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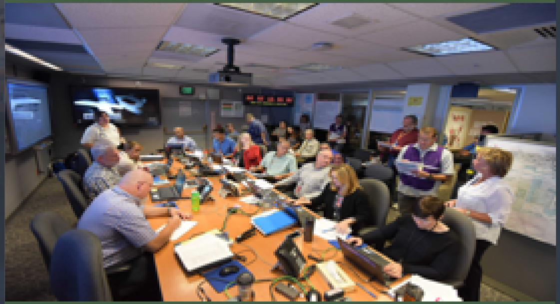
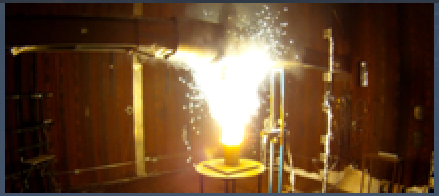
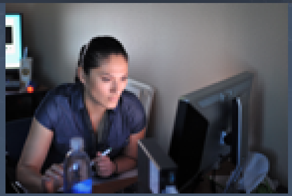
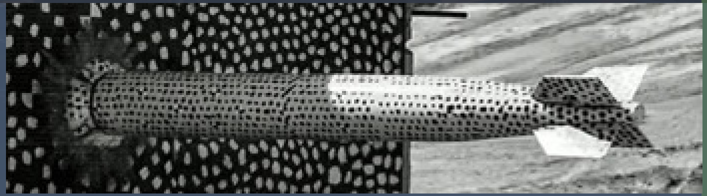


Modeling for Design of Microgrid Protection

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Michael Ropp, Ph.D., P.E.

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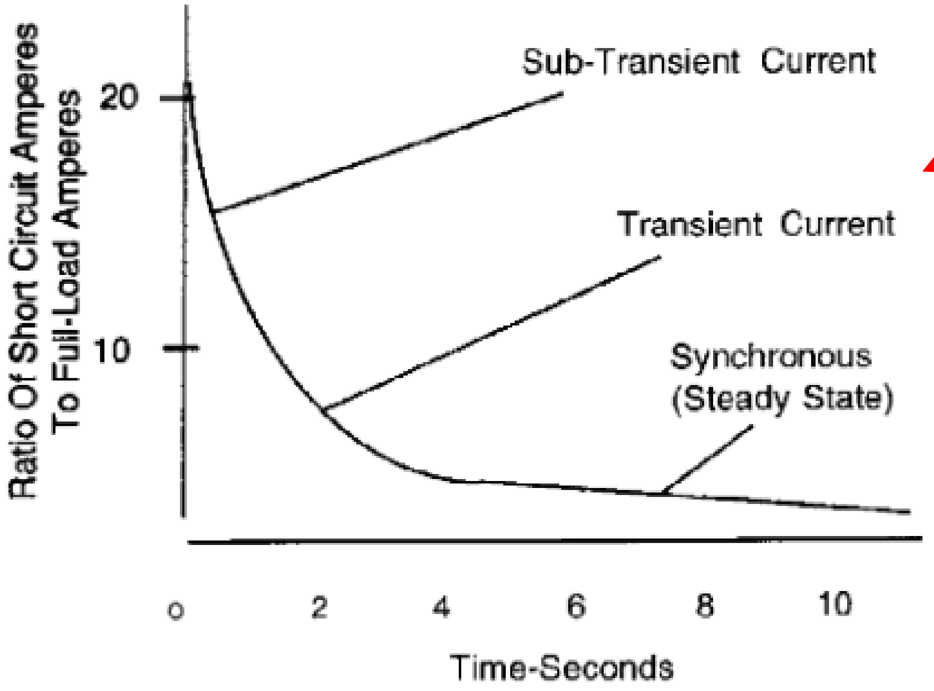
Challenges for microgrid protection design

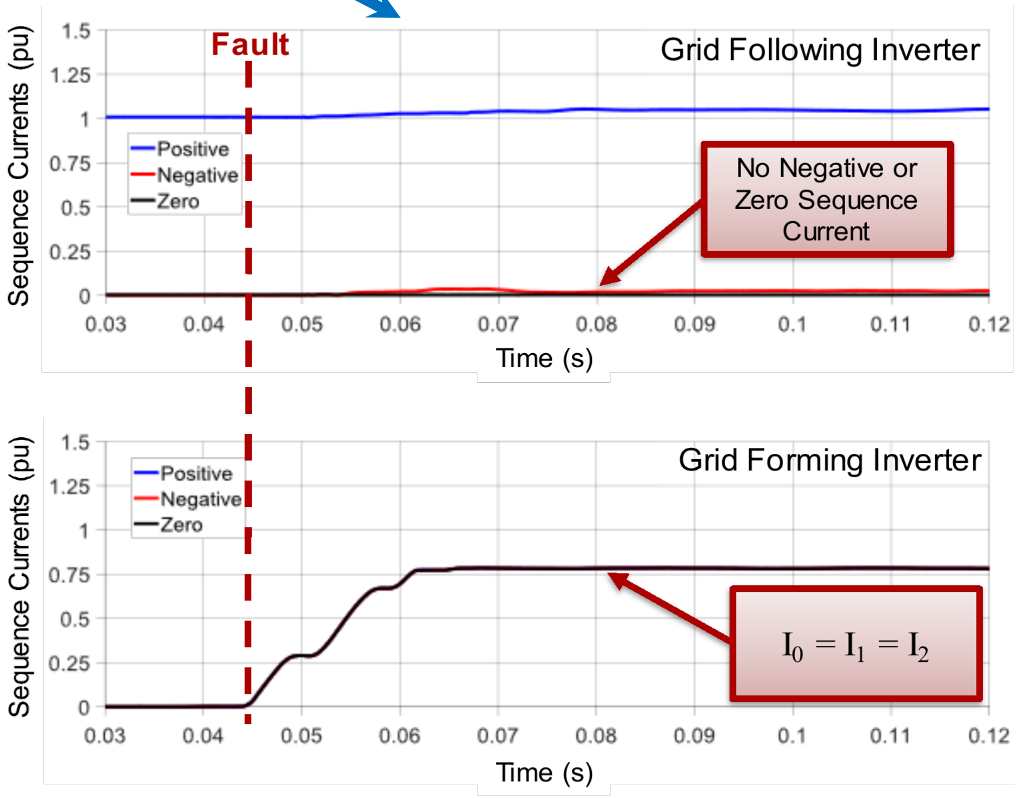
- Need protection for both on-grid and off-grid modes
- No infinite bus, and often no slack bus
- Multiple-source configurations
  - Current may come from any direction
  - Must remain protected for all feasible combinations of sources
- Combinations of rotating and inverter-based sources
  - Fault current limitations
  - Manufacturer-specific and programmable behaviors
  - Challenges in negative- and zero-sequence current prediction at relay locations
- May need to design both a protection and a communication system

Source dynamics

Synchronous generator



Inverter

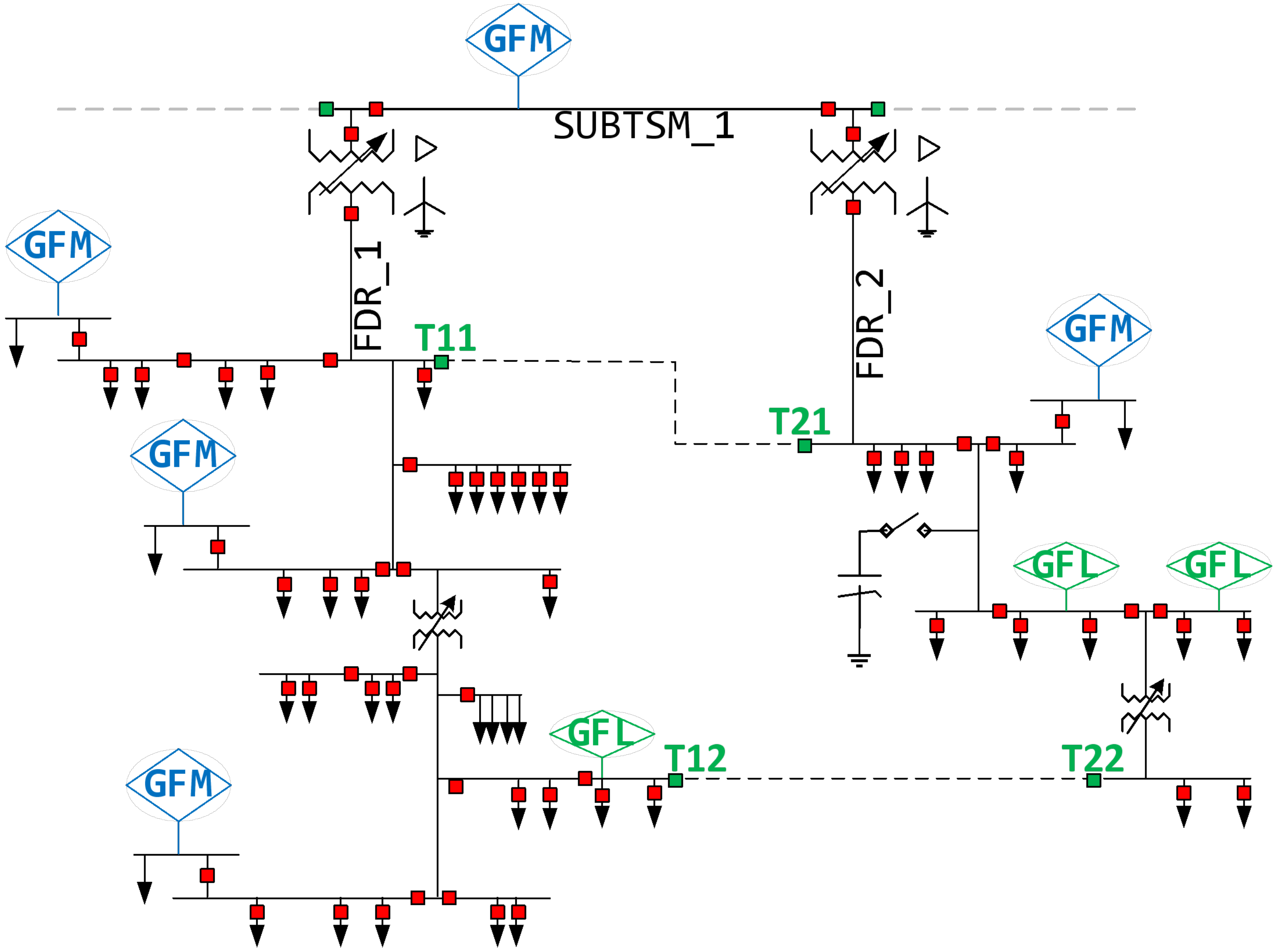


Microgrid sources have strongly time-varying dynamics. Software for protection design must take this into consideration.

Distributed sources

A system like the one to the right may be partitioned into microgrids in several different ways. The system must remain protected for every configuration and every feasible combination of sources.

This system has both grid-forming (GFM) and grid-following (GFL) assets. Both must be considered in the protection design.



Comparison of tools

Tool	Pros	Cons
Phasor-domain distribution modeling tools (CYME, CAPE, ASPEN, ETAP, …)	☑ Well-known in industry ☑ Circuit databases already exist ☑ Relatively simple to use ☑ Minimum data input requirements	💣 Fundamental limits in simulating key time-domain behaviors—e.g., highly simplified inverter models that do not (cannot?) capture all relevant behavior 💣 Most do not yet have good capabilities for modeling the off-grid mode
EMT modeling tools (PSCAD, MATLAB/Simulink, EMTP-RV, DigSilent…)	☑ Capable of addressing all of the listed microgrid protection modeling challenges ☑ Code-based DER models are becoming widely available	💣 Building of system models is cumbersome and error-prone 💣 Expensive—requires a lot of time from expert users 💣 Burdensome data input requirements 💣 Need for model validation
Relay Control Hardware in the Loop (CHIL) (Opal-RT, RTDS, Typhoon…)	☑ Uses real relay firmware in real relay hardware in real time (RT)	💣 Expensive—costly simulators, lots of time 💣 System size limitations for RT simulation 💣 I/O limitations 💣 Need reasonable-fidelity DER models that are compatible with RT simulation

Conclusions

Accumulated experience and R&D efforts will lead to development and standardization of effective microgrid protection techniques. Standardized protection approaches will suffice for *most* microgrid protection design.

Commercial distribution protection modeling tools will eventually include many useful capabilities for setting the parameters of standardized microgrid protection in “typical” cases.

In the near term, and into the future for “non-typical” cases, EMT simulation will be the go-to. Better, faster, easier-to-use EMT tools would be great.

Relay CHIL will become increasingly common for testing implementations of novel microgrid protection functions in relays.

References

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Thank you!

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