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ESIG

Grid Forming Inverters, What's the Buzz?

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All conventional inverters require short circuit capacity to operate

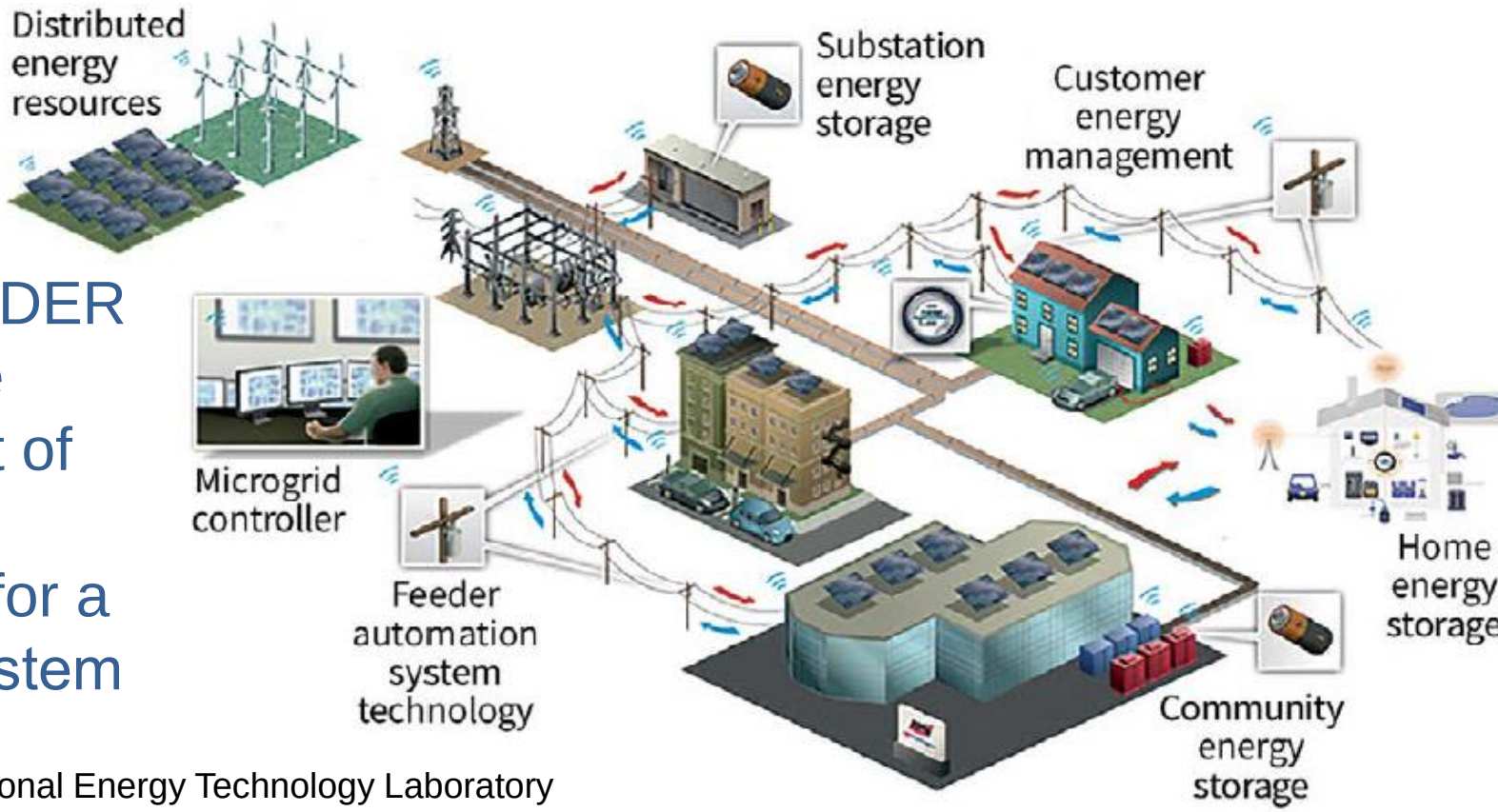
Source: Tesla

Common converters on wind plants, PV solar, STATCOMs, HVDC etc., do not contribute system inertia or short circuit strength to the grid

Courtesy of Connecticut Municipal Electric Energy Cooperative.

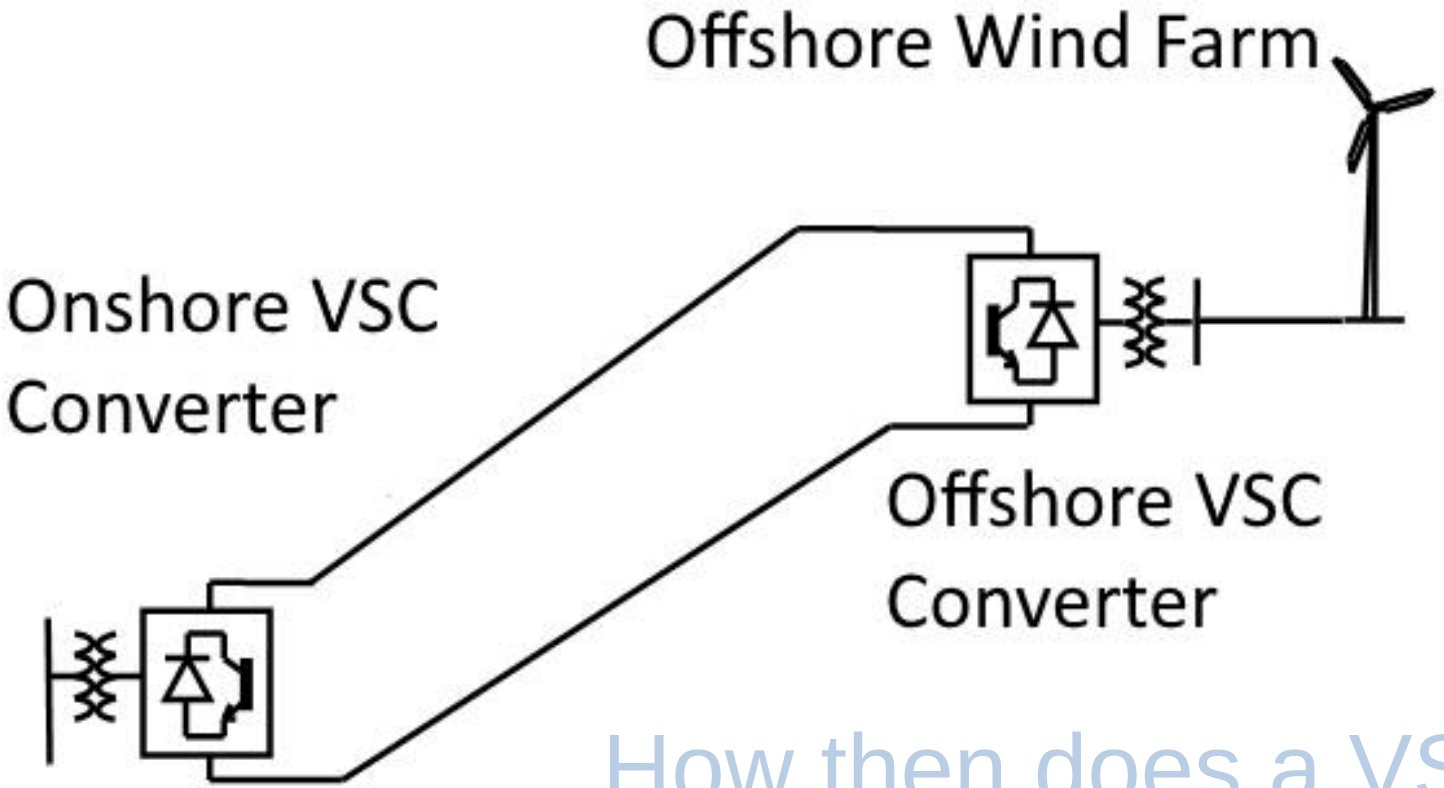
As synchronous generators are displaced with just grid following inverters, the grid is destabilized – the heart of weak system issues

A possible DER with a wide assortment of energy resources for a “robust” system



Courtesy of US National Energy Technology Laboratory

What are the solutions for increasing amounts of wind/solar/converter based generation are added to the grid?



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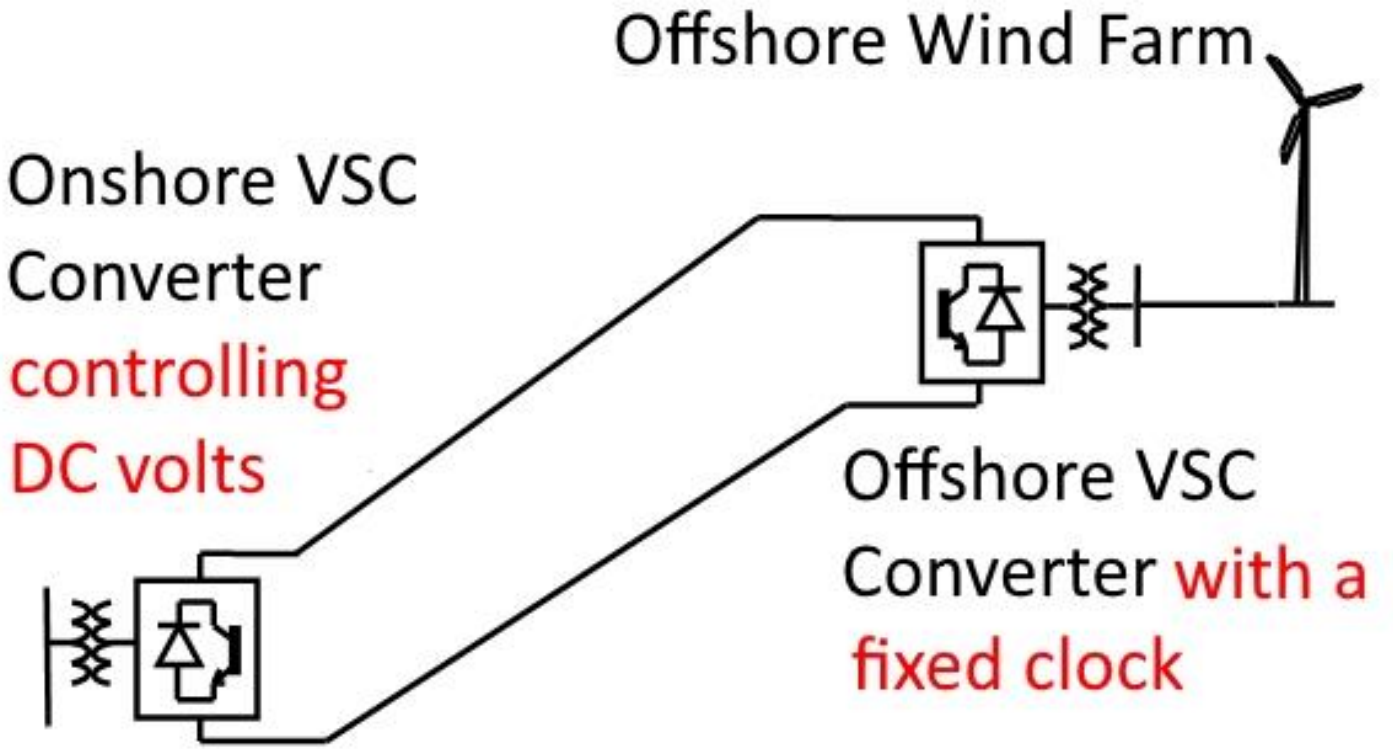
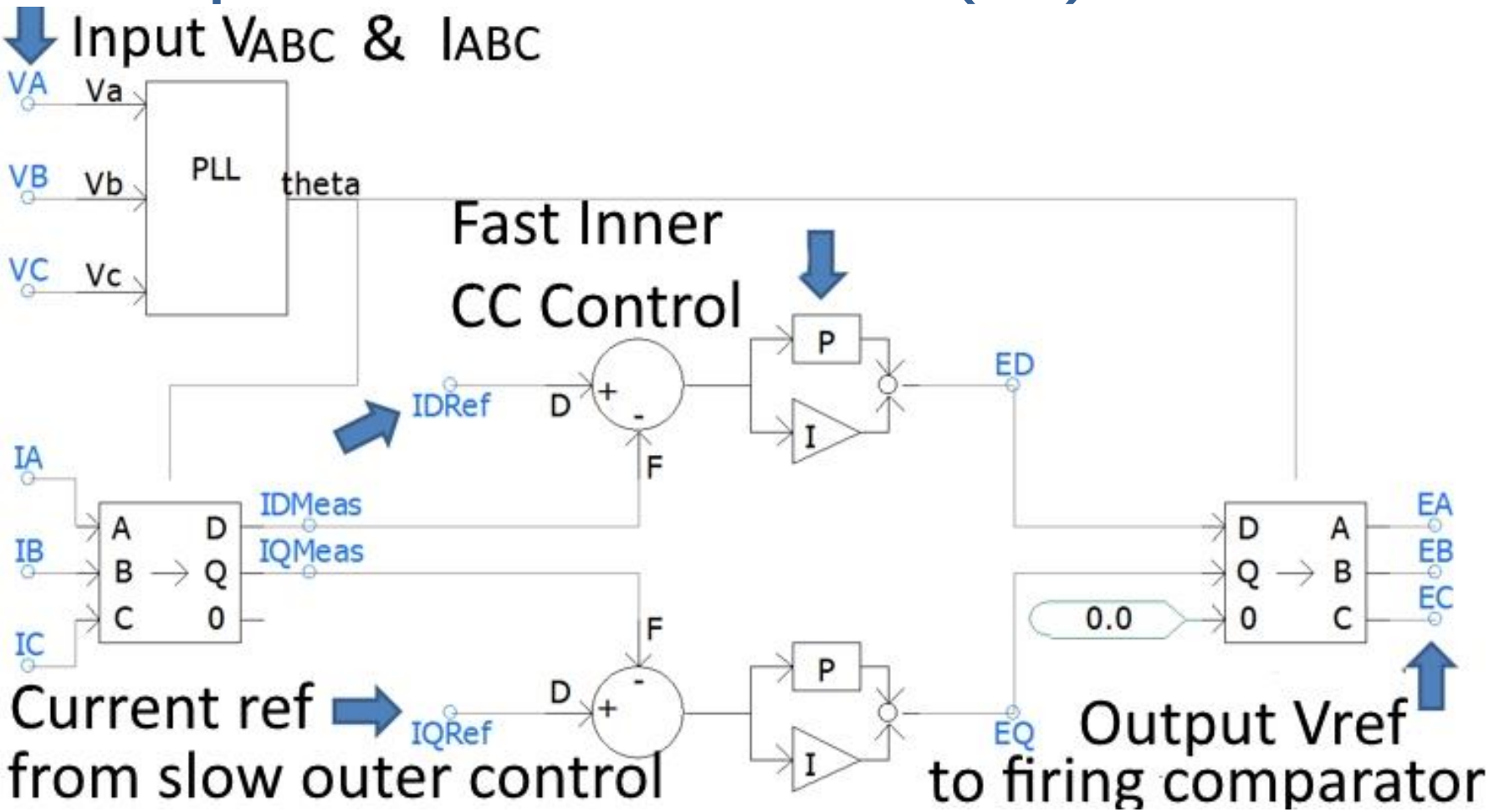
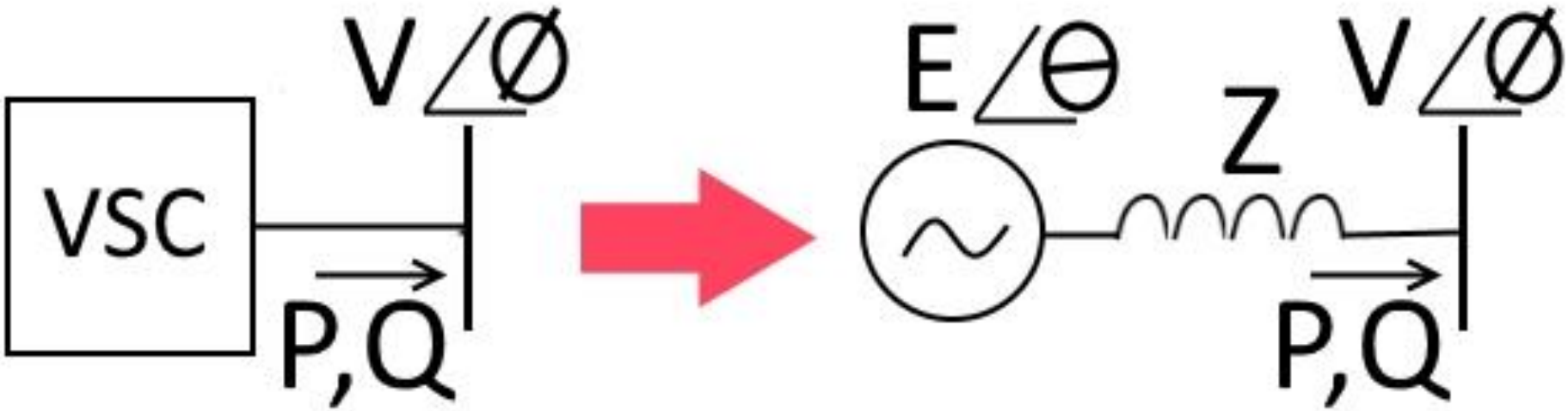


How then does a VSC offshore converter and wind farm operate?

The conventional VSC converter operates with a fast responding inner loop constant current (cc) control



What is a fast VSC voltage source instead of the fast current source of regular VSC converters?



Can a VSC converter respond like a synchronous generator with an E behind Z? i.e.. Grid Forming

Today's power systems without Grid Forming are facing or will face weak system or short circuit ratio (SCR)

Desert Sky Wind Farm, NW Texas

There is a limit on how many inverters with CC inner control loops that can be accommodated in a power system due to “weak grid issues”.

These are:

- Oscillations and instabilities
- Prolonged over-voltages of voltage collapse during fault recovery
- Protection operations
- Failure to ride through disturbances

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How will California with SB 100 and New Mexico with SB 489 plus other states and provinces deal with the massive displacement of synchronous generation with inverter-base resources”?

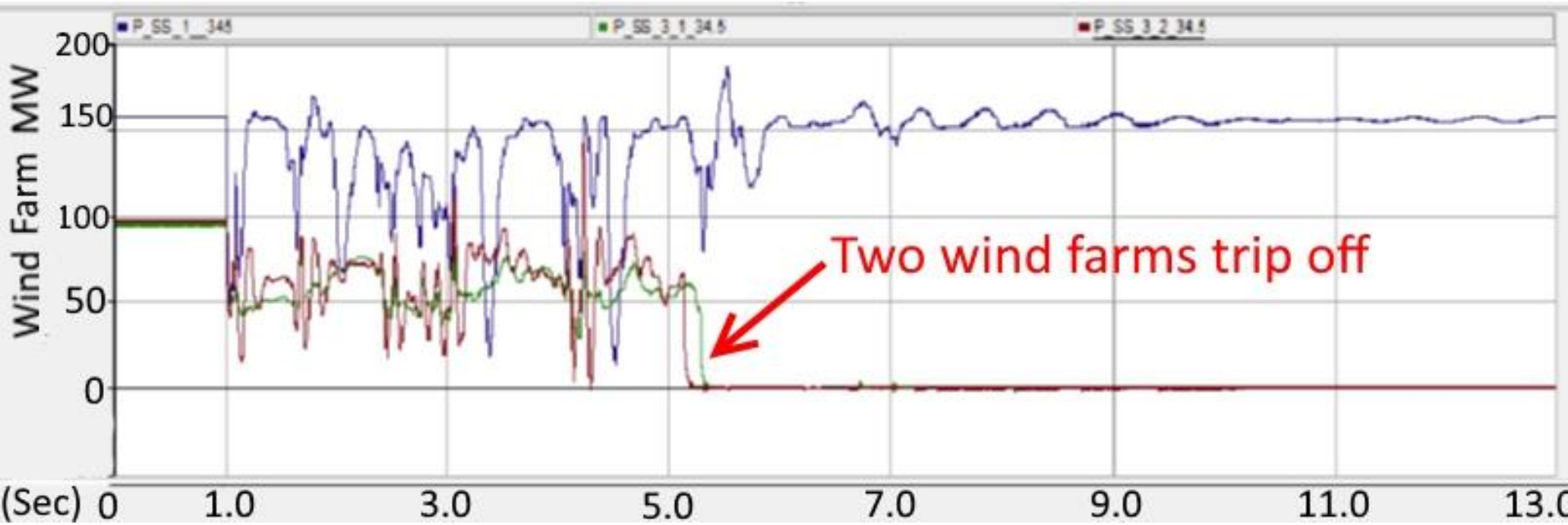
- Grid Forming with CV Control

And for balancing:

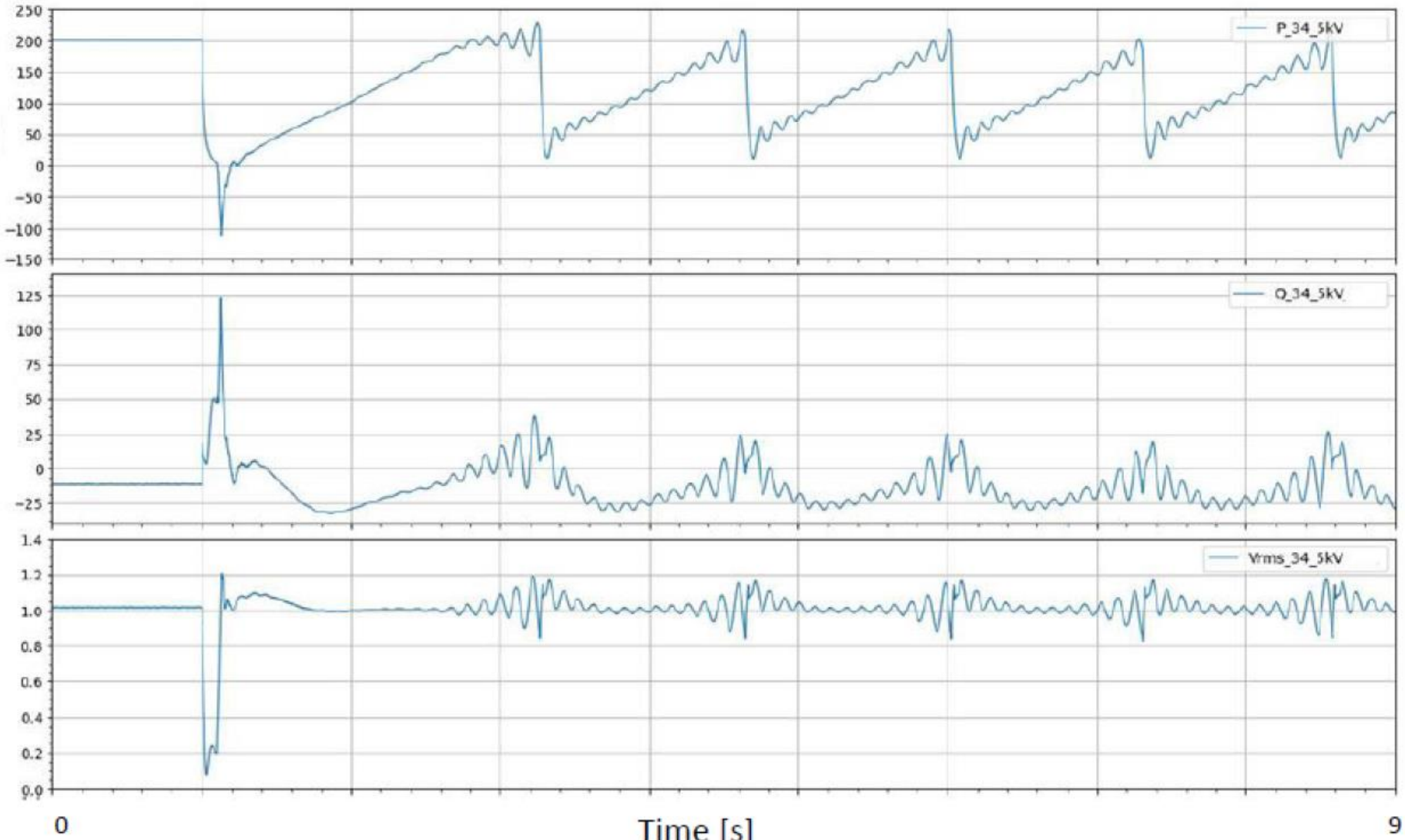
- Storage
- Wide area transmission: Macrogrid

An Example Contingency Study

- 37 wind generation projects with a total of 6891 MW capacity with STATCOMs, an SVC, two synchronous condensers & 435 busses – no Grid Forming inverters



Solar PV plant in weak system going into mode cycling after system fault



As plans are made to add HVDC, wind, solar and batteries, SCR or weak system considerations are almost always ignored in most high-level energy discussions.

There is more focus on renewable penetration levels and energy storage requirements, ignoring the technical reality that a system without conventional synchronous machines simply will not work today without some major modifications!

As plans are made to add HVDC, wind, solar and batteries, (SCR or weak system considerations) are almost always ignored in most high-level energy discussions.

Included in the focus on high renewable penetration and energy storage requirements, there must be recognition that a system without conventional synchronous machines simply will not work today without some major modifications!

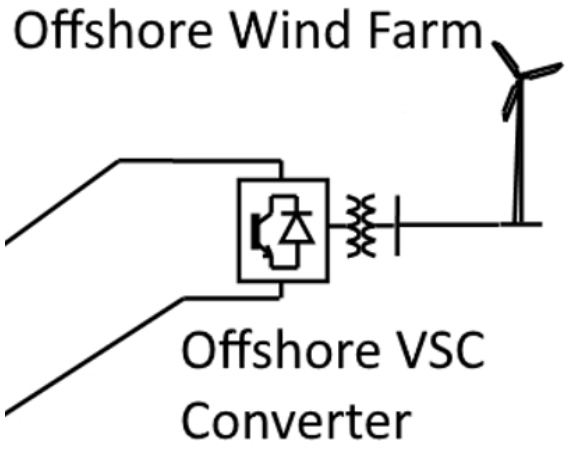
So, what can be done to avert weak system concerns?

- Add “conventional inertia” via synchronous condensers – high cost

Source: Wikipedia

Or,

- Apply CV (Constant Voltage)/Grid Forming control for VSC converters.

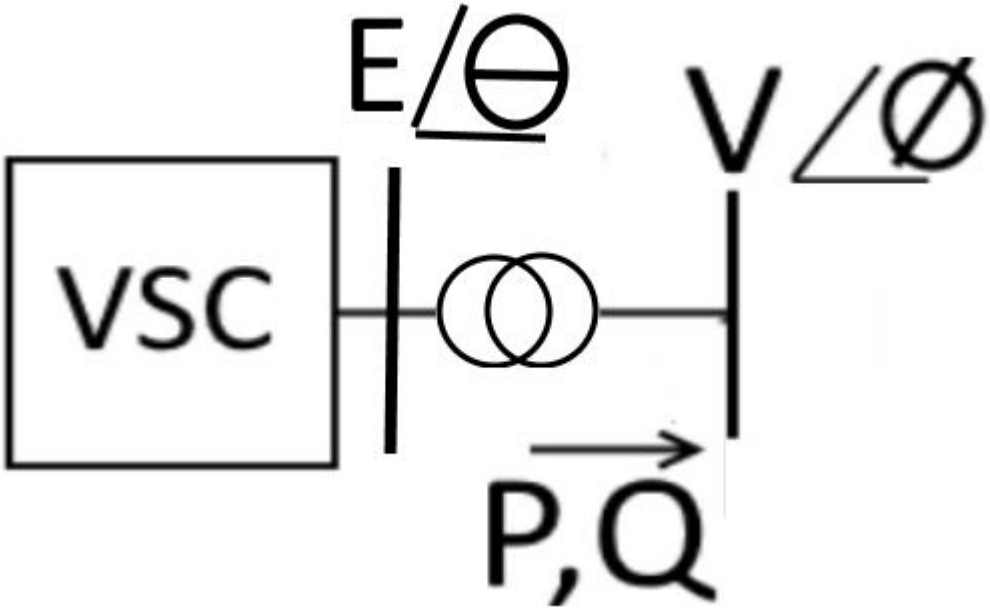


1. Grid forming for isolated systems

2. Mackinac HVDC B2B in Michigan has Grid Forming for weak SCR

Grid Forming Includes CV Control

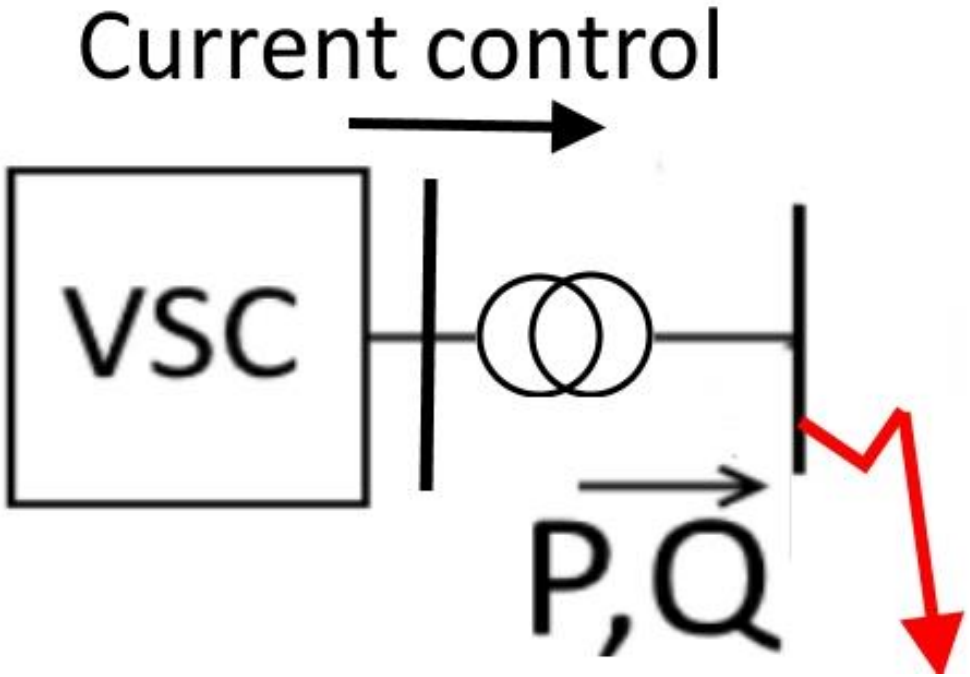
- CV control can control real power by relatively slow/smooth modulation of the voltage source angle, which inherently provides a stabilizing, inertia-like quality.



CV control is when the voltage source angle Θ is modulated slow & smoothly

Grid Forming Includes CV Control

- When a close in AC fault occurs, the CV control reverts to current control (CC) to protect against overcurrent in the IGBTs



Circuit breaker fault clearing current is not increased.

Is protection a problem?

How will these changes be instigated?

The control systems in wind, solar and BESS converters need to evolve to Grid Forming such as CV Control in order to meet the challenges of tomorrow's grid and to ensure future system reliability.

Universities:

Industry:

How will these changes be instigated?

- Lots of synchronous condensers (costly)

- Standards and rules: e.g. North American Electric Reliability Corporation (NERC)

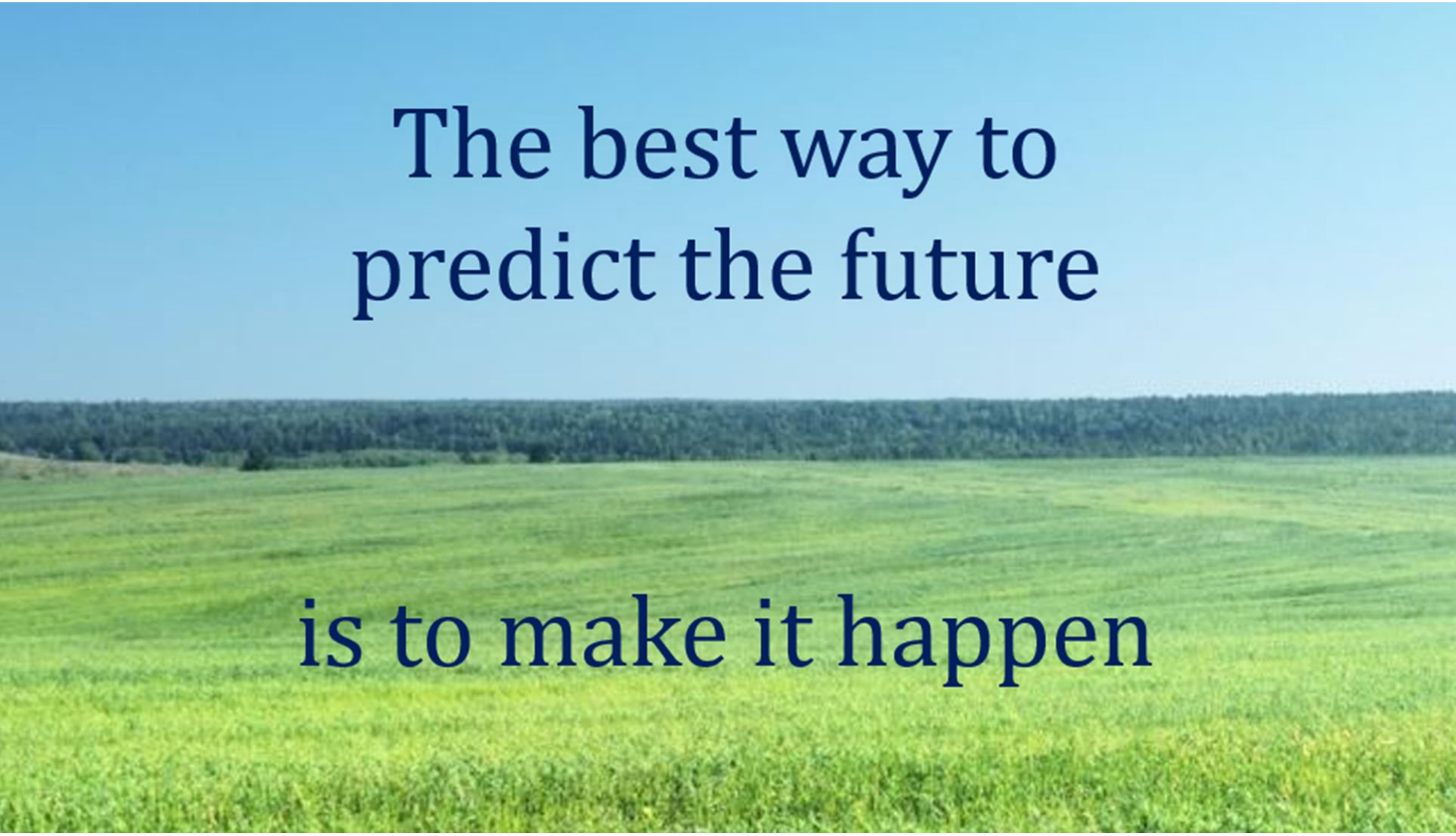
NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

How will these changes be instigated?

- IEEE & CIGRE Joint Task forces & Working Groups. E.g. CIGRE WG B4.77: “AC Fault Response Options for VSC HVDC Converters

- National Laboratories

- ESIG & Others


The best way to
predict the future
is to make it happen