Dominion's VCEA Compliance Plan is Disastrously Unreliable

A Research Report
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Abstract

Dominion's proposed Plan for VCEA compliance will likely lead to disastrous blackouts and price spikes. The Plan contains only a tiny fraction of the energy storage required for reliability. VCEA requires ever-increasing amounts of intermittent wind and solar power, accompanied by the progressive retirement of all existing fossil-fueled generating capacity. Reliability can only be maintained by adding massive amounts of battery storage along the way. Dominion's proposed Plan adds almost no storage. Reliability problems are likely as early as winter 2023-24.

We need an Integrated Resource Plan from Dominion that is both reliable and VCEA compliant, whatever the cost. As of now Virginia has no reliable Plan for VCEA compliance.

Executive Summary

Reliability means designing for the likely worst case. With conventional generation this means supplying peak need, also called peak demand. When counting on solar or wind there is also the critical issue of minimum supply backed up by storage. The basic reliability analysis reported here looks at minimum supply with battery storage under VCEA, in two separate steps.

Step one is a simple reliability analysis for solar power. In this first step the storage requirements for reliable solar energy around the clock are derived for the period of five days of dark cloudy weather. That Virginia will see five dark days from time to time is certain. (See Section 2: A simple reliability analysis for solar power.)

The second step applies the step one results to Dominion's compliance plan for VCEA. This plan is called Plan C in Dominion's recent Integrated Resource Plan. The primary focus is on Plan C through 2036, because Dominion gives year by year generation startups and retirements for this period. (See Section 1: Dominion's VCEA Plan makes the Virginia grid dangerously unreliable.)

The primary step one finding is that to reliably produce just 1,000 MW of solar power, around the clock for five dark days, requires at least 6,000 MW of solar generating capacity and at least 120,000 MWh of storage capacity. Based on EIA's standard cost estimates this works out to around $60 billion per 1,000 MW of reliable solar power. A more refined analysis will find much larger numbers, some of which are discussed.

In step two we find that Plan C includes just a tiny fraction, less than 6%, of the storage capacity required to make their solar generation reliable. Thus, the proposed solar generation is completely unreliable. Moreover, our estimated cost for reliable storage is around $65 billion, just through 2036. This is more than Dominion's cost estimate for the entire Plan C. Adequate storage for all of VCEA could cost hundreds of billions of dollars.

It is important to keep in mind that wind generation cannot be relied upon to help when it comes to minimum solar power supply events. This is because there may be no wind generation during an extended dark cloudy period. In fact, wind power has its own storage needs, which are on top of the solar power case analyzed here.

Dominion says they are doing a lot of reliability analysis. Clearly that analysis has yet to find its way into their Integrated Resource Plans. The present Plan is disastrously unreliable.

The IRP does specifically say that importing electricity from other power producers is not a viable way to make intermittent solar power reliable. The reason is that the other utilities will also need energy due to their growing reliance on solar. The IRP gives the example of "extended cloudy winter periods," so Dominion appears to be well aware of this crucial design issue.

Clearly what is needed at this point is an Integrated Resource Plan by Dominion that properly considers the storage required to make the VCEA's solar and wind mandates reliable. The numbers will be very large.

As of now Virginia has no reliable Plan for VCEA compliance.

Section 1: Dominion's VCEA Plan makes the Virginia grid dangerously unreliable

The oddly named Virginia Clean Economy Act (VCEA) mandates the phaseout of fossil-fueled power generation by 2045, with deadlines all along the way. Dominion Energy, Virginia's primary electric utility, recently filed what is called an Integrated Resource Plan (IRP). In their recent IRP, Dominion's Alternative Plan C is designed to comply with the VCEA.

This design is not sufficient to maintain reliability. The inevitable result will be price spikes and blackouts.

Where is the storage?

The basic problem with the Plan C design is that there is not nearly enough storage to adequately backup the intermittency of the planned solar and wind generating capacity.

Under VCEA the Virginia grid is mandated to transition to all solar and wind power. This entails that power from these intermittent sources being reliably available around the clock, day after day. During much of this time the solar and wind generators will be producing very little power, so a great deal of storage is required. In today's world this means batteries -- lots of them.

The Dominion IRP actually points to this problem. Dominion argues that they cannot backup their solar and wind generators using imported power, because other utilities will be facing the same backup need. Here is a telling quote. In particular, note the reference to solar generation and extended cloudy winter periods.

There is a good bit of jargon but that can be ignored for our purposes. The SCC is Virginia's State Corporation Commission, which oversees Dominion's electric power monopoly. PJM is the Mid Atlantic power coordinator. The DOM Zone is basically Dominion's territory.

> ***"The SCC directed the Company to consider market purchases during the winter from the PJM wholesale market or from merchant generators located in the DOM Zone. The Company is concerned that over-reliance on the market for purchases could present issues if other states within PJM build significant amounts of solar generation and those zones expect the market to provide energy at the same time the Company is expecting that energy (e.g., extended cloudy winter periods). If that were to become reality, either energy shortages or extreme price spikes would occur. Concerning purchases from merchant generators located within the DOM Zone, those generators would likely be needed to meet the non-DOM LSE load within the DOM Zone, which is also winter peaking." (Emphasis added)***
>
> ***- Dominion***

The point is that without enough storage, extended cloudy winter periods can cause energy shortages (including protracted blackouts) and extreme price spikes. As we shall show, Dominion's Plan C does not provide nearly enough storage to prevent such catastrophic results.

A simple reliability analysis

Here we use the results of a simple, but somewhat technical, generic reliability assessment. That generic reliability analysis is explained in Section 2 of this report.

The focus of Dominion's VCEA IRP is the period 2021-2036. During that time they plan to build about 14,000

MW of new solar generating capacity. They will also retire around 3,000 MW of CO_2 emitting generation, including power plants that burn coal, oil and biomass.

The solar build sounds like a lot, more than enough to cover the retirements, but it is not. According to our generic analysis, it takes at least 6,000 MW of solar capacity to reliably produce just 1,000 MW of electricity.

The reason you need so much solar capacity is pretty simple:

First it takes 1,000 MW of capacity to generate 1,000 MW during the eight-hour solar production period on a sunny day.

Second it takes 2,000 MW or more of capacity to generate, during that same period, the electricity needed to charge the batteries that will then produce 1,000 MW all night long.

Third, we need to recharge a lot of other batteries that get us through five dark cloudy days. This takes another 3,000 MW, assuming we also have five sunny days to do it in. In reality we may need a lot more than this, depending on the actual meteorology of Virginia. See the generic explanation for some discussion on this issue.

> Working with our 6,000 MW number it turns out that the 14,000 MW of solar generating capacity only provides about 2,300 MW of continuous power. This does not cover the 3,000 MW of retired capacity.

However, that is not the big problem, because Plan C also calls for building 1,600 MW of nuclear generating capacity. Given the projected growth of the need for Dominion power, this combination of solar and nuclear generation just about covers that need.

On the other hand, the retirements occur years before the proposed nuclear plants come online in 2032 and 33. The retirements begin sometime in 2023 and end in 2028. Thus reliability problems may occur as early as winter 2023-24 and become increasingly likely until 2033. Also it can take ten years to procure, build, and commission a nuclear power plant and there is no sign of that with Dominion.

Two tangential points need to be made here. First, the projected growth does not include the massive switch to electric cars and trucks that is also supposed to happen during this period. Second, Plan C also includes over 5,000 MW of wind capacity, but this is irrelevant to our case, because the wind need not blow hard during the five cloudy days for which we are building. Power systems must handle relatively extreme events. That is what reliability means.

There is almost no storage in Dominion's Plan

Now we come to the really big problem, the one that makes Plan C a total failure in reliability. Our generic analysis says that, in order for the 6,000 MW solar capacity to reliably produce 1,000 MW of electricity, it needs at least 120,000 MWh of batteries. (It may need 200,000 but we ignore that for now.)

Given the need for 120,000 MWh of batteries for each 1,000 MW, Plan C's 2,300 MW requires an enormous 276,000 MWh of batteries.

Plan C appears to only provide a minuscule 16,000 MWh or so. In fact the IRP never says what the storage capacity of the added batteries is. It just gives their discharge rate, at about 4,000 MW. But the standard grid scale battery provides 4 MWh for every MW, which gives us 16,000 MWh.

The required storage is extremely expensive

So we are short an enormous 260,000 MWh, as far as reliability goes. In the generic analysis we use the EIA standard battery cost estimate of $250 per MWh. Multiplying this by 260,000 gives an added cost of $65 billion.

The huge added cost of these batteries, just to make solar work through 2036, is more than Dominion's estimate for the entire cost of Plan C, which is around $50 billion. The 2036 solar battery requirement more than doubles the cost of Plan C.

Note that this does not include the storage needed to make the wind power component of Plan C reliable. This too will be a very big number.

But it gets worse, much worse in fact. Between 2037 and 2045, Plan C retires all the rest of Dominion's fossil-fueled generation. The IRP does not give the amount but it is a lot more than the roughly 3,000 MW retired by 2036, perhaps three times more. Making this much solar and wind power reliable could add another $200 billion or so to the cost of Plan C, for a total add-on of something like $265 billion.

Plus, as discussed above, there are several reasons why this huge cost could in fact be much greater. These factors include things like electrification of transportation and gas heat, the need for a reserve capacity, the fact that batteries cannot be used to 100% of their capacity, etc.

Dominion's Plan is potentially disastrous

It is obvious from this analysis that Plan C is completely unreliable. The amount of battery storage in Plan C is almost nothing when compared to that needed for reliability under VCEA.

This extreme unreliability could begin to show up as soon as winter 2024-25, when the first big capacity retirements take effect.

Dominion needs to go back to the drawing board and present a Plan that maintains reliability in the face of VCEA's drastic requirements. Only then will we know what VCEA really costs. That cost will be astronomical.

A careful read of Dominion's recent 2021 Integrated Resources Plan indicates that they are well aware of the potentially disastrous reliability issues we analyze here and have been for some time. For example they say this:

"As discussed in Chapter 5.6 of the 2020 Plan, when the Company adds increasing amounts of solar resources to the system, this will result in intra-day, intra-month, and seasonal challenges posed by the interplay of solar generation and load. These challenges could expand as neighboring states increase the amount of renewable energy generation on their systems, potentially leading to higher peak prices and a reduction in the level of imports available, similar to what happened during the Texas power crisis of February 2021." (Emphasis added)

They also say this:

"In the 2020 Plan, the Company provided an initial overview of the reliability analyses that it would need to perform to investigate the probable system reliability issues resulting from the addition of significant renewable

energy resources and the retirement of synchronous generator facilities."

We need a reliable VCEA Plan

Dominion says they are doing a lot of reliability analysis. See the end of this report for more details from Dominion. Clearly that analysis has yet to find its way into their Integrated Resource Plans. The present Plan is disastrously unreliable.

What is needed at this point is an Integrated Resource Plan by Dominion that properly considers the storage required to make the VCEA's solar and wind mandates reliable. The numbers will be very large.

In lieu of a comprehensive reliability analysis, we below present a simplified version that was used above to determine the magnitude of the challenge of making VCEA reliable.

Section 2: A simple reliability analysis for solar power

Finding: Reliability makes depending on solar power impossibly expensive

Given the high intermittency of wind and solar, the idea of running on solar and wind turns out to be an extremely costly prospect. It is all about reliability. Electricity must be there when we need it. Below we present some simple calculations that show just how bad this idea really is.

Reliability analysis of large scale solar and wind power generation can be very complex. Both depend on the weather, which can vary dramatically and quickly. Both can depend heavily on other available power sources, if available. They can also depend on each other under some conditions.

Here we will simply analyze certain basic features of power generation, as a way to scale the issues. For a start we will simply consider what a standalone 1,000 MW solar system with battery storage requires for reliability.

The 1,000 MW is power reliably delivered to the grid around the clock. Because of intermittency, considerably more than 1,000 MW of generating capacity will be required. A lot of battery storage will also be required. Thus the capital cost will be a lot more than simply the cost of 1,000 MW of generating capacity. We will discuss these additional costs. Note that adding wind power does not reduce these very large costs.

Given this simple 1,000 MW analysis it will be relatively easy to then consider other possible systems of different size and with different features.

Reliability requirements for 1,000 MW of round the clock solar generation

Solar is relatively simple because of the predictable daily cycle of night and day. Generating times do differ depending on the time of year. They also vary depending on how moveable the panels are -- that is, to what degree they can track the sun's daily movement across the sky.

The full sun case

For simplicity let us first assume eight hours of full sun and full power every day. Clearly we need 16 hours of storage every night. That is 16,000 MWh of battery storage. We also need another 2,000 MW of generating capacity to charge the batteries every day.

So the full sun requirements are 3,000 MW of solar generating capacity and 16,000 MWh of storage capacity, in order to reliably generate 1,000 MW around the clock.

The five dark cloudy days case

Solar generating capacity can be drastically reduced on dark cloudy days. When very cloudy the output can be reduced to just 10% of nameplate capacity. Dark cloudiness can last for days, thus requiring more battery backup along with the generating capacity to charge these dark days batteries.

How many successive days of dark cloudiness to design for is a complex question of local and regional meteorology. Here we simply use five days, but it easily could be more. Five dark days certainly happens from time to time in most states. In Virginia's case it can happen over the whole Mid-Atlantic region, so no one has significant solar power. This rules out buying solar power from the neighbors.

Reliability requires designing for these relatively extreme events. With conventional generation you design for maximum need for power, but with wind and solar you also have to design for minimum supply. That minimum case is what I am looking at here.

The required battery capacity is simple. Five days at 24 hours a day is 120 hours. To supply a steady 1,000 MW that is a whopping 120,000 MWh of storage.

However, the required additional generating capacity to charge these dark days batteries is far from simple. It all depends on how long we have to do the charging. The more time we have the smaller the required generating capacity.

It is vital to get the dark days batteries charged before the next dark days arrive, which in some cases might be very soon. This too is a matter of meteorology. To be conservative we here first assume that we have two bright sunny days to do the job.

Two days gives us 16 hours of charging time for the needed 120,000 MWh, which requires a large 7,500 MW of generating capacity. We already have 3,000 MW of generating capacity, but that is in use providing round-the-clock sunny day power. It is not available to help recharge the dark days batteries. Turns out we need a whopping 10,500 MW of solar generating capacity.

This 10,500 MW is a lot considering we only want to reliably generate 1,000 MW around the clock. Moreover, some of this additional generating capacity will seldom be used. But reliability is like that due to the great variability of weather. In conventional fossil-fueled generation the extreme event that drives design is peak need (also called peak demand). Special generators called "peakers" are used for this case. In the solar case the special equipment is batteries or other forms of storage.

Note that if we have five days to recharge the dark days batteries then the amount of required generation is a lot less. Five days gives us 40 hours to charge the 120,000 MWh, so one only needs 3,000 MW of additional

At this point we need 120,000 MWh of battery storage and from 6,000 to 10,500 MW of generating capacity, in order to reliably supply 1,000 MW of round-the-clock power.

generating capacity, added to the 3,000 MW we need to produce daily power on sunny days.
These large numbers occur because following a period of dark cloudy days we are doing three things simultaneously during the daylight generating hours. We are (1) generating 1,000 MW of immediately used electricity, while both (2) recharging nighttime batteries and (3) recharging the dark days batteries.

Note too that the numbers should actually be bigger. Batteries are not charged 100% and then drained to zero. The standard practice is to operate between 80% and 20%. In that case the available storage is just 60% of the nameplate capacity. This turns the dark days 120,000 MWh need into a requirement for 200,000 MWh.

The cost of the dark days case

A standard figure from EIA for the cost of grid scale battery arrays is $250 per kWh, which gives $250,000 per MWh. At this cost the required 200,000 MWh of storage for around the clock 1,000 MW is $50 billion.

A standard EIA figure for PV solar capacity is $1300 per kW or $1,300,000 per MW. This makes the 6,000 to 10,500 MW cost $7.8 to 13.7 billion.

> This makes $60 billion for just 1,000 MW a good rough estimate for standalone solar capacity to meet the five dark cloudy days case.

(As explained below, adding wind power does not reduce this number because the five dark days may also see zero wind output.)

The partly cloudy case

The partly cloudy days case is far more complex. Much of the time this loss of solar generation might be handled with the dark days batteries. But this may not be the case if the dark days event is either preceded or followed by partly cloudy days, especially if these are relatively dark. Note that partly cloudy here includes complete cloudiness where the cloud cover is light enough to still enable significantly more than the 10% generation under the dark days case.

Given these complexities the partly cloudy case is beyond the scope of this simple analysis. It is very likely that this case will require additional battery storage and generating capacity. How much is hard to say.

Note too that several costly features are not included. One example is transmission to get solar power from point of origin to load centers, which may be distant. Another is a reserve generating capacity or margin of safety, which might be as high as 20%. One cannot assume everything will work perfectly when the system is stressed. This is especially true if the dark days include widespread heavy snowfall, which can greatly delay recharging.

Wind generation cannot back up solar

Wind generation does not share the predictable daily cycle that solar enjoys so it is more complex from the beginning. With solar we can count on relatively good ongoing generation on most days. Wind power can drop to nothing frequently during a day, as well as delivering nothing for several days in a row and very little for long periods of time in many locations.

It is not a matter of no wind, just low wind. Wind generators require sustained winds of considerable velocity in order to begin to generate substantial amounts of power. In many parts of the country stagnant, multi-day high pressure systems cause both low wind and a heavy need for electricity.

It is very important to note that because of this great variability wind power cannot be used to reduce the massive requirements of the dark days solar case. This is because it is always possible that there will be no wind power during the dark days, as well as during the recharge time after this extreme event. A standalone solar and wind system has to be designed to handle this extreme, but common, possibility.

Solar and wind power cannot replace coal and gas at a reasonable cost. Intermittency makes solar and wind power impossibly expensive. This is likely true in all states and certainly in Virginia.

Section 3: Dominion's discussion of their reliability analysis in the 2021 IRP

Here is what Dominion says in their 2021 Integrated Resource Plan. Note that "Transmission System" here means the entire electric power system, from generation through transmission to final delivery to end users.

Transmission System Reliability Analysis

In the 2020 Plan, the Company provided an initial overview of the reliability analyses that it would need to perform to investigate the probable system reliability issues resulting from the addition of significant renewable energy resources and the retirement of synchronous generator facilities. This included commitments to:

Analyze impacts associated with the loss of traditional synchronous generators as well as the impacts of inverter-based generation at varying levels above and below their capacity factors. These impacts include the changes in system characteristics, such as inertia and frequency control, short-circuit system strength, power quality, reactive resources and voltage control, and system restoration and black start capabilities.

Research the capabilities of inverter-based resources to provide needed system characteristics.

Study the probability and impact of concurrent periods of generation excesses and deficits between the DOM Zone in PJM and neighboring regions.

These newer reliability concerns and issues are actively under study and development by the Company, and include the traditional reliability concerns that are also essential to continue to study. These include North American Electric Reliability Corporation ("NERC") Reliability Standard criteria and violations, PJM reliability criteria, existing Company criteria, thermal loading issues, voltage issues, and more. In addition to investigating these newer and traditional reliability issues, the Company is also investigating solutions, which include existing and new technologies, that may be needed to address these reliability issues in the future.

Existing technologies include — transmission substations, transmission lines, synchronous generators, transformers, capacitor banks, reactor banks, static var compensators, and static synchronous compensators. Some of the new technologies the Company is investigating include: advanced grid monitoring and control capabilities; energy storage technologies; flexible alternative current transmission system ("FACTS") devices, such as high-voltage direct current ("HVDC"), and synchronous condensers; grid-forming inverters; high-capacity transmission substation and line technology; and advanced software and computational hardware for modeling, simulations, and analytics.

Over the past year, the Company has continued to work on these long-term modeling and analysis efforts in order to ensure the future reliability and resiliency of the grid. For example, the Company has been developing new system models for future years, studying areas of the system with large load increases expected, evaluating new renewable energy generation interconnection projects, and developing new methodologies and tools to study the new reliability issues and concerns. The Company has also been testing new simulation software platforms and researching new grid technologies and solutions, including grid forming inverters, energy storage technology, and synchronous condensers.

Conclusion

Dominion is clearly well aware of the reliability issues with solar and wind power. They have been analyzing these issues since at least early 2020, but there is no hint of this in the 2021 VCEA compliant Plan C.

We need an Integrated Resource Plan from Dominion that is both reliable and VCEA compliant, whatever the cost. As of now Virginia has no reliable Plan for VCEA compliance.