Optimizing Voltage on Feeders with Distributed PV Using Dynamic Secondary Voltage Controllers

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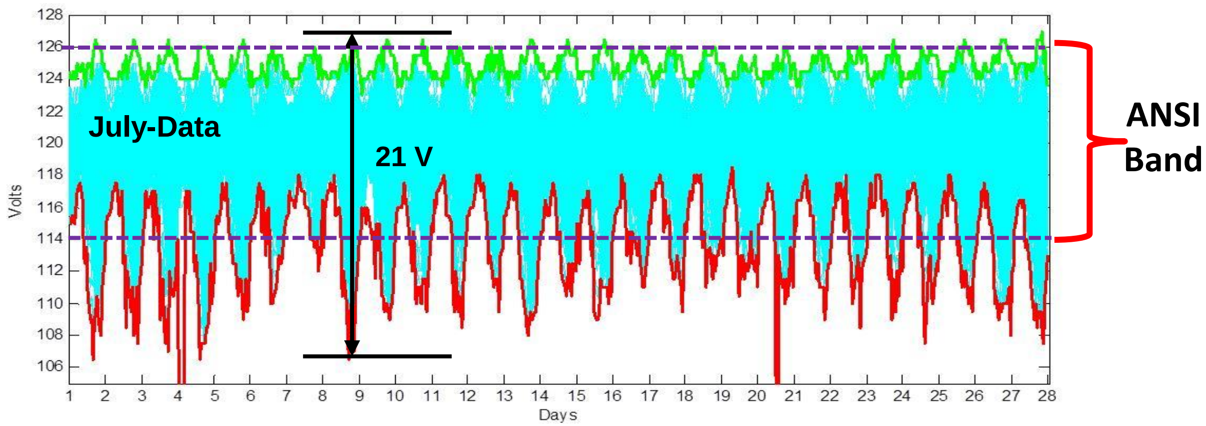
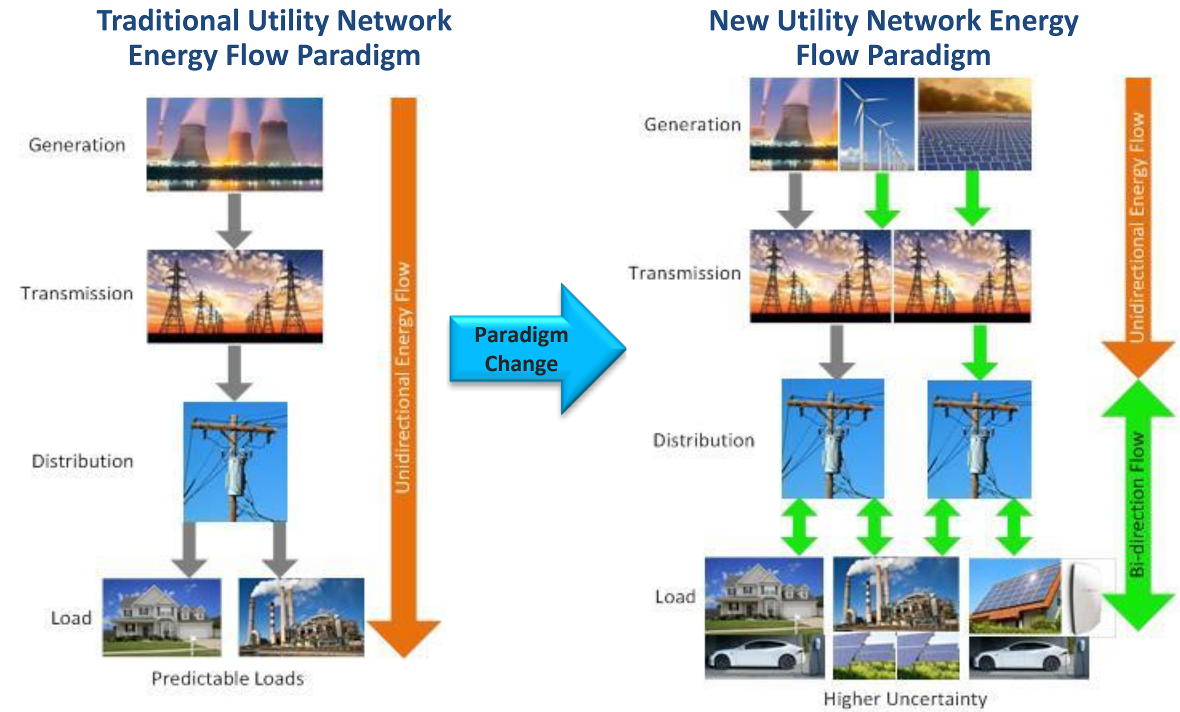
Utility Challenges





AMI data confirms high variability on Low Voltage side affects VVO/CVR benefits:

- All meters show consistent V < *ANSI low* voltage violation on a daily basis for several hours
- Max. variation between lowest and highest meter read at any time is around 19-21 V - a 17% variation (120V base)

+

Fast growth of distributed solar PV is increasing challenges today:

- High voltage fluctuation due to PV generation volatility (especially during daytime)
- Voltage boost at peak insolation
- *V > ANSI high* voltage violations
- Interference with VVO/CVR objectives (Energy Savings, Peak Demand Reduction)

ENGO® + GEMS™ provides enhanced CVR from the Edge Up

15 years lifetime

ENGO® hardware

No O&M costs

+

GEMS™ software

Cloud-Based Solution

ENGO HW Functions

1. Installed on service side of transformer
2. Monitors voltage @ 32 samples/cycle
3. Stores & transfer data to utility
4. Autonomous control of voltage fluctuations

GEMS SW Functions

1. Browser based central control
2. Set ENGO voltage set points
3. View ENGO & feeder status
4. Volt-VAR data & analytics

Real-Time Single Phase VVC/VVO (Local Impact)

Voltage & KVARs Measured on 15 ENGO Units

Californian Municipality: November 14th – November 17th 2016

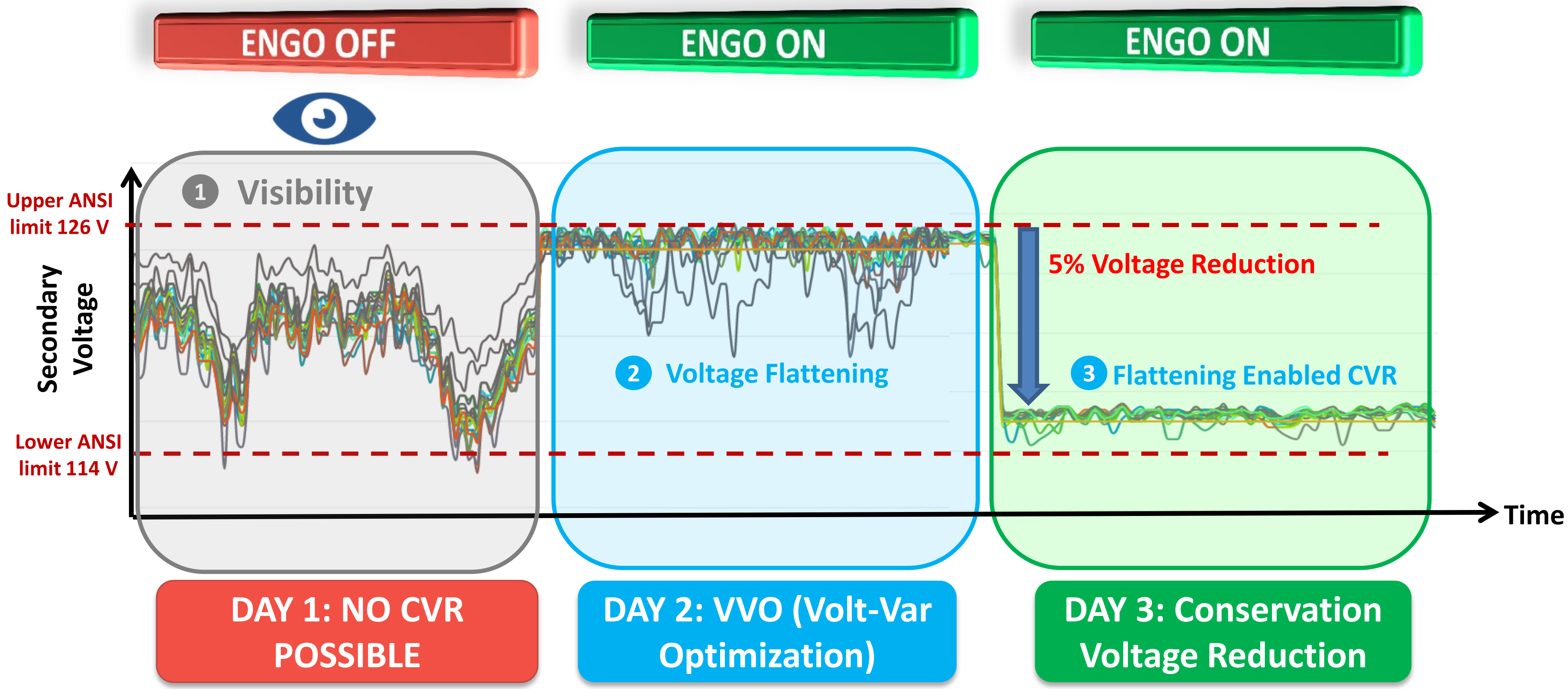
1 **Voltage Flattening (VVC/VVO)**

2 **Dynamic VAR Injections**

ENGO ID Legend

- V_007
- V_008
- V_009
- V_010
- V_011

Real-Time Single Phase VVC/VVO (System-Wide Impact)

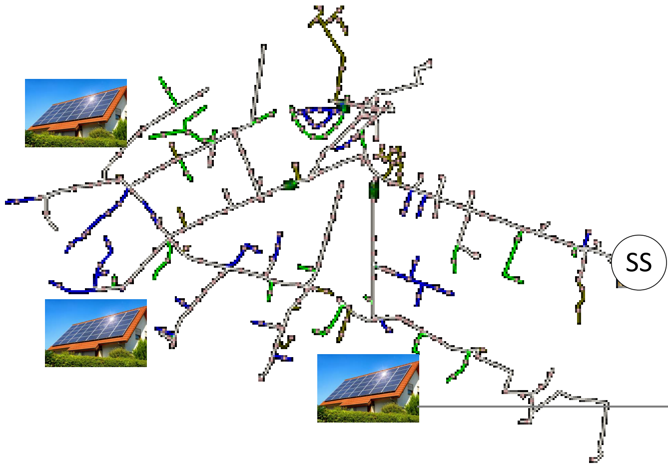


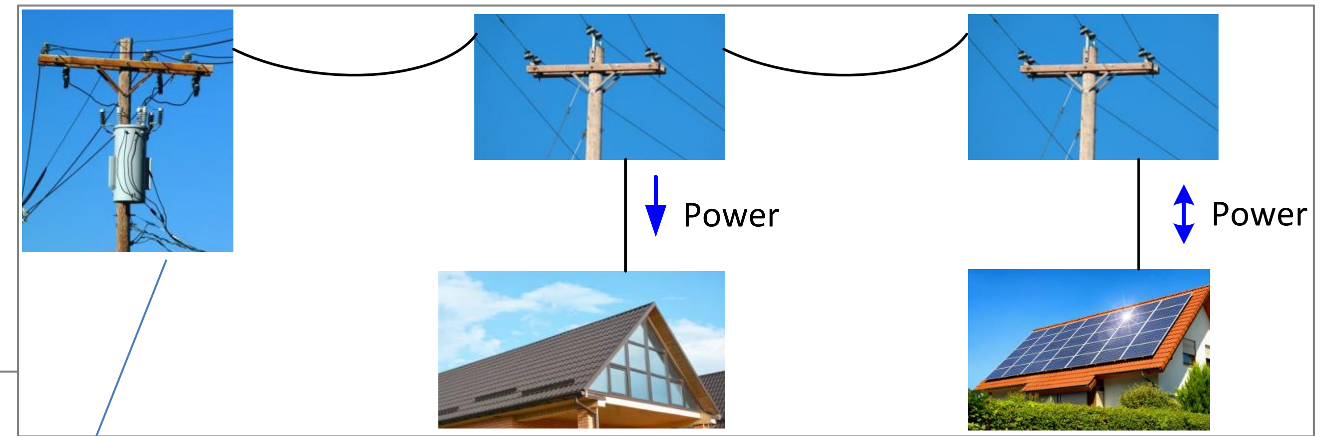
CVR can be used to achieve multiple utility Objectives:

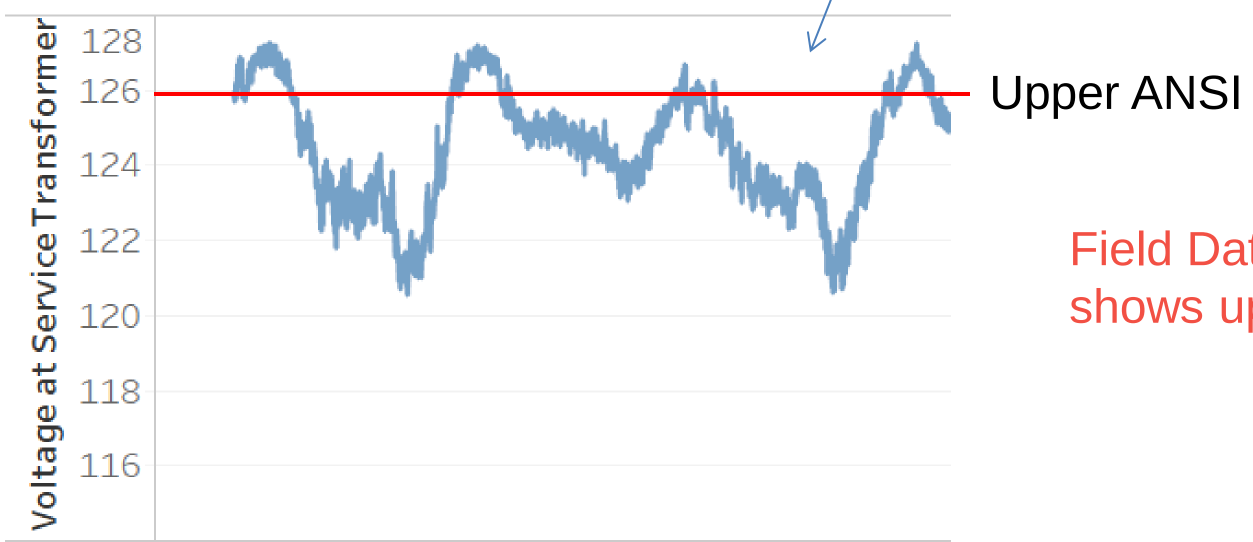
- PV Hosting Capacity
- Energy Savings
- Peak Demand Reduction

Voltage Problems with Low-Moderate PV Penetration

Distribution Feeder with low-moderate PV Penetration

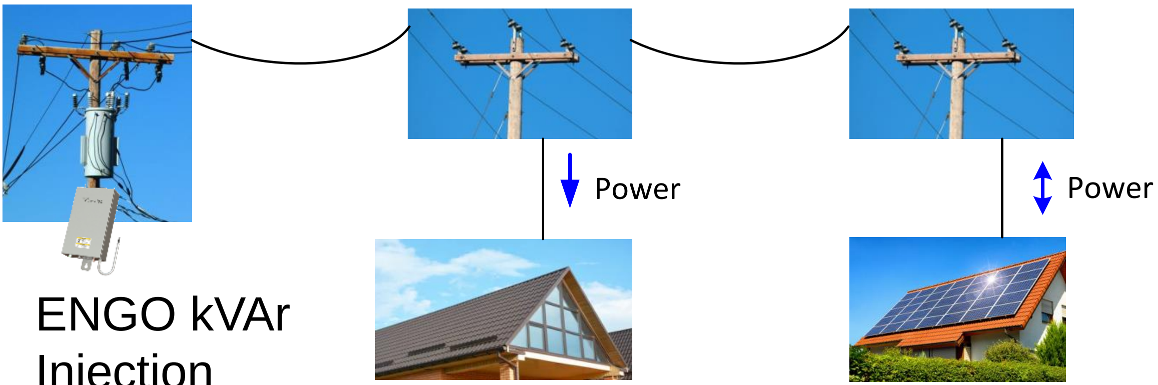






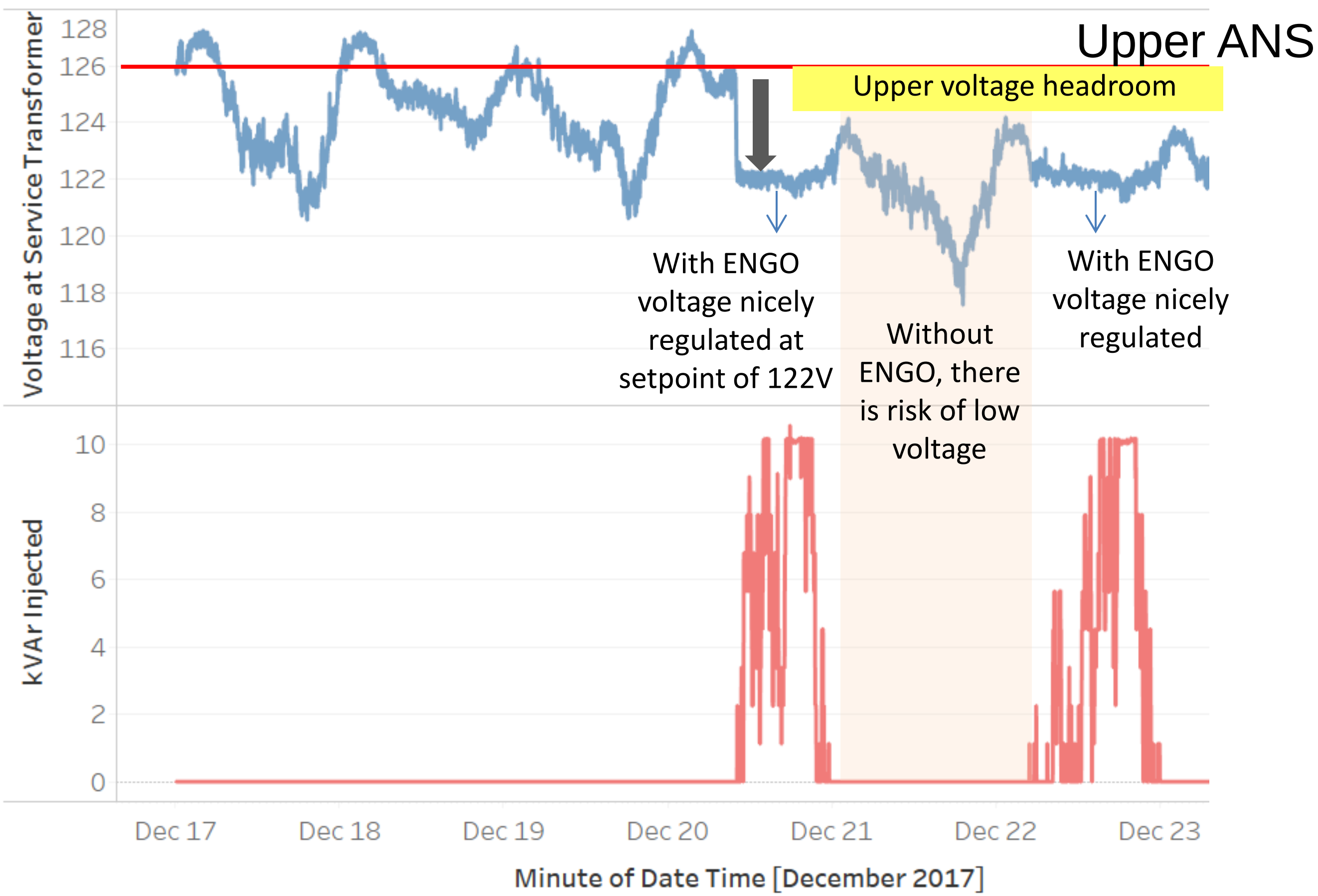
Field Data captured at the transformer shows upper ANSI violation

Voltage Problem Mitigation with Low-Moderate PV Penetration



ENGO kVAr Injection Enabled

Transformer tapped down by 2.5% and ENGO kVAr injection enabled to support voltage



For circuits with Low-moderate (5% – 30%) PV penetration, tapping down service transformer permanently and using ENGO to support voltage works like a charm!

HECO Project Objectives

Hawaiian Electric
Maui Electric
Hawai‘i Electric Light

Primary Objectives (VVO)

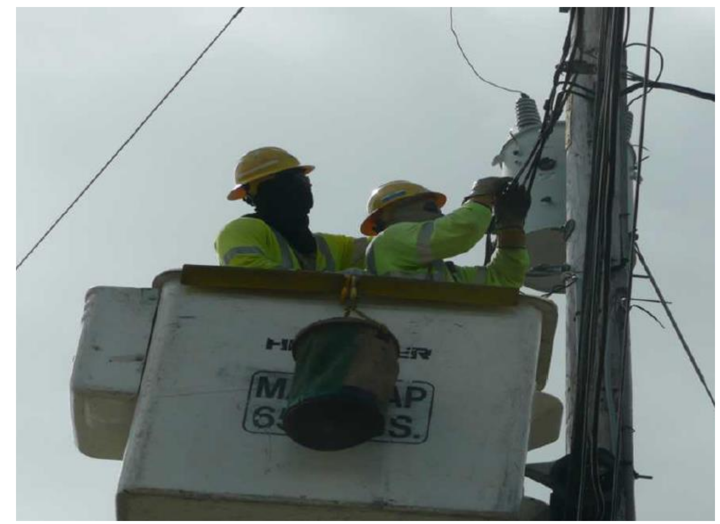
- Demonstrate ability to avoid out of tariff voltages by reducing the large voltage fluctuations caused by PV
- Estimate any increased PV hosting capacity potential

Secondary Objectives

- Measure VVO/CVR benefits for Energy Savings
- Estimate economic benefits

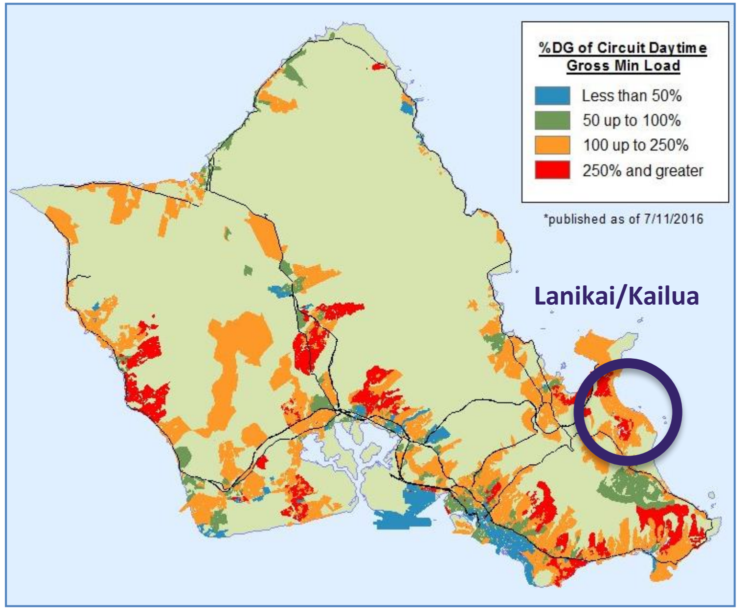
ENGO Pole Unit

ENGO Installation

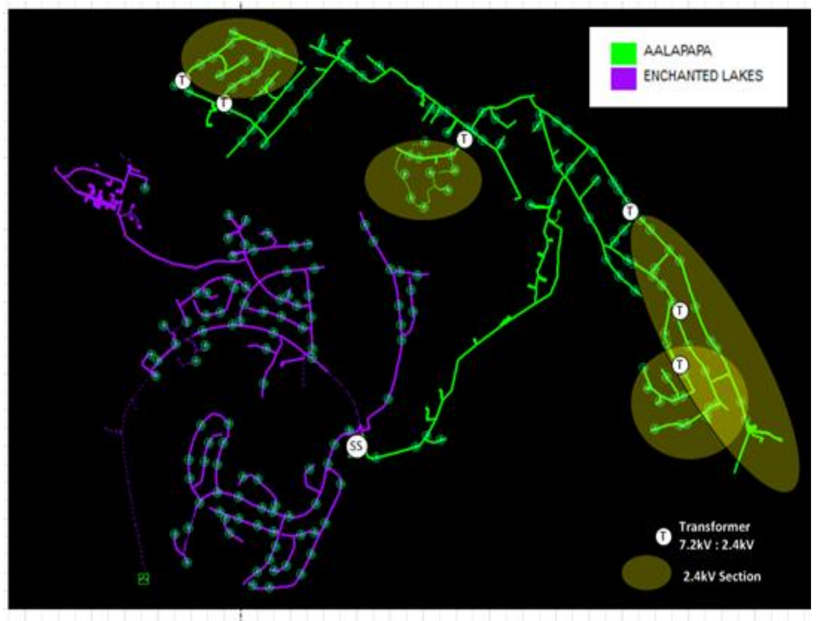


Pilot Deployment

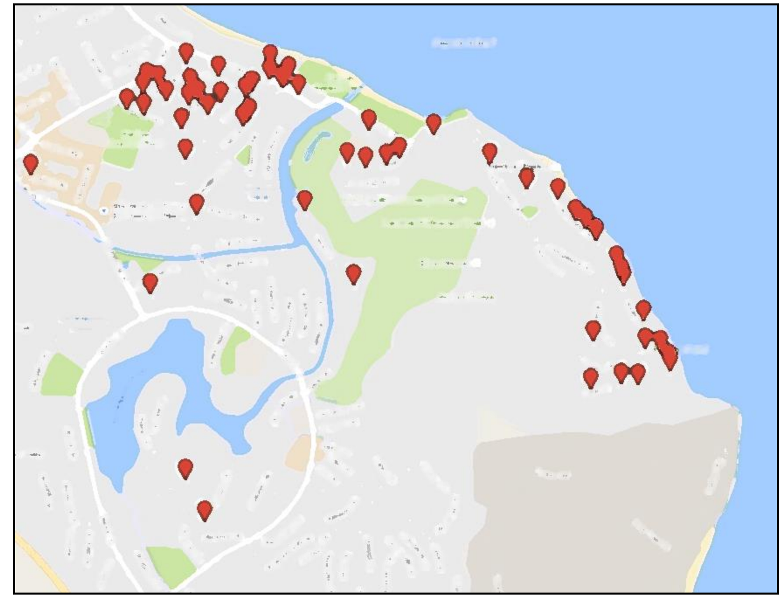
Selected Area: Lanikai / Kailua



Substation A: Feeder Model



ENGO unit deployment location map



F1 Circuit
7 ENGO Units

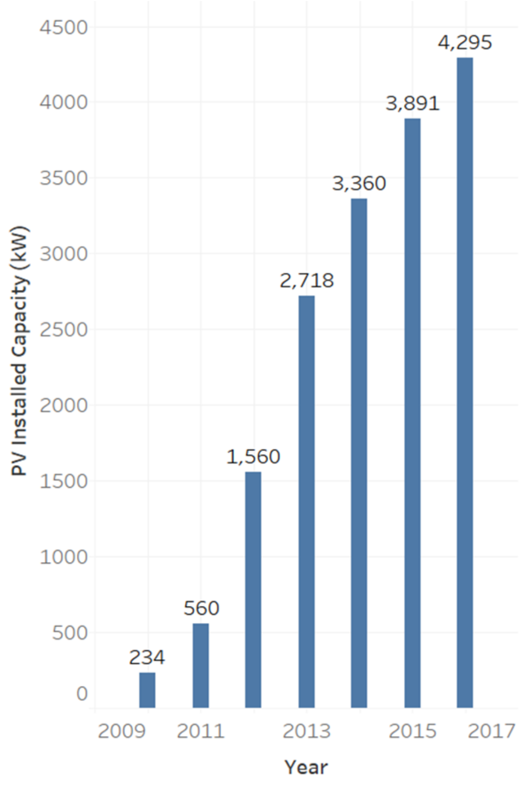
F2 Circuit
54 ENGO Units

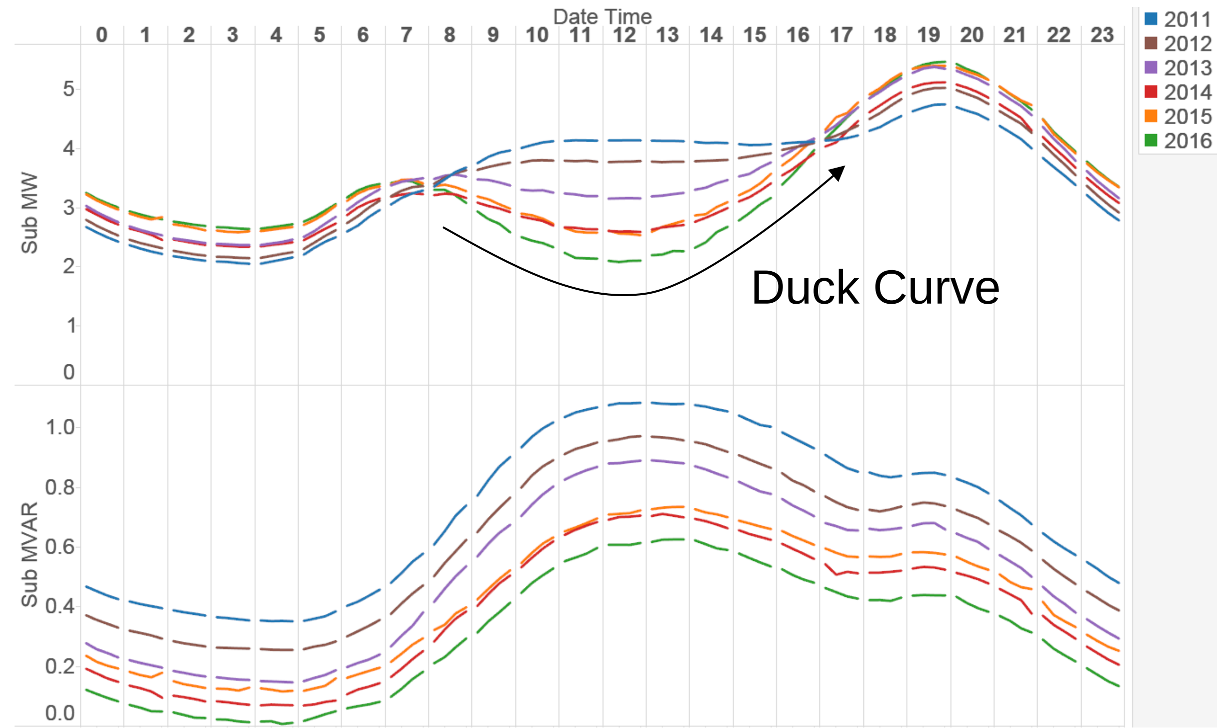
12.47kV Keolu substation

- **Day Time Peak Load: 4.7MW … 5.7MW**
- **Night Time Peak Load: 6.7 MW**
- **PV Generation: 4.3 MW**
- **LTC/LDC Control (SP=120V, R=6,X=6)**

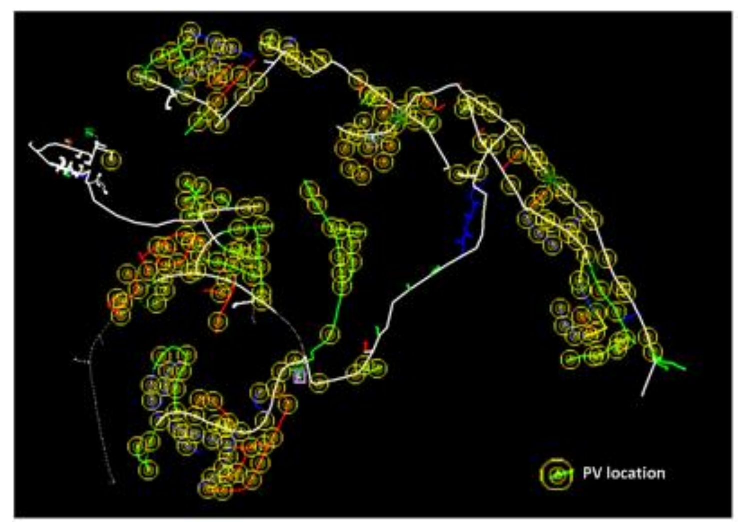
Substation Name	Type of Circuits Connected	Feeder Names	Length (miles)	Peak MW	Average MW	Installed PV (MW)	# of Cap Bank	# of Line Voltage Regulator
Sub A	Residential Feeder	F1	3.3	3.38	1.74	2.15	0	0
		F2	1.8	3.19	1.88	2.15	0	0

Historical Load and PV Generation Capacity

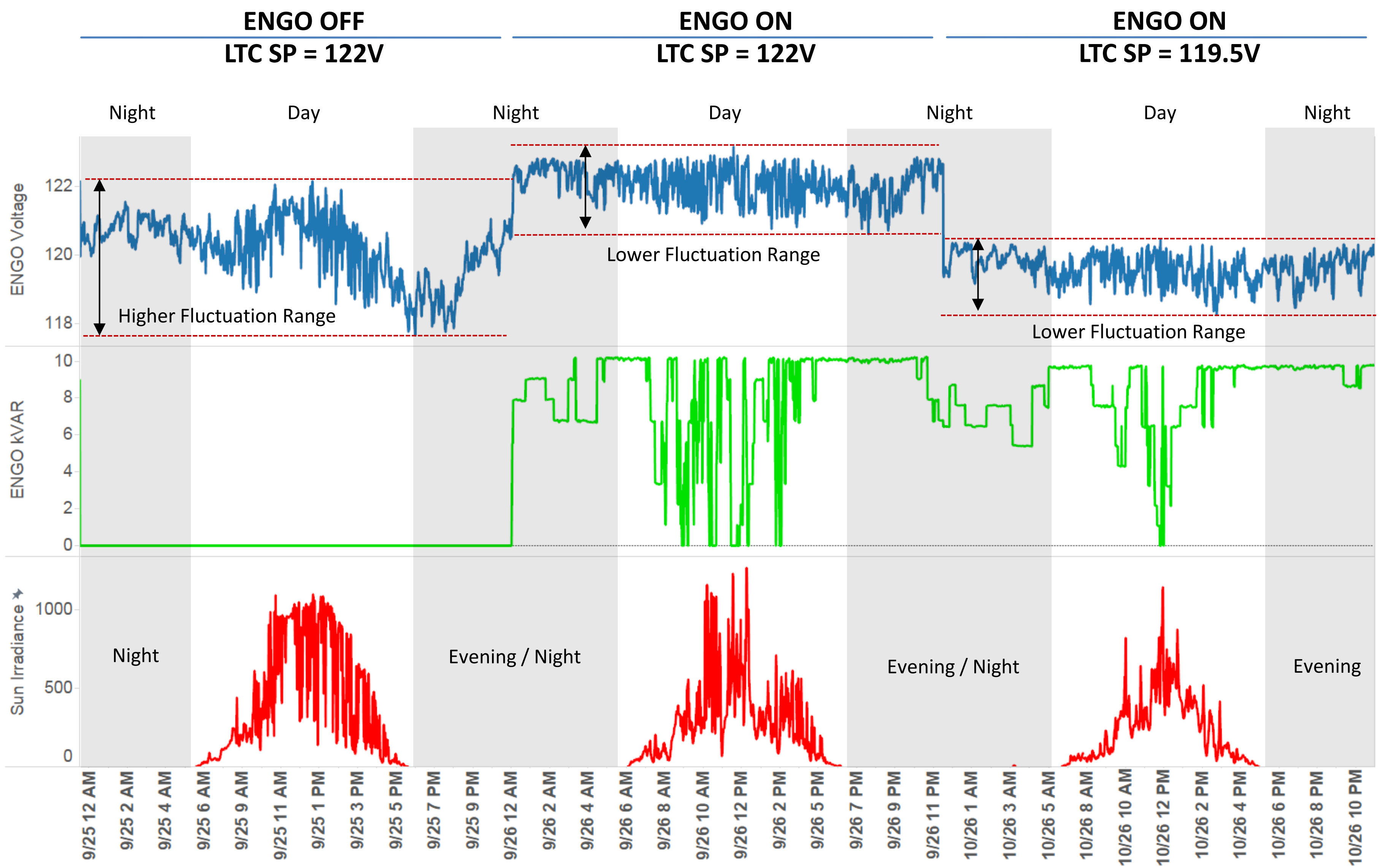




Solar Installations on Keolu Today

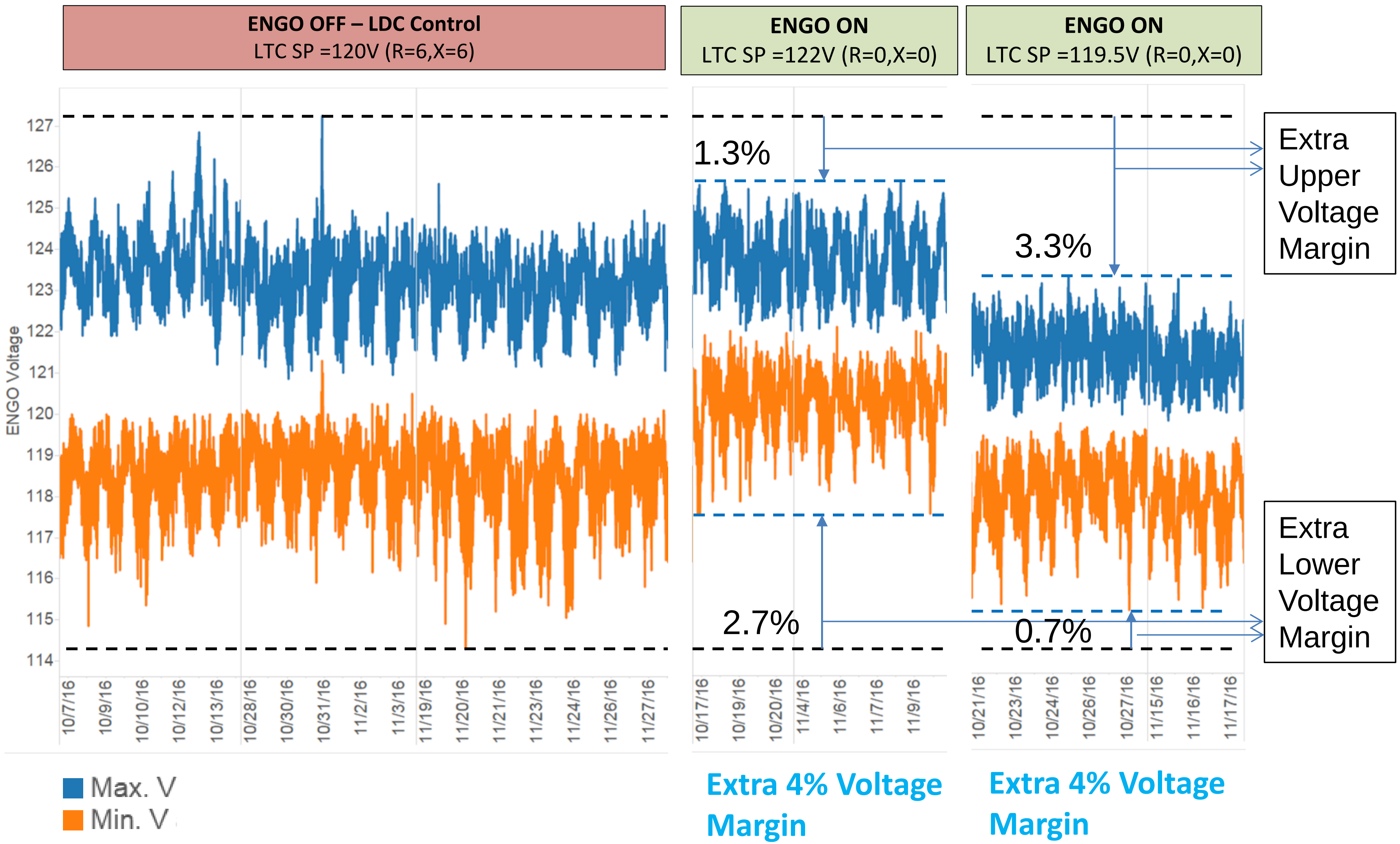


Increasing PV Hosting Capacity



Additional upper voltage headroom created by ENGOs allows hosting more PV

ENGO Provides Extra Upper and Lower Margin (System-Wide Effect)

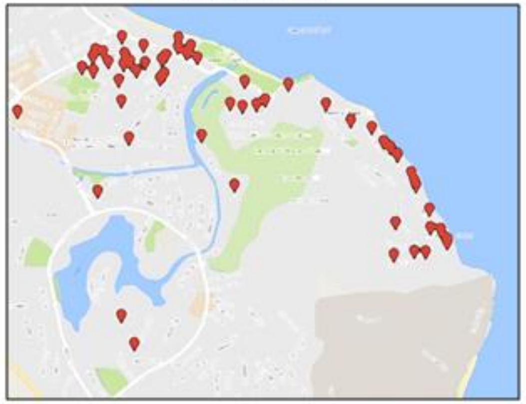


ENGO deployment provides an extra upper and lower voltage margin to the grid which allows:

- Extra PV hosting capacity
- Extra voltage reduction for Energy Saving (CVR)

Swarm Effect due to Multiple ENGO

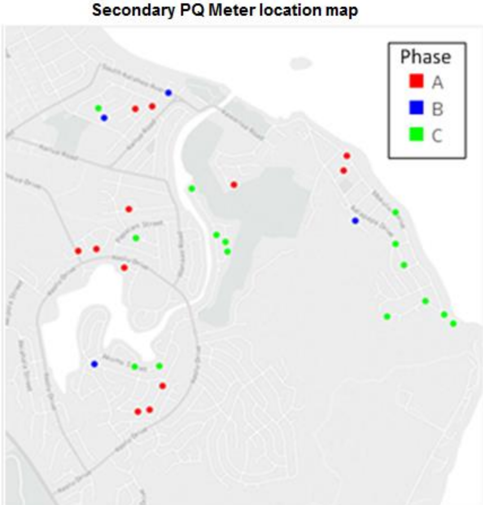
ENGO unit deployment location map



F1 Circuit
7 ENGO Units

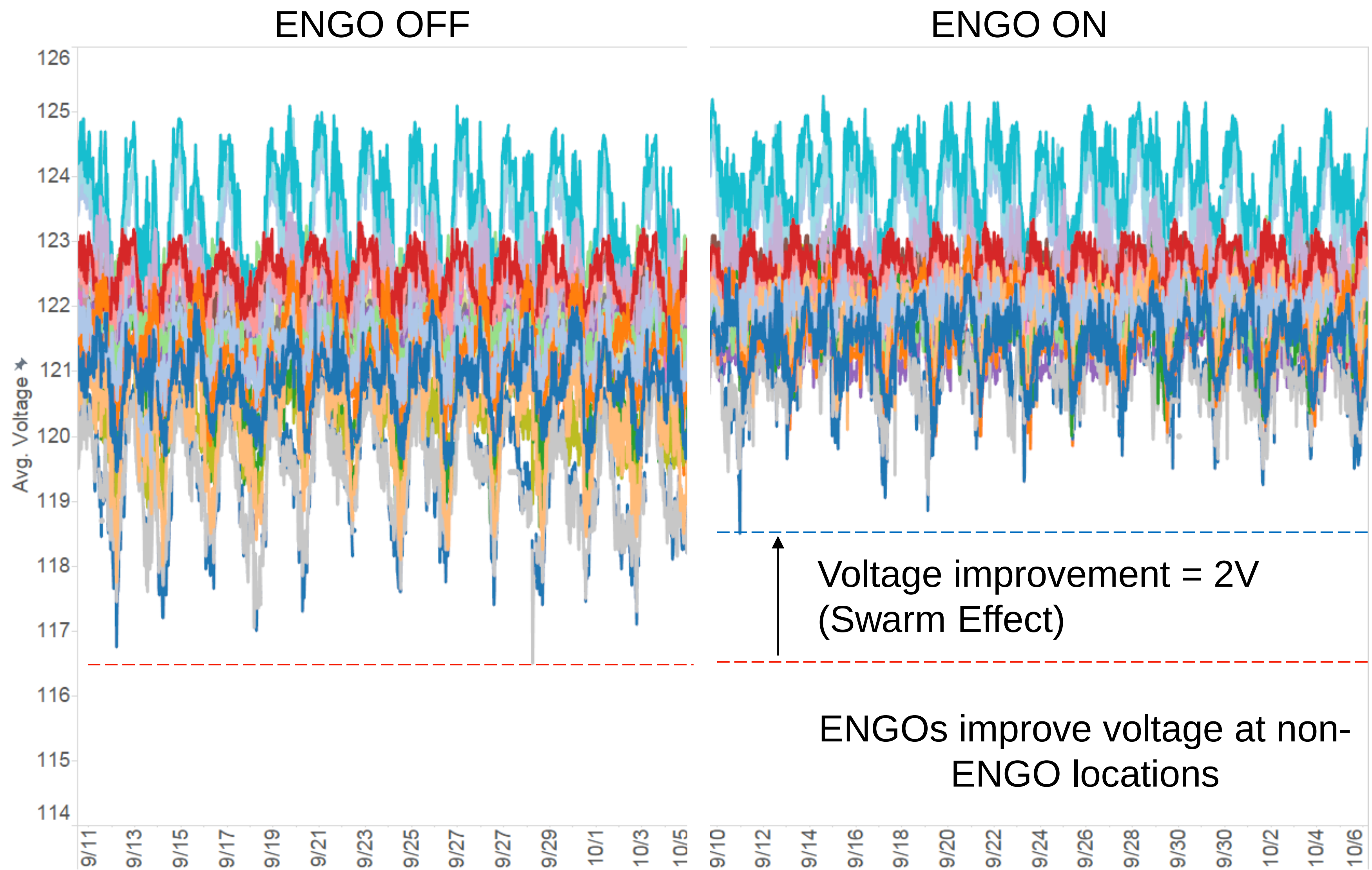
F2 Circuit
54 ENGO Units

Secondary PQ Meter location map



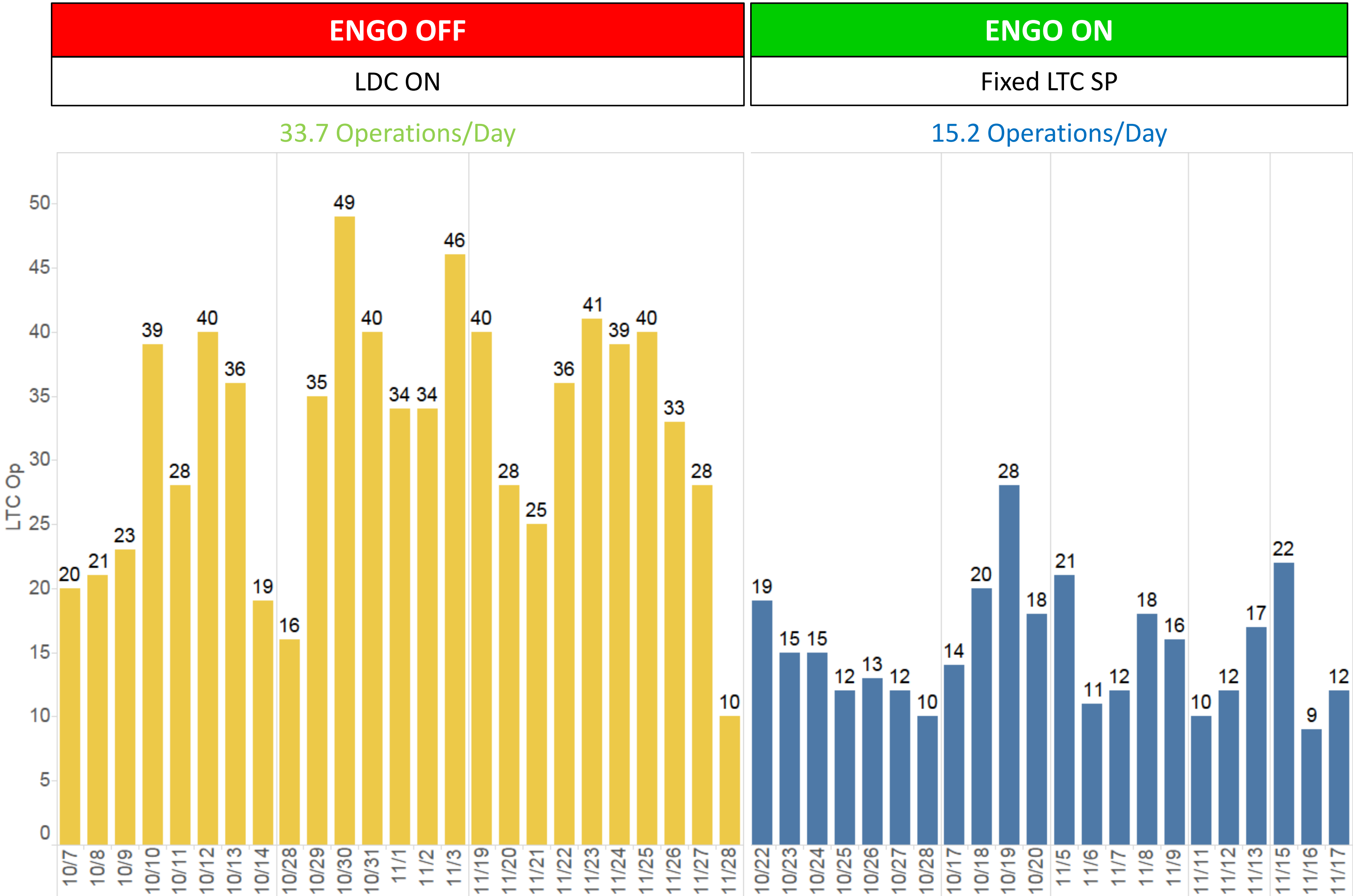
Secondary PQ meter
31 Opta Node Units

Secondary Voltage Measurement from 31 PQ meters at location without ENGO



- Note: 8 over 31 OptaNodes overlapped with ENGO units

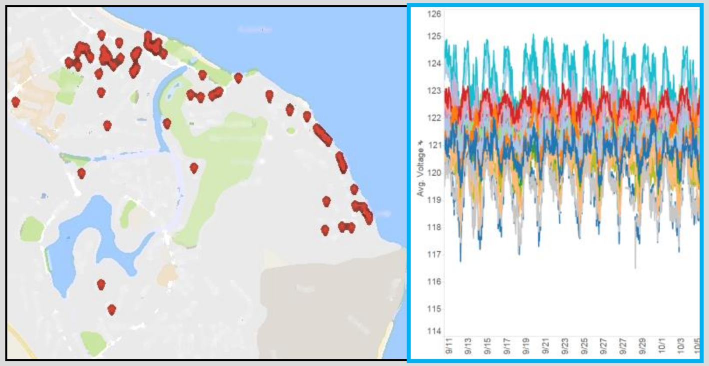
ENGO Reduces LTC Operation

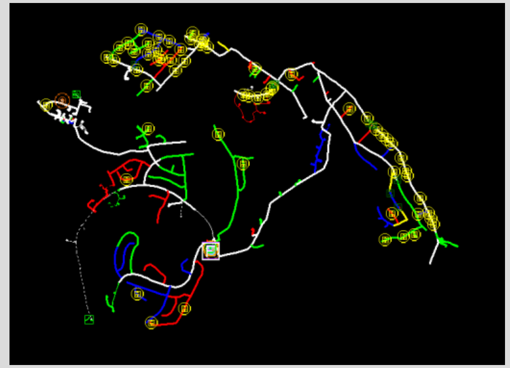


	LTC Ops/day
ENGO OFF (LTC with LDC Control)	≈ 34
ENGO ON (Fix LTC SP)	≈15
% LTC Operation Reduction	55%

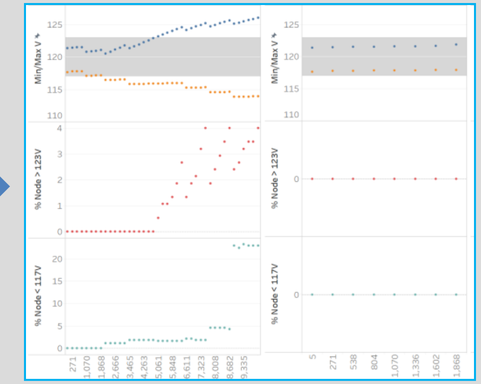
PV Hosting Capacity Calculator

PV Hosting Calculator Tool





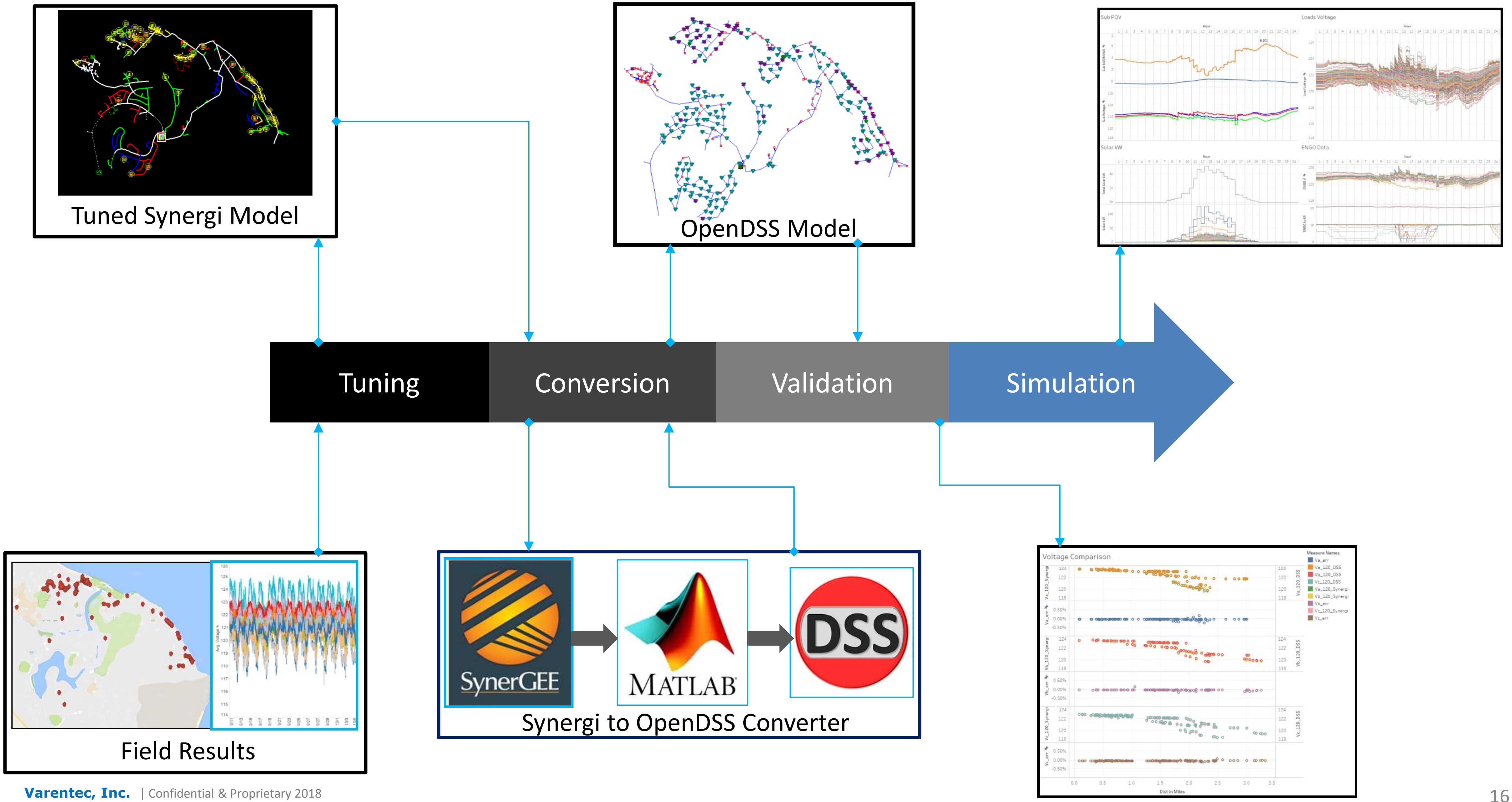
SynerGEE python



Solution #	Solution	PV Hosting Capacity (MW)	Energy Saving	Avg. LTC Tap Operation / Day
1 (Basecase)*	LDC control (R=6, X=6) (Band Center = 120) ENGO OFF	2.7 - 3.2	---	34 Ops/day
2	Fixed LTC (Band Center = 120.5V) ENGO ON	5 - 5.4	0.7 -1.4%	15 Ops/day
3	Fixed LTC (Band Center = 120V) ENGO ON Relocation of 13 ENGO Devices	5.5 – 5.7	1.4 - 1.7%	15 Ops/day
4	LDC control (R=8, X=8) (Band Center = 119.5) ENGO ON	6.3 – 6.9	----	>15 but < 34
5	LDC control (R=8, X=8) (Band Center = 119.5) ENGO ON Relocation of 4 ENGO Devices	6.9 – 7.1	----	>15 but < 34

GEMS+ENGO solution helps to increase PV hosting capacity on the substation from 3.2 MW to 7.1 MW
PV hosting capacity increases by ~ 123%

PV Hosting QSTS Simulations: Smart Inverter + ENGO Complementary Solution



Perspectives on Smart Inverters for Voltage Support

- **Buck-boost capability**: role is to primarily solve local over-voltage problems that are introduced by PV injecting real power
- **Volt-Var Curve**: Use Volt-VAr curve (priority) with Volt-Watt used on a case-by-case basis
- **Curtailment**: With VW, there may be curtailment that reduces sales revenue for PV owner
- **Critical Mass**: As per the default VV curves, to inject 10 kVAr need 25 inverters
- **Ownership & Location**: Utilities do not control where the next PV panel (and hence smart inverter) appears
- **Communication**: reliability and fidelity of comms is an issue
- **Night Time Support**: As inverters are not responsible for creating low-voltage – they are not responsible for fixing it
- **Losses**: Draw 1-5% losses that may be $50 - $100 per year per consumer
- **Inevitability**: But, Smart Inverters are being adopted and they are the way to move forward for PV owners

A complementary solution of ENGO and Smart Inverters can work wonders for the grid.

ENGO being utility-owned and in complete control by Utilities brings tremendous value **today and future proofs the grid for tomorrow**!

Let's see what happens under various scenarios (ENGO-only, Smart Inverters-only, ENGO+Smart Inverters)

PV Hosting Capacity with LDC Control

LTC Setting:

LDC Control optimized for each case

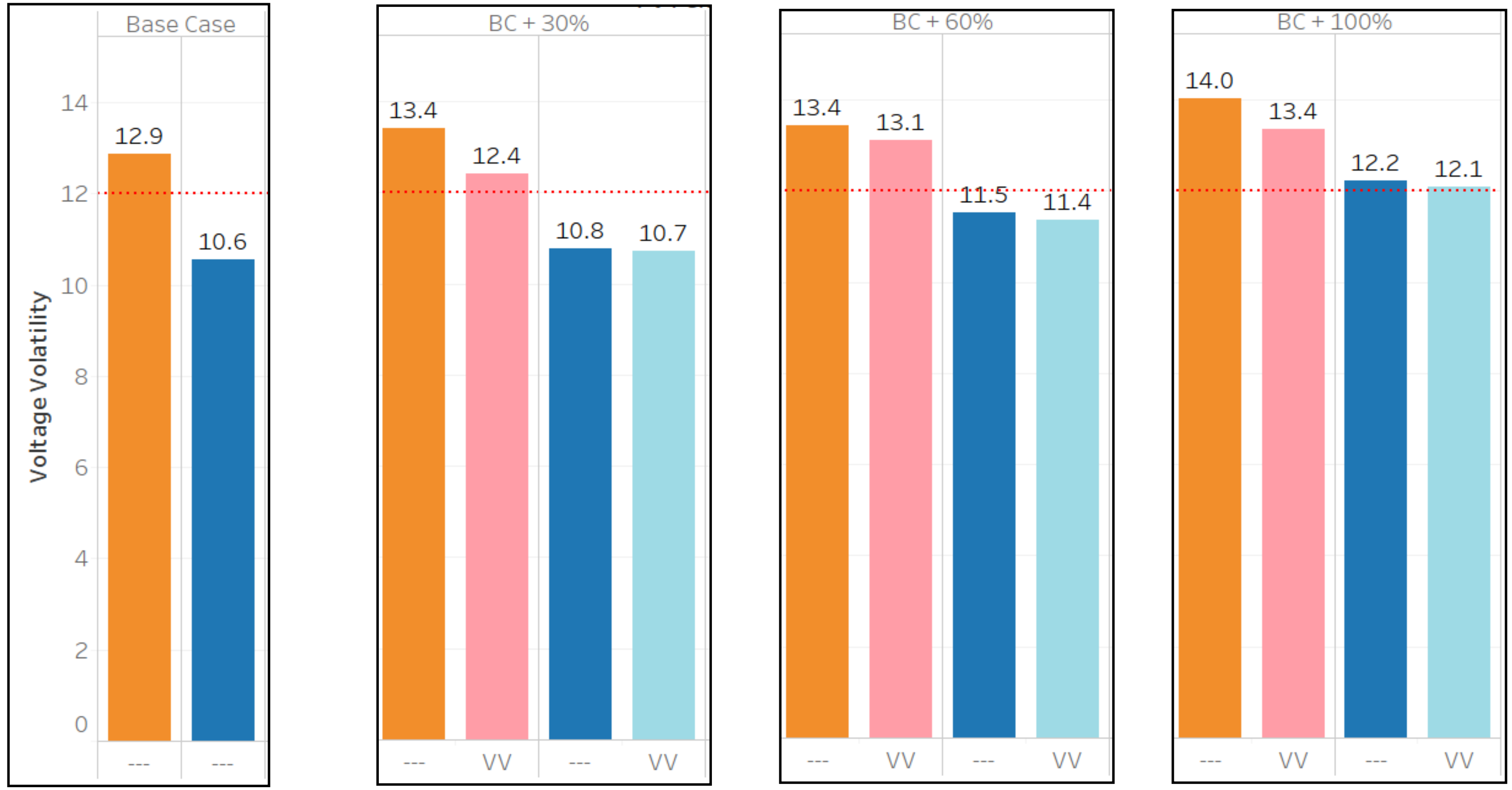
ENGO Setting:
Optimized for each case (Day-Night)

SI Setting:

VROS VV curve

Curtailment due to VW not considered

BaseCase (HC = 77%) PV = 4.86 MW	BC + 30% (HC = 100%) PV = 6.3 MW	BC + 60% (HC = 122%) PV = 7.7 MW	BC + 100% (HC = 154%) PV = 9.6 MW



- LDC Baseline
- LDC SI ON
- LDC ENGO ON
- LDC ENGO & SI ON

Legend Explanation:
Baseline: Legacy Inverters
SI ON: New Installation are Smart Inverters
ENGO & SI ON: New Installation are Smart Inverters + ENGOs Added to the System
ENGO ON: Only ENGO present in the system

- Under basecase (4.86 MW PV or 77% hosting capacity), even with optimal LDC control, voltage volatility is higher than 12V
- With only ENGO, 146% PV hosting (9.23 MW PV) can be supported without voltage violations
- A complementary solution of ENGO and Smart inverter does provide marginal additional benefit, 150% PV hosting can be supported without voltage violations

HECO Project Results

Tariff Avoidance

1

- Ensure that secondary voltages are above the required lower voltage limit (ANSI-A 114 V – 126V)
- Coordinate LTC and ENGO SetPoint to ensure no lower/upper voltage limit violation
- Reduce voltage fluctuation from 10.8% to 6.8%
- Improve voltage margin by 3.7% to 4.0% based on 114V – 126V range

PV Solar Integration

2

- Alternative to primary investment (LVRs or conductor/transformer upgrade)
- Increase PV hosting capacity from 87% to 123%
  - 7 MW (Simulated per field results)

3

- Reduce O&M costs (LTC operation reduced by 55% from 34 daily operations to 15)

Energy Savings

4

- Potential of 0.7% - 1.4% Energy Savings (CVR factor for Energy = 0.8)

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