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Communication Infrastructure Development to support VVO: Lessons Learned from National Grid's RI VVO Experience

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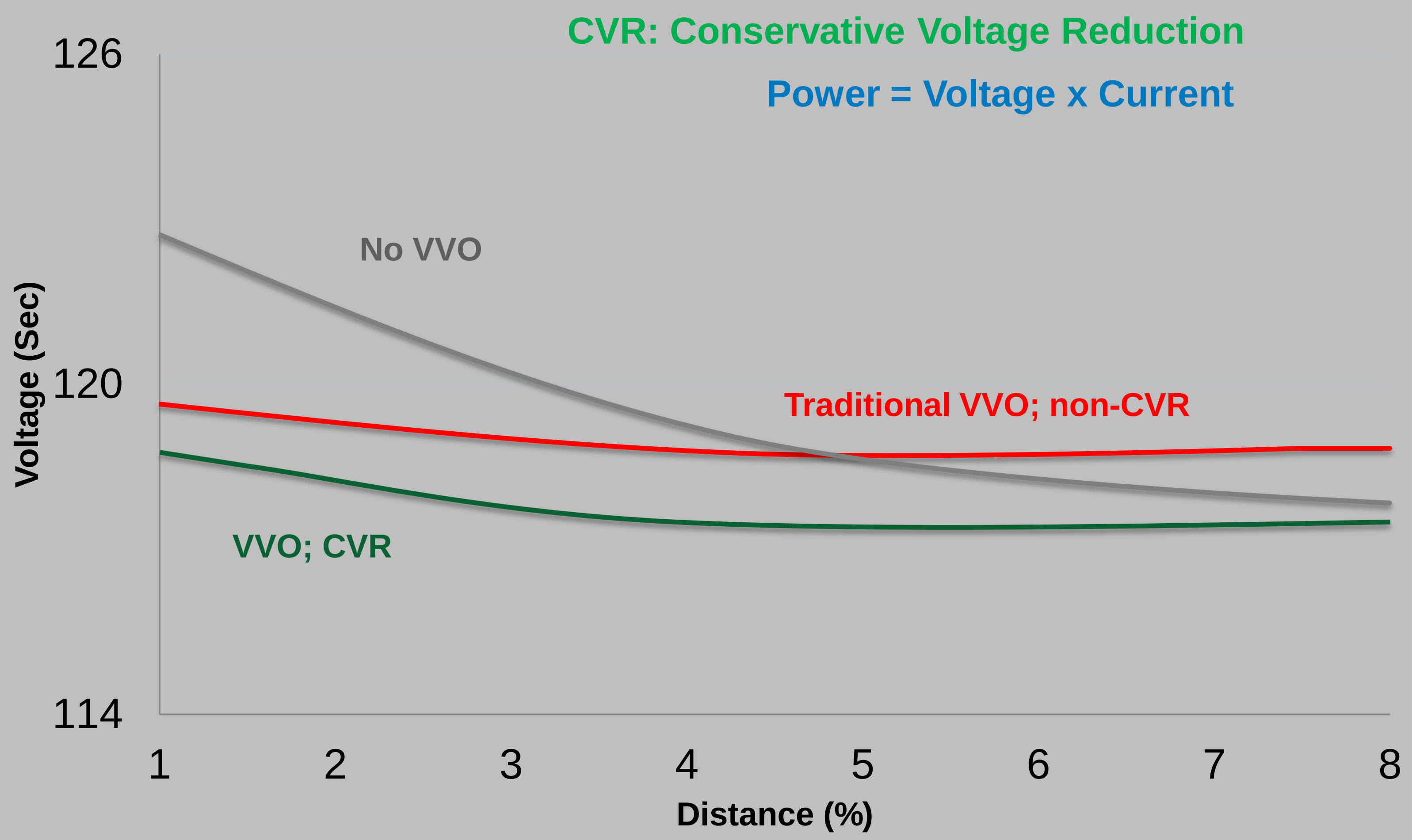
Technical Overview
What is Volt VAR optimization (VVO) ?

Volt/VAR optimization (VVO) is a process of optimally managing voltage levels and reactive power to achieve more efficient grid operation by reducing system losses and reducing peak demand.

Source - http://www.elp.com

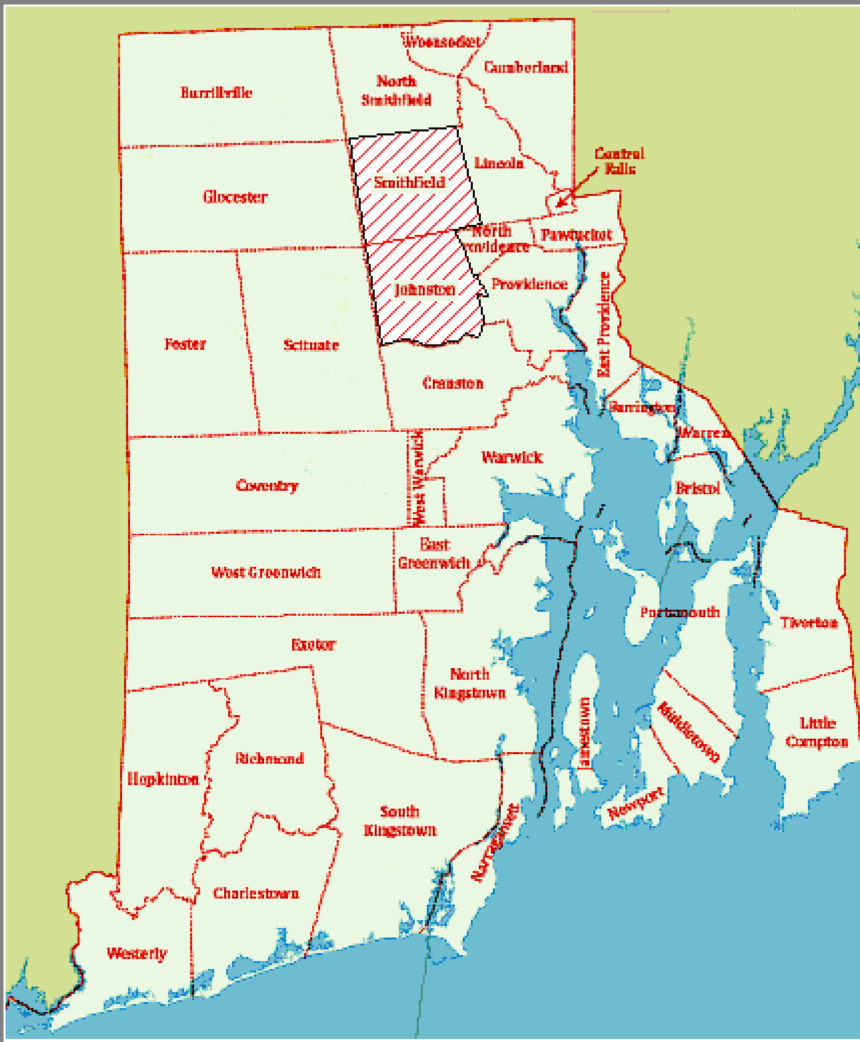
Technical Overview
Feeder Voltage Profile



National Grid's Choice for the VVO Model

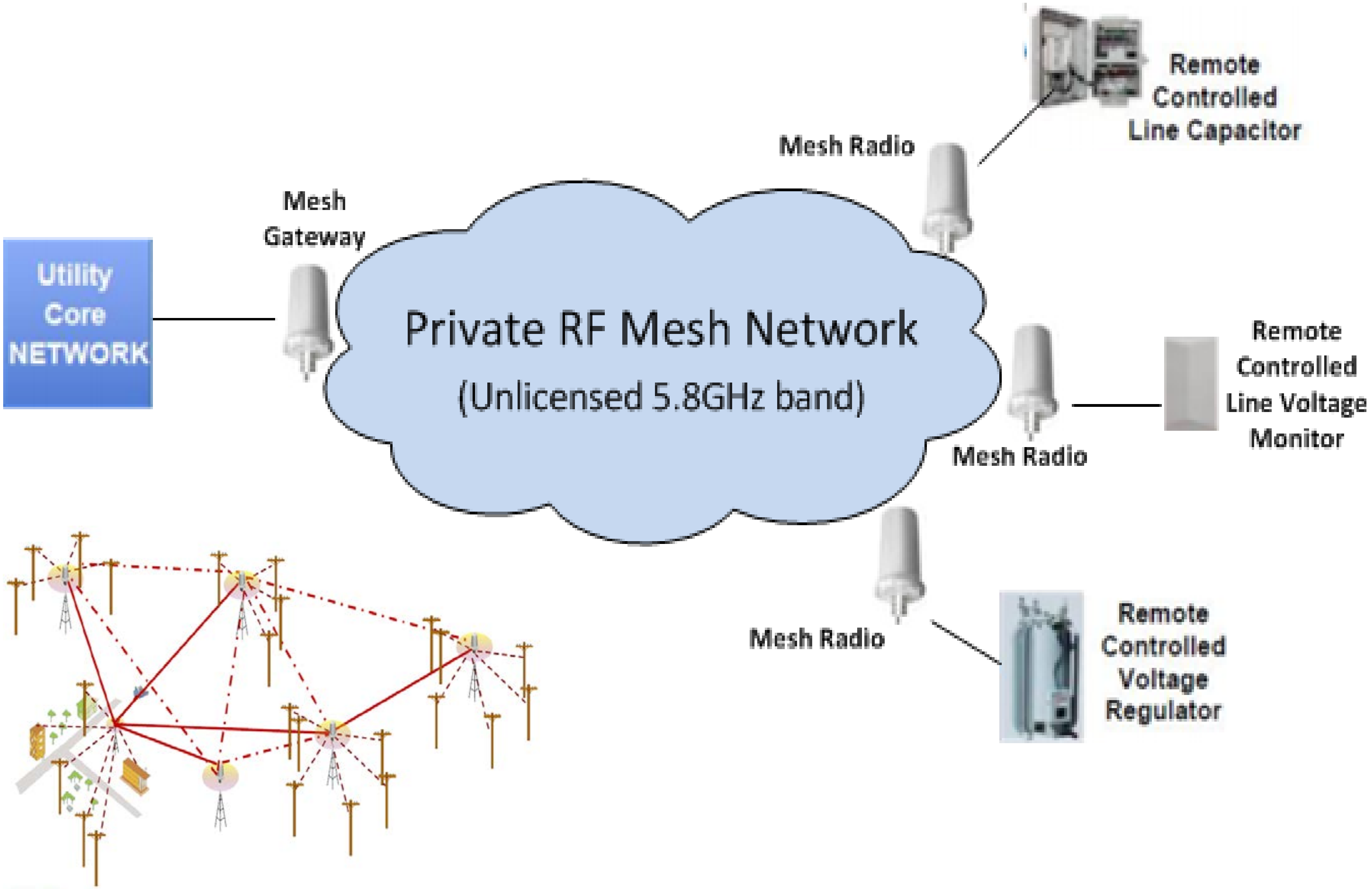
- Heuristic VVO
  - Auto adaptive with real-time system information from distributed sensors
  - Reliable communications infrastructure is therefore critical for enabling the Heuristic method
- Expected Benefits (provided by vendor)
  - 2.9% Energy reduction
  - Peak demand reduction
  - 30% Less voltage regulator tap operations
  - Improved customer reliability through feeder monitoring

Phase 1: Putnam Pike



- Putnam Pike
  - 38F1
    - (6) 1 Phase Line Regulators
    - (3) Line Voltage Monitors
    - (6) Capacitors
  - 38F3
    - (3) 1 Phase Line Regulators
    - (2) Line Voltage Monitors
    - (5) Capacitors
  - 38F5
    - (6) 1 Phase Line Regulators
    - (2) Line Voltage Monitors
    - (6) Capacitors
  - Substation
    - (9) 1 Phase Regulator

Phase 1: Use of Private RF Mesh Network



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- ***Operations:*** Fast Polling and data rates offer near real-time gathering of data as required by the heuristic VVO
- ***Security:*** Field Area Network traffic protected by encrypting the wireless traffic using the radio's native algorithm
- ***Management:*** Existence of a network management software package instrumental in troubleshooting network problems as well as managing field network radio settings and pushing firmware updates
- ***No Recurring Cost:*** After the network design was complete, it was privately owned by National Grid. No monthly costs or licensing fee!

Challenges associated with Private RF Network

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- Radios had to be mounted on the primary space to get better line of sight. This required coordination between Overhead line crews and EMS personnel for installation and troubleshooting of the radios
- Particularly difficult to schedule for poles in the 23 kV lines where line crews require notification of work weeks in advance

Challenges associated with Private RF Network

- Two Overhead Crews were required for installation of the antenna.
- Telecom Operation (separate group) required to terminate network and radio cables etc.

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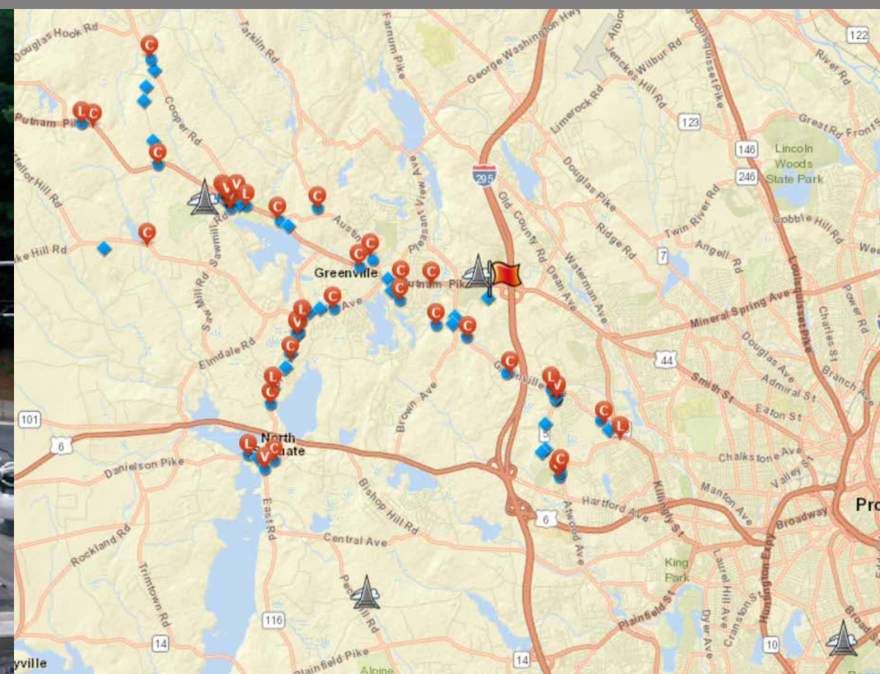
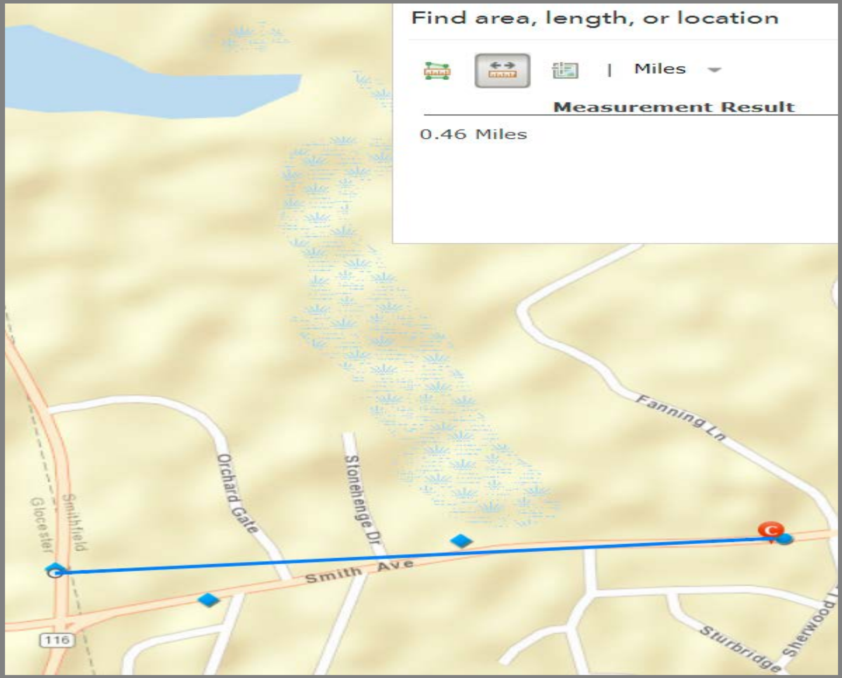
- ***Line of Sight:*** Some of the locations required replacing 40 ft. poles with 50 ft. poles to get better line of sight. 4 Leased Towers were used to cover 44 sites spread around a 5 miles radius.



Challenges associated with Private RF Network

- ***Foliage:*** Computer simulated RF propagation models did not accurately account for foliage. Due to time constraints, most of the sites were surveyed during fall and winter when there was little to no foliage on the trees

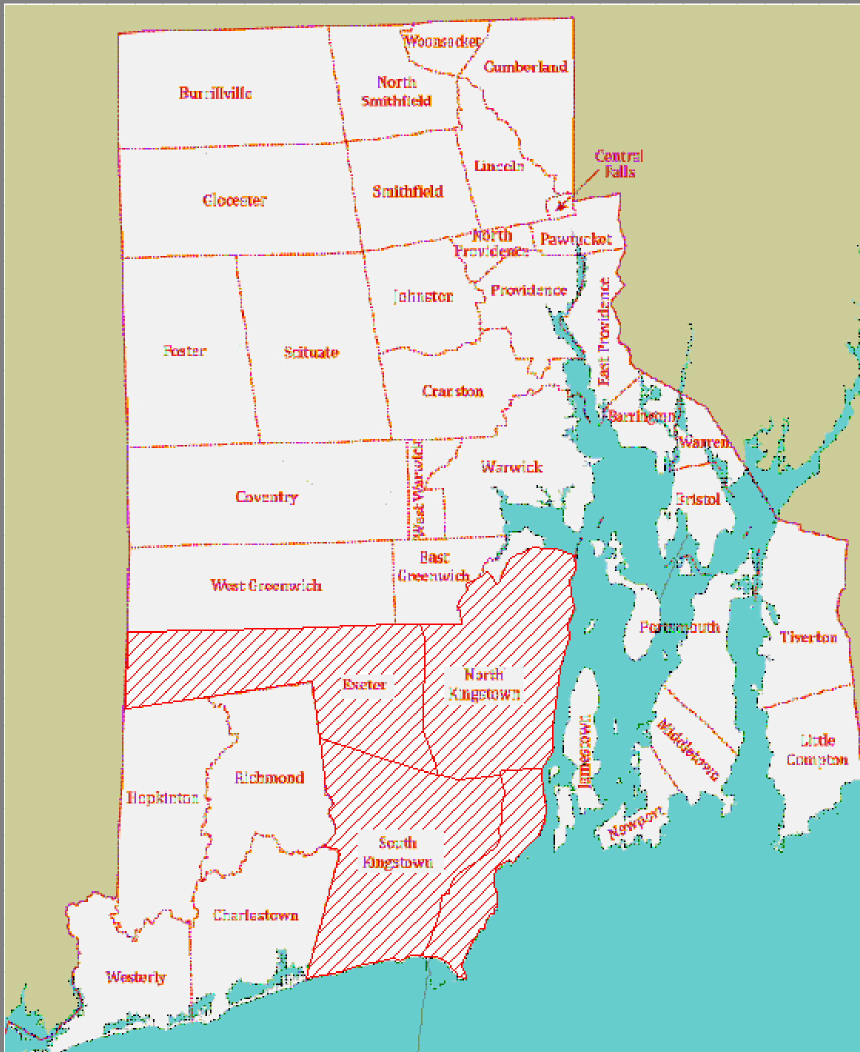
- ***Density of the RF Mesh:*** Radios have a range up to 10 miles between each hop on a flat terrain. Due to the terrain in RI and the foliage, this distance was greatly reduced. Solution was to make the network dense by adding more radios to the mesh.
- In the example below, 3 hops were required to communicate over a distance of just 0.46 miles.



Radio Interference:

- The private RF mesh system operates in the unlicensed 5.8 GHz spectrum. Movement Sensor systems, Wireless Ethernet & Amateur Radio Systems share the same frequency band
- It was assumed initially that there was no interference at the proposed locations and this needed to be validated during RF testing.
- National Grid found interference with other radio systems at a number of sites that required migrating to a different frequency within the unlicensed band
- In some cases, there were self-interference issues between the radios that had to be addressed as well

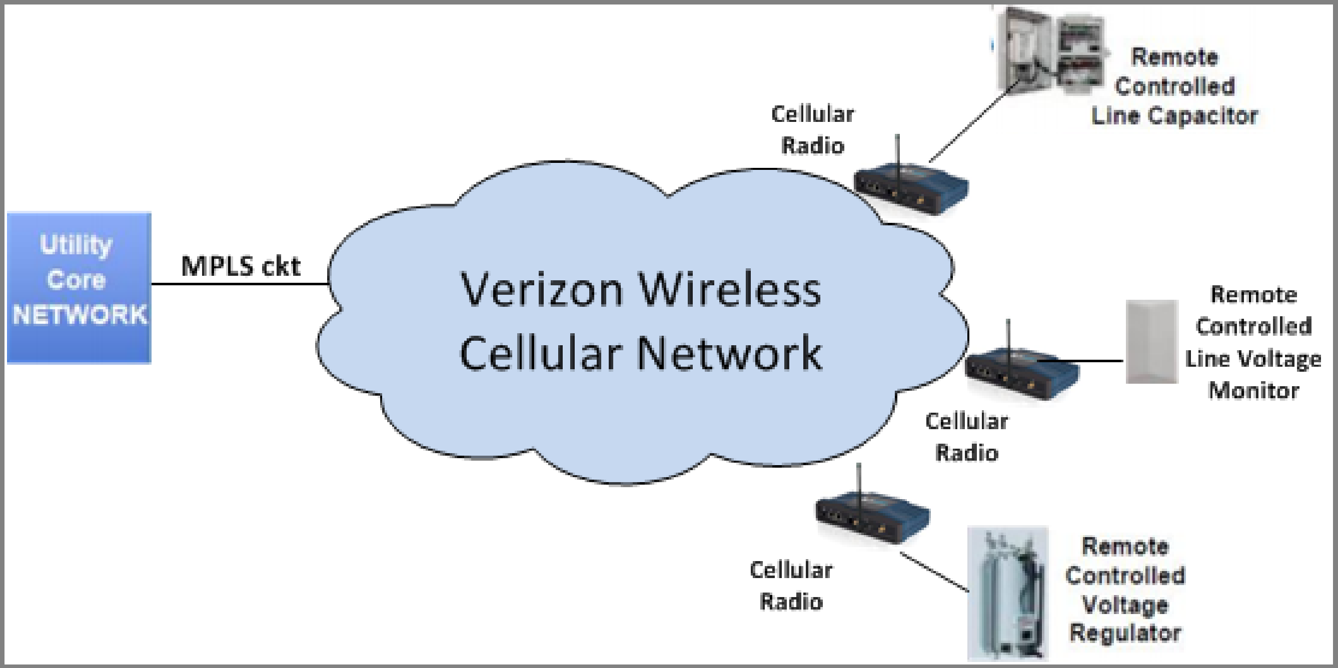
Phase 2: Tower Hill



- Tower Hill
  - 88F1
    - (4) Capacitors
  - 88F3
    - (1) 3 Phase Line Regulator
    - (4) Capacitors
  - 88F5
    - (4) Capacitors
  - 88F7
    - (4) Capacitors
  - Substation
    - Beckwith M-2001C LTC Controller

Phase 2: Use of Cellular Network

- The challenges associated with the private RF mesh forced National Grid to re-think the comm design for remainder of the VVO Project
- Cell Service is present in all locations where the pilot program is to be implemented. Use of cell radios and Verizon Wireless network seemed to be a great choice



Benefits of Cellular Communication

- ***Cost:*** There are recurring costs per radio to communicate on the VZ Wireless network, but that is still insignificant compared to building a private radio network
- ***Ease of Install:*** Deployment of cell radios took fraction of the time compared to building out the private RF Mesh Network
- ***Security:*** Device level security offered by the radios. Wireless security provided by VZW Cloud on which National Grid had reserved a network space. A secure MPLS circuit connects the Cloud to the Utility Core Network
- ***Management:*** After carefully testing the configuration and firmware of the radio and locking these down with the vendor, we eliminated the need for routine device management

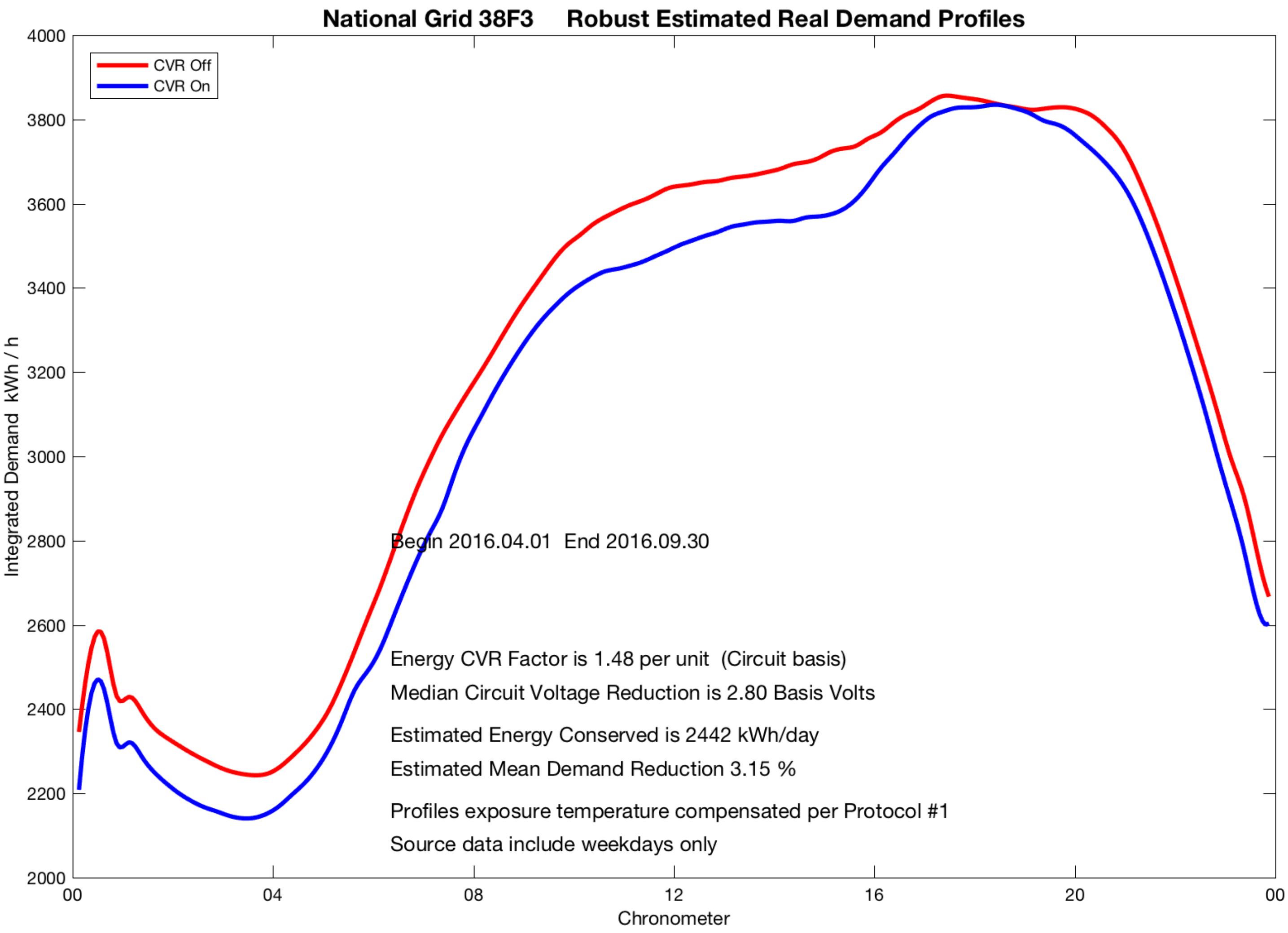
Challenges with Cellular Communication

- ***Frequency of Polling:*** Contract with Verizon mandated that we should not actively poll the field devices more than once every 5 minutes. The heuristic VVO model needed more frequent data from devices.

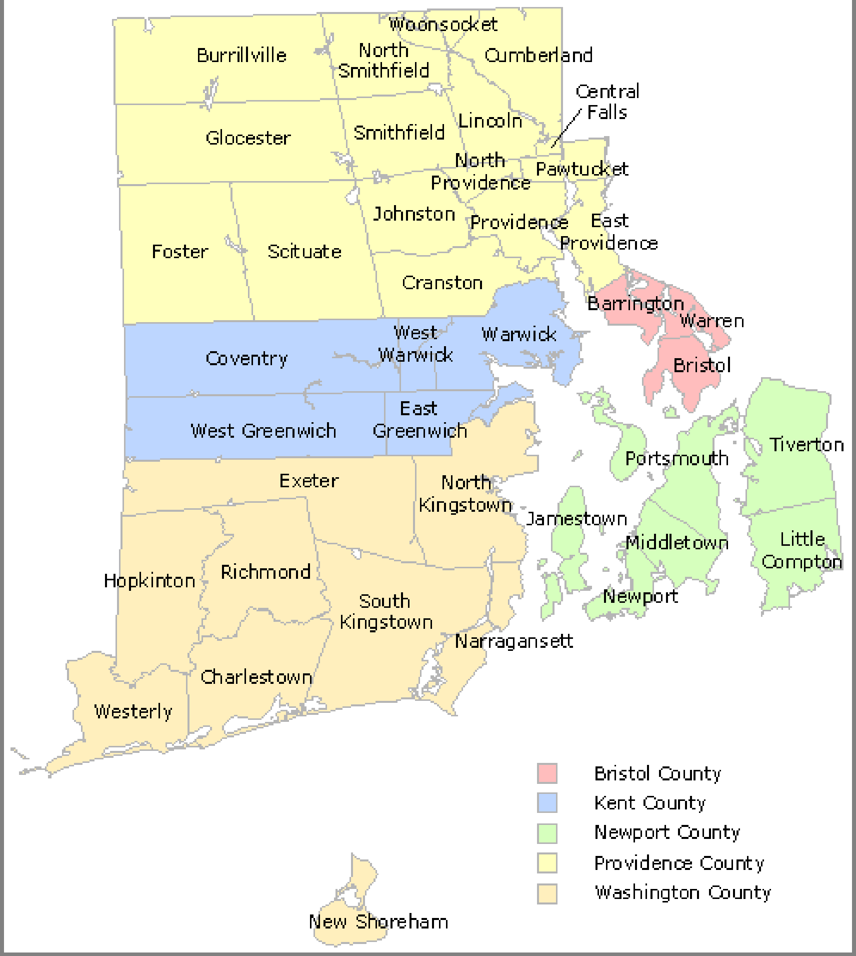
  This problem was solved by enabling unsolicited messaging in the grid device controls with specific deadbands defined for Analog quantities. Verizon did not object to unsolicited messages from the grid devices to the Utility Core Network.

- ***Management:*** Since the wireless network in this case is not owned and managed by National Grid, all troubleshooting calls regarding comm issues are forwarded to Verizon Wireless and that adds some delay towards resolving the trouble.

38F3 Median Circuit Demand Reduction



- Expansion of original pilot footprint
- 3 substations being added 2017-2019
  - Langworthy Corner 86
  - Lincoln Ave 72
  - Tiogue Ave 100
- Following the 'no study' approach and using cellular communications



Questions?

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