

Transforming Distribution Networks – Applied Voltage Control to Manage Disruptive Trends

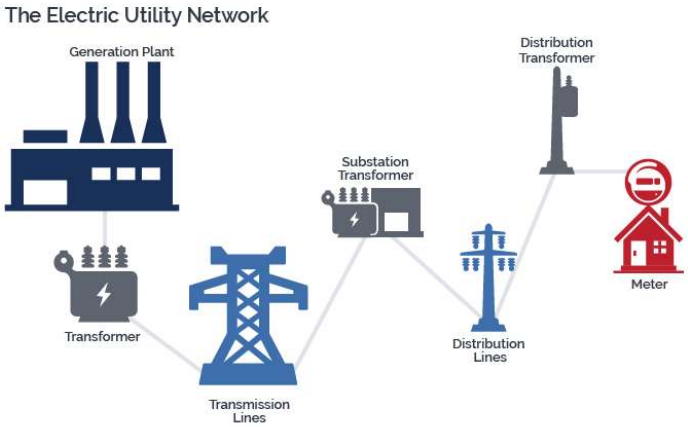
Cali Wilton

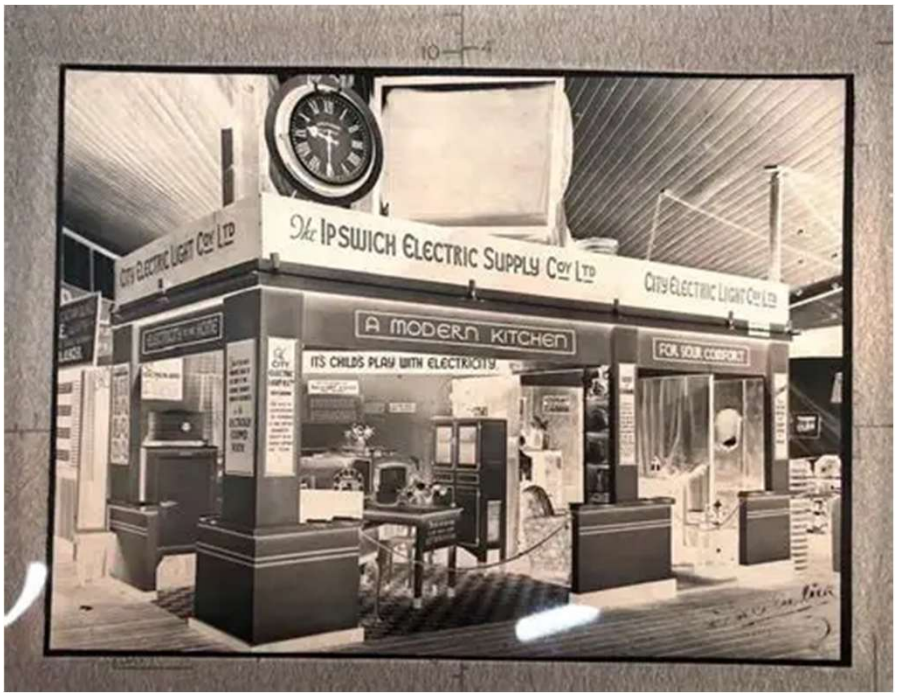
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PPA 2026

Distribution Networks – then…

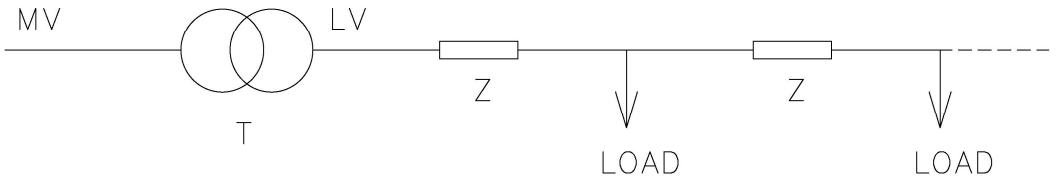
- Australia's distribution networks constructed to service a growing population spanning 60,000 km and containing 350,000 distribution substations
- Mixed voltage, architecture and circuit arrangement
  - Distribution Voltages at: 6.6, 11, 22, 33, 44, 50, and 66kV,
  - SWER system at 11, 12.7, and 19.1kV
- Like most traditional networks load flow was uni-directional and predictable based on installed load network impedances.



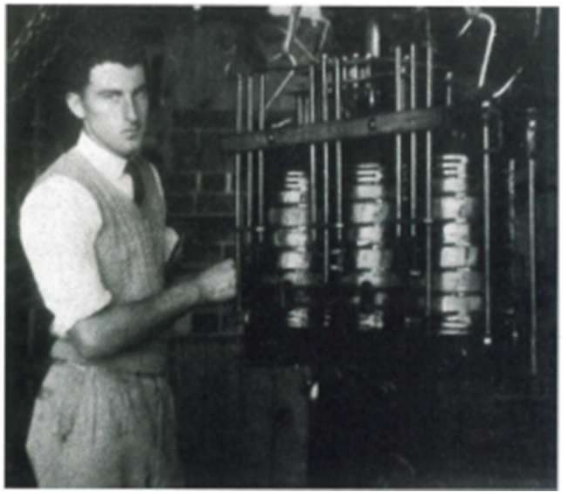


Distribution Networks – then…

- Transformers are primarily used to step-down transmission-to-distribution-to-end use low voltage
- Transformer taps were set based on no-load voltage and based on load and impedance calculation at commissioning with an opportunity to adjust/correct at commissioning



- Historically taps we adjusted maybe once in the transformers 30-year life.

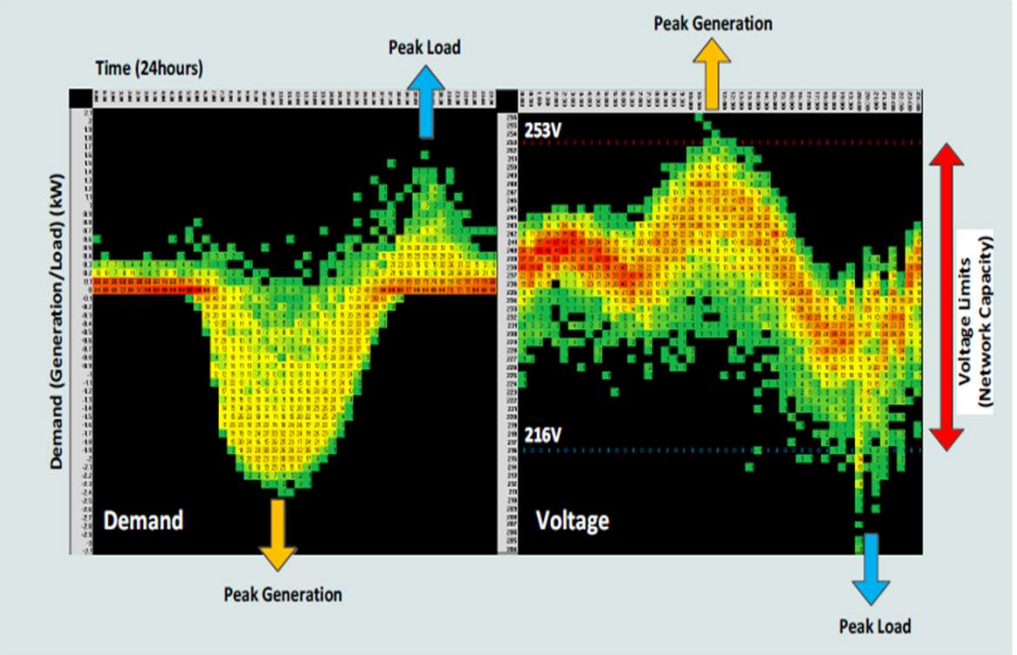




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Distribution Networks – now

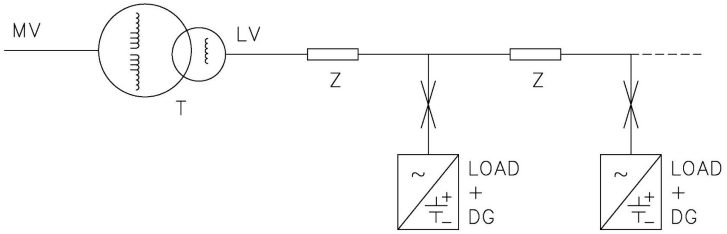
- Australia's distribution networks continue to grow to include 1,450,000* distribution substations in service
- Load flow in these distribution networks is largely bidirectional
- Many low voltage networks operate with high power factor, leading and/or with PFC
- Highly dynamic load with large swings resulting from distributed generation.
- Voltage excursions in low voltage, distribution and sub-transmission networks prove to be one of the largest challenge for the network operators.
- **Q: What hasn't changed?**



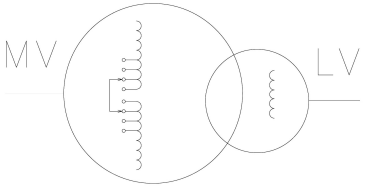
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Distribution Networks – now

- Distribution transformers are used to step-down distribution to end use low voltage and set the nominal float voltage.
- Distribution transformers increasingly facilitate connection of distributed generation.



- >99% of distribution transformers deployed have no ability to actively control the voltage yet are the utilities principal asset to set voltage.



- Off-circuit taps are set based on no-load voltage at commissioning an operate at fixed ratio.
- Distribution transformer tapchangers continue to be based on 1950's technology **Q: An opportunity?**





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Voltage Control at the Distribution Substation

- Multiple voltage regulating methods applied to distribution networks including:

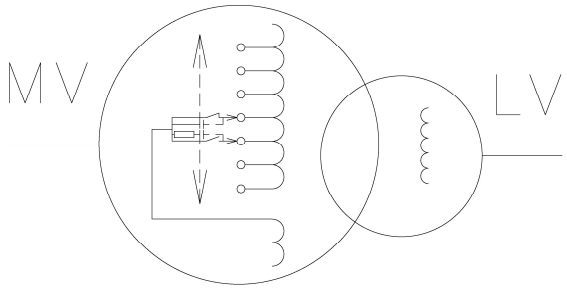
VOLTAGE REGULATING METHOD	APPLICABLE RATING	PRO	CON	INDICATIVE COST ($)
Off-circuit Tap change	10->5000kVA	Existing plant	Remains a fixed solution	$ - Average Outage Cost $7,000 per event
Re-conductor and Replace Transformer with Low Impedance/Larger Unit	10->5000kVA	Existing plant	Remains a fixed solution	$$$ uses existing plant - Antecdotal cost up to $80,000 for a single substation
Inverter based LV Regulators (LVR)	5-150kVA	Sub-cycle Control	Reliability, and Rating Limit	$$ new acquisition
DSTATCOM	5-150kVA	Sub-cycle Control	Relies on PF, and Rating Limit	$$ new acquisition
On-Load Tapchanging	10->5000kVA	Reliable, Indepedant of PF	Slow and Coarse Control	$ as an incremental cost

- All of the above apply distribution transformers….

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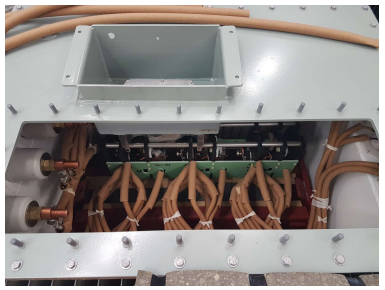
Voltage Control at the Distribution Substation

- Voltage Regulating Distribution Transformers (VRDT's)
- The proven VRDT technology utilizes MV tappings to adjust transformer voltage ratio.
  - Reliable, fault tolerant and flexible
  - Based on proven construction and applied technology. In all voltage controlled networks the transformer still exists
  - Transient voltage and short circuit capable.
  - Control can be local at the substation or central co-ordinated.
- BS, EN and IEC now recognise VRDT's as an important technology commonly working to develop. BS EN IEC60076.24:2020







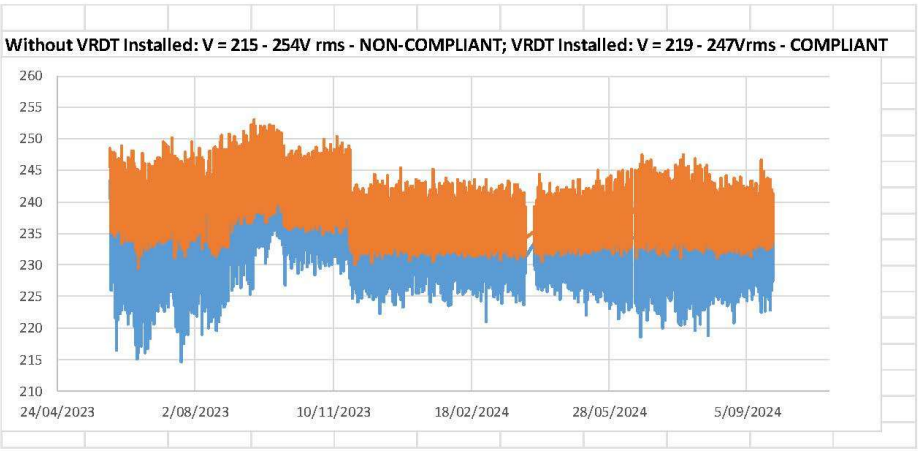


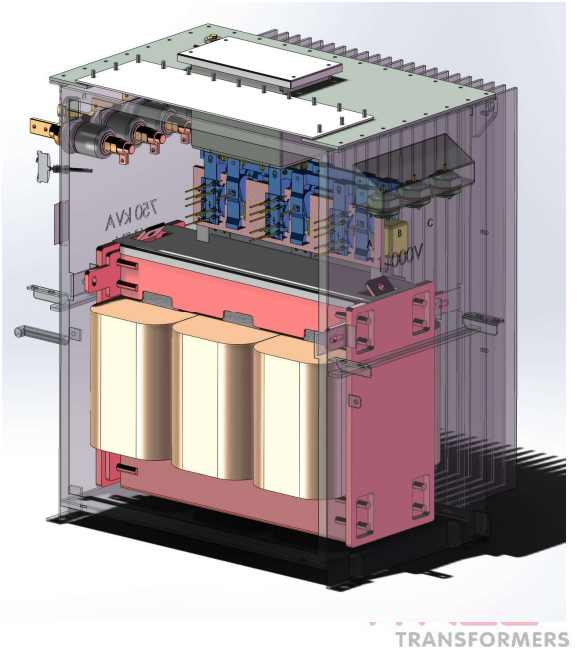
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Voltage Control at the Distribution Substation

- Padmounted Substation VRDT application
  - 500kVA, 11kV/433-250V kiosk transformer
  - Tapping range: +/- 4 x 1.88% steps
  - Self Powered regulator with remote and SCADA capability
  - Equivalent footprint size of existing 500kVA Kiosk Substation
  - **Weight:** increase of 90kg or 1.5% for substation relative to conventional
  - **Cost:** increase of 38% for substation relative to conventional
  - **Benefits:** This substation is installed in a location which experiences >100% of it's rating daily swing from load to generation.





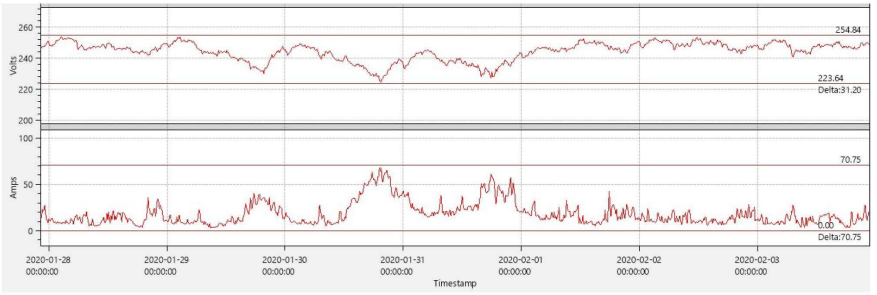


Voltage Control at the Distribution Substation

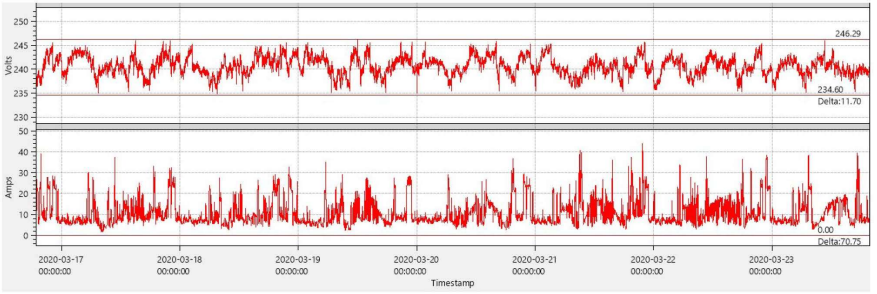
- Polemounted SWER VRDT application
  - 25kVA, 19.1kV/500-250V polemount transformer
  - Standalone regulator
  - Self Powered
  - Type tested and hardened for remote aerial networks
  - **Size and weight**: 25kVA results in less than the size and weight of a 50kVA conventional unit.
  - **Cost**: increase of 3x of conventional, BUT consider a conventional DT is approx. $3,000
  - **Benefits:** This substation enables rural solar in South Australia SWER network



Without VRDT Installed: V = 224-256 V_{rms} **NON-COMPLIANT**



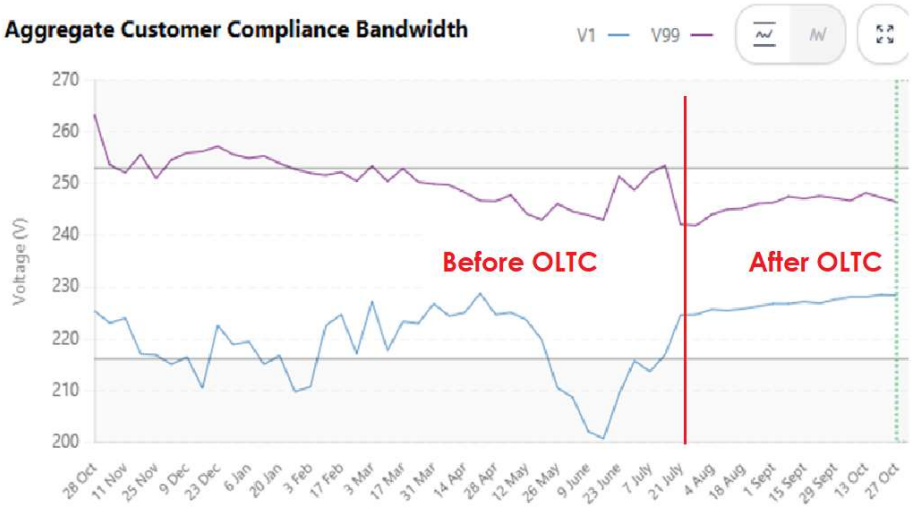
VRDT Installed: V = 236-246 V_{rms} **COMPLIANT**

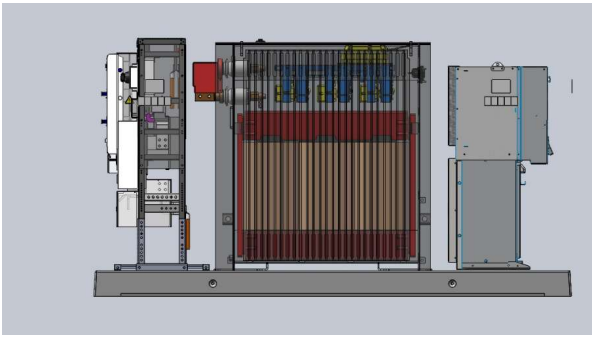


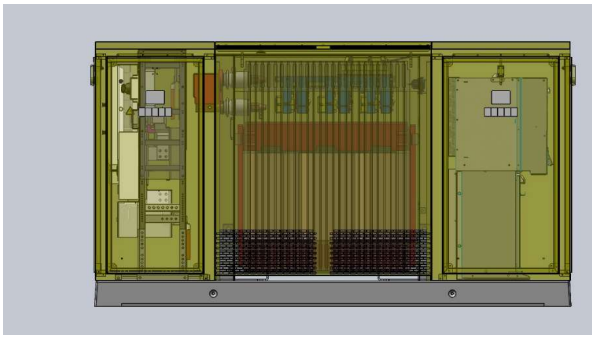
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Voltage Control at the Distribution Substation

- Padmounted Substation VRDT application
  - 750 and 1000kVA, 11kV/433-250V kiosk VRDT
  - Equivalent footprint size of existing 1000kVA Kiosk Substation
  - **Cost:** <20% incremental cost to include OLTC
  - **Benefits:** Integrated with NON-SF6 switchgear, K-Rated Ester Fluid and Internal Arc Contained Type Tested Kiosk arrangement









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Voltage Control at the Distribution Substation

Other benefits:

- Every modern DNSP construction standard has integrated examples in service of VRDT in some form. i.e **DEVELOPMENT RISK IS LOW**
- Voltage adjustment without an outage
  - Currently tapchanging a distribution substation requires a planned 30-60 minute outage with an outage cost $6,000-7,000 per event
  - Historical float voltage for >50% of the distribution substation fleet is 4% greater than nominal (ie 430V for 415V) network. Why?
    - This setting provided a 10% load drop swing to maintain voltage standard
    - This setting only provide 2% generation rise to maintain voltage standard
    - RESULT: Most DNSP's have a tapchange process underway
- Down-stream benefits:
  - Conservation of voltage
  - Curtailment of solar in-feed due to over-voltage
- Future proof the asset
  - Primary plant >25 years life. OLTC is rated for the life of the transformer
  - Incremental cost is 1/3 the cost to upgrade or replace in the future.
  - >75% of new connections are funded by the developer so why not future proof the asset for greater ROI



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Questions?

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Thank you