# Grid Strength Metrics and Evaluation in Converter-Dominated Grids

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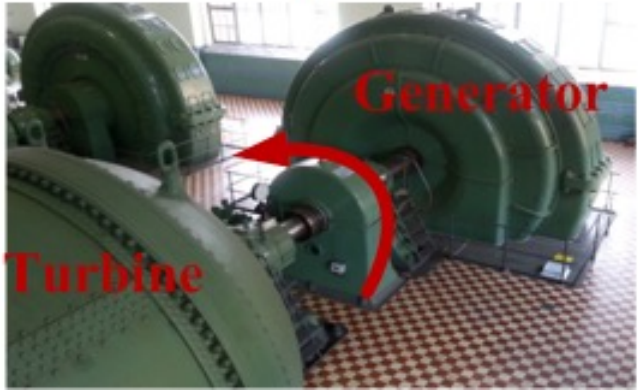
# Shift in Generation Technology

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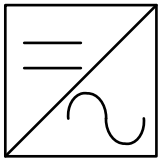

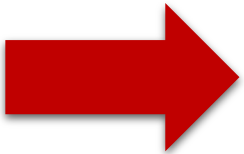

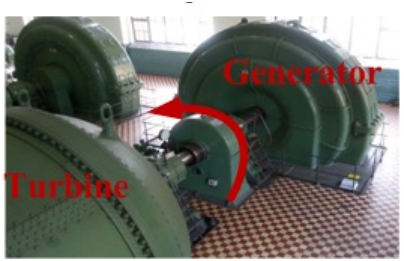


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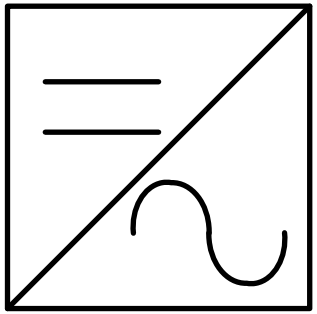
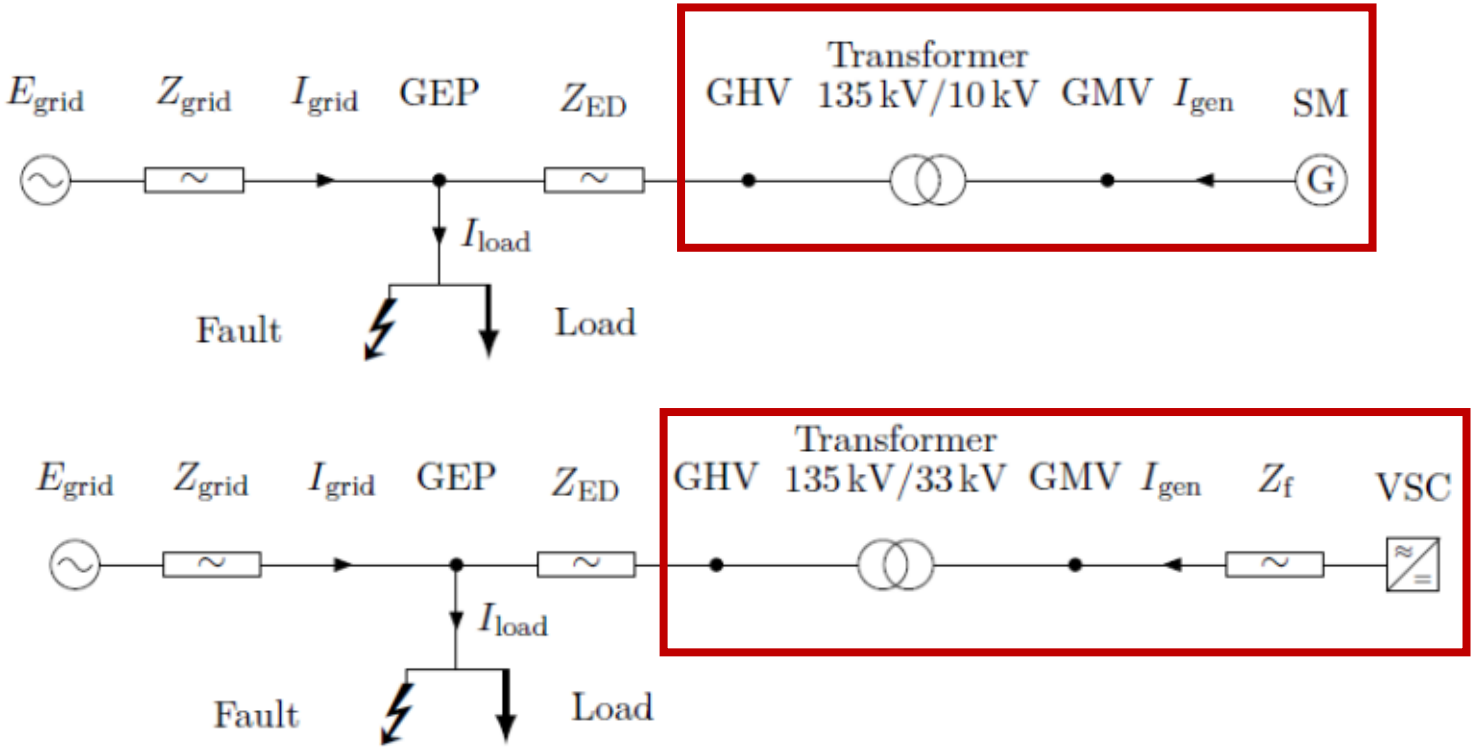


# Grid voltage strength

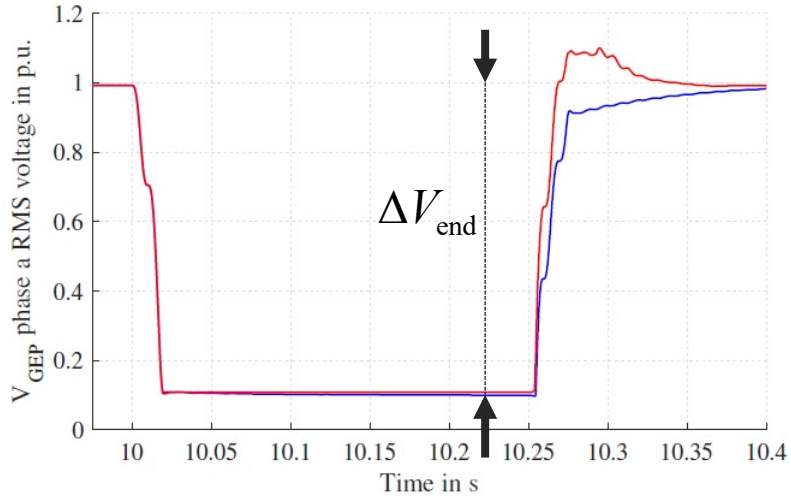
- **Main research question:**

**Under what conditions are classical indicators, such as fault current and short circuit capacity (SCC), able or not able to represent the stiffness of grid voltage in a grid with high penetration of converter-based generators?**

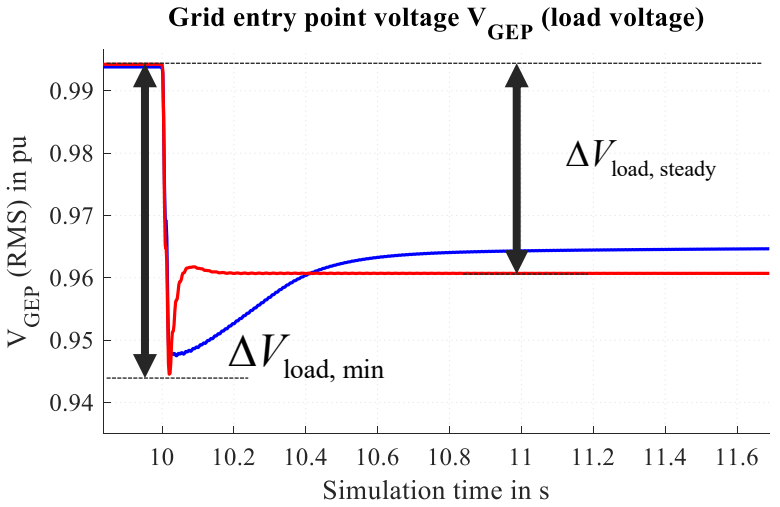
# Electrical system



# Voltage strength measures




**Fault**

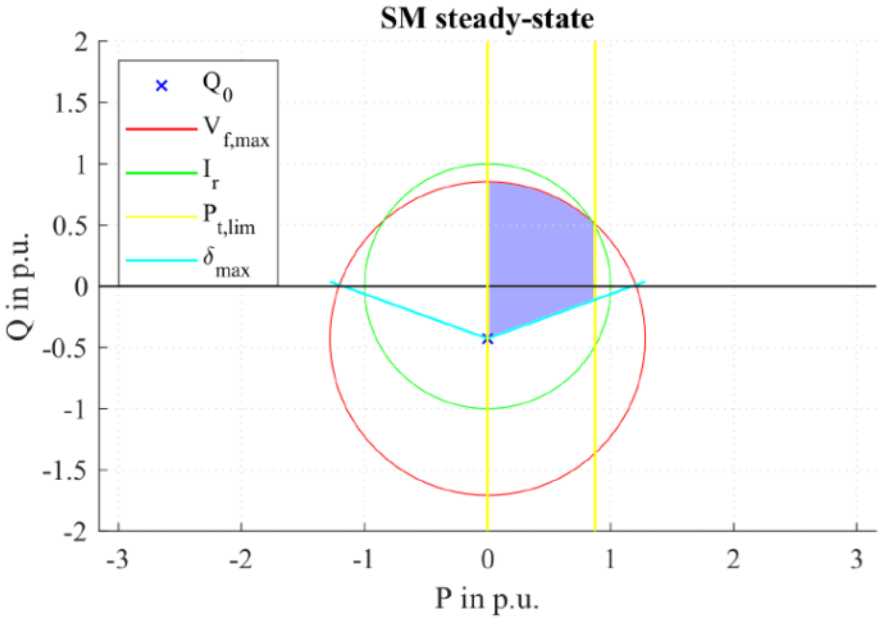


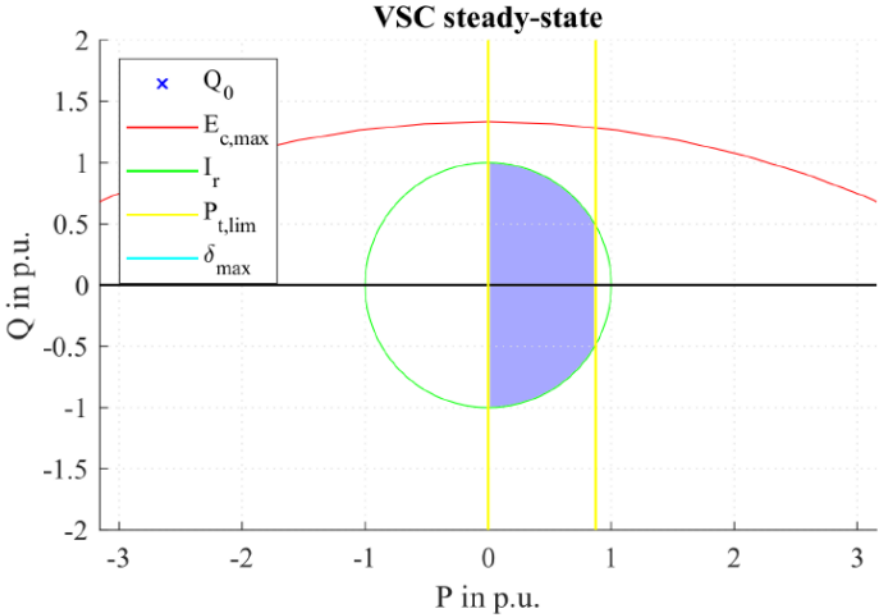

**Load steps**

# Voltage indicators

- Fault current
- Short circuit capacity
- Thevenin impedance
- Voltage regulation strength

# PQ diagram – steady state

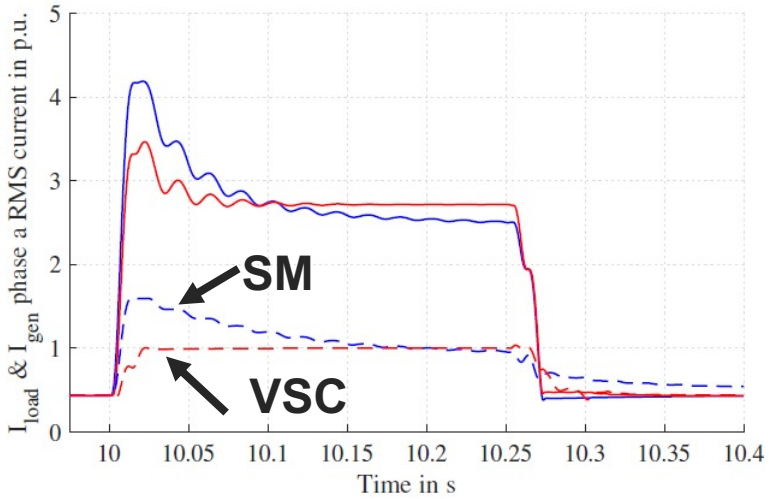


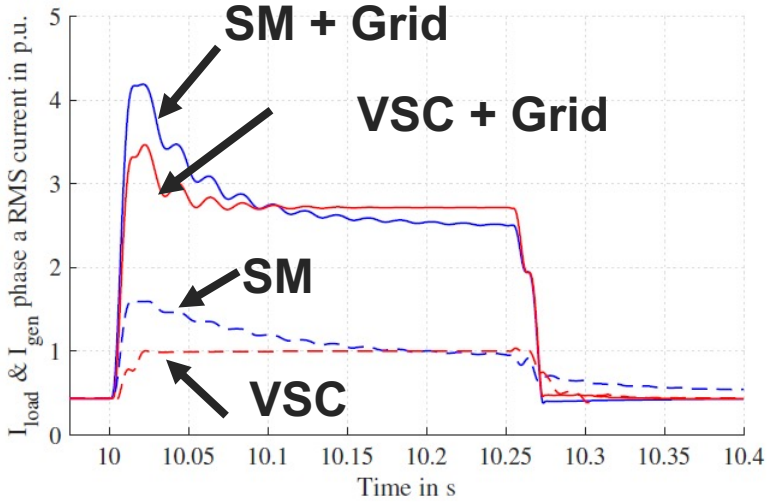
# VSC behavior during fault

- Phase lockd Loop
  - frequency freeze during severe voltage dips
- Fault current limitation
  - maintain current angle vs voltage angle
- Reactive current contribution during and post fault
  - differs in different grid codes

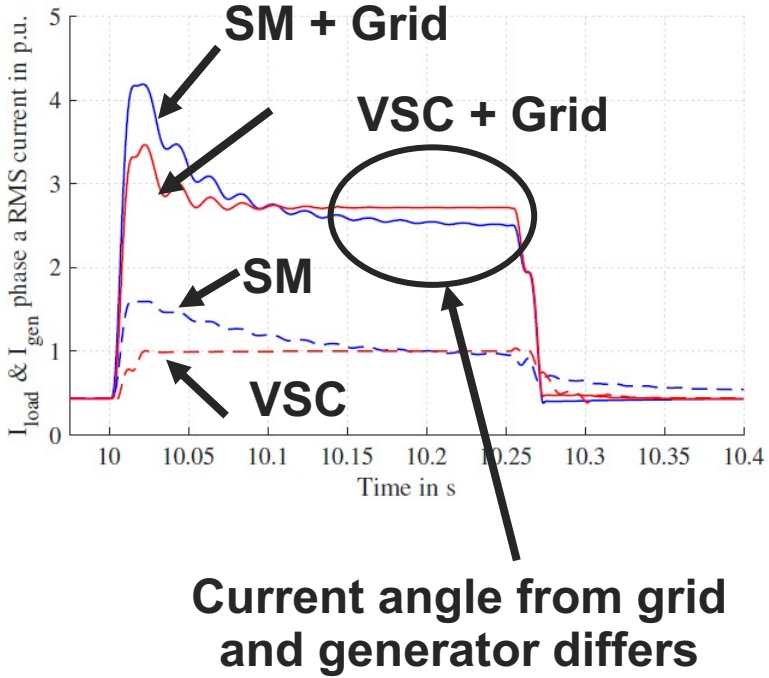
# Example fault current from SM & VSC



# Example fault current from SM & VSC



# Example fault current from SM & VSC

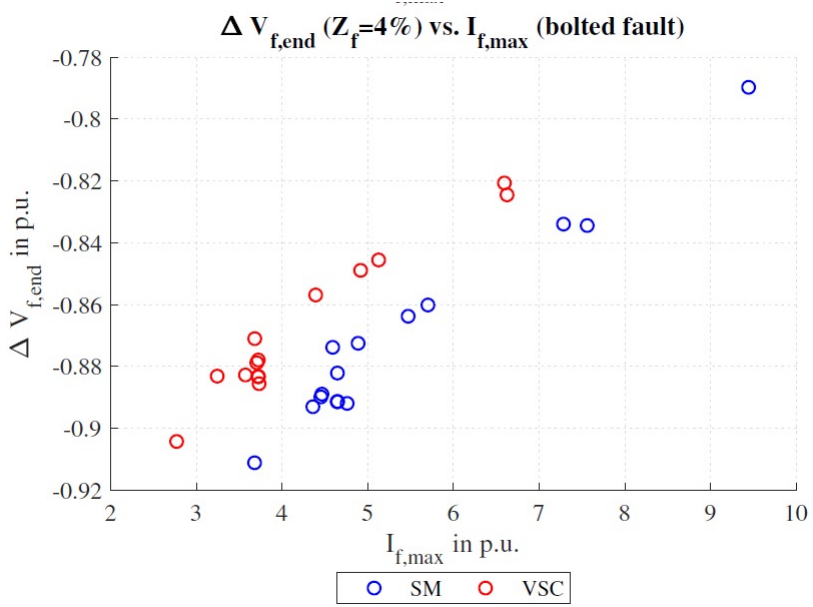


# Cases evaluated

| Case number & disturbance | Voltage strength measure | Stable cases (SM + VSC) |
|---|---|---|
| 1: Bolted Fault | $\Delta V_{\text{f,end}}$ | $16 + 16$ |
| 2: $Z_{\text{fault}} = 0.04\,\text{p.u.}$ | $\Delta V_{\text{f,end}}$ | $16 + 15$ |
| 3: $Z_{\text{fault}} = 0.08\,\text{p.u.}$ | $\Delta V_{\text{f,end}}$ | $16 + 16$ |
| 4: $\Delta P = 0.1\,\text{p.u.}$ | $\Delta V_{\text{load,min}}$ | $15 + 15$ |
| 5: $\Delta Q = 0.1\,\text{p.u.}$ | $\Delta V_{\text{load,min}}$ | $15 + 15$ |
| 6: $\Delta P = 0.25\,\text{p.u.}$ | $\Delta V_{\text{load,min}}$ | $15 + 15$ |
| 7: $\Delta Q = 0.25\,\text{p.u.}$ | $\Delta V_{\text{load,min}}$ | $15 + 15$ |
| 8: $\Delta P = 0.5\,\text{p.u.}$ | $\Delta V_{\text{load,min}}$ | $15 + 15$ |
| 9: $\Delta Q = 0.5\,\text{p.u.}$ | $\Delta V_{\text{load,min}}$ | $15 + 5$ |
| 4: $\Delta P = 0.1\,\text{p.u.}$ | $\Delta V_{\text{load,steady}}$ | $15 + 15$ |
| 5: $\Delta Q = 0.1\,\text{p.u.}$ | $\Delta V_{\text{load,steady}}$ | $15 + 15$ |
| 6: $\Delta P = 0.25\,\text{p.u.}$ | $\Delta V_{\text{load,steady}}$ | $15 + 15$ |
| 7: $\Delta Q = 0.25\,\text{p.u.}$ | $\Delta V_{\text{load,steady}}$ | $15 + 15$ |
| 8: $\Delta P = 0.5\,\text{p.u.}$ | $\Delta V_{\text{load,steady}}$ | $15 + 15$ |
| 9: $\Delta Q = 0.5\,\text{p.u.}$ | $\Delta V_{\text{load,steady}}$ | $15 + 13$ |

- **Different line length**
- **Different grid strength**
- **Different active power reference**
- **Different short circuit ratio**
- **Different locations of disturbance**

# Evaluation of fault current/SCC as an indicator



# Some take aways

- **The change in fault current due to the generation technology shift is not only characterized by the initial fault current, but also enhanced controllability from converters**

- **Same fault current (or SCC) does not necessarily represent the same voltage strength in two grids with different generation mix.**

- **For a fixed generation mix, a higher fault current (or SCC) does reflect a higher voltage strength under the cases evaluated**