

Impact of a 47 MVA Aeroderivative Gas Turbine Generator on a 346 MW Bulk Wind Farm - Case Study on Voltage & Frequency Response

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Agenda

- Introduction
- Wind Turbine Generator Model
- Gas Turbine Generator Model
- Hybrid Arrangement
- Study Methodology
- Findings/Results
- Summary

Introduction

- Most popular source of renewable energy.
- Increased penetrations of bulk wind farms are causing significant operational challenges.
- Need for Spinning Reserve sources to firm the capacity and balance the demand to counteract the variability of wind and solar.
- Lack of rotational/synchronous inertia
- Lower short circuit ratio
- Ancillary services to support grid stability – voltage and frequency

Wind Turbine Generator Model

- 3-phase Doubly Fed Induction Generator
- ACCIONA AW3465 WTGs
- At 35 degree C, AW3465 is rated for 3.465 MW at +/- 98.5% power factor (+/- 600 kVAR)
- 6-pole machine, with rated slip of 20% and rated speed of 1440 RPM
- $X''_d = 20\%$, $X'_d = 23\%$ and $X_d = 400\%$
- $T''_d = 68$ ms, $T'_d = 78$ ms and $T_d = 1.13$ s

	Speed	Power Electronics	Voltage Control Capability	Reactive Power Capability
Type 1	Nearly Fixed	None	None	Only via PFCC*
Type 2	Limited Variable	None	None	Only via PFCC*
Type 3	Variable	Partial	Yes	-0.9 to +0.95
Type 4	Variable	Full	Yes	-0.9 to +0.95
Type 5	Variable	Full	Yes	-0.9 to +0.95

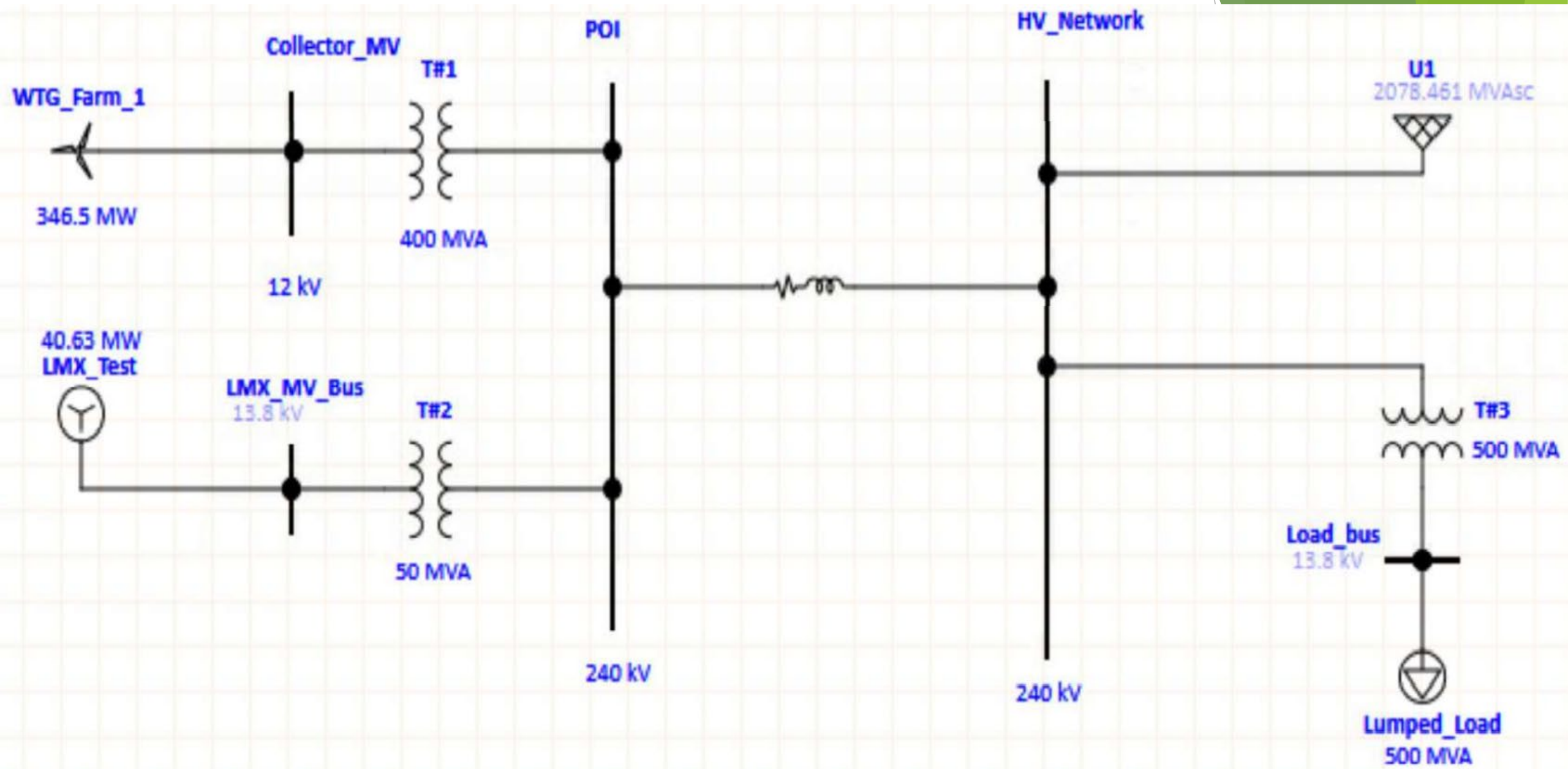
*PFCC: Power Factor Correction Capacitor

Gas Turbine Generator Model

- GE's LM2500Xpress coupled with Andritz A03OP-T
- Multi-shaft 2-pole machine with rated speed of 3600 RPM
- At 35 degree C, rated for 30 MW at 80% power factor
- Can deliver up to 40 MVAR and consume up to 16 MVAR in Synchronous Condensing mode
- $X''_d = 16\%$, $X'_d = 23\%$ and $X_d = 230\%$
- $T''_d = 20$ ms, $T'_d = 700$ ms and $T_d = 7.2$ s
- Total drive train $H = 1.375$

Hybrid Arrangement

- Thermal hybrids are gaining popularity to address grid firming challenges
- Single LM2500Xpress (47.8 MVA) operated in parallel with 346.5 MW wind farm
- Voltage response and reactive power support at POI
- Network frequency profile during short-term load adjustment cases



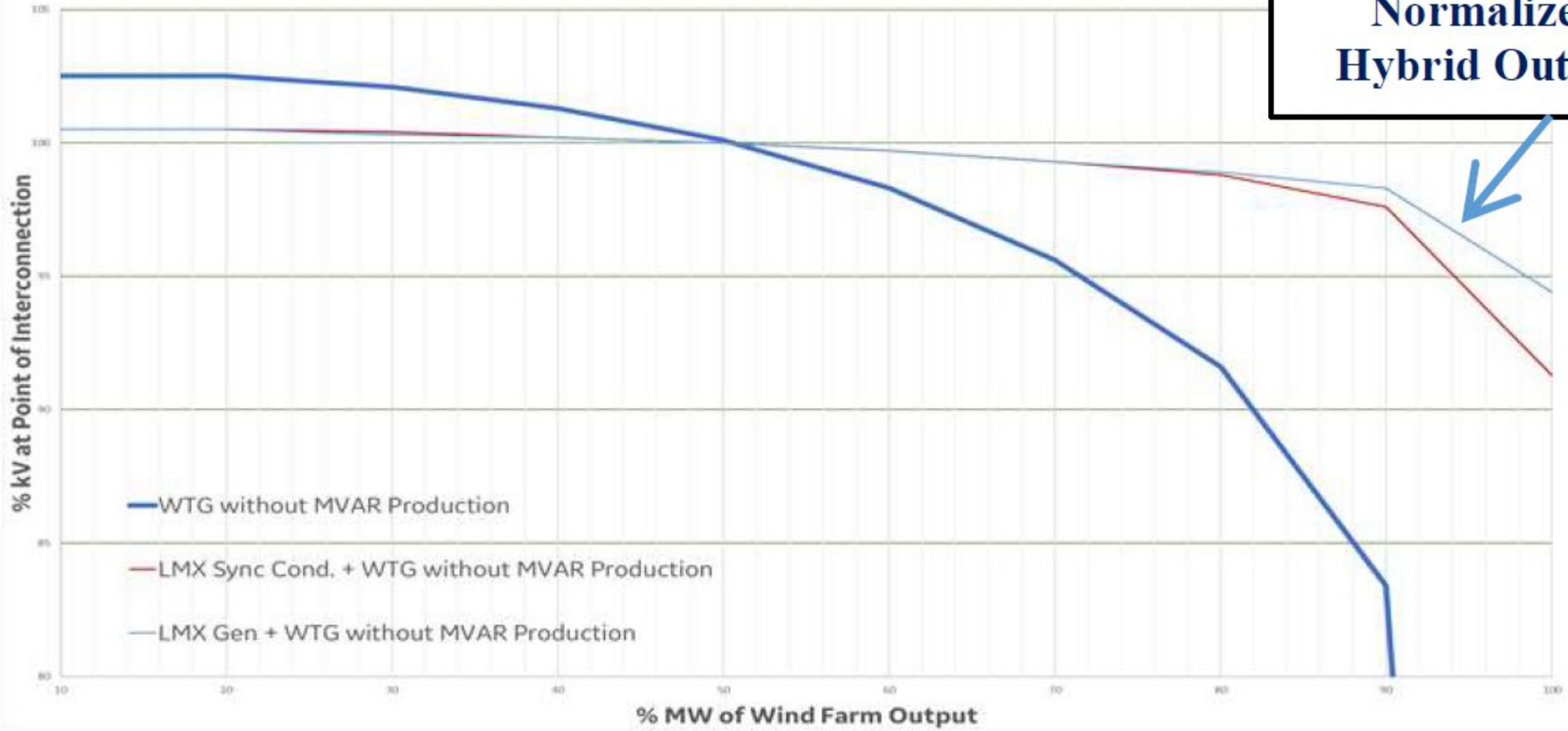
Study Methodology

- WPP (Type 4) penetration considered at 25% of total generation sources
- GTG Governor (GGOV1) droop set at 5%
- Grid (Swing bus) represented as equivalent synchronous machine (GGOV3), with $H = 5$
- Steady-state (voltage) responses with and without reactive power production at WPP; GTG operating in “Synch Cond” and “Power Gen” modes
- Transient (voltage) responses for 3-ph fault at POI cleared in 150 ms
- Frequency response with and without GTG during +/- 2.5% load ramp over 5 seconds

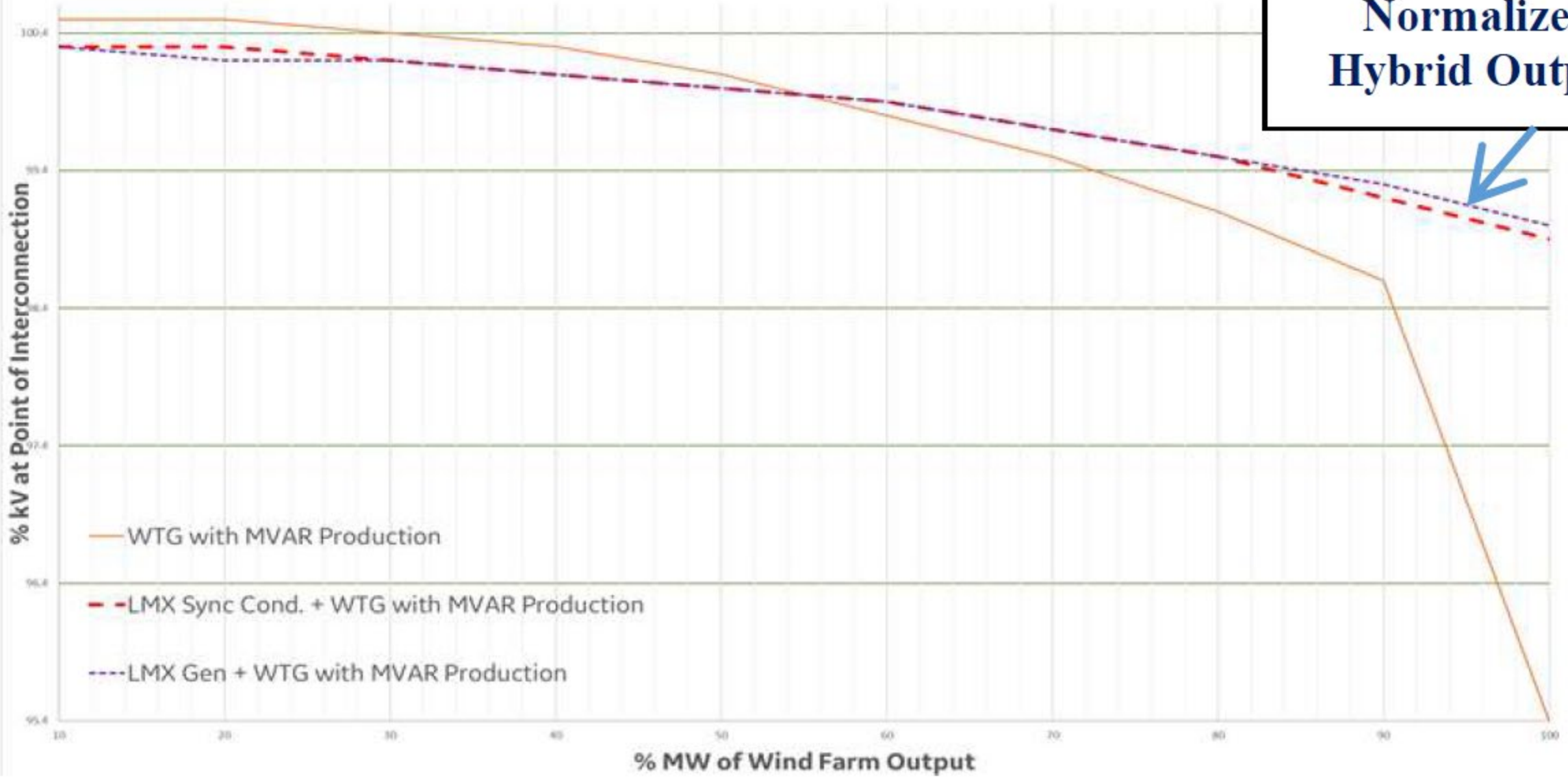
Simulation Results

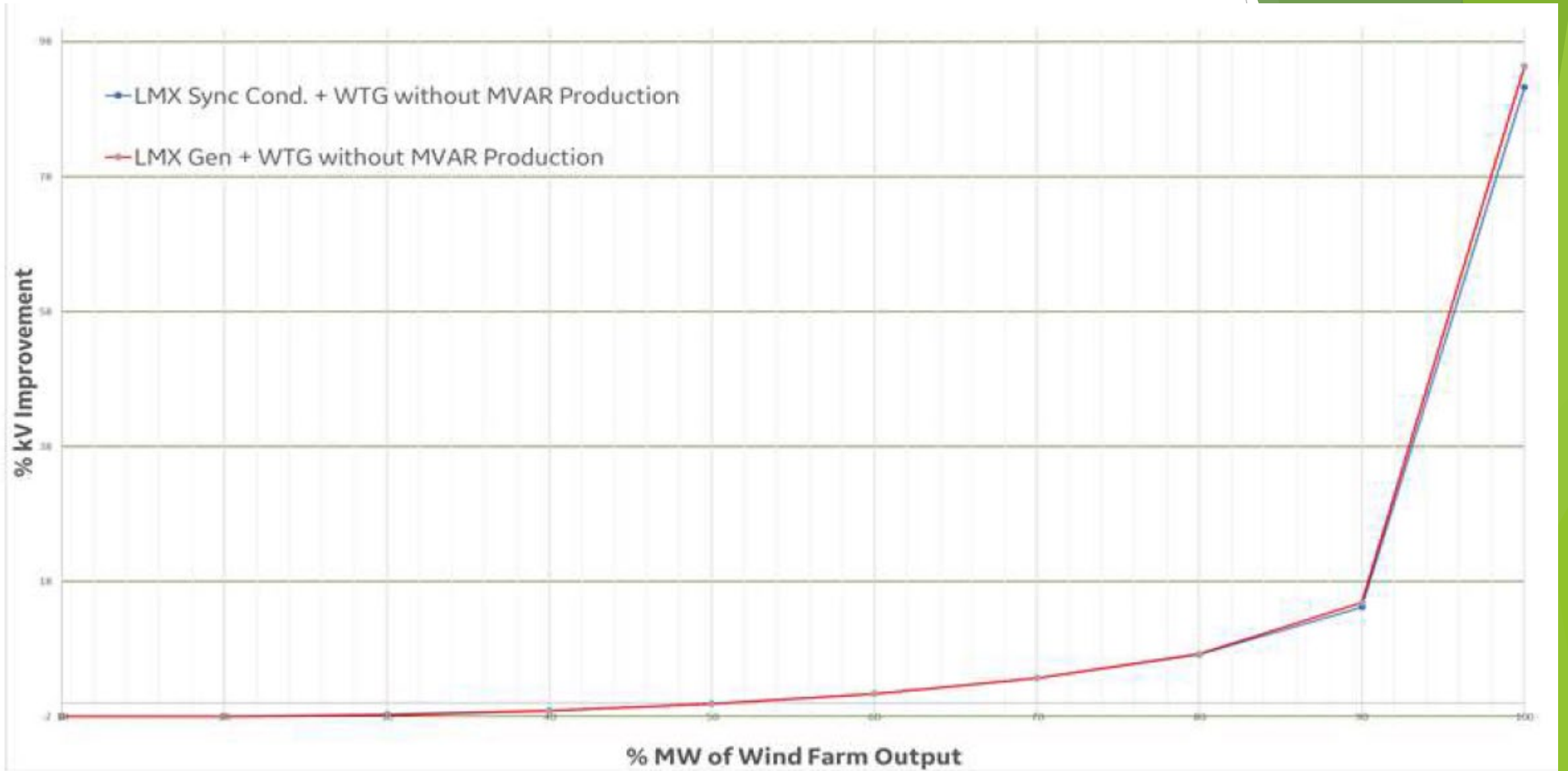
The background features abstract, overlapping geometric shapes in various shades of green, ranging from light lime to dark forest green. These shapes are primarily located on the right side of the slide, creating a modern, layered effect. The text 'Simulation Results' is centered in a clean, black, sans-serif font.

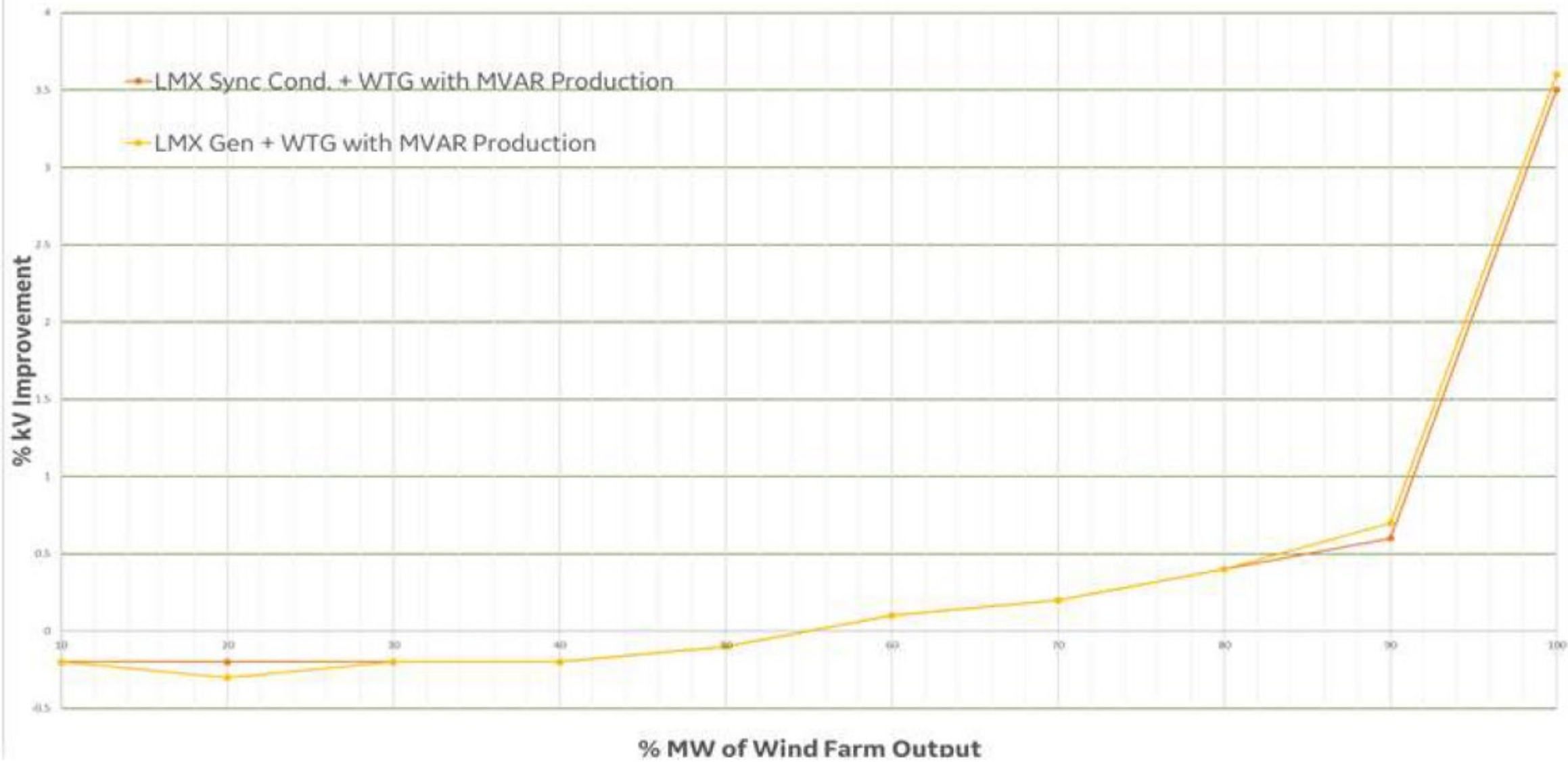
**Normalized
Hybrid Output**

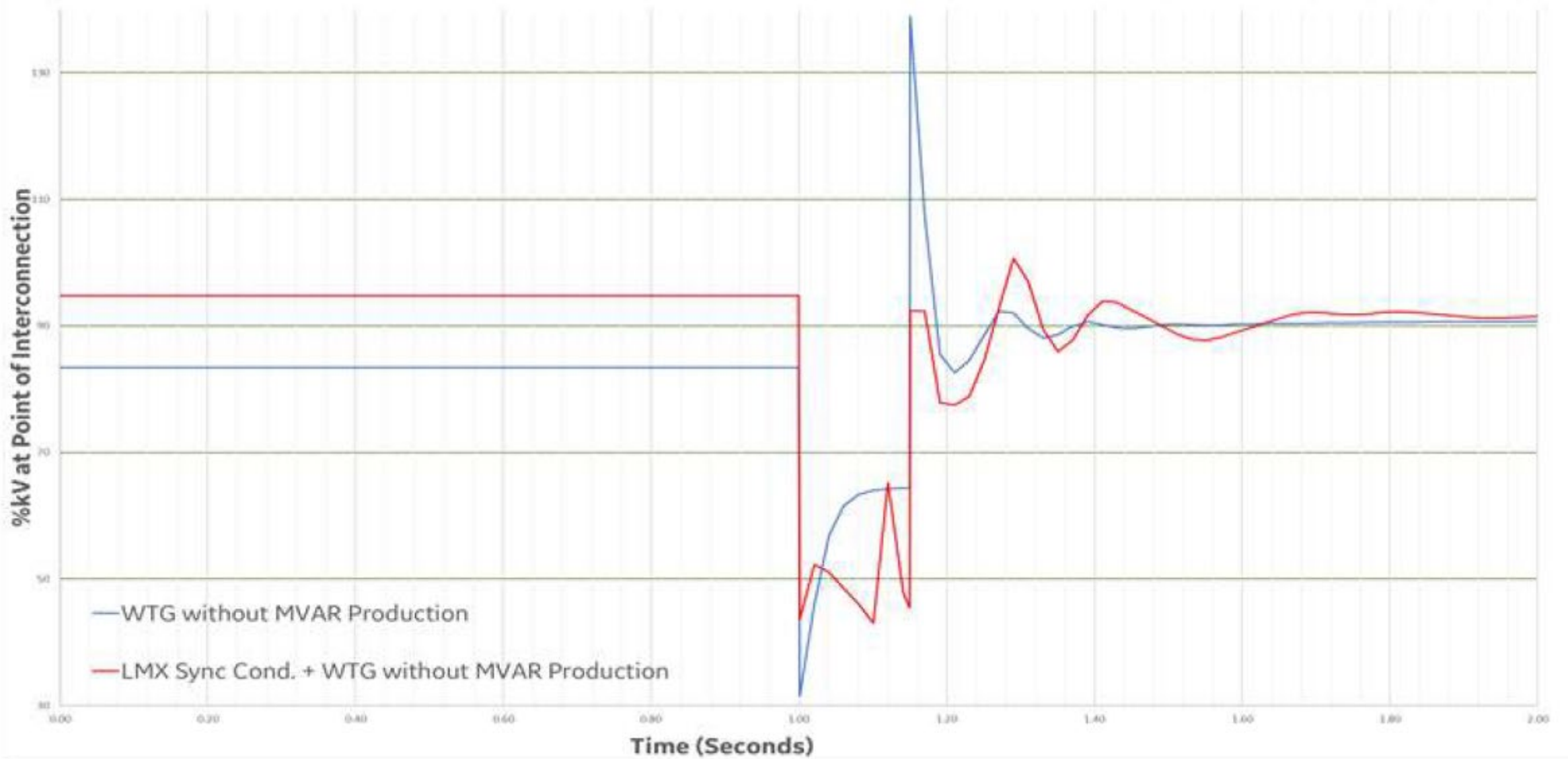


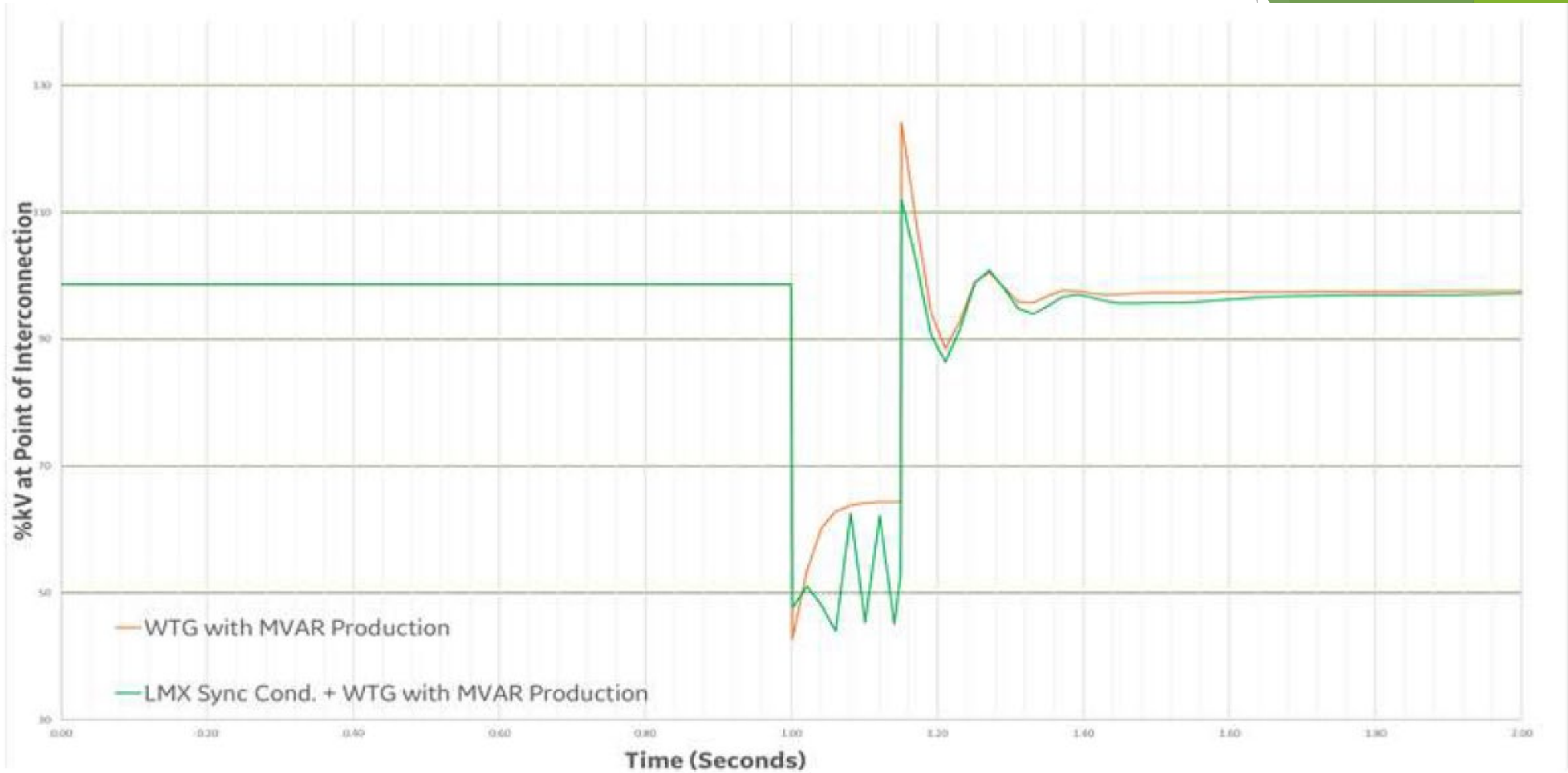
**Normalized
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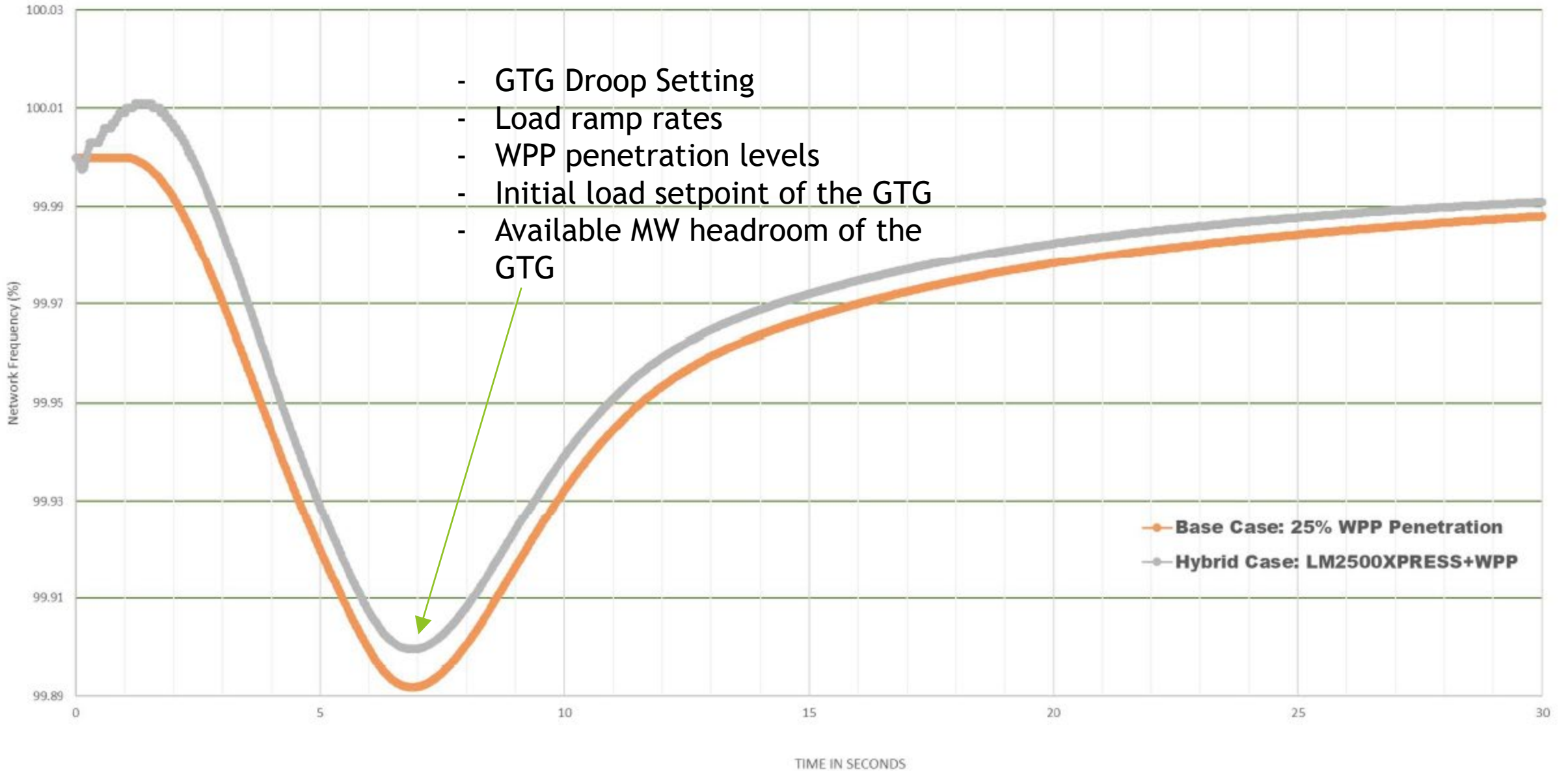


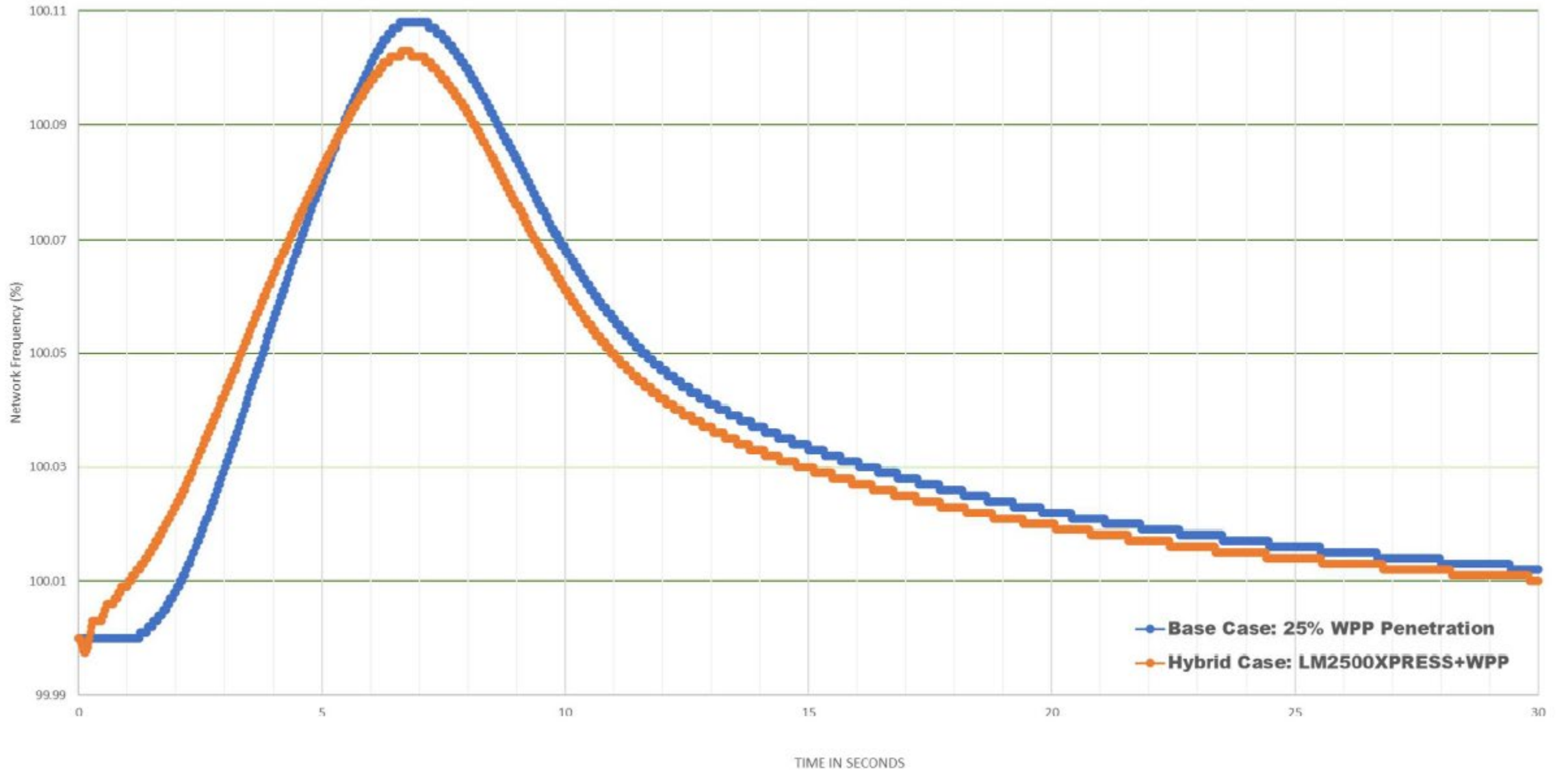




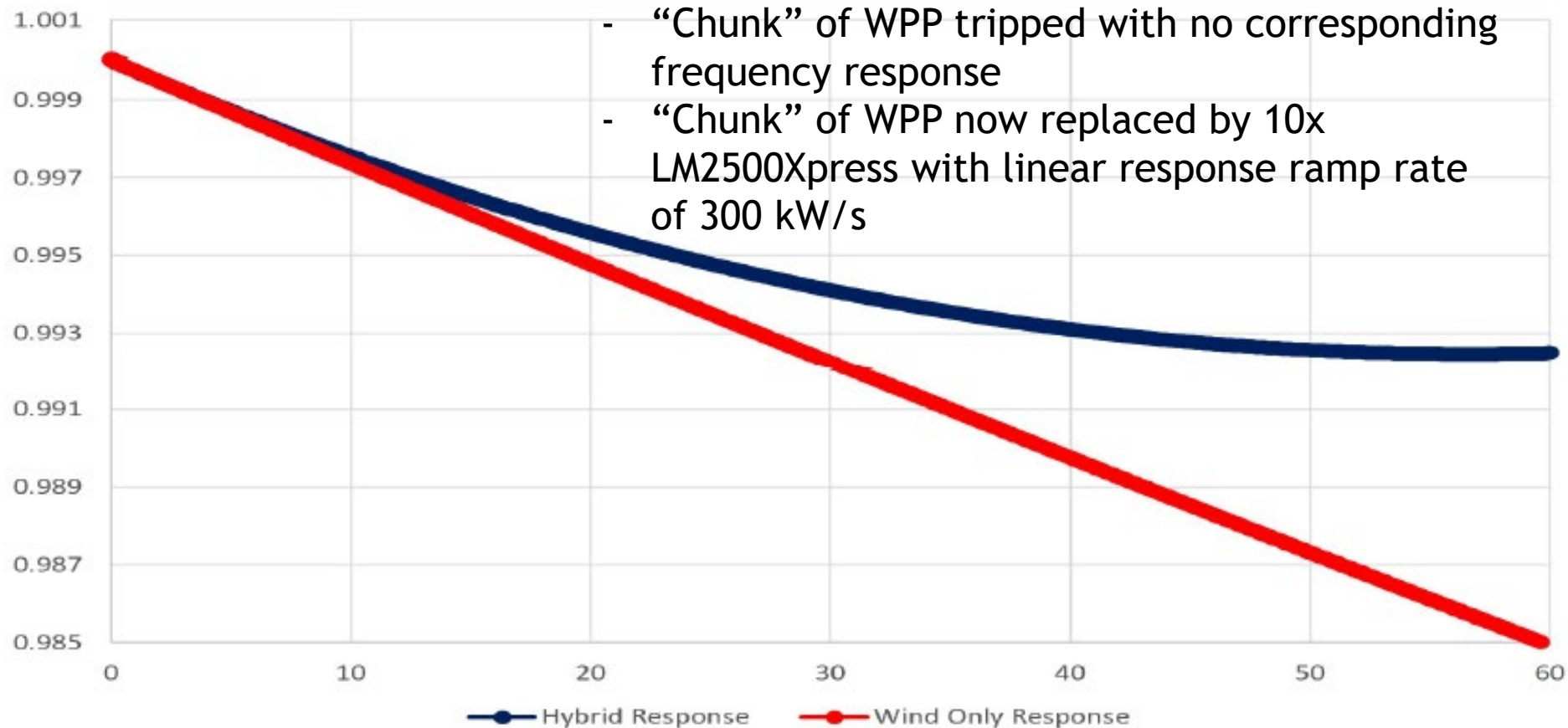


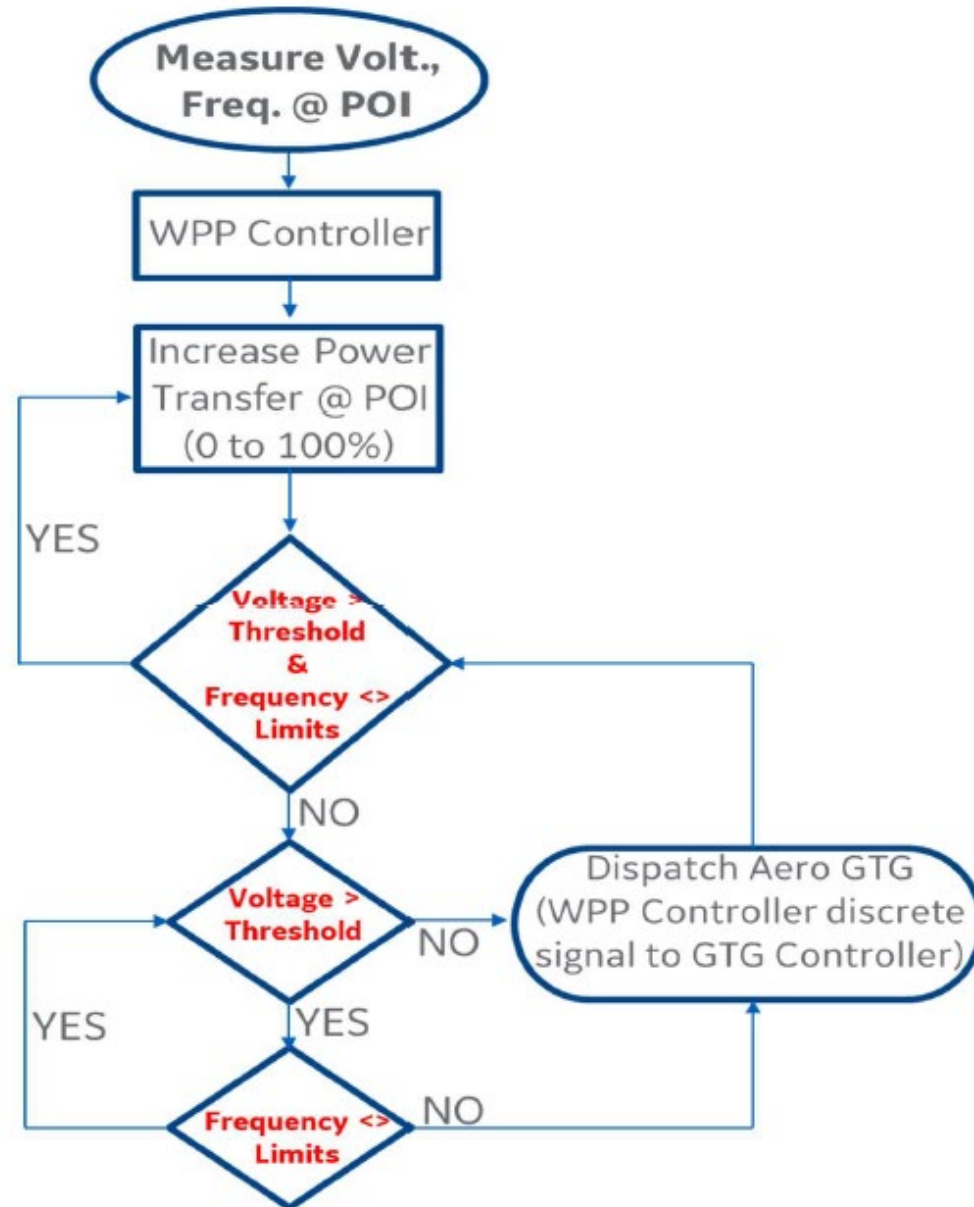







Time Scale	Response Type
0 to 1 second	Machine Inertia/kinetic energy
1 second to 1 minute	Primary (i.e. Governor action)
Greater than 1 minute	Secondary (i.e. MW setpoint adjustment)
Greater than 10 minutes	Tertiary (i.e. Plant re-scheduling)





Q & A

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