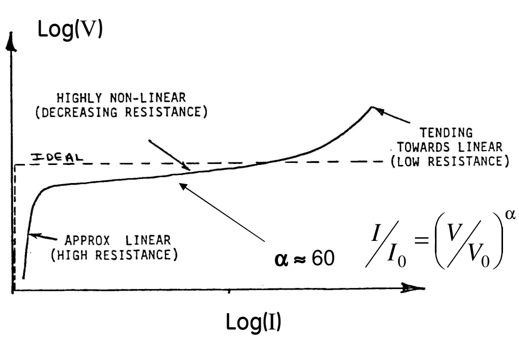
Overvoltage Protection and Arrester Selection for Large Wind Plants

Reigh Walling
GE Energy

GE imagination at work

Metal-Oxide Surge Arresters

- Near-ideal "clamp" of voltage across arrester
- Draws whatever current needed to clamp voltage
- Can fail from excessive energy
- Sensitive to stiff voltages for extended durations



imagination at work

Overvoltages on Wind Plant MV Collector

Arrester protects equipment from these

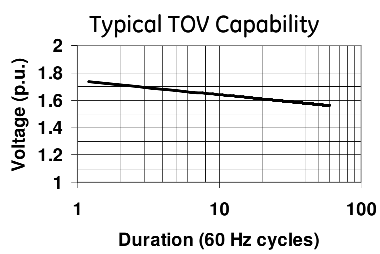
- Lightning
  - Coupling through substation transformer
  - "Sneak paths" from tower strikes
- Switching transients
  - Coupling through substation transformer
  - Capacitor bank switching and restrikes
  - Feeder energization

Arrester selected to "avoid" these

- Temporary overvoltages
  - Ground faults
  - Feeder islanding, loss of ground reference
- Continuous operating voltages

Surge Arrester Parameters

- Maximum continuous operating voltage (MCOV)
- Temporary overvoltage capability

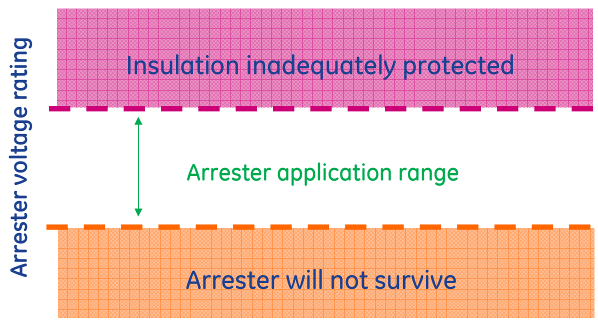


- Duty cycle rating - legacy of obsolete technology
- Discharge voltage – at specified currents and waveshape
- Energy capability

Insulation Coordination

The process of selecting equipment insulation levels, surge arrester ratings and surge arrester locations such that:

- *Equipment voltage withstand is not exceeded*
- *Surge arresters survive*



Classic Insulation Coordination Process

1. Select arrester rating meeting MCOV and TOV constraints
2. Determine arrester protective level at a selected “coordinating current”
3. Select arrester location with respect to protected equipment
4. Determine voltage across each equipment – consider separation distance and lead length
5. Select equipment insulation level
6. Check to ensure protective margin is at least 20%
7. If not, revise design, and repeat Steps 1 – 6.

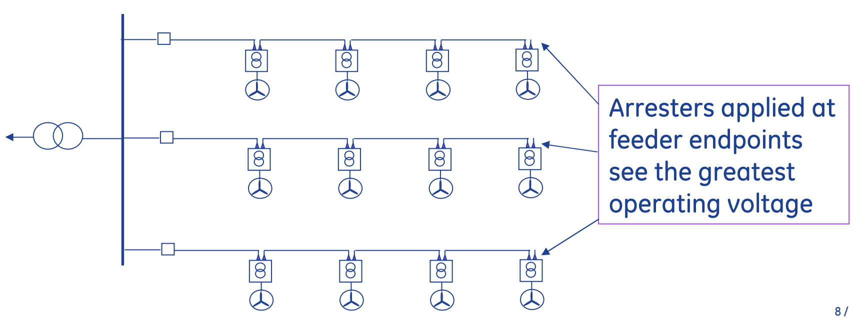
The Realities of Wind Plant Collectors

- Vast majority of North American wind plants use 34.5 kV collector systems for:
  - Capacity
  - "Reach"
  - Efficiency
- Commodity distribution-class equipment is preferred for economics
- 34.5 kV utility distribution feeders are almost always multigrounded-wye
  - Therefore, most equipment is available only up to 150 kV BIL
- MCOV and TOV are severe constraints in most wind plants
- Arrester application on wind plant collectors is often tightly constrained from both ends

Maximum Continuous Operating Voltage

Consider:

- Maximum grid operating voltage
- Substation transformer tap
- Rated wind plant real power output
- Maximum required reactive output

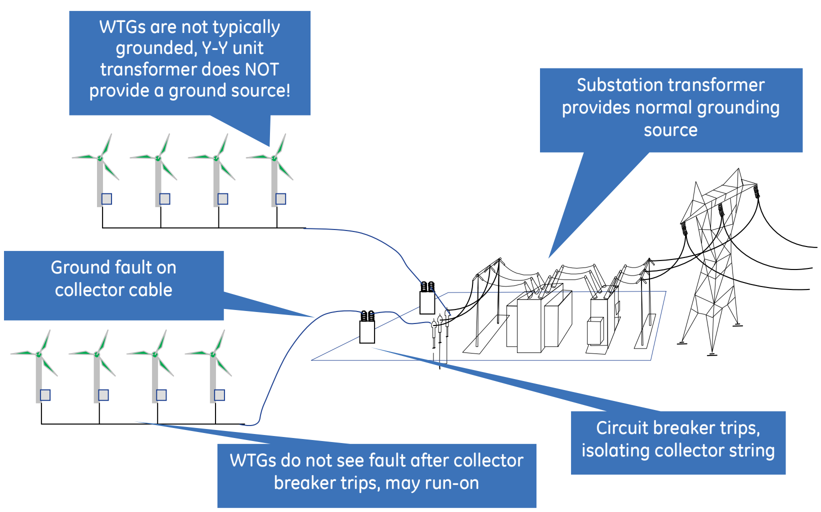


Temporary Overvoltages

- Excess capacitive compensation
  - e.g., tripping of VAR demand
- Ground faults; unfaulted phase voltage rise
  - In an effectively grounded system, voltages may rise as high as 1.35 p.u.
  - Some wind plants have high-impedance grounding; unfaulted phase voltage can rise > 1.73 p.u.
- Collector feeder isolation

9 /

Collector Feeder Isolation



Run-on is more likely with ride-through requirements

10 /

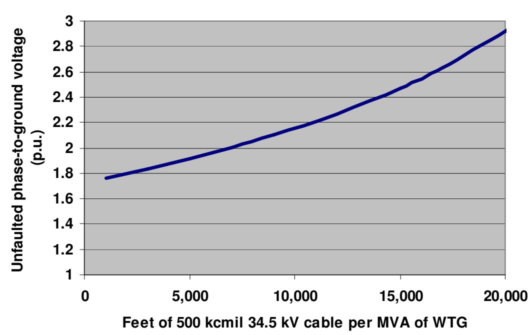
The Complications

Overvoltages on an "ungrounded" collector cable can be far greater than 173% of normal…

- Feeder cable capacitance
- Transformer saturation
- WTG interaction

Cable Capacitance

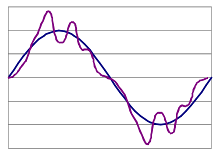
- Cable capacitance provides a high impedance "ground" with a <u>negative</u> reactance
- Can greatly amplify over voltage due to resonance



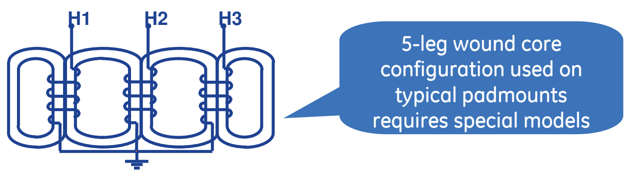
Transformer Saturation

Transformer saturation usually **does not** reduce crest voltages

- Fundamental voltage reduced, but
- Large amount of harmonic current injected
- Harmonics interact with system resonance to create high crest overvoltages



Only detailed simulation can determine the peak overvoltages



13 /

Wind Turbine Generator Interaction

Induction generators

- Continue to generate if sufficient capacitance is present (*self-excitation)*
- Cable capacitance and pf capacitors, relative to WTG rating
- Voltage uncontrolled, WTG voltage can become high if sufficient capacitance islanded with generators

Converters (full conversion and DFAG)

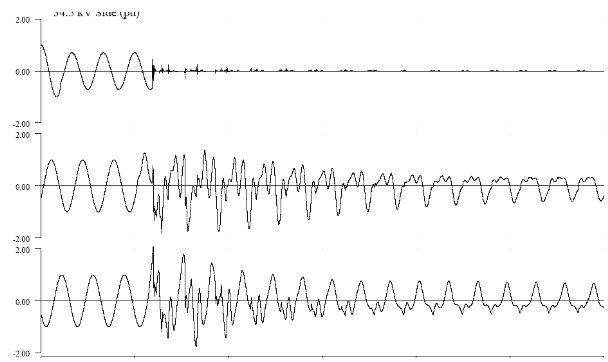
- Continue to create a voltage unless tripped
- Can adversely interact with the high impedance

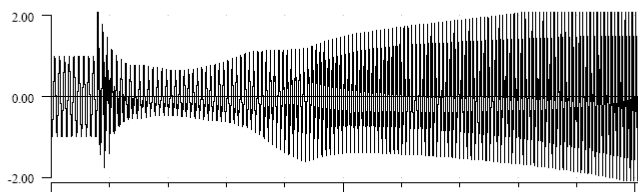
WTG run-on after feeder isolation is an issue for all technologies

14 /

Simulation Results – Induction Wind Turbine Generator

- Ground fault to 70% voltage on one phase
- 900’ of 34.5 kV cable per WTG MVA + 0.51 p.u. power factor caps





Solutions to the Feeder Isolation Issue

1. Trip Wind Turbine Generators

Local detection is generally not effective

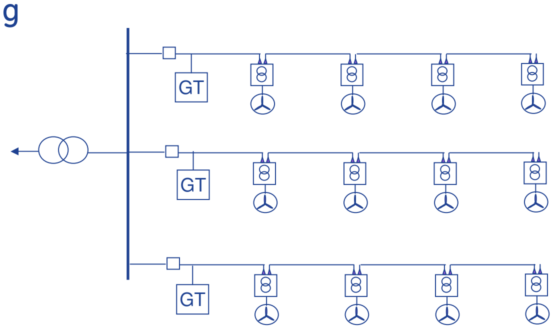
- Initial fault cannot be readily distinguished from grid ride-through event
- Overvoltage not always visible to WTG
- Islanding detection is inherently too late

Transfer trip

- Requires high-speed protection-grade communication (not ordinary SCADA)
- May need to delay collector breakers to allow WTGs to trip first

2. Provide Ground Sources

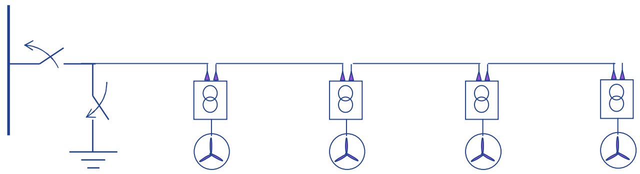
- Install dedicated grounding transformers on each collector string



- Grounding transformer sizing requires detailed simulation analysis

3. Use a Grounding Switch

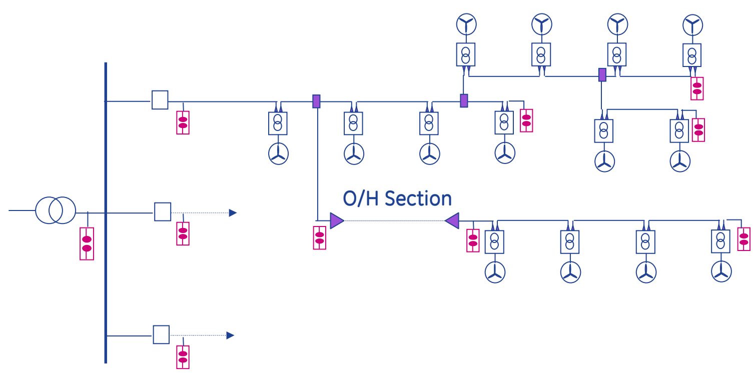
Synchronized, interlocked grounding switch applies a 3-phase fault to the feeder immediately after the feeder breaker interrupts



Arrester Placement

Arrester Placement on MV Collector

34.5 kV feeder example, using 150 kV BIL equipment



21 /

Conclusions

- Overvoltage protection and arrester application generally similar to that for utility distribution systems
- Special considerations for wind plants:
  - Equipment generally designed for multigrounded-wye distribution used for a uni-grounded (or hi-Z grounded) wind collector
  - TOV from islanded feeder scenario can make it impossible to achieve proper insulation coordination
  - There are means to mitigate severe TOV
- Proper insulation coordination can provide a more reliable wind plant

22 /