved with all these states as the technologies evolved. California and Hawaii, after 2014, started throwing out these new technologies, specifically inverter-interface technologies, to understand what these do.

In between 2003 and 2014 what happened was there was significant penetration from new technologies such as solar. And until a point there was very little idea about what could be the downside of having new technologies for execute generation. However, after the penetration level exceeded a certain point, what was when the studies related to PV hosting capacity became relevant.

Once that became relevant there were numerous studies performed, funded by California Department of Energy that led to a point where there is a safe percentage of solar that can be included in an area that's safe for operation. However, the growth kept increasing in Hawaii and California. That led to a point where even if there is an issue, instead of stopping inclusion of these technologies the better way is to use them to mitigate the problems.

That was an NREL started working with California and Hawaii to understand how can these inverter technologies be used to manage its own voltage, or maybe provide frequency support or voltage support or reduce its active power generation to maintain the voltage in the grid. Here the idea is to make sure, in long term, the grid doesn't fail, and also using these technologies enable increased penetration in the future.

Some of the essential services expected from solar and wind are voltage support, frequency regulation, which is also referred to as automated generation control, ramp control services as decided by the local balancing authority, spinning reserves, again as referred by the balancing authority.

The graph on the right is an example of how these technologies, solar or wind, can be used for dispatching, instead of treating it as a variable resource which is non-dispatchable. It's a graph that has X-axis which is time, in seconds; Y-axis is power in megawatts. As you can see, the green curve is available megawatts from a resource, whereas the commanded megawatt, which is the bark blue, which is kind of overlapping with the orange, is what we were trying, at NREL, to see whether can a resource be dispatchable to my wind advantage.

And with that we can clearly see that the measured megawatt can exactly follow a certain commanded megawatt within a certain buffer, which means that all the research and development happening in leveraging these technologies are particular renewable resource which was previously considered as a variable, non-controllable resource, can be mostly regulated and controlled.

Before getting into a little more details I would like to get into some key definitions, just read out what it means. If there is any questions on this, I'm very happy to answer later on.

So here I'm trying to caveat a few words. A DER stands for Distributed Energy Resource. It typically used to include solar storage and controllable loads. And DERs typically get connected at a residential level or medium voltage level. But however, to reinforce certain standards doesn't apply to controllable loads, it only applies to generators.

DG has been another word which has been used in this area which is referred to as distributed generation, which is a proxy for solar if you go back in time. A big distinction between distribution and transmission, any voltage level above 59 kV in the USA is referred to as transmission or bulk energy system, whereas any voltage level, any system that's below 59 kV is referred to as distribution. It can go as low as 120 volts, or the distinction between downstream distribution depends on nation to nation, however in USA this is the number where 69 kV is what the big pot is.

Every new technology that gets connected should be capable of communicating in two levels. It should be able to connect in two levels. One is the moment you connect the system it should be able to provide electrons back and forth, and that's referred to as electrical connection for the flow of electrical power. And these devices should also be capable of communicating with the grid, maybe for just measuring, or maybe for communication or controls. That's referred to as logical connection, or data connectivity.

And most of the renewable resources are always interfaced with inverters. These inverter systems make the DC power that gets connected as a renewable resource to AC, that's what the consumable way of electric power is.

A quick run-through of active power, reactive power and apparent power. Any resource such as solar, wind, storage, generate primarily is used for active power, because that's measurable, that's easy to monetize, that's what is actual power that's unit is watt.

Reactive power is basically that extra power that's needed to compensate any consumption inductive and capacitive power differentiated. Active power is typically used for frequency control; reactive power is typically used for voltage control, although active power sometimes is used for voltage control it's more effective for frequency control.

Combination of these two becomes a vector sum and becomes apparent power. The most typical way to describe all these three is the power triangle on the right. As you can see, the X-axis is active power; the Y-axis is reactive power. They are mutually perpendicular to each other, and both of the vectorally add up to apparent power.

Power factor, on the other hand, it's one way to identify how much—what percentage of apparent power is active power. Ideally these should be one. That means all of the apparent power needs to be active power, but it depends on the need and the voltage to say that what proportion of apparent power should be active and reactive power. And that measurement unit is power factor.

To quickly illustrate what is active power and reactive power—I have two examples here—one example on the left: the wheelbarrow analogy. In order to make the wheelbarrow move we have to apply force to the handle. The force to be applied in the forward direction only after lifting the handle. Active power force that propels the wheelbarrow in the forward direction, whereas reactive power is that force that serves to keep the wheelbarrow in the lifted position.

As you can understand in this analogy the force that's applying the power direction becomes effective only after lifting the wheelbarrow from the ground. That's where reactive power is more effective: it could just keep efficiency high and not fall below a certain acceptable number.

On the analogy that's on the right the second technology which is the inclined plane angle, here if I want the ball to roll in the forward direction, I can't make it happen unless there is some extra force that's needed to keep the ball away from rolling down.

There's where we can say that the force that's used to keep the ball from rolling down is reactive power, so the force that's used to keep the ball moving in the forward direction is active part.

This slide is just to give a quick detail of what an inverter is because a lot of things that I'll speak in the next few slides is all about leveraging inverters and technology. Inverters are those devices that convert DC power to AC power, or in the bigger sense these are that technology that enables the user of renewable resources and make things more controllable. Solar and storage are almost always beefy, which means that part is not consumable in local grid. That's the reason inverters make it go from DC to AC and makes it controllable and usable. On the left we have an example, a picture of residential inverter which is very small in size, as opposed to on the right it's a megawatt-scale inverter, which is huge.

Grid codes play an important role when there are adapters of new energy technologies. Just to—so here what I'm trying to make is to distinguish what records do and how at what point the grid codes break, meaning what voltage or power level. As you can see on the left, I am referring to a solar farm that's connected at the transmission level, like 220 kVr, about, whereas on the right you can those renewable resources like the roof-solar, which I on the residential scale, or connected at 12 kVr below. There is a significant difference between these two.

On the left all these solar or wind that get connected at megawatt level, or that get connect to 100 kVr about systems there is no yet significant grid code that says what should devices be doing. Whereas as opposed to on the right all the rooftop solar, or those systems that get connected to medium voltage or lower there is a significant need for grid code and therefore 1547 is dead.

One of the reasons why, so far, there has not been a standing up standard on those systems that get connected to transmission level is maybe because there are fewer players. To give an example, in a single feeder there could be a few hundred, maybe up to 1,000, rooftop solars as opposed to in the whole USA there could be a few hundred such big projects that have multi-megawatt solar connected to, or wind connected to transmission level.

Typically, transmission _____ inverters interface technologies operate through power switches agreement and it's easy to monitor and control and go in case by case. However, with all the recent developments there's been a new standard that's currently being developed which is 2800.1, which might take that form in the next few years. On the right on this slide, which is of the residential roof-top solar, since there are a lot of players, numerous vendors—and at the same time there could be few hundred installations happening in a single region or state, there's a significant need for standards that govern.

And secondly, there has not been a clear incentive mechanism as to what should, or what will, the investor or the customer get if they provide all test support. So there has been a little bit of confusion on. And that's the really all these standards, irrespectively, say that you should be able to provide some services, whether there is incentive or not, just to keep the grid running and from failing.

And all these—and just to give one of the quick descriptions, there is no one word that says, or that refers to those solar or wind that get connected to bona fides systems, as opposed to DERs, or those that's referred to solar or storage that get connected to medium voltage or lower. So, from now on, if I say DER that's happening at distribution level, and if I say anything that's connected to _____ that's the transmission level systems.

The basic expectation out of DERs in the real world, is to be a good citizen, which means these devices should be able to provide some local service just to keep the grid from failing, or keep the old data within acceptable limits. In the past all these systems used to just generate active power and shut down when there was any problem, whereas what is expected from now on is to also do something when there is a little bit of problem on the grid. It could be outage; could be frequency or anything.

Additional interest of investing. As the penetration of these DERs increase for utilities, instead of investing in additional technologies when we get issues, they can use these systems to provide some service or adopt them.

Some of the key considerations for grid codes. There still are too many devices that operate in a local region; all these devices that go on distribution should be capable of mutually agreeing on what voltage support modes are, should be capable of providing voltage frequencies supporting a particular way, should fail-safe and should not cause any fire hazard, and all these devices, DER, should be capable of communicating in a particular way and complies with some acceptable set of protocols, which means all these devices should be speaking somewhat in similar language and should be capable of understanding.

And as the penetration keeps increasing a second need here is -- or the most important need is how quickly are these devices pluggable and playable, or what's the minimum time required to just connect and make it run?

In order to make a grid code, especially in the world of distribution systems, or DERs, there are numerous stakeholders as opposed to what happens at well systems. The hardest part is to make a grid code agreeable to all these diverse stakeholders. Every device should be performing a very particular way, and that's what can be done, only if all the inverter manufacturers talk with each other and talk with the state entities.

All the distribution utilities, state governments, should work in tandem with the inverter manufacturers, along with their governing entities such as public utility commissions. Along with all this voluntary organizations such as IEEE, NIST, National Energy Code, Underwriters Laboratories—there are numerous to keep mentioning. All these voluntary organizations should somehow provide—get the funding and should kind of push this momentum in the direction that helps the nation.

On top of all this comes the consumers. These are the people who really buy or invest in these devices. These no-policy, or technology or grid codes, should act against the need for buying these technologies. If a consumer wants to buy it these grid codes should enable them to buy it and make them usable in a particular way.

On top of all these, national labs and universities play a very important role in documenting all these and pushing these technologies or grid codes in a very particular, usable way. Along with all these there are sufficient legal firms that try to make sure that no policy acts against its usability.

Just to provide an example, in California, in order to make the grid codes to the current state, smart inverter working group was set up in 2014 and right now there are only 200 organizations that sit for a phone call or meet a few times a year to make sure all stakeholders' interests are properly answered.

Among all the stakeholders the key stakeholder, I would say, is vendor because—it's inverter vendor is because inverter is that technology that connects all these renewable technologies to connect to the grid. And in order to make all these devices work a particular way inverter vendors should be in tandem with all these verticals that we state here, such as local/state rules, UL, which is for performance standards, voluntary organizations such as IEEE, NEC-NIST and SunSpec, which is for communication, which is particular to USA here. But this is a particular example how many organizations or institutions that inverter organizations should work with. As already discussed, 1547 is a voluntary grid code and that governs all the DERs that get connected in the mainline USA.

From September 2017 onwards, California and Hawaii said all the inverters that get connected to the main grid should be capable of providing some advance inverter functionalities. And to make it happen it take four to five years. However, after that happens, in 2018 is when IEEE updated all its standard grid codes and announced that it's going to be a national requirement. However, it doesn't mean that every state will start using technology then and there. The requirement here is, to give you an example, if Arizona wants to make, or comply with 1547 then the PUC should make an announcement or some sort of a legal binding document that says that we will comply to 1547 2018. If they don't do it, they should come up with an equivalent rule such as Rule 21 or Rule 14H, that can override 1547.

So, what is 1547? 1547 is a standard for interconnection and interoperability of DERs with associated electrical power system interfaces. 1547 governs all that that happens between a DER and the local grid. 1547 is a standard which suggests, or which provides the requirement from a device and it's not a design handbook but it's not descriptive, it's all about what technique to be done.

1547, to the specific as I already have said, is only for those systems that connect to distribution level; there is no size limit; it can be as large as it can get in a load. 1547 took a lot of effort. To give an example, it had—it took almost three to four years to make this happen. It had up to 120 industry experts in working group. Working groups are those set of people who dedicate to make a standard happen, and in the end, it was balloted with up to 400 people, and the last few years developed _____ 1500 comments that were resolved.

As you can see, it's a big effort to make a standard happen. What 1547 did was it categorized the operation of DERs into two verticals, which is what should the device be doing when the grid is operating normally, or in other words when there is a continuous operation, or what should the devices be doing when there is an event on the grid, or a fault.

So, within 1547 2018 provided two modes, which is category A and B when a DER is operating in a normal, all data operating condition. Whereas it provided three categories, 1, 2 and 3, when there is a fault, or an event, on the system. Category A and B, as you can see, has different limits. There are quite a few things, but the main difference is percentage of a load reactive part. Category A is a little more conservative on how much reactive our should be limited to because that, in a way, limits the active part curtailment on the inverter on the solar. Whereas Category B is for those scenarios with a high penetration of renewables, and the provides higher limit on reactive part.

On the other hand, Category 1, 2 and 3 provides time limits on at what point should—up to what time should the DER provide some dynamic support, and Category, 1, 2 and 3 go from provide very little support to a lot of support in Category 3. California and Hawaii run with Category 3.

So, Category A and B it's all about providing voltage support. And the way it works is the inverter, which is the interface between the renewable resource and the grid, or generator and the grid, should be able to regulate its reactive power, depending on voltage at the point of common coupling. Just to clarify, the standard mentions that reactive power has the priority over the active power, which means even if there's a voltage event in the system inverters flush twice to inject the reactive power, and then it starts curtailing the active power to make necessary voltage improvement. As third Category A is the more conservative as opposed to Category B.

This is when the voltage likes to happen—that means when there is an event on the system. Could be a fault, could be a tree falls on a line or whatever could happen when there's an event on the system what should DER be doing? In that sense what were watts expected out of these DERs before the recent update on 1547. It's a graph with X-axis as time; Y-axis as voltage.

If the voltage at the point of common coupling or interconnection exceeds, above or below—above 110 percent or below 88 percent it was expected out of DER to just trip, or don't do anything, cut down. Whereas after 2018 we want more of it, which is if there is a voltage event, which is about one-tenth percent of below 88 percent, we still want something out of the device. It can keep generating up to 12 seconds, which is the most time in Category 3. As the voltage becomes lower the limited time is limited to one second.

There is a very detailed description of this in 1547. And most importantly, as the penetration of these DERs increase these devices should be communicable, which means they should be able to talk. They should talk somewhat similar. They should be able to understand. There are numerous communication protocols. So what 1547 did is they listed these three, which is 2030.5 or also referred to as smart energy provides 2.2, which was a Zigby, DNP 3, which is a very popular protocol, or SunSpec Modbus.

SunSpec Modbus is a variant of Modbus but it's specifically for inverters. That means any DER that gets connected in USA should be capable of managing one of three, one of these three. And one more thing that happens significant in the past year is in order to make communication as easy as possible SunSpec, the organization came up with the communication standard, which means every inverter now can be certified with SunSpec to have communication possible. That means all inverters should be all performing a very particular way.

Going on to the next part of the slides, or the webinar, which is International Grid Code Development. Europe has been a leader, as well as in the area of grid codes and adopting to renewable technologies, which is—and in this case, in the interest of time we are limiting to Germany, Italy and Spain.

Germany has been a leader specifically when it comes to penetration levels to have very high penetration. There are two main standards that govern renewable penetration in Germany, which is BDEW and VDE 4105.

BDEW became active in 2009; VDE 4104 became active in 2012. The next slide I'm going to separate them—what are they? BDEW—so the prominent functionalities end up by these grid codes are feed-in management, which is ability to limit its active power in order to make the grid better; provision for reactive power, which means ability to inject reactive power for better voltage management; and third, dynamic grid support. When there is an event or a fault, for whatever reason, the device should be performing a particular way.

So BDEW arranges the grid architecture as shown in the top right corner. As you can see, the way they are arranged they start with the basic topology and they insist that the most important, the second more important thing is communications. That means all of these devices should be able to talk a particular way. Then comes information, which is all of these devices should, whenever they talk, should be able to be saved in a particular way and should be able to be retrievable and communicable.

Then comes the functions, which is active power management, reactive power management, right through all these. The last layer is business, which is making users of it, the aggregators where third party vendors come in and try to use all these layers and make a business model out of this. As you can see, the architecture here seems to be the thing that _____ _____ _____. So, a lot of people think of functions first, but here they suggest communications first, which I wanted to point out.

Between BDEW and VDE they are not the same. A lot of people kind of use it interchangeably but they're not the same. BDEW is applicable for those interconnections that happen at medium voltage, which is in Germany anything above 6 kV up to 30 kV, whereas VDE is applicable for those systems that connected to residential level, which is typically 400 volts or lower.

But the reason VDE 4105 insists on reactive power support, where voltage support is mostly needed, as opposed to BDEW, where let's say we speak a lot about frequency support. And as you can see, these standards were in place well ahead of time, 2012. And let's hope that Europe took it well. They inherited most of these requirements and at the European level ENTSO-E, which is European Network of Transmission System Operators for Electricity inherited all these and made it a blanket standard or requirement in Europe. Similarly Italy and Spain as well did the same thing; they upgraded their requirement as soon as BDEW came out in 2009, and that means in Italy, December 2011 is when all the medium voltage standards came in place and AEEG from March 2012 came in requirement, which means as soon as somebody in Europe identified the need for these decides or the point sequences if the penetration increases, identified the rest of the Europe more or less. And the same thing happened in Spain as well.

Going through a specific example in India, because I have been part of a few efforts in India. With my reference I'm trying to say how is India taking care of increased penetration in renewables.

India, as you can see, is governed by CEA. CEA covers all the requirements and standards on renewables penetration, along with the support of MNRE and numerous other organizations. India is having a significant increase in wind and solar. The way the penetration of transmission level interconnected renewable resources are handed is very well. There are a lot of pilots going on in India that by already trying frequency regulation and automatic condition controls, whereas one zone that could be organized is the DER standards. As I mentioned, that's where the hard part is. In U.S. it's a little bit more than ten years to make standard out of all the requirements.

When I was in India, I could see a lot of multi-megawatt projects going on in solar and wind, and the hard part is the odd year. So one of the good practices that developing nations, or nations that are seeing these DER penetrations can do is maybe they can learn or we all can share our knowledge and learn from how these lessons learned from the past can be implemented, which means—at that time when the requests for information keep coming it's better to categorize them quickly, screen them, and identify whether that means a quick run through or that needs to be dealt in detail.

So typically, in California, in Hawaii what they do is they break the interconnection requests into three categories. One is immediate pass-through, needs a quick screen, which takes a few days, maybe weeks, and a detailed run which is a case-by-case, which can take months. And more than that, it's good to have a few bonds, such as at the site of the DER, which needs to be interconnected, not exceeding a certain percentage of the maximum peak loads. They can get immediate requirement and pass-through or that needs to be analyzed.

In a typical scenario in California [audio glitch] utility might be a few hundred cases or requests that can come every week. And it can be the case in most of the initial _____. So as long as not well organized what happens is it becomes a big burden and very hard to pass through.

And more than that, as the advance inverters of all these 24/7 standards coming in, just along with saying yes to interconnection requests the requirement here is to also use the technology and make benefit out of it. That means if I way I want reactive power support from these DERs it's also important to have a way to optimally identify them and use them.

Just to summarize, some of the key things that I mentioned I wanted to throw light on. 1547 or grid codes, do not apply for all interconnections that happen at all voltage levels. They both are handled separately. In USA P2800.1, which is currently a work in progress with NERC and IEEE is trying to come in play in the next few years to handle those interconnection requests that need to happen at transmission level. Could be PV and storage. Whereas 1547 is applicable only for those interconnections that happen at medium voltage or lower.

Since there is a big count, sheer magnitude and count of these DERs it's hard to come up with a new standard as opposed to transmission levels. It's better to just learn from all these existing standards that have been thought through. There has been a lot of effort that has gone through to make these grid codes happen and a lot of arguments and time has been spent on this, which means to say that every number you see in a standard or a grid code has been well thought through. If I say 44 percent there's a reason why there's 44 percent—why not 43 percent?

Every detail that you see in a standard there is some analogous report by a national lab or a university as to justify that particular requirement or a number. It's much easier to learn from these kind of—there is Europe, there is USA, there is Australia. All these new standards can be picked up and learned from for all the other future developments.

And all these standards are documents that keep changing, which means every few years they need to adapt and be managed. It's better to always keep tabs on what are the next things that can happen.

More than anything, one thing which I would insist is if third party vendors or customers are buying these technologies such as DER it's going to be an advantage for utilities or transmission coordinators to use these technologies to make advantage out of that and maintain power factor or voltage in a local system.

So that's my slides. Thank you.

Katie Great. Thank you, Adarsh, for talking about the need for an evolution of grid codes, both in the U.S. and internationally. I think there's a lot that can be learned, especially without needing to reinvent the wheel, as you've pointed out.

So, before we go into questions and answers I'd like to encourage our viewers and listeners to submit any questions you might have in the questions pane. And we already have a few questions coming in. Before we go to those, I want to encourage everyone to find more resources, not only on grid codes and the evolution of grid codes at many other grid integration-related topics at GreeningtheGrid.org.

So, the first question that we had come in, and I think is very relevant is a question about cost. So how does meeting more stringent requirements for these DERs and for these more advanced grid codes, does it impact the overall cost? Or does it add incremental costs to the system?

Adarsh I would say the answer is yes. These grid codes do add some cost. However, the point here is the incremental benefit that we can get out of these devices certainly exceed the cost that gets added because of these new technologies.

So give an example, if there is a high penetration scenario in a particular region and if every inverter costs a little bit more because of these new technologies the benefit that the grid gets out of it from avoiding upgrades, or totally avoiding the need for voltage control equipment such as capacitor buying for voltage regulators certainly exceeds the extra costs that comes from this avoidance.

And these costs, because it's implemented at the worldwide national-scale level they're very minimal. So certainly, there is more benefit than to the cost. And when it comes to energy storage these grid codes might say that use a battery in a particular way but there is a lifetime associated with the battery. That's another scope that is still currently being evolved and being tried to understand. And there are things that have been done as well to manage that part. For example, if an inverter that's currently used for _____ reactive power support might die a little faster than not using it. In order to manage that there is some research going on as well. But this is summarized, what has been learned so far as the costs are certainly—the benefits are more than the cost that needs to be added, and also the life of the device is then significantly decreased because we are using these for new benefits out of this.

Katie Great. You talked quite a bit about DERs and a question has come in on efforts—if there are similar efforts at the transmission levels for wind and solar, or if these grid codes can be applied in the same way or are there major differences that people should be looking out for?

Adarsh That's a good question. As I brought up previously, P2800.1 is currently an ongoing work in progress. It's a little bit of a primary state at this point but that's one standard that's currently being worked upon to address the questions related to interconnection and transmission level.

The idea here is maybe 1547 provides some blanket requirement that all these DERs, all these inverters are technologies that get connected at transmission level can do, however that needs to be custom tailored, and that's the reason by 2800.1 is focused on being developed. It's at a hard level which is the primary level where people are still working on and maybe in the next few years there's going to be some draft document submitted out of it, just have to wait for it.

Katie Data privacy and cybersecurity is a very hot topic right now, as I'm sure you're aware of. And so how are cybersecurity and privacy considerations included in current grid codes? Are they included, or how might people address that?

Adarsh Yes, so that's one more effort going on. Cybersecurity requires—there's a very high-level requirement at the 1547—if you just scroll the document it's included; it's being addressed at a very high level. It's not the scope of 1547 to get into details of cybersecurity or its layers or the way it's handled. There is a separate standard that addresses that particular side of cybersecurity. So that's already been addressed to some extent in a different standard and also it is currently being evolved at this point of time.

Katie Islanding is certainly an issue that has come up in terms of providing additional resilience at facilities and the grid. Are there certain ways that islanding is being addressed in some of these grid codes? How are DERs being asked to respond in this situation?

Adarsh That's where the grid codes specific to fault right through kind of coming feature. If you go long back in time, as soon as there was a fault or a bad voltage or a bad frequency system needs to disconnect, which means it needs to go into islanding mode is to shut down, do nothing. There was sufficient requirement on that after that time it should shut down, how fast can it identify, what are the scenarios where the system might not be able to identify it because that might lead to personal issues. If there's a fire hazard the system will then shut down in time and you have a fireman who goes on the house. And if it's still working it's going to be a personal _____.

So, NEC and other organizations tried to come up with a lot of requirements on that. However, the most important thing now is if there is a bad frequency event, if there's a low frequency event which is already high load, load generation scenario and because of that all the local generation shuts down that will further exacerbate the whole scenario. And that's the reason why 1547 came up with three categories to identify how to behave or how not to behave.

[Inaudible] as I said Category 3 is how Hawaii and California have chosen when to island. The idea here is to be able to identify what should the device be doing when there is a fault. And if the device is still operating and there's a fault—could be a fire—in order to avoid that what NEC did is came up with a red button, which is if there is a solar panel on the house and if the person doesn't know whether the panel is operating or not what the fireman should do is go and press the red button, a single switch, outside the house, that disconnects the device, irrespective if it's right through, not a right through frequency event, voltage—or whatever it is. Personal safety takes the priority there.

So, as I said, 1547 says device should be operating above 12 seconds but we don't know whether what common scenario there. And that's where all other standards cover those questions, which have NECs and _____ come in and say, "Hey, that could be a problem. So that needs to be addressed in a particular way. So, what we show here is more like people's site books. There's a whole world outside other than that which needs to be understood to get the whole context.

Katie Another question. We talked a lot about DERs, rooftop solar, which is a pretty established technology but what about emerging technologies? You touched a little on this. Like the high meter battery storage is easy; how are those being incorporated into grid codes. What are you seeing as that evolves?

Adarsh Sure. Storage, there is another effort going in place that's going to be 1547.9 subcommittee that will address some of the questions related to storage. Let us go to the storage itself; we'll go back to the some of the questions someone already asked which is if I use the storage directly will the battery die in the next few days? It's a lot of sensitive area surrounding there. So there again, NREL is leading its way there. We are trying to come up with those considerations that needs to be thought through even before, or what are the things that need to be done to address or modify the current 1547 2.9. That's still under development and there are a lot of research projects currently going on with utilities in the USA that's trying to understand how a customer would typically use storage and why would they use it? Because all the usage of storage is driven by human behavior or tariff schemes as opposed to inverters for solars which is driven by voltage and frequency. So, there's a human component in voltage storage which makes the whole thing a little more interesting and also complicated.

The second technology that you spoke about which is electric breakers, which is certainly yet another topic. There is a lot of standard development, SAE that is currently going on—electric breakers is certainly coming a major thing which is currently also under development. So, as you can under 1547 gives blanket rules that are expected of it but there are all these subcommittees that break down to see what needs to be striked or what needs to be added to make some sense out of this or it almost needs to be inherited to make it applicable to new technologies.

Katie So we have all of these wonderful grid codes, trying to ensure the safety and reliability of the grid with new technologies coming online. How do we make sure people comply? So, is compliance an issue? And how in the U.S. is compliance ensured to these grid codes?

Adarsh So in the end what makes things compliant is in U.S. it's UL, Underwriters Lab. That says that every inverter should be part—should go through UL 1741 SA, which means all the _____ should behave a particular way. That's in U.S. In other nations there'll be their local standards, maybe ISO, maybe something else. All these—so there are—everything should happen in two levels, which is the local entity or the nation should come up with a requirement, for example what happened in California. The governor of California sent us a letter that says all IOUs for utilities should comply to a certain rule, that's Rule 21, in their territory. That says that—okay, so now it's a blanket rule that things should work a particular way, but there is no requirement that inverters operate a particular way. That's where the UL comes up and says, "Okay, hold on. So, before you make the inverter go on a particular roof or somewhere you will need to pass these set of tests, test conformance standards. And there's also a _____ for communication now. So, all these things when passed are checked, then that means you can say the blanket rule that, okay, all these devices operate a particular way; compliance is taken care of. It should operate in different levels to make sure all inverter vendors are aware of all these. And that's the reason why I spent a slide on this topic where a transfer in stakeholder process is a key to make sure everybody, all important stakeholders, are on the same boat. Otherwise it's going to be a gap between what needs to be done as opposed to what is going on because they might say [inaudible] or I don't even know. I'm doing a very different way or—it's—that leads to a lot of diverse scenarios that's very hard to manage.

Katie So it really sounds like it's all about the inverter.

Adarsh That's one thing. So that's where all the growth is happening. For example, if you go to a 1547 standard goal and to say that _____ that they say that this _____ code is applicable to all generators—could be diesel generator, could be something else. But however, when you look at the proportion of the growth happening there is a significant growth happening when it comes to inverter interface technologies as opposed to diesel generators. So, what are the odds that somebody might go and buy a diesel generator? But the whole idea is any generator or technology that has the ability to operate in parallel with the grid, not when there is a shut down or a microgrid scenarios, that's where the whole grid codes comes into picture. But inverters are the key interface that makes these technologies or any other resources, could be emerging technologies like storage or car, electric breakers, all these technologies applicable and controllable and usable.

So, there is a significant need for inverter manufacturers and vendors to work in tandem, state nations or entities.

Katie The last question for you is if I were living in a country where perhaps I didn't have a large penetration yet of the ERs or I was starting to see the scale-up of DERs rapidly what advice would you give me to start thinking about grid codes or the evolution of my grid codes? Where do I start? Where do I go?

Adarsh First thing I would say is this is my firsthand experience being in working with utilities in the first decade, which is don't wait for too long, not knowing—or it's very little we can leverage there, but don't wait for too long. Look at these technologies as assets, more than just somebody wants solar, just let them go with it. Be aware of all the development happening in their part of the world. There is a very particular need or purpose behind every sentence, every grid code in their part of the world.

The reason why everybody is working on a grid code is to handle a problem that they had in the past. Maybe if you're a nation or if the country—not right now I'm seeing some penetration, it's a good scenario for them to just learn from what's already being done and just make it a standard before anybody gets to a high definition scenario. So, don't wait too long, just jump on things, learn—there are numerous things that happen surrounding this to share the knowledge, make it a requirement even before it goes out of hand.

Katie Excellent, Adarsh. Thank you so much. And I do want to point folks, again, to GreeningtheGrid.org for more resources, and now I'm going to pass this over to Katie to finish up.

Great. Thank you again, and on behalf of the Clean Energy Solutions Center I'd like to extend a special thank you to our expert panelist and to our attendees for participating in today's webinar. We very much appreciate your time and hope in return there are some valuable insights that you can take back to your ministries, departments or other organizations. We also invite you to inform your colleagues and those in your networks about the Solutions Center resources and services including no-cost policy support through our Ask an Expert service. I invite you to check the Solutions Center website if you'd like to view the slides and listen to a recording of today's presentation, as well as previously-held webinars.

Additionally, you'll find information on upcoming webinars and other training events. We are also now posting the webinar recordings to the Solutions Center training page and YouTube channel. Please allow about a week for the audio recording to be posted. Finally, I'd kindly like to ask you to take a moment to complete a short survey _____ when we conclude the webinar. Please enjoy the rest of your day and we hope to see you again at future Clean Energy Solutions Center events. This concludes our webinar.