SAND2013-5119P

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Time Series Simulation of Voltage Regulation Device Control Modes

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U.S. DEPARTMENT OF ENERGY | NNSA

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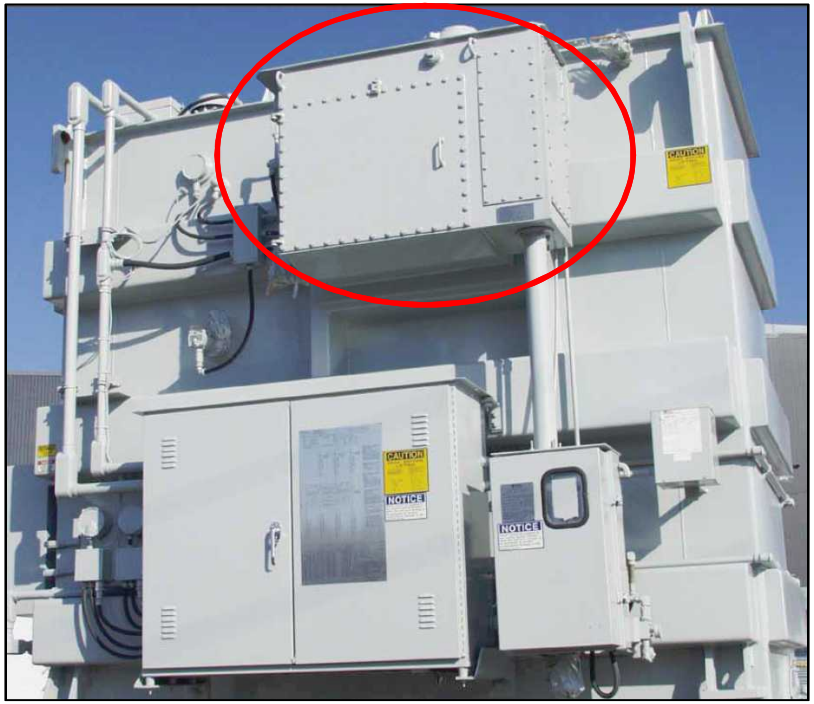
Main Points

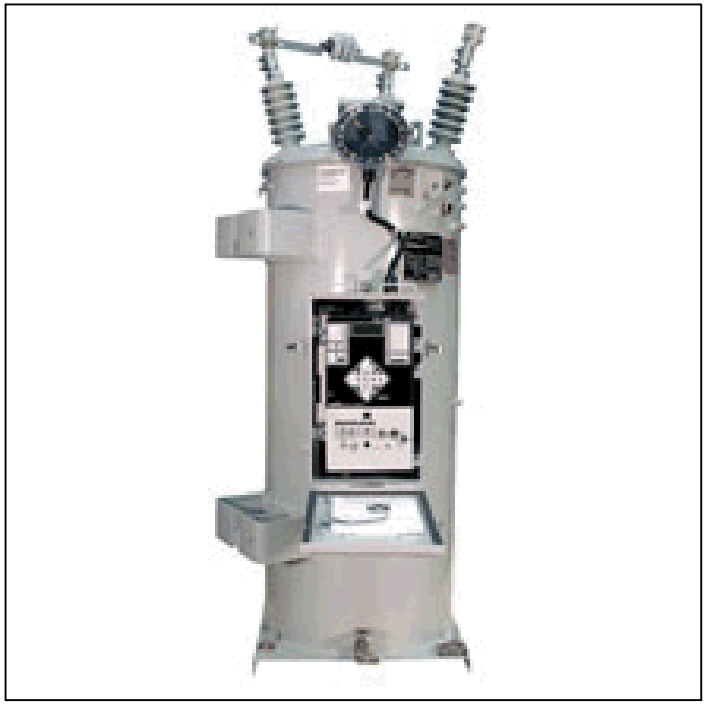
- Concerns – The integration of PV on a distribution feeder resulting in:
  - An increase in voltage regulation device operations, resulting in a shorter life span and/or a more aggressive maintenance schedule.
  - The need to reevaluate device control settings to accommodate for the changes that come with PV.
  - The need to develop an effective mitigation strategy for negative impacts.
- Common voltage regulation devices and their controls.
- Proper simulation of time dependent aspects and control modes.

Voltage Regulation Devices

- Load Tap Changers (LTCs) and Voltage Regulators (VREGS)
  - Capable of changing voltage up to ±10% through incremental tap positions.
  - Make-before-break mechanisms allow for voltage changes without load interruption.



Waukesha® Transformer



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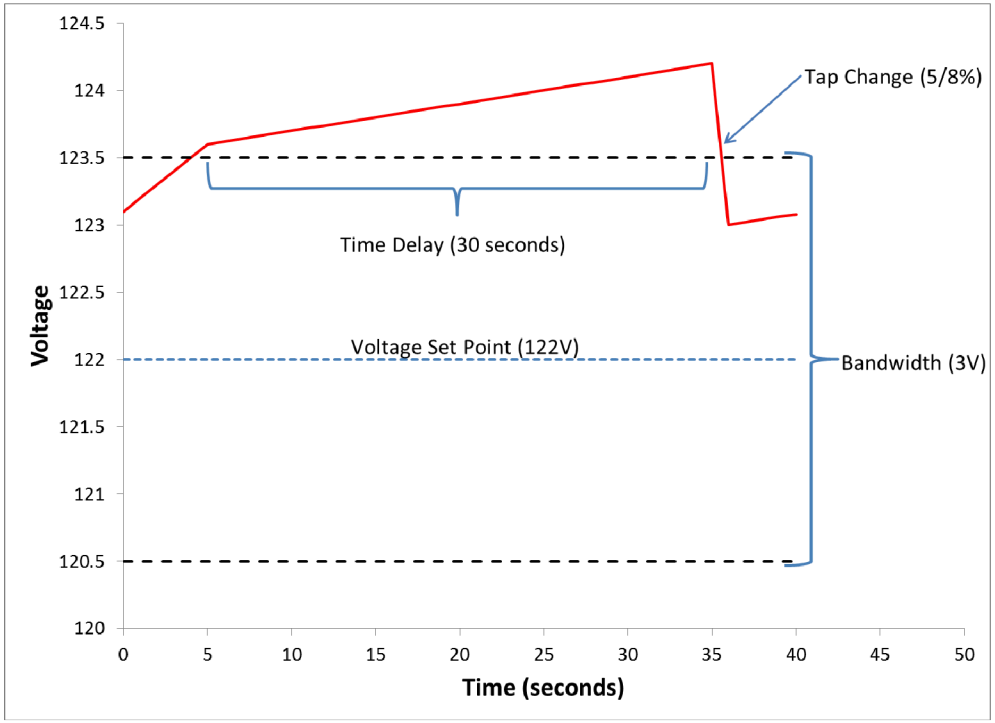
Voltage Regulation Devices

- Switched Capacitor Banks
  - Defined by kVAr rating of bank.
  - Voltage rise proportional to rating.

http://www.energyinnovationcorridor.com/page/wp-content/uploads/2011/01/IMG_0574.jpg

Device Controls and Modes

- LTCs and VREGs Basic Settings
  - Voltage set point
  - Bandwidth
  - Time Delay
  - Line Drop Compensation (LDC) – Resistance and Reactance



Device Controls and Modes

- LTC and VREG Operating Modes
  - Sequential – Timer begins with a voltage excursion outside of the bandwidth and initiates a tap change if voltage remains out-of-band for duration of time delay. Timer resets if voltage returns within band before duration of time delay.
  - Time Integrating - Timer begins with a voltage excursion outside of the bandwidth and initiates a tap change if voltage remains out-of-band for duration of time delay. If voltage returns within band before duration of time delay, the timer is decremented.
  - Voltage Averaging - Timer begins with a voltage excursion outside of the bandwidth and during the excursion the voltage is monitored and averaged. If excursion remains out-of-band through the time delay duration, the number of taps required to bring voltage back to the voltage set point is calculated and the taps are executed without delay.

Device Controls and Modes

- VREG Reverse Power Operation Modes
  - Locked Forward Mode – Always operates with the forward direction settings and monitoring. If reverse power is sensed, tap position remains on last position regardless of reverse current level.
  - Neutral Idle Mode – When the reverse current threshold is exceeded for 10 continuous seconds, the control will tap to neutral and holds there until forward current threshold is exceeded again.
  - Bi-directional Mode – Uses reverse power settings when reverse current exceeds the reverse power threshold, and returns to forward settings when forward power threshold exceeded.
  - Cogeneration Mode – Focuses voltage regulation on cogeneration side of VREG, even under reverse power, by always using forward power metering and only changing LDC settings to account for changes in power flow direction.

http://www.cooperindustries.com/content/dam/public/powersystems/resources/library/225_VoltageRegulators/S225701.pdf

Device Controls and Modes

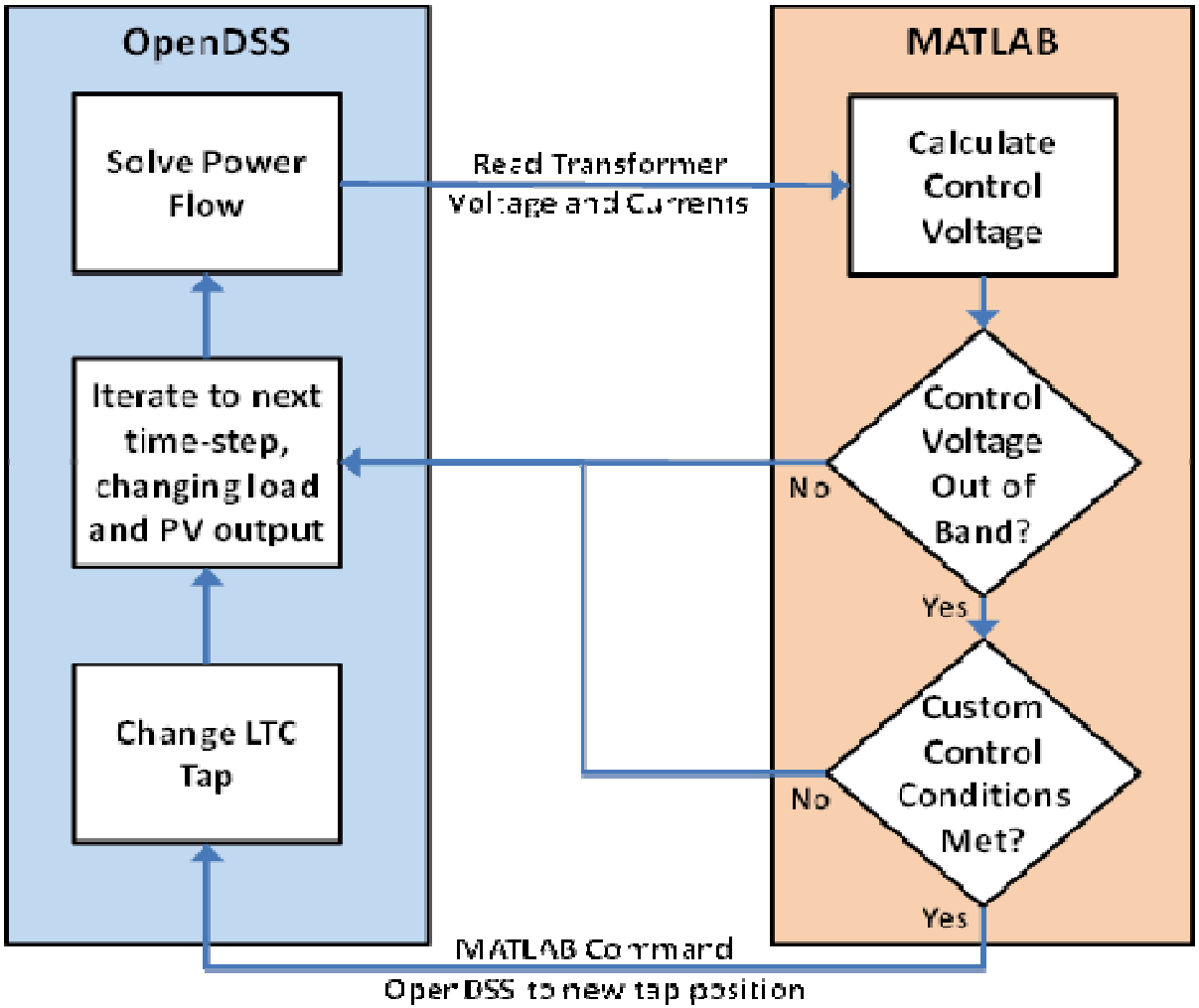
- Switched Capacitor Control Modes and Settings
  - Time Schedule – Time on and time off.
  - Voltage – Voltage threshold on and voltage threshold off, time delay.
  - Temperature – Temperature threshold on and temperature threshold off, time delay.
  - VAr (PF) – PF/VAr threshold on and PF/VAr threshold off, time delay.
  - Current – Current threshold on and current threshold off, time delay.

http://www.abb.us/product/db0003db004279/9b04ded0266732fac1257af700221a88.aspx

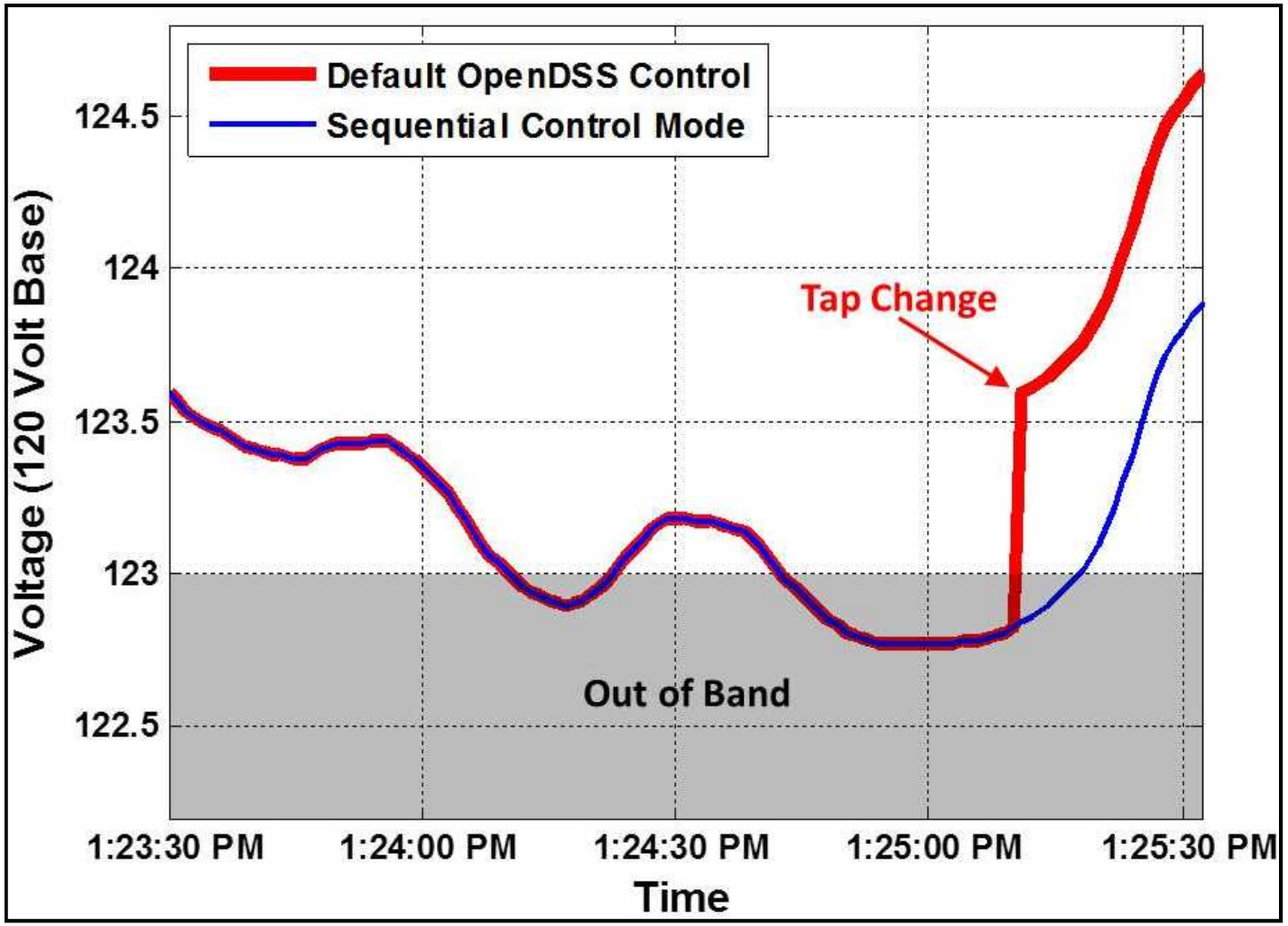
Proper Analysis

- Quasi-Static Time Series (QSTS) Simulation
  - Advantages
    - Time-dependent aspects
    - Operation quantity
  - Challenges
    - Model conversion
    - Data intensive
      - Low load data resolution
      - PV Output estimation
      - Computation burden
    - Customization

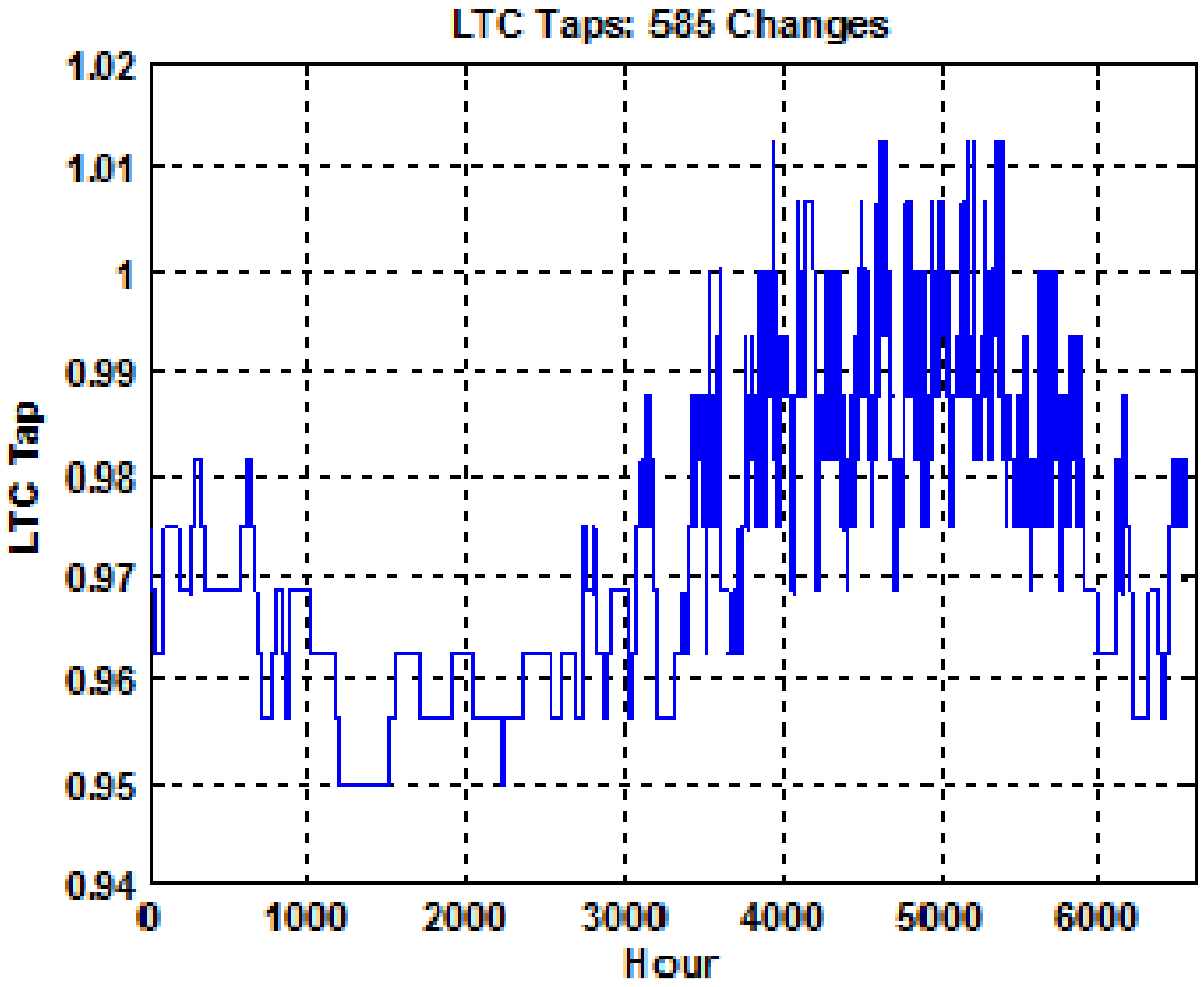
Implementing Custom Controls



Implementing Custom Controls



Implementing Custom Controls



Moving Forward

- Field validation:
  - How much closer to actual operation counts does customized control simulation get you than simple defaults?
  - How much error does the underrepresentation of load variability cause?
- More sensitive examples:
  - Voltage regulator near large PV deployment with daily reverse power flow.
  - Voltage or PF controlled capacitor banks near PV deployment.