Sea Green

Bringing Offshore Wind Online

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Introduction

One of the challenges of switching to a renewable energy source from fossil fuels is controlling the variability of power generation. This is especially true when the plant is originally being brought online. Unlike fossil fuels, renewable sources like wind and solar do not generate power at a consistent rate for the entire lifetime of a power plant. For example, solar panels cannot generate power at night, but they generate enormous amounts of power on sunny summer days. Because of this, renewable energy power plants require more technology simply to prevent damage to the entire power grid and to ensure that everyone has enough power in their homes to keep the lights on. The same technology is also used to protect the power plants from damage from changes in the power grid caused by outages or downed lines. Although you won't likely see your neighbor considering this type of equipment when they're installing solar panels on their roof, it becomes much more important when you're powering thousands or millions of homes.

Just as you wouldn't install the hoover dam across a creek in your backyard or expect a beaver dam to stop the Mississippi river, the equipment you use to control the power flow from an offshore wind farm must be matched to the size of the farm that it is controlling. However, what size dam would you use if the river you wanted to block varied from a trickle to the size of the Mississippi? This is the type of problem designers face when trying to connect a renewable energy source to the power grid. For offshore wind, the amount of power generated during a hurricane will be much greater than that on a day with a slight breeze. Designers must fit equipment to each wind energy farm to be able to handle not just the highest amount of power the turbines can generate, but also to account for the times where the power generation is much lower. This includes the time where the wind farm is coming online for the first time, which has the largest likelihood of a sudden jump in power generation. In this scenario, the power would be jumping from zero to a value close to the maximum possible amount. The rest of this paper will be dedicated to describing why this moment is dangerous for the grid if proper precautions are not taken and to describing the precautions that must be taken to protect offshore wind farms from damage from power returning from the rest of the grid.

Risks

To the Grid

The highest risk moment in using offshore wind energy is actually the moment that the farm is brought online. Returning to the analogy of a dam, imagine that you built a dam for a creek, but a flash flood comes. Suddenly, there is a lot more water than you were planning for, and the dam breaks. In the case of the power grid, this is what could happen if engineers do not carefully monitor everything while connecting a new generator to the grid.

To the Wind Energy Farm

Once the wind farm has been successfully brought online, its operation is largely risk free to the rest of the power grid. However, if a line onshore gets damaged, is removed for repairs, or another problem arises that causes power to be rerouted from its normal path, this can cause power to actually travel the opposite way down the line connecting the wind farm to the grid. Instead of sending power to the grid, the wind farm would be getting a large amount of power all at once from onshore. This could cause catastrophic damage to many components of the wind farm, which could ultimately lead to it shutting down early. This risk must be addressed using equipment that can monitor the amount of power flowing through the line connecting the farm to the grid, as humans wouldn't be able to react in time to prevent damage.

Mitigating Risks – the STATCOM

What It Is

Fortunately, both these risks are addressed using the same piece of equipment called a static synchronous compensator, or STATCOM. Figure 1 shows a simplified diagram of how the STATCOM connects to the circuitry of the wind farm. The STATCOM is not in the direct path of power between the farm and the grid, which means it will not interfere with day to day operations. Instead, it can be used to mitigate the damage done in the scenarios outlined in the previous section. Figure 1 outlines where the STATCOM connects to the rest of the circuitry of the wind farm.

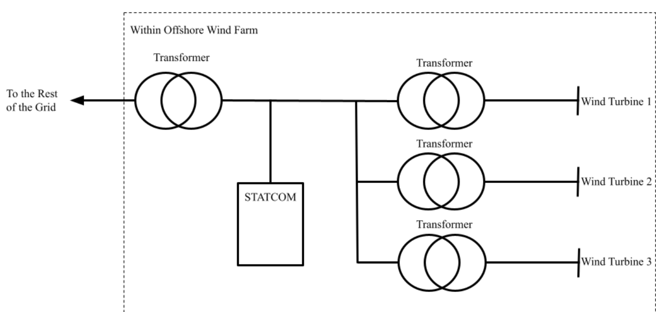

Figure 1. A model showing how the STATCOM device is connected to the circuitry of the offshore wind farm. Transformers are represented by two overlapping circles to emphasize the change in cable typing.

How It Works

The STATCOM is used to prevent the amount of power going to the grid to jump up from zero to maximum. Instead, the power slowly ramps up, allowing for engineers and other workers to adjust the system overtime to avoid strain. A large jump in power can cause power lines to explode, which can not only lead to widespread power outages, but can lead to fires if there is a tree or other flammable material nearby or even severe injury or death if a person is too close when this occurs. Likewise, if a large amount of power were to hit the wind farm's systems all at once, it could cause just as much damage there.

Although very important, this equipment is not without its downsides. STATCOM can only work on an AC line as it uses electric fields to allow for the slow "ramping up" of released power. DC lines generate no electric fields. This means that the power generated by the wind turbines, which are already DC power sources, must be turned into AC, fed into the STATCOM system, and then transformed back into DC power before being sent onshore to be used by the public. This is done using a series of transformers, which are each shown as two overlapping circles in Figure 1. Each time the power is switched from AC to DC or from DC to AC, there is some unavoidable power loss. However, this loss is accepted as necessary due to the importance of including the STATCOM device.

Conclusion

Without the proper equipment, it would be almost impossible for a new power plant, especially one as variable in power output as an offshore wind farm, to be connected to the grid without causing damage elsewhere in the system. However, the use of a STATCOM device does not only allow for this to occur safely, it also protects the wind farm from being overloaded by power returned from the electric grid. This important function is why engineers and designers have included this device in constructed offshore wind farms in other countries, and why it is very likely to be a part of any offshore wind farm in the United States. Although there are no large offshore wind farms in the United States at the time of writing, multiple companies have purchased plots and have plans to construct largescale farms off American coasts in the near future. Other countries, like Denmark, have set the example that this is a technology that can be incorporated on a large scale, and with the technology outlined above, American engineers and designers can safely follow in others' footsteps.

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