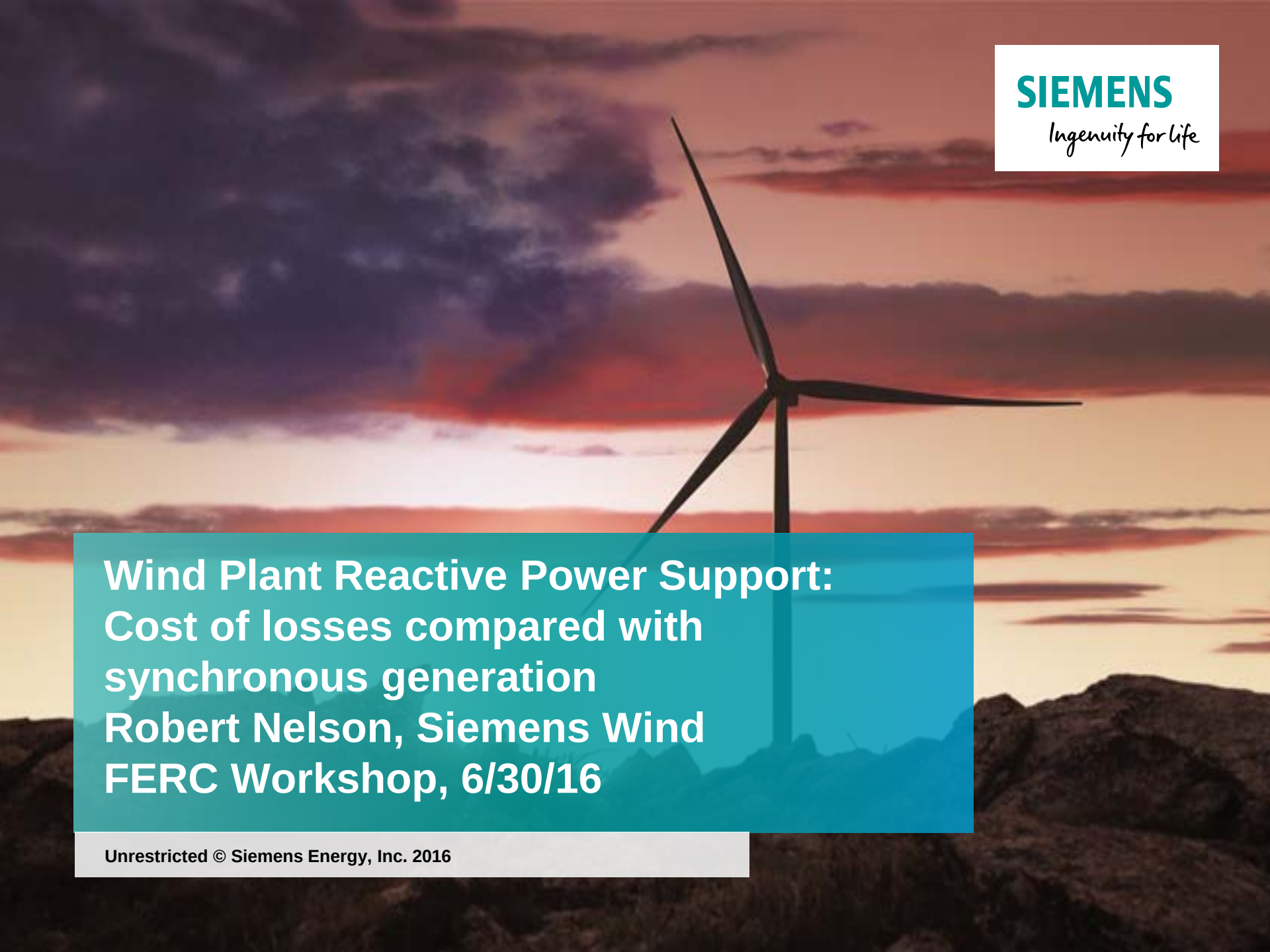


Wind Plant Reactive Power Support: Cost of losses compared with synchronous generation

Robert Nelson, Siemens Wind

FERC Workshop, 6/30/16

Background

- Manager of Codes and Standards of Siemens Wind - Americas, since 2008.
- 27 years with Siemens and predecessor (Westinghouse Power Generation)
- Background in synchronous generator and excitation design and control, as well as Flexible AC Transmission Systems (FACTS) applications
- Previous positions in utility organizations (Bulk System Planning and Operations), as well as utility consulting.
- M. Engr. In Electric Power Engineering from Rensselaer Polytech
- IEEE Fellow

How is reactive power support presently provided by synchronous generation?

- Usually local voltage regulation at low side of plant step-up transformer
- Normally, generation is close to load centers, so little need for line drop compensation for interconnecting transmission; transmission losses generally low, except for mine-mouth plants
- Narrow operating voltage range (95% to 105% at generator terminal) – good at supporting system in normal range (90% to 110% transmission voltage), but limited outside of this range.
- Generally narrow active power (MW) operating range because of emissions limits

How is reactive power support presently provided by synchronous generation?

SIEMENS

Synchronous generation

- Limited ability to absorb reactive power because of steady-state stability concerns and Minimum Excitation Limiter (MEL) settings
- Generally cannot provide reactive power when off-line unless specially equipped with clutch for synchronous condenser operation

How is reactive power support presently provided by synchronous generation?

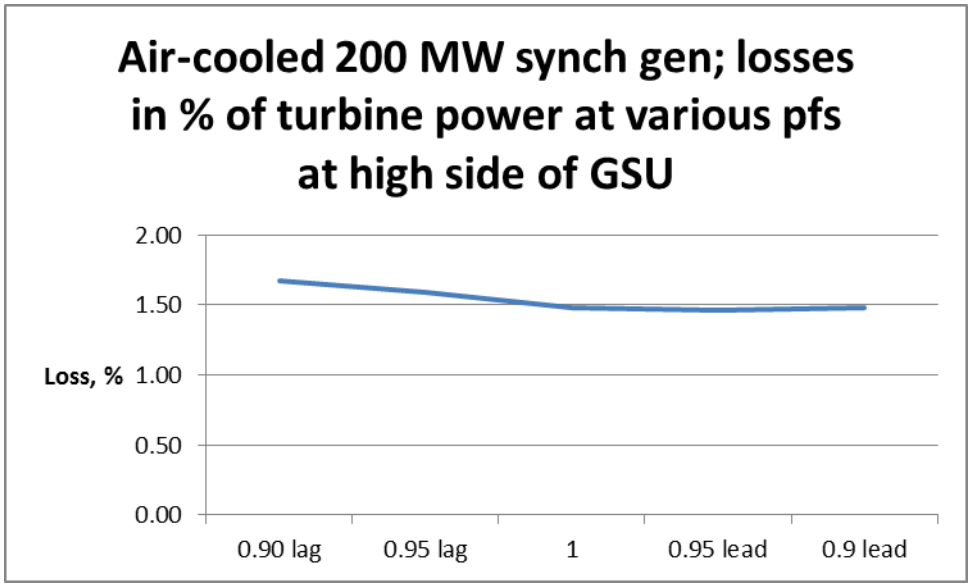
SIEMENS

Efficiency and losses

- Modern synchronous generators have very high operating efficiency – generally ≥98.5% efficiency.
- Recent tendency has been use of air-cooled generators:
  - High efficiency
  - Low stator and excitation loss (losses are predominantly fixed – windage, core, bearings, etc.)
  - Only minor increase in loss associated with reactive power production; usually a reduction in loss for reactive power absorption

How is reactive power support presently provided by synchronous generation?

Efficiency and losses



Little variation in loss with reactive power output (pf)

Voltage regulation for BES Wind Plants

- Typically, voltage schedule at POI – may be remote, requiring line drop compensation
- Generally remote from load centers; often a long distance over transmission lines with high transmission losses (both real and reactive)
- Wide operating voltage range – 90% to 110% at turbine level; can support system voltages outside of normal range
- Wide active power range – 0% to 100%; can be curtailed and ramped quickly on command
- Can provide dynamic reactive power without active power production (i.e., “synchronous condenser” operation)

Voltage regulation for BES Wind Plants

- Wind plants comparable voltage response to synchronous machines (required in Ontario and other systems)
- Few transient stability concerns – use phase-locked loop (PLL) control to stay in synchronism
- Excellent ability to stay on-line for extended low voltage events
- Better at absorbing reactive power than providing reactive power because most elements between wind plant and power system are inductive

Voltage regulation for BES Wind Plants

Efficiency and losses

- Relatively high real power losses inside plant. Typical load (I^2R) losses at rated power:
  - WTG Converter: 2% to 3.5%
  - Turbine Transformer: 0.7% to 1.2%
  - Collector System: 1% to 3%
  - Plant Transformer: 0.2% to 0.3%
- High reactive power losses inside plant. Typical I^2X losses at rated power:
  - Turbine transformer: 5% to 6%
  - Collector system: 1% to 5%
  - Plant transformer: 9% to 14%

Voltage regulation for Wind Plants

- Because of reactive losses, at rated plant output, turbines must produce at least 15% to 25% more reactive power at the turbines than can be supplied to the system
- Reactive power is provided by increasing current flow, which increases reactive power (I^2X) and active power (I^2R) loss → reduction in active power production; reduction in power (MW) that can be supplied to system
- Incremental loss cost of providing reactive power can be estimated from load flow analysis of plant and interconnection
- Loss costs from wind plants for reactive power production can be considerably higher than comparable cost from synchronous generators of similar capability.

Wind plants have excellent ability to provide reactive support, but it may come at the cost of reduced active power delivery to the system, which must be assessed on a case-by-case basis.

Thanks for your time.

Questions?