# How Not To Short-Circuit the Clean Energy Transition (Text Version)

This is the text version of the video How Not To Short-Circuit the Clean Energy Transition.

This video outlines the options NREL is investigating to ensure the energy grid is protected if there’s a fault, such as a short circuit. Examples provided show how fault protection can be maintained with higher levels of renewable energy sources.

[Insert video: <https://youtu.be/cSk5EH5bN-U>]

[Narrator speaks]

At NREL, we have learned a lot about how to integrate large amounts of wind and solar onto the grid. But our work isn't done yet. There are a few outstanding challenges, mostly around the fact that wind and solar use inverters instead of the synchronous generators you see in conventional power plants.

One of these challenges is the potential decline in power system inertia, which has led grid operators to develop new approaches to maintain stable frequency. Check out [our other video on that topic](https://youtu.be/b9JN7kj1tso).

[Video title "Understanding Inertia Without the Spin"]

Our next challenge is a bit more, well, challenging, and it's about making sure the grid is protected if there is a fault, which means abnormally high or low current. The most typical type of fault is a short circuit. On the power grid, short circuits can occur, for example, when two wires touch, or when a tree touches a wire. This causes the generators to produce a big surge of electrical current. This is called fault current, and it can be bad because it can lead to fires and damage equipment if not corrected.

But we can also use fault current to our advantage. It's relatively easy for circuit breakers in the grid, which are basically giant versions of the circuit breakers you see in your house, to detect these abnormally high levels of current and disconnect the part of the system with the fault. They can respond really fast, which prevents damage to the grid.

We have come to rely on detection and response to fault current as an important way to protect against short circuits. In today's power system, fault current is mostly produced by synchronous generators in fossil nuclear and hydroelectric plants, which inherently have the ability to produce large amounts of current.

But what happens if we replace those synchronous generators with inverter-based resources like solar PV and wind?

[Animation of solar panel and wind turbine power lines connecting to an inverter, which connects to grid]

Today's inverter technology typically isn't designed to produce large amounts of fault current, so in a grid dominated by inverter-based resources, we may need to find new ways to provide fault protection. But don't worry. We have some ideas about how to do this.

If we keep the grid running the way it is now, with grid protection schemes that are based on fault current, we have a couple of options. One is to design inverters that can provide fault current. We can do this by oversizing certain components in the inverter.

Another is to continue to rely on synchronous machines that automatically inject fault current ... just not the fossil-fueled ones. This could mean adding more renewable resources that use synchronous generators, including hydro, geothermal, concentrating solar power, and biofueled power plants.

But these renewable resources may not exist in all the locations where we need fault protection. In these cases, we could add synchronous condensers. These are electrical generators that are modified to spin using grid power instead of hooked up to a turbine. If a fault occurs, they will rapidly inject current into the grid using the stored rotational energy, just like in a normal generator.

Synchronous condensers can be repurposed from existing generators that are retiring. New or existing generators can also be modified with clutches so they can run even when the power plant isn't needed for power. This means rarely used peaking plants can provide value to the grid even when they're not providing energy. They also add inertia, which helps address that other challenge with inverter-based resources.

[Video title "Understanding Inertia Without the Spin"]

And it's proven technology that is already making the grid stronger in locations throughout the U.S.

[Animation of U.S. map with synchronous condenser icons popping up over southern California, west Texas, and the Northeast]

So we know there are multiple options to maintain grid protection schemes that rely on fault current even with high levels of inverter-based renewables. And, there's a totally different approach that involves designing an entirely new way to protect the grid from short circuits.

Engineers are working to develop new technologies for electronic-based protection schemes that don't rely on large fault current.

One idea is to add sensors that will take careful measurements of the flow of electricity at many points on the grid and compare those measurements to what they should be under normal conditions.

[Animation of sensors popping up along power lines connecting solar panels, wind turbines, inverters, transmission towers, homes, and energy production and management buildings]

Deviations could indicate a fault, and then signals could be sent to disconnect the part of the grid with the fault. But this option could be complex, and we don't understand the costs, particularly compared to proven solutions that use more traditional methods.

All this to say, while we know we can maintain system protection on the grid, we don't yet know what the most cost-effective approach is going to be in the future. So at NREL, our work continues, solving one challenge at a time on the road to a cleaner, more affordable, and more resilient grid.

[Narration ends, music stops]