Evaluation of Voltage & Reactive Power Management Schemes for Distribution Circuits with RTDS

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Volt/VAR Control in the Era of the Smart Grid

July 29, 2015 (1-3 pm)

Outlines

- Introduction
- Objectives and approach
- Existing methods
- Reported issues and gaps
- Solutions and verifications
- Control Hardware in Loop (CHIL) testing
- Test results and summary
- Next steps

Introduction

- Almost every utility is re-evaluating and investing their Volt/VAR management schemes:
  - Business drivers are strong ! Many stakeholders are involved
  - Customer complains and regulatory requirements to enhance voltage quality at service entrance (voltage sensitive appliances)
  - High penetration of DERs, especially PV and wind, causing voltage issues due to sudden changes and reverse power flow
  - Automation and optimization opportunities to reduce demand through managing losses and demands with CVR (conservation voltage reduction)
  - Use the schemes to detect faulty devices and reduce maintenance (e.g. fuse blown on switched caps)

Investigation Approach

- Investigate methods presently applied in the field
- Analyze the issues and gaps in the existing methods
- Identify solutions for enhancing existing schemes – incremental improvements (what other utilities have done!)
- Verify proposed solutions through Control Hardware in Loop (CHIL) testing
- Investigate cost and benefits of advanced Volt/VAR control methods – business aspects and visions
- Methods of incorporating Inverter-based voltage control strategies: pf, dynamic Var, Voltage regulation
- Evaluate control schemes (vendor offering)
- Develop deployment roadmap

Key Targets for Volt/VAR Program

- To manage the voltage profiles of distribution circuits within a prescribed voltage range according to circuit designation (e.g. CVR versus non-CVR circuits)
  - In addition, the method should prevent and correct any impact on the voltage profile of adjacent circuits due to variations in operating voltage set points or reactive power of a target circuit.
- To reduce energy consumption, line losses, and demand by optimizing voltage level and adjusting reactive power flow throughout the circuit
  - maintaining the designated reactive power (or power factor) requirements on transformer banks at the substation

Existing Volt/VAR Methods

- Two generation of schemes:
  - Passive schemes, using localized (device-level) controls and time delay (time-bias)
    - no communications, standard settings and controls
    - Pre-programmed delays
  - Limited number of SCADA controlled feeder devices
    - Operator control of switched capacitors (remote on/off) and adjusting of tap position on voltage regulators
    - To control with D-SCADA, a device needs to be in manual mode
    - Not a large coverage of circuits

Reported Problems

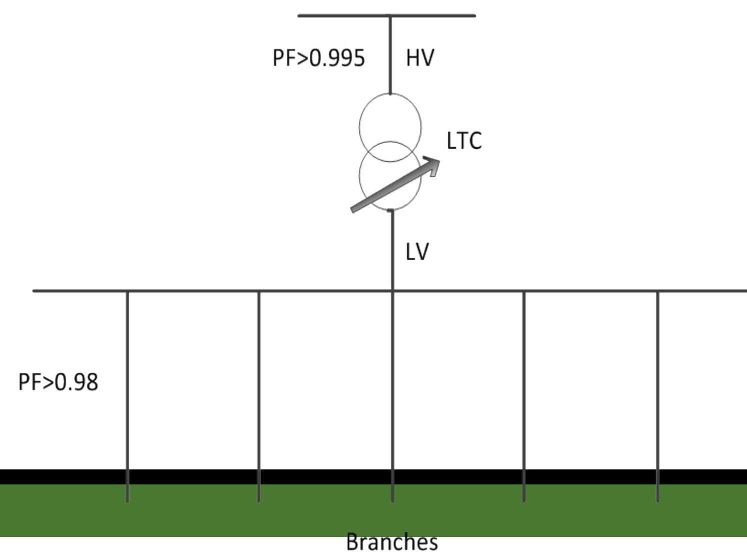
- **Voltages going out of acceptable ranges**
  - DG additions, time biased Capacitors, and VRs with tap saturation
- **Reverse power flow affecting operation, due to large DG installations**
  - Increase in voltages, possible impact on forward looking VRs
- **Low accuracy CTs and PTs (or no CTs) + bad measurements**
  - Bad (or no) measurements → how can they trust data?
- **Ringing phenomena produced by switching on/off capacitors**
  - Can the number of switching be limited or can we control the transients?
- **Nuisance voltage alarms from SCADA Caps – too many alarms**
  - Alarm processing and prioritization is needed!
- **Excessive voltage regulator (tap) operations – wear/tear impact**
- **Excessive VAR injection to transmission systems during light loading of circuits, causing transmission overvoltage problems**
  - Step by step cap switching for substation cap, or adjusting time bias on circuit caps

Regulatory and Planning Requirements

- Operating voltage for the circuits:

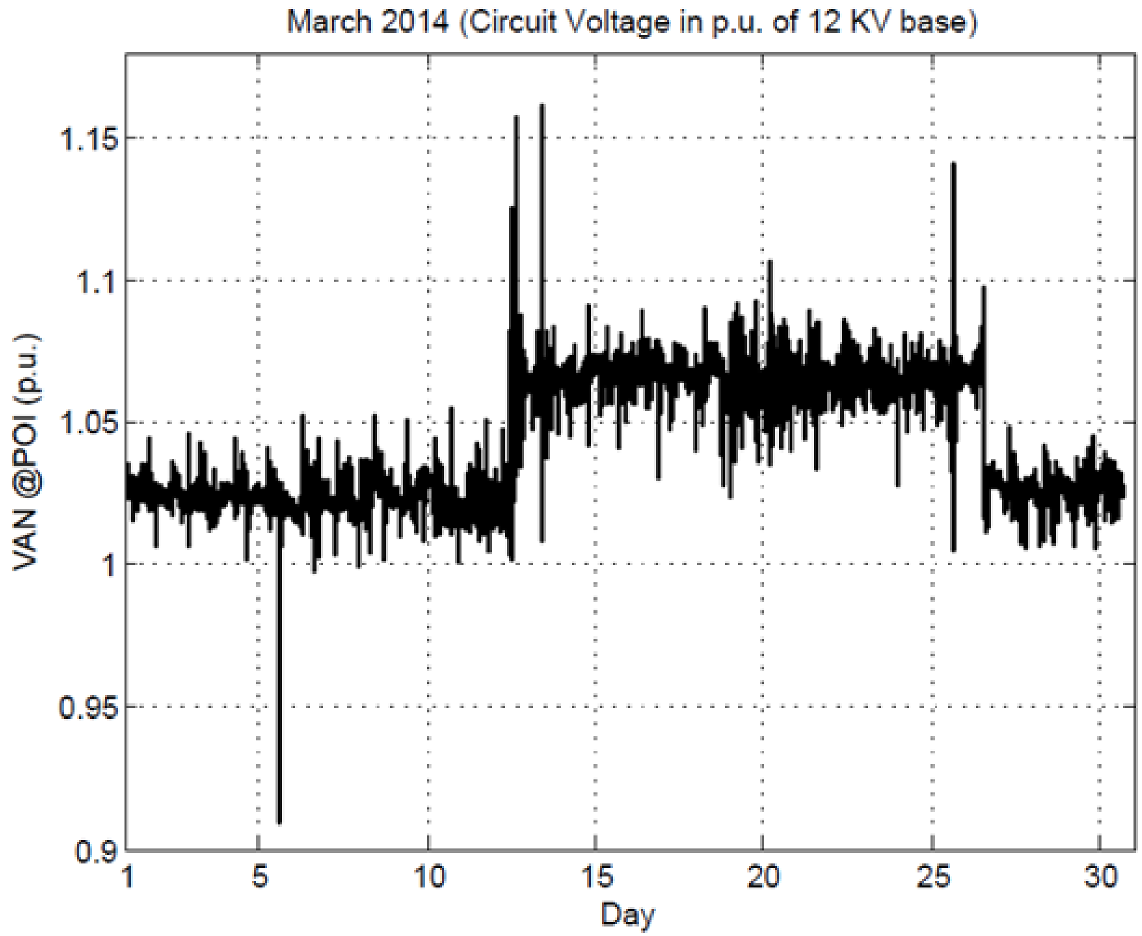
	Maximum Voltage	Minimum Voltage	Contingency Voltage (min)	Service entrance voltage
Non-CVR circuits	12.6 kV (1.05 pu)	11.9 kV (0.992 pu)	11.5 kV (0.958 pu)	120V ±5%
CVR circuits	12.3 kV (1.025 pu)	11.9 kV (0.992 pu)	11.5 kV (0.958 pu)	120V ±5%

- Power factor and reactive power constraints:



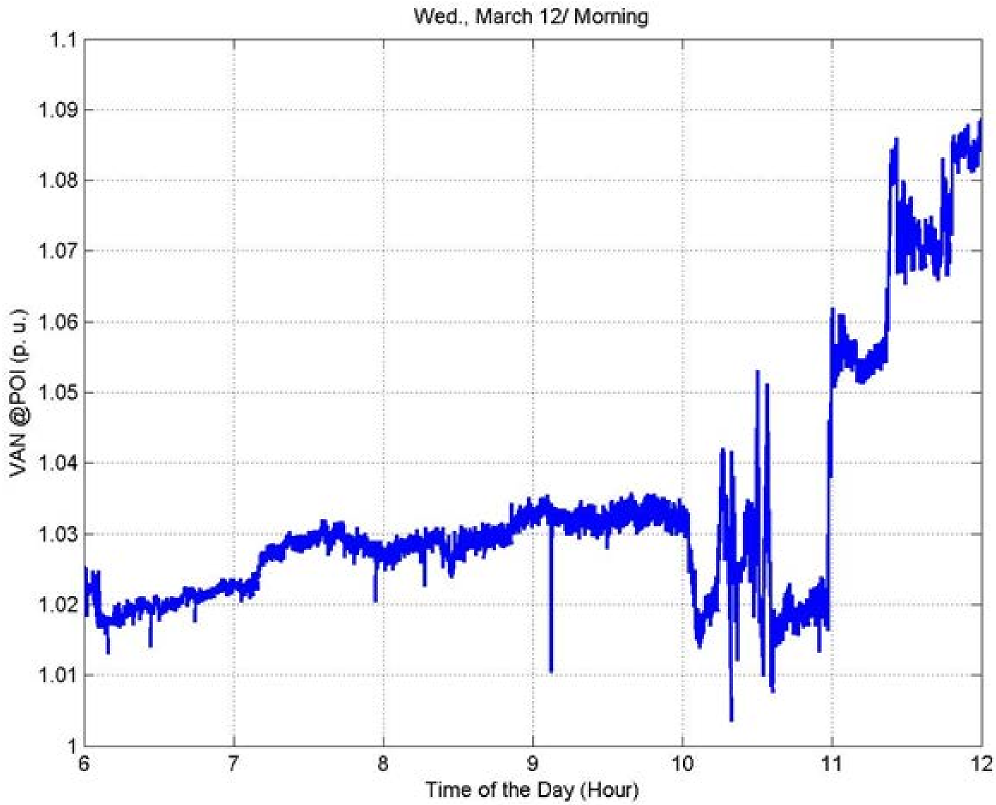
Enhance Monitoring to Detect Issues

- Extensive overvoltage on part of a circuit



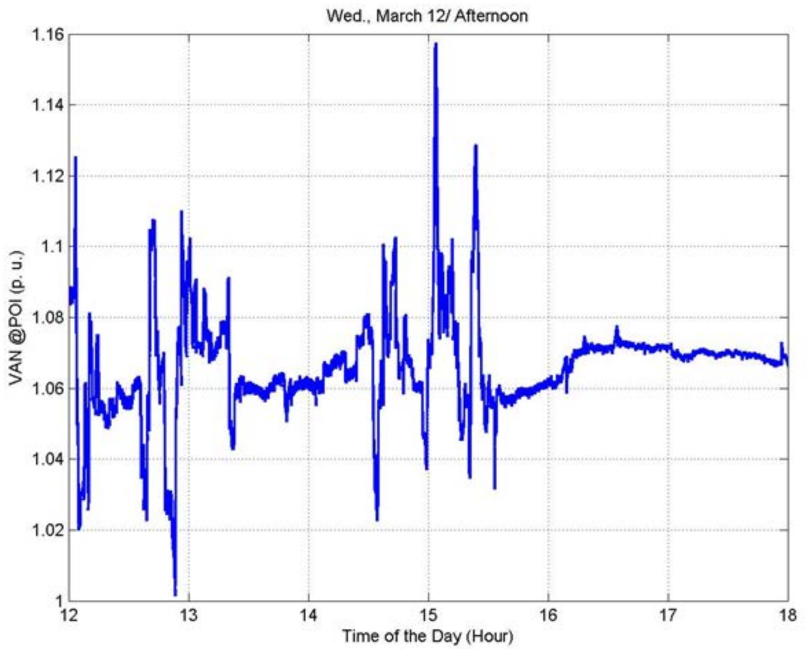
Voltage Increase due to High PV

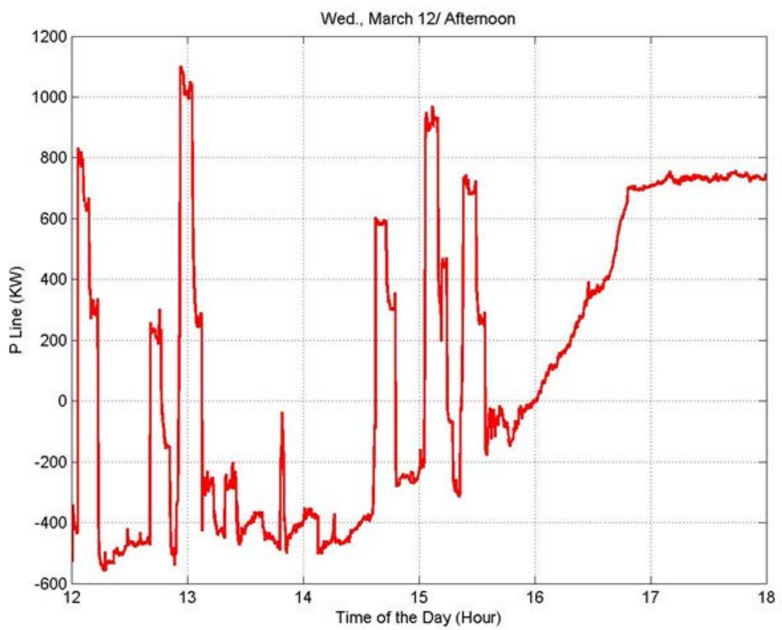
- Significant voltage increase during noon time (1.09 pu)



Extreme Voltage Fluctuations

Voltage Variations

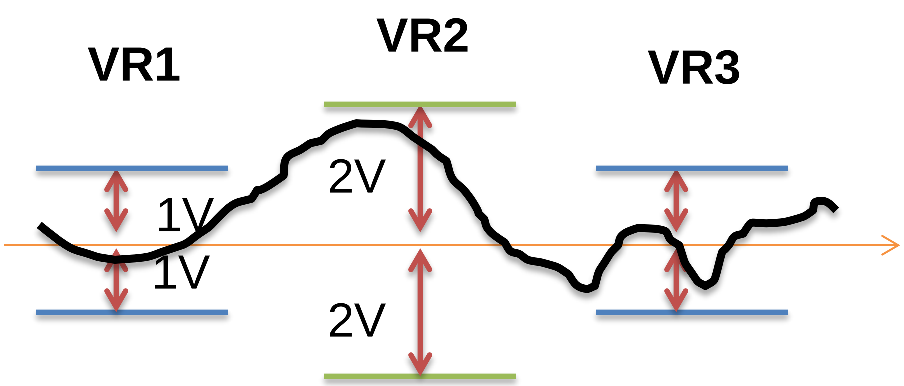




Effect of PV fluctuations

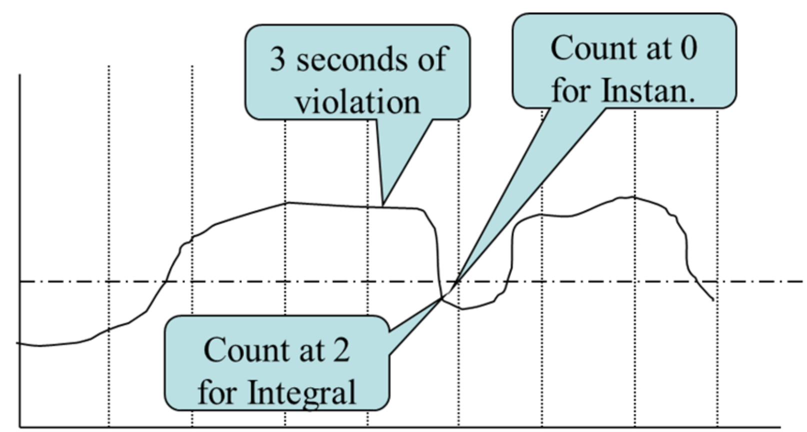
Solutions and Test Cases

- Base case evaluation – No PV and with PV
- Change of control modes on Voltage Regulators: Lock forward, co-gen, or bidirectional
- Change of timer resetting methods for controllers (Fast reset, Disk)
- Change of bandwidth range for adjusting the control response
- Change of power factor at PV facility (fixed, non-unity power factor on legacy inverters)

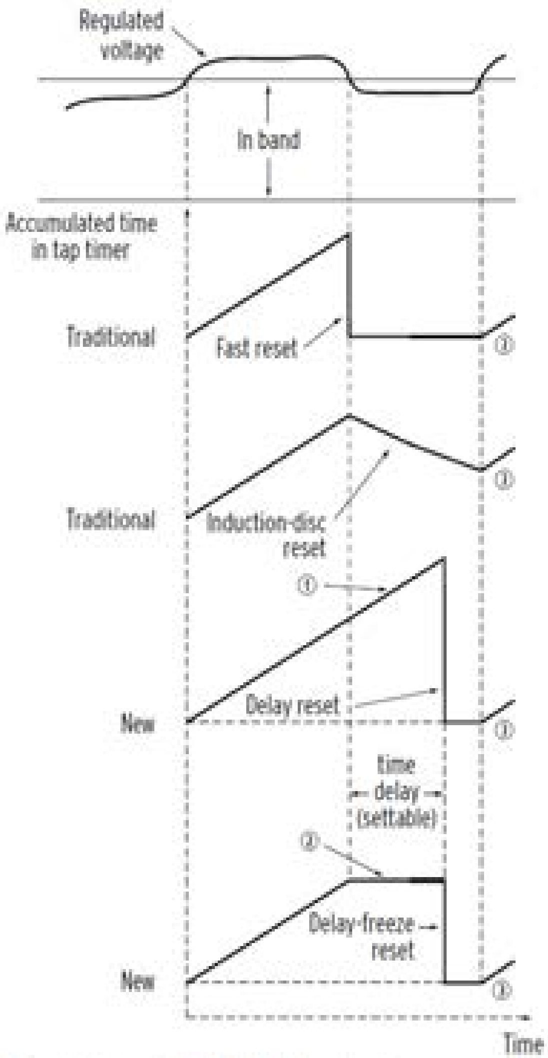


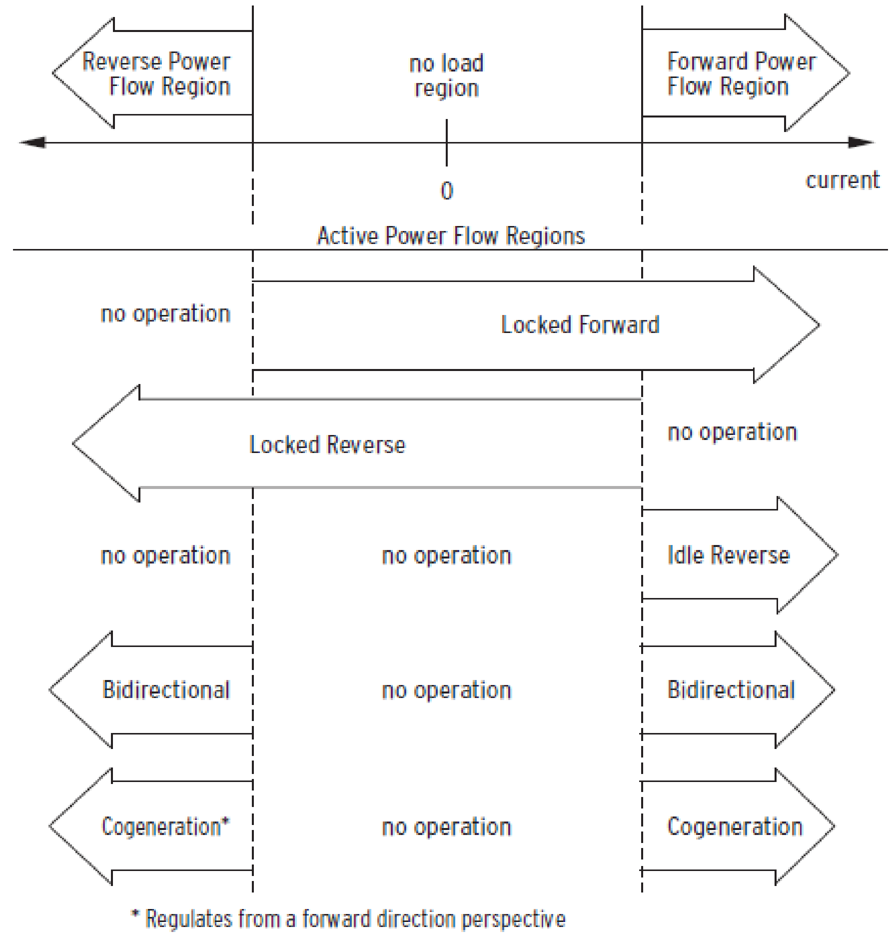
Bandwidth Control

Timer reset methods

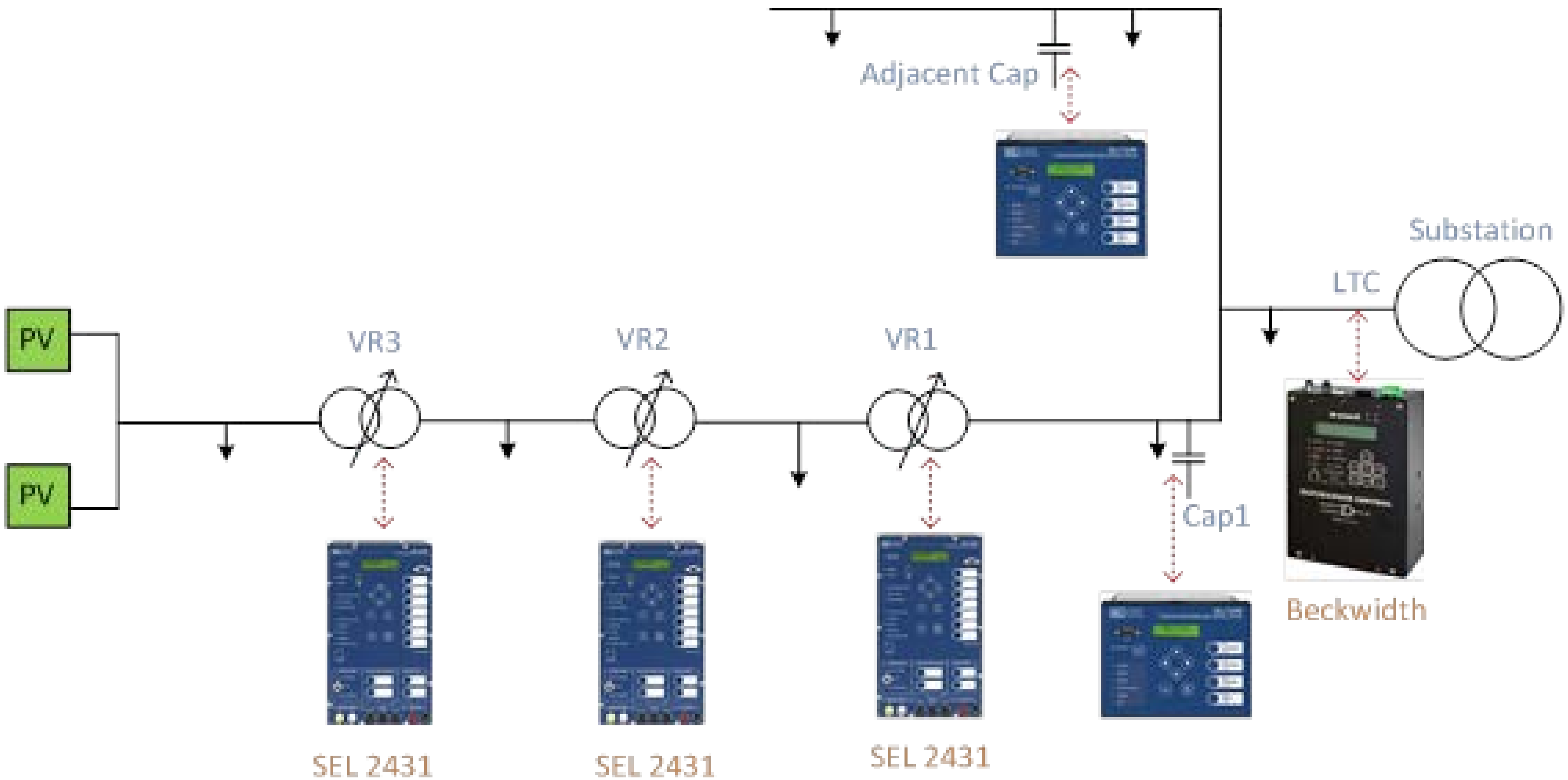


VR Operating Modes & Controls

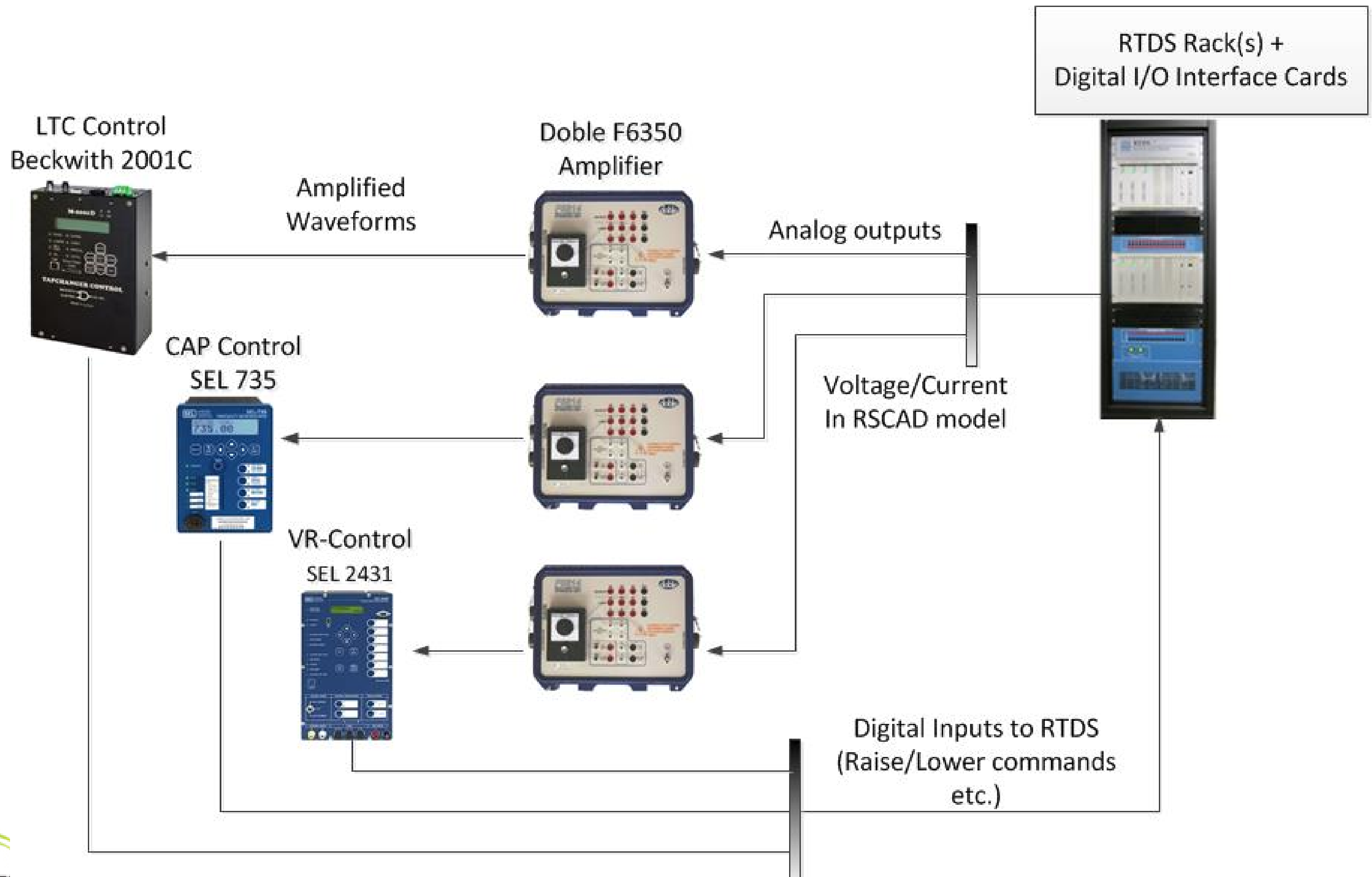




Study Circuit



RTDS – Control Hardware in Loop



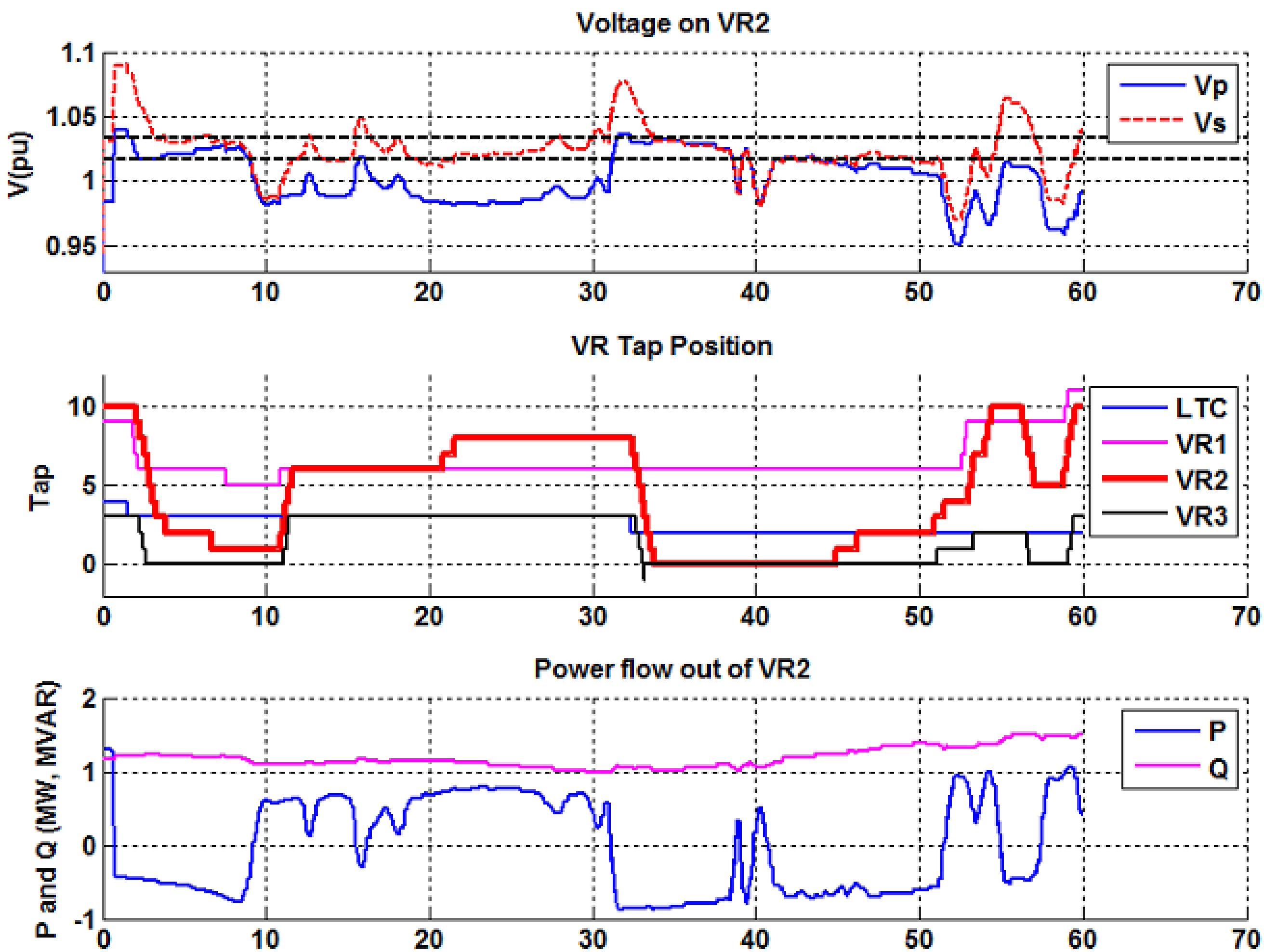
Test Results

	Case #	1	2-a	2-b	3-b	5-a	5-b
	Device	Cogen with Fast Reset	Cogen with Disk Reset	Cogen with Disk Reset & 0.95 lagging PV PF	Cogen with Fast Reset & High-range LDC setting on VR3	Cogen with Disk Reset & Wide Bandwidth setting (4V) for VR2	Cogen with Disk Reset & Wide Bandwidth setting (4V) for VR2 & 0.95 lagging PV PF
Tap operations	LTC	1	1	1	1	1	1
	CAP	0	0	0	0	0	0
	VR1	8	11	5	3	6	3
	VR2A	42	45	19	51	31	10
	VR2B	40	42	21	45	31	12
	VR2C	52	47	18	53	33	10
	VR3A	22	23	15	29	36	17
	VR3B	21	33	13	27	31	22
	VR3C	24	24	9	26	36	21
% of time voltage in the acceptable range (0.98 - 1.05 pu)	LTC	100%	100%	100%	100%	100%	100%
	CAP	100%	100%	100%	100%	100%	100%
	VR1A	99%	99%	100%	99%	99%	100%
	VR2A	90%	89%	97%	88%	90%	97%
	VR2B	91%	90%	96%	89%	90%	98%
	VR2C	88%	88%	98%	89%	90%	98%
	VR3A	86%	84%	95%	82%	87%	95%
	VR3B	87%	86%	96%	84%	87%	95%
	VR3C	86%	86%	96%	83%	87%	96%
	PV	81%	80%	99%	80%	81%	99%

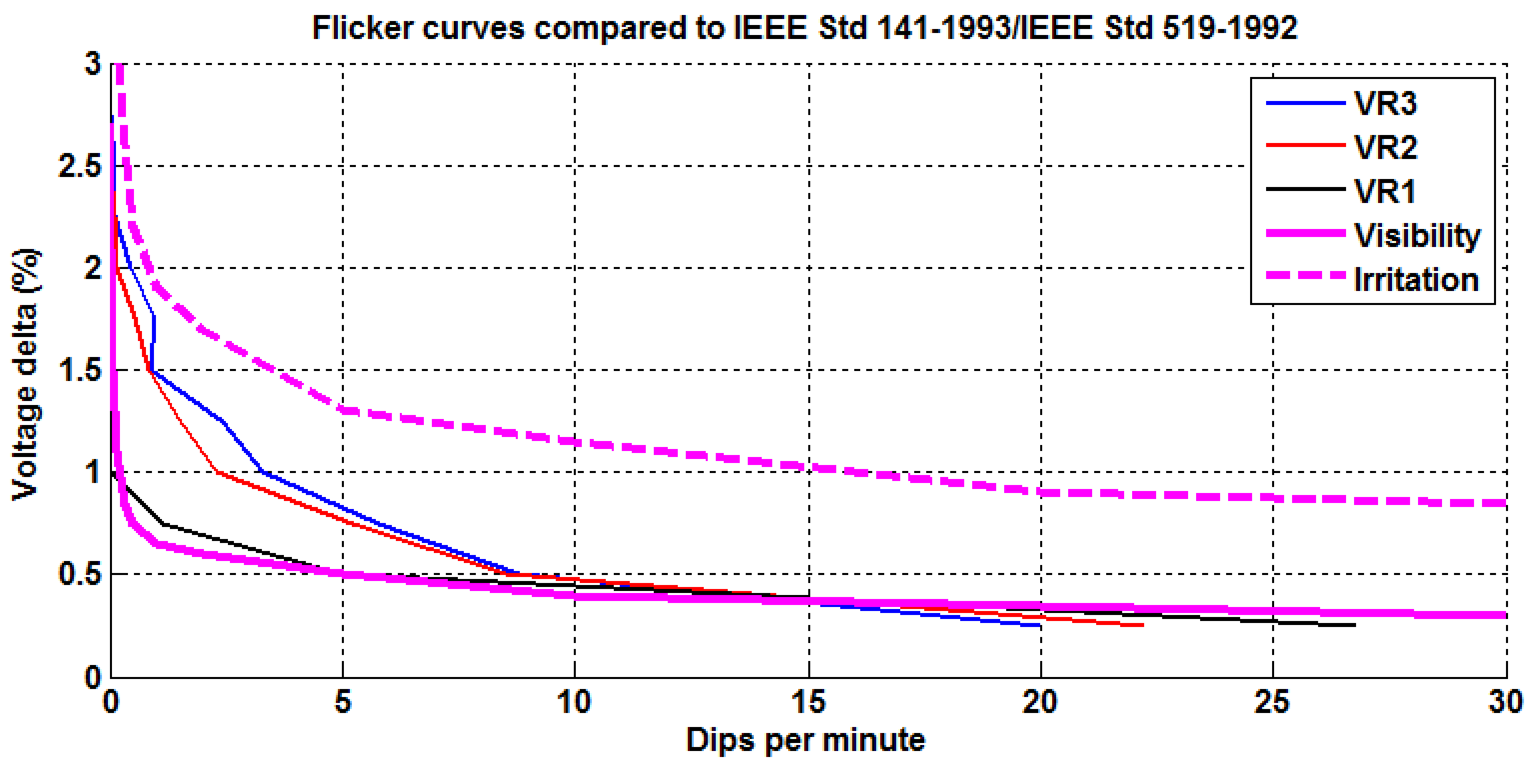
Case 1 – VR2 Operation and Voltage Profile

14% out of band

52 tap change



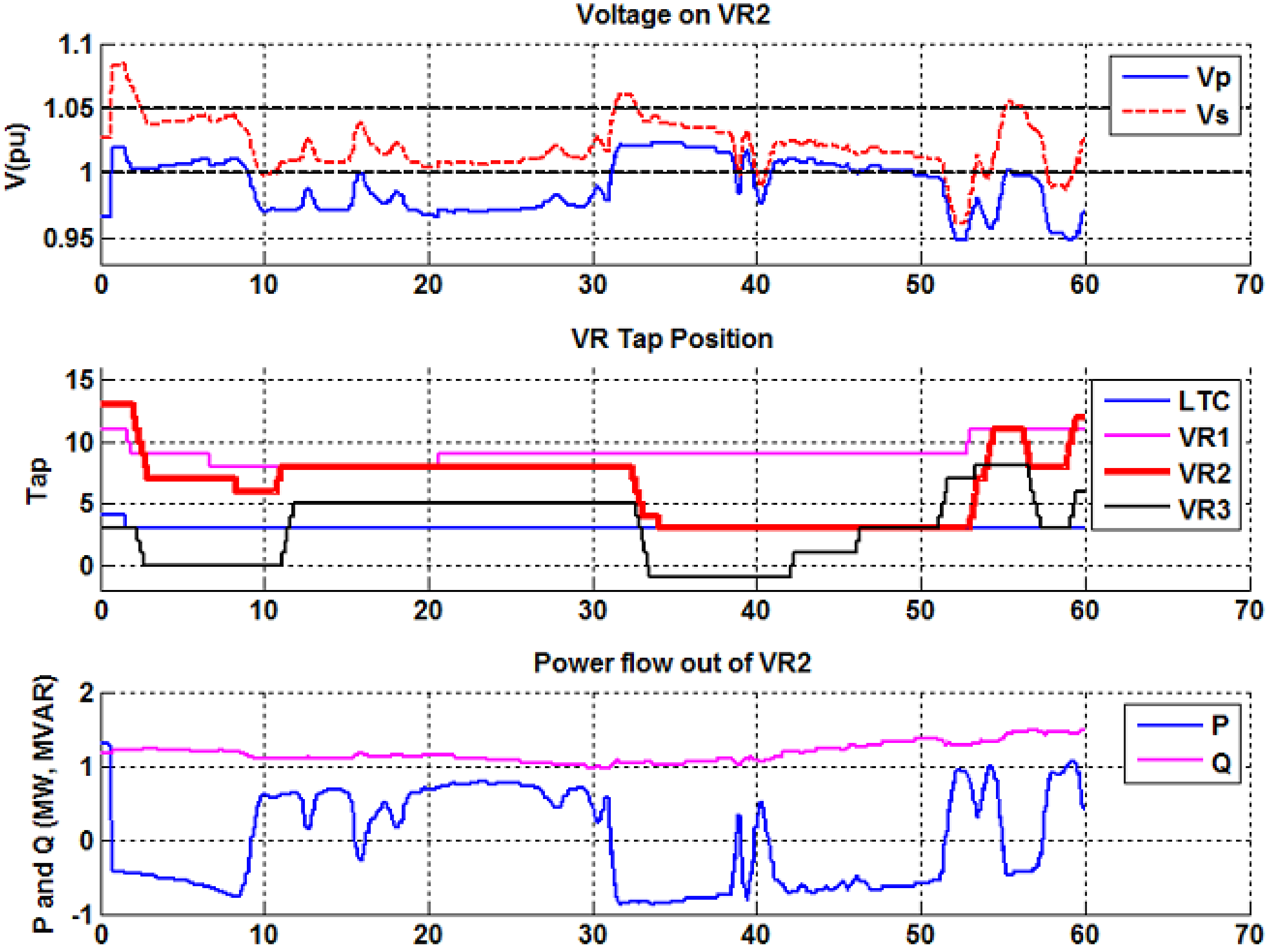
Flicker due to Frequent Voltage Changes



Case 5-a: VR2 Operation and Profile

10% out of band

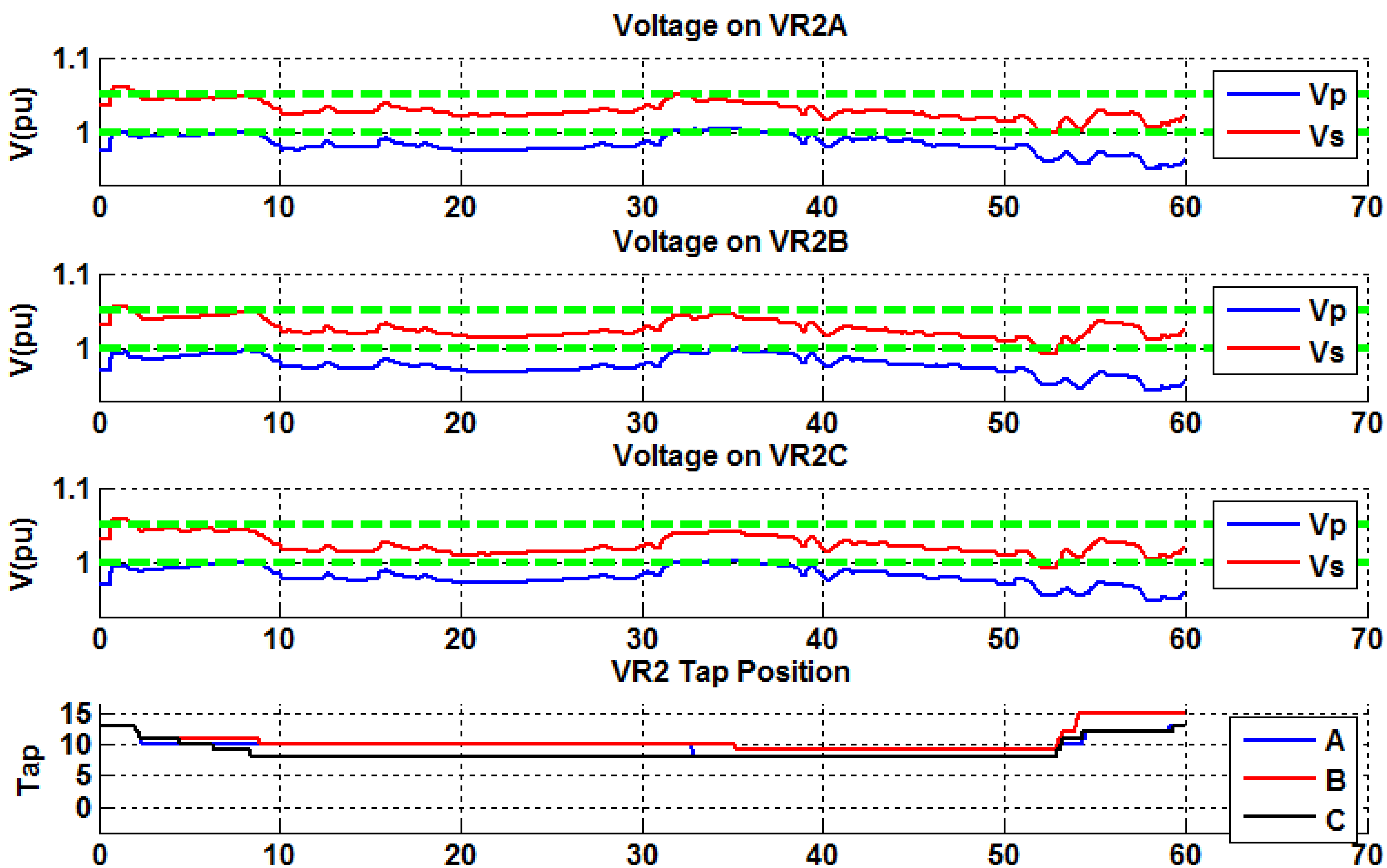
31 tap change



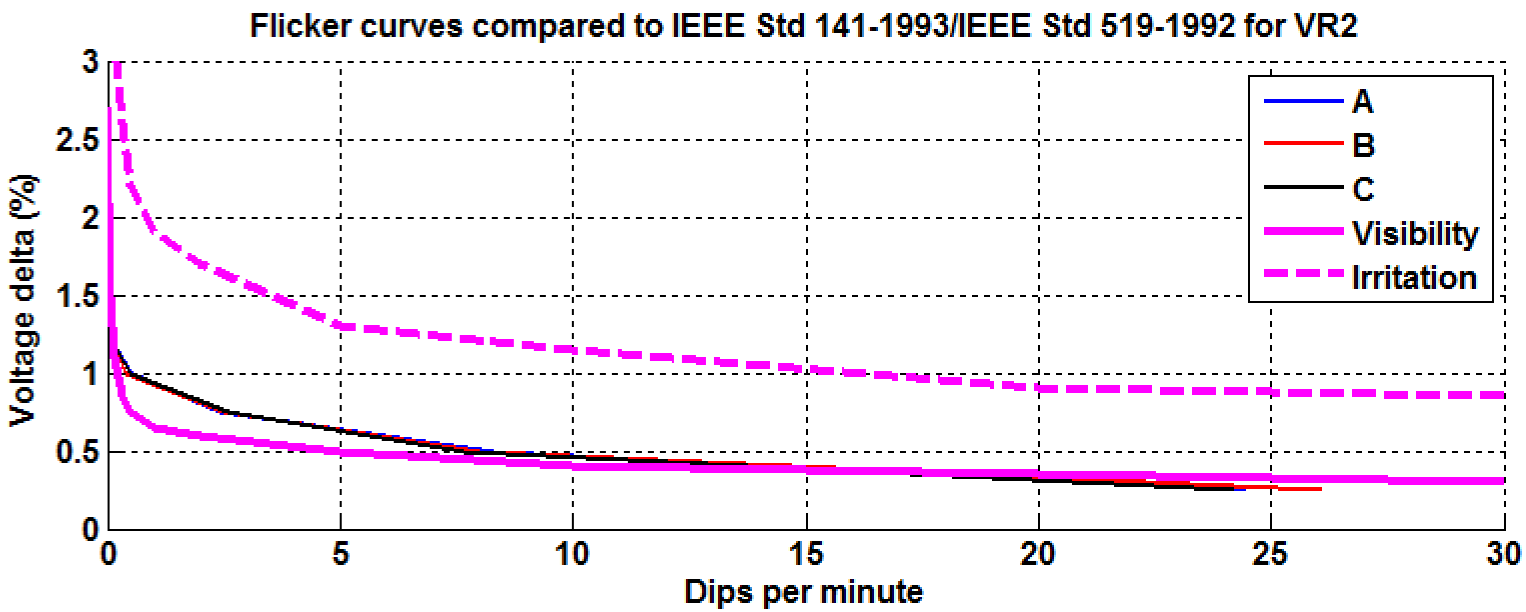
Case 5-b: VR2 Operation (non unity pf)

2% out of band

10 Tap change

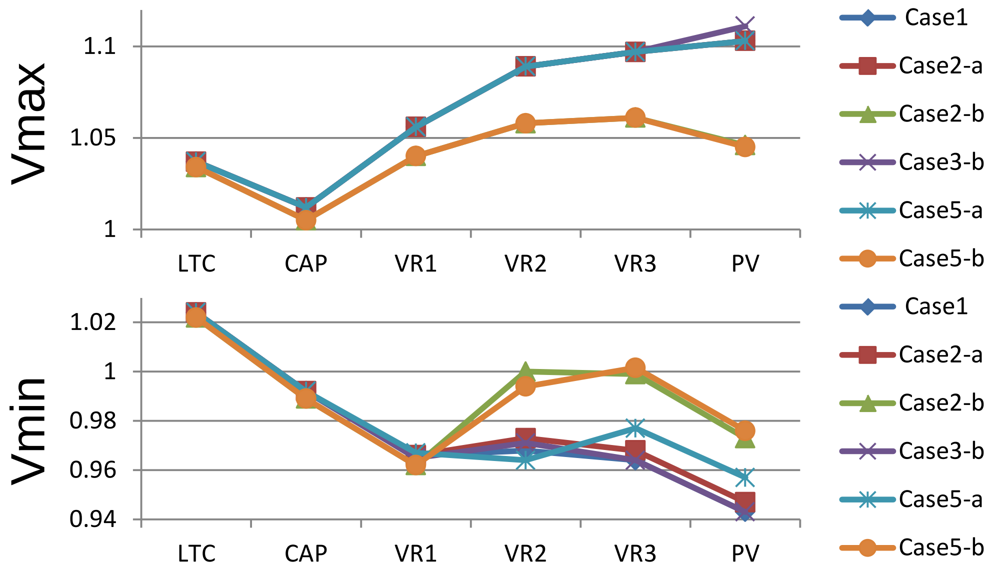


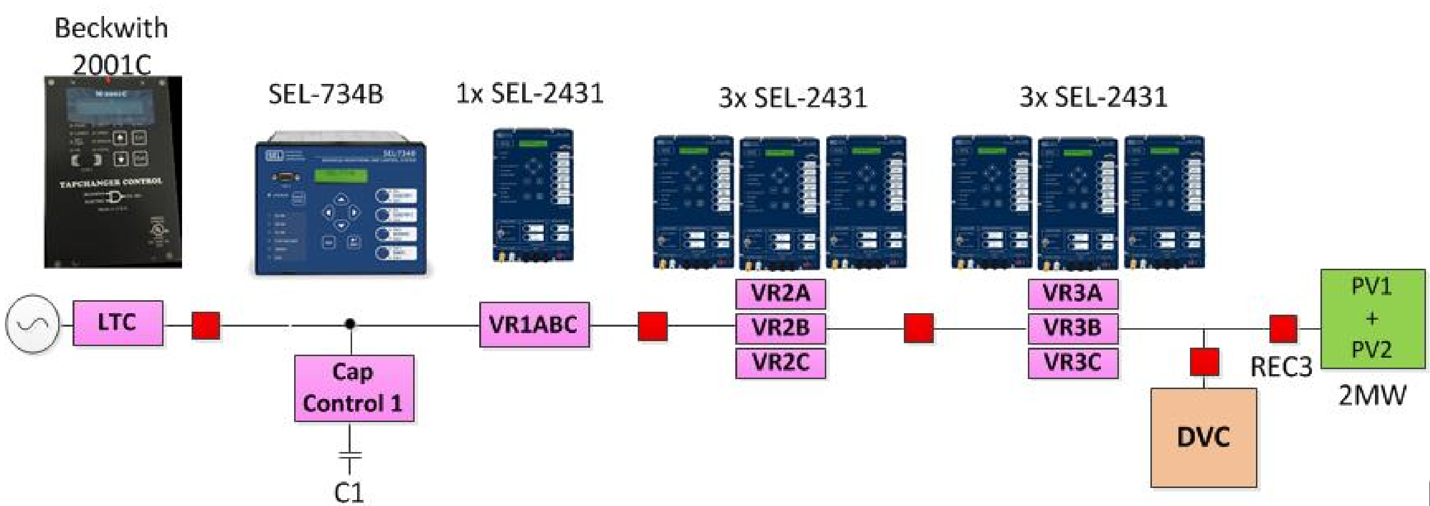
Flicker due to Frequent Voltage Changes



Change in bandwidth and power factor adjustment

Test Results - Voltage Profiles





Summary of Observations

Action	Impact
By customizing the regulator settings and control schemes the voltage profile and device operation can be enhanced	
Setting customization approach adds the burden of additional studies and engineering design for each circuit, as well as establishing setting database (O&M) for all the circuits	
Settings need to be re-visited and re-evaluated seasonally or after re-configuration	
Applying non-unity power factor to large PV systems is a great approach	
Non-unity power factor increases reactive power exchange of the circuit	

Thank You!

Questions and Discussion

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