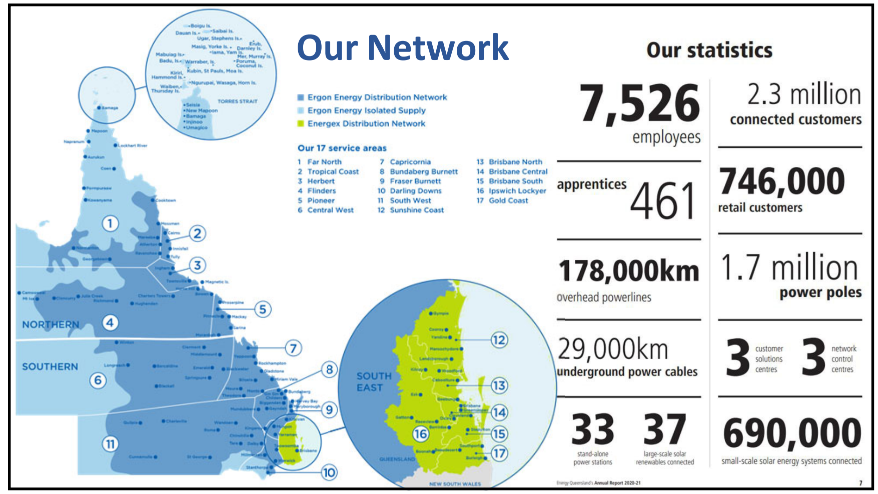
Integrating Growing PV Installations on Queensland's Distribution Network
ERGON ENERGY NETWORK
energex
Part of Energy Queensland
Electrical Engineers Association NZ, January 2022

1



Our Network
Ergon Energy Distribution Network
Ergon Energy Isolated Supply
Energex Distribution Network
Our 17 service areas
1 Far North
2 Tropical Coast
3 Herbert
4 Flinders
5 Pioneer
6 Central West
7 Capricornia
8 Bundaberg Burnett
9 Fraser Burnett
10 Darling Downs
11 South West
12 Sunshine Coast
13 Brisbane North
14 Brisbane Central
15 Brisbane South
16 Ipswich Lockyer
17 Gold Coast
NORTHERN
SOUTHERN
SOUTH EAST
TORRES STRAIT
QUEENSLAND
NEW SOUTH WALES
Our statistics
7,526 employees
2.3 million connected customers
apprentices 461
746,000 retail customers
178,000km overhead powerlines
1.7 million power poles
29,000km underground power cables
3 customer solutions centres
3 network control centres
33 stand-alone power stations
37 large-scale solar renewables connected
690,000 small-scale solar energy systems connected
Energy Queensland's Annual Report 2020-21
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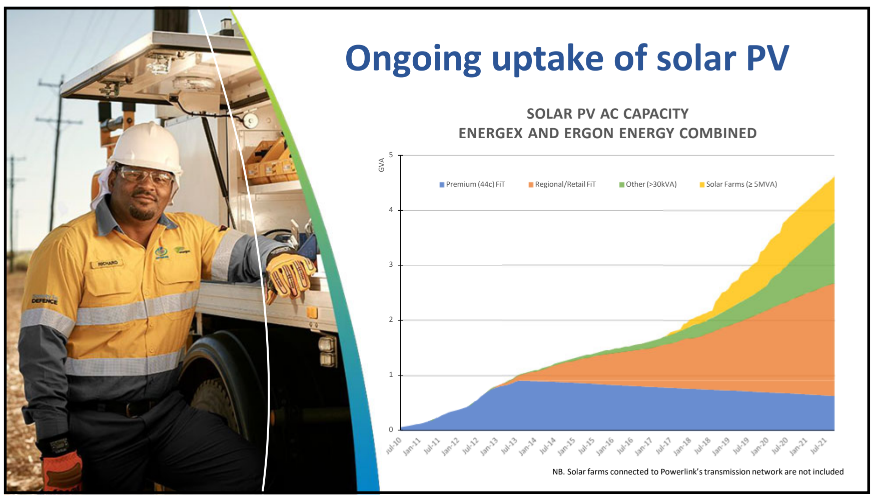
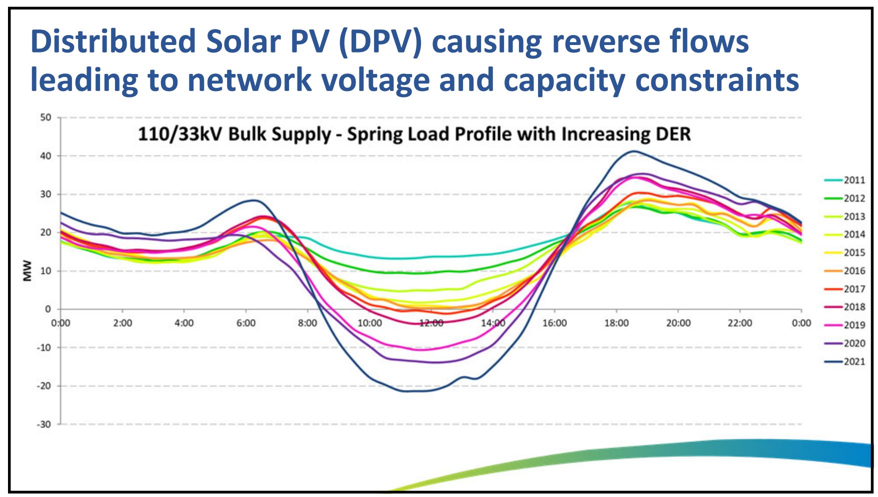
2



Ongoing uptake of solar PV
SOLAR PV AC CAPACITY
ENERGEX AND ERGON ENERGY COMBINED
GVA
Premium (44c) FiT
Regional/Retail FiT
Other (>30kVA)
Solar Farms (≥ 5MVA)
0
1
2
3
4
5
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
Jan-15
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20
Jul-20
Jan-21
Jul-21
NB. Solar farms connected to Powerlink's transmission network are not included

3



Distributed Solar PV (DPV) causing reverse flows leading to network voltage and capacity constraints
110/33kV Bulk Supply - Spring Load Profile with Increasing DER
MW
50
40
30
20
10
0
-10
-20
-30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021

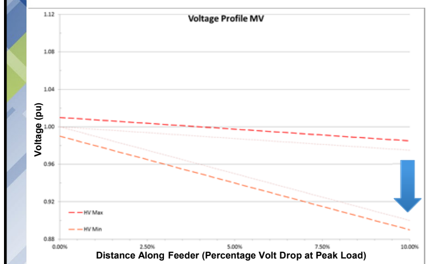
4

Distribution voltage management

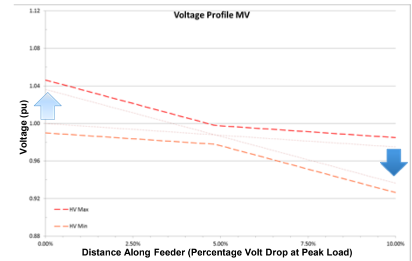
5

MV Regulation

Fixed



Line Drop Compensation (LDC)



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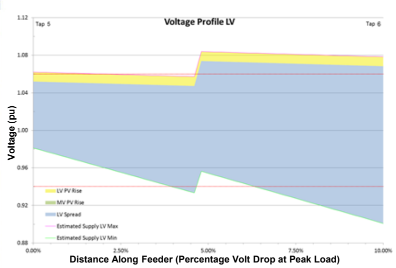
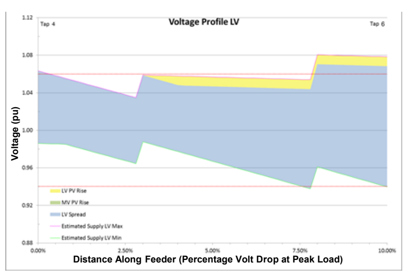
240V (±6%) Regulation

Fixed



Line Drop Compensation (LDC)

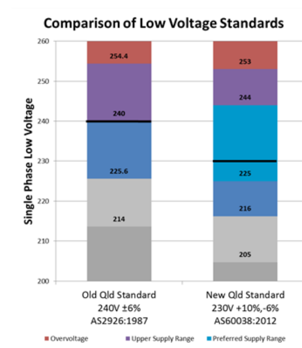


7

230V Standard in Qld

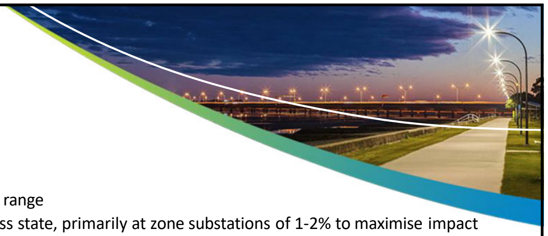
In October 2017 an amendment was made to the Queensland Electricity Regulation mandating a transition from the 240V to 230V standard by 26 October 2018.

Qld Supply Voltages		Existing (AS2926-1987)	Proposed (AS60038-2012)
Nominal	V_{ln}/V_{ll}	240/415V	230/400V
% Range		+6%/-6%	+10%/-6%
Max/V99%	V_{ln}/V_{ll}	254.4/440V	253/440V
Min/V1%	V_{ln}/V_{ll}	225.6/390V	216/376V
Range	V_{ln}/V_{ll}	29/50V	37/64V
V50% (AS61000.3.100)	V_{ln}/V_{ll}	-	225V-244V /392V-424V



8

230V Transition



- Phase 1 (Nov 2017 – Oct 2018):
  - From 225.6-254.4V to 216-253V LV range
  - MV (11kV & 22kV) reductions across state, primarily at zone substations of 1-2% to maximise impact (limited by OLTC buck taps/high transmission voltages)
- Phase 2 (Nov 2018 – June 2020):
  - Increased compliance with Preferred range 225-244V (AS61000.3.100)
  - More targeted reductions at remaining substations, MV regulators and also distribution transformers based on revised tap plans, monitoring and customer feedback
- Phase 3 (July 2020 onwards):
  - Ongoing response to issues identified by maximum and minimum demand forecasts, by monitoring and customer feedback

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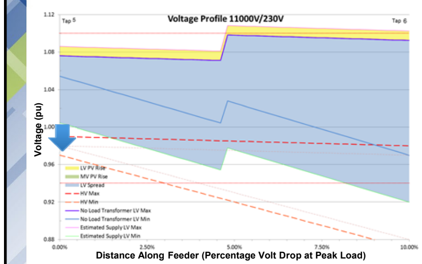
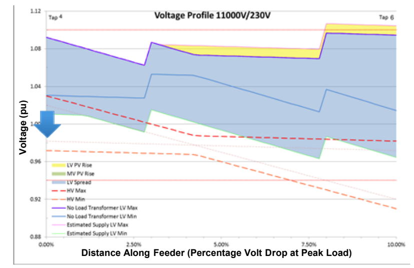
230V (+10/-6%) Regulation

Fixed



Line Drop Compensation (LDC)



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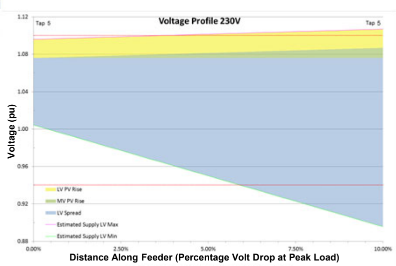
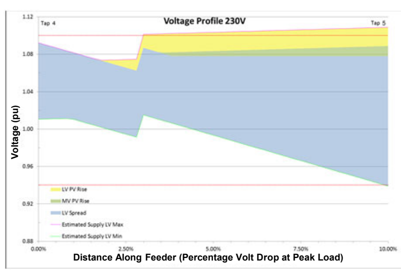
Reverse Flow & Voltage Regulation

Fixed



Line Drop Compensation (LDC)



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Voltage and capacity constraints on the LV network

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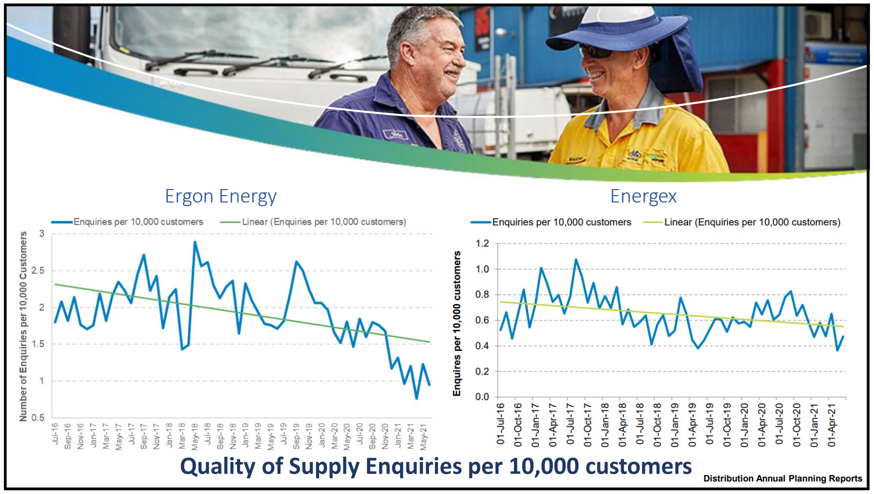

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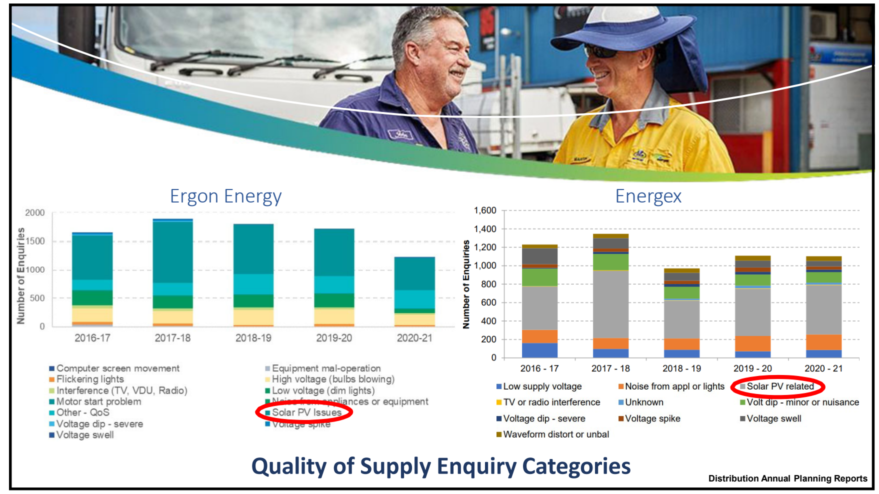

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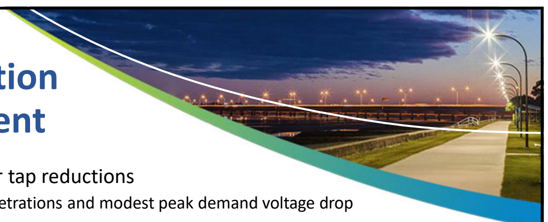
Improved distribution voltage management



- Targeted distribution transformer tap reductions
  - Targeted at sites with high PV penetrations and modest peak demand voltage drop
- Widespread MV reductions to transition from the 240V standard to 230V
  - From 225.6-254.4V to 216-253V LV range
  - Increased voltage headroom for reverse flows
  - Median supply voltage compliance with Preferred range 225-244V (AS 61000.3.100)
- Application of line drop compensation to buck MV during reverse flow & minimum demand
  - Applied at zone substations and on MV feeder regulators
  - Reduces voltage spread at end of distribution feeders and accommodates additional feeder voltage rise
  - Constrained by buck tap range on some On Load Tap Changers (OLTCs)

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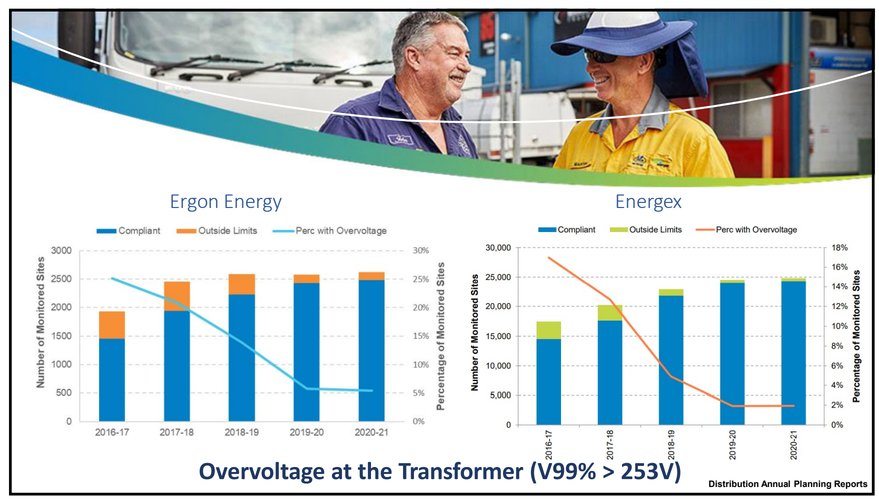

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Steady-state voltage distribution

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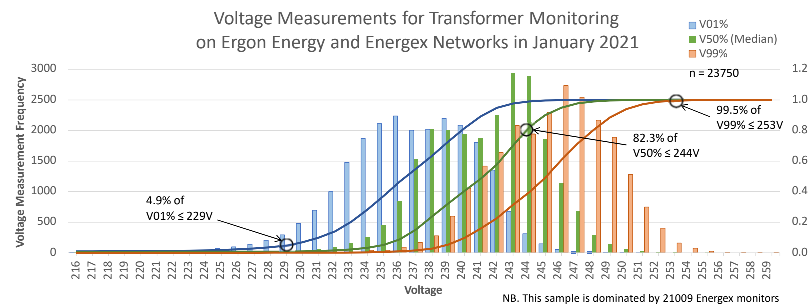
Transformer Monitoring – Jan 2021



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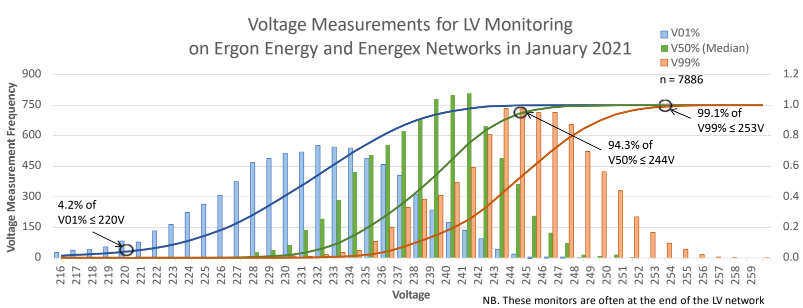
Low Voltage Monitoring – Jan 2021



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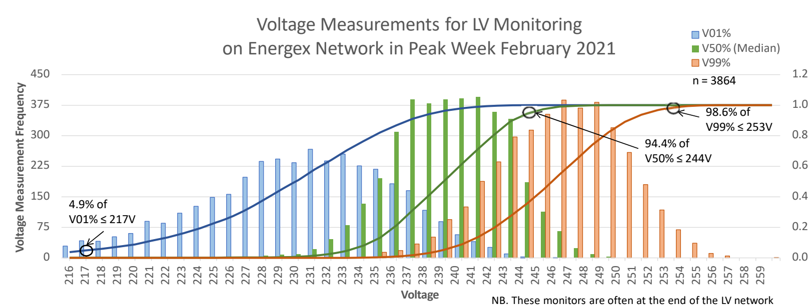
Low Voltage Monitoring – Peak week Feb 2021



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Smart Inverters and Grid Support Functions (GSF)

AS/NZS 4777.2:2020 Grid connection of energy systems via inverters, Part 2: Inverter requirements

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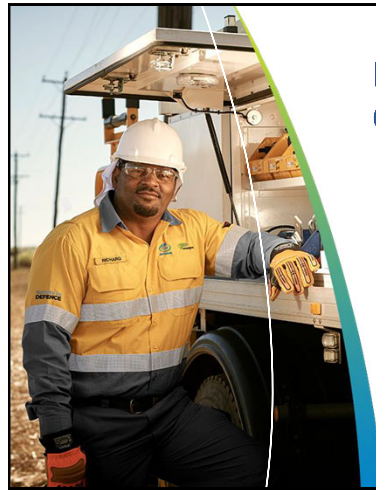
Large Reactive Power Capability



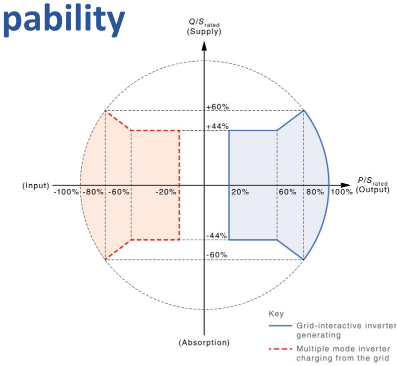


Figure 2.1 — Minimum reactive power capability

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Volt-var response, mitigating voltage rise from reverse flow

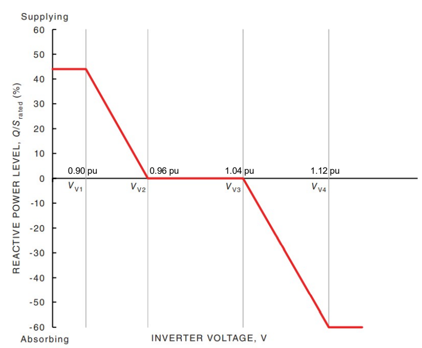

Figure 3.2 — Example curve for the volt-var control mode AS/NZS 4777.2:2020

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Volt-watt response, limiting active power above 253V

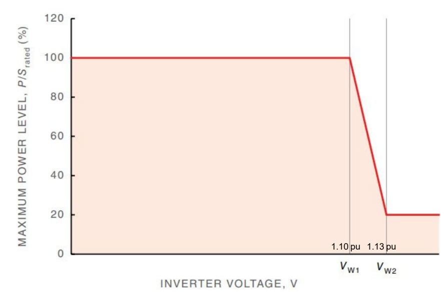

Figure 3.1 — Example curve for the volt-watt response mode

AS/NZS 4777.2:2020

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Changing reactive power demand

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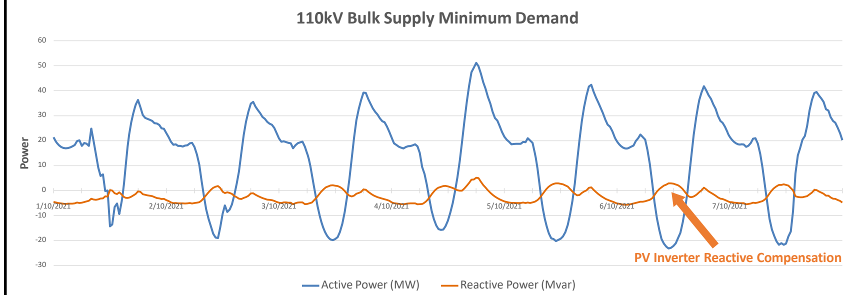
PV inverters with GSF are absorbing reactive power at minimum demand



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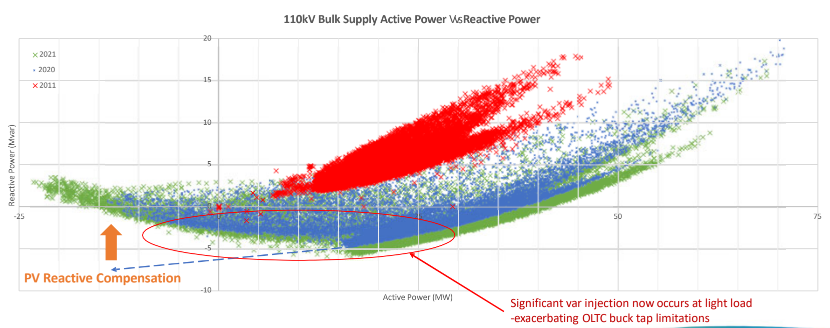
Active Power Vs Reactive Power



C.G. Kaloudas, L.F. Ochoa, B. Marshall, S. Majithia and I. Fletcher, "Assessing the Future Trends of Reactive Power Demand of Distribution Networks", IEEE Trans. on Power Syst., vol. 32, no. 6, 2017.

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Dynamic Operating Envelopes (DOE)

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Dynamic operating envelopes

- A DOE specifies a varying operating range at the connection point for exports and/or imports.
- This can apply to a range of distributed energy resources (DER) including PV, BESS, EV etc.
- It can be used in conjunction with autonomous GSF to ensure network/system constraints are not breached by DER operation.
- While DOE are initially limited by existing visibility and systems, as capabilities scale and grid visibility increases, the DOE we send to active DER can be optimised
- IEEE 2030.5 Smart Energy Profile (SEP2) is the proposed protocol
  - CSIP-AUS – Australian version of the Common Smart Inverter Profile

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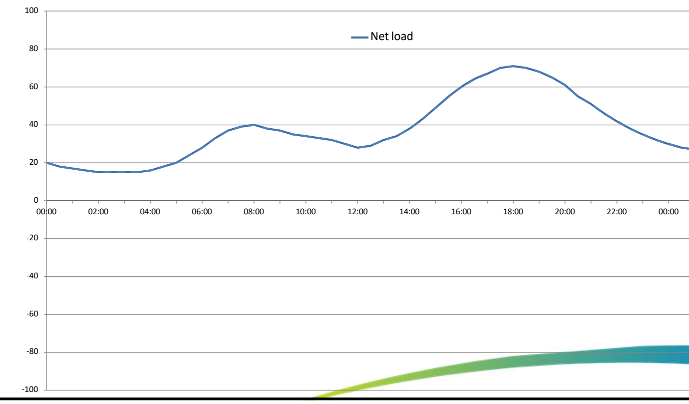
Native/underlying Load (before DER operation)



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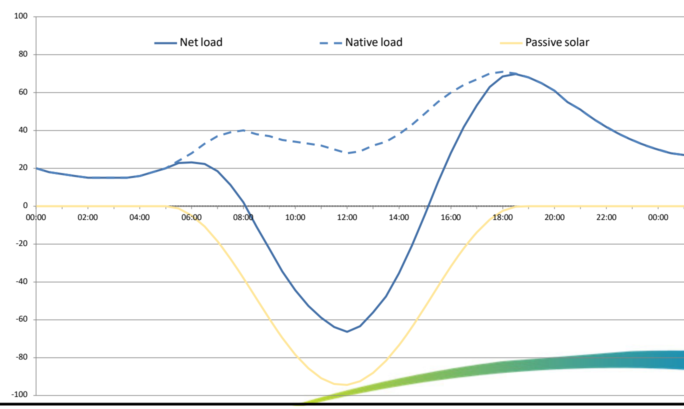
Net Load with significant PV generation



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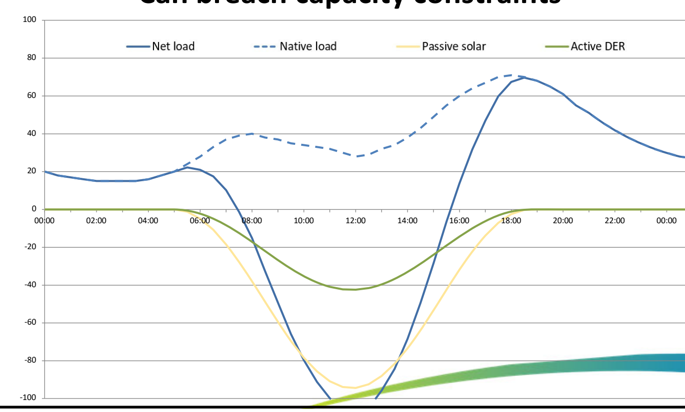
Net Load with additional PV generation Can breach capacity constraints



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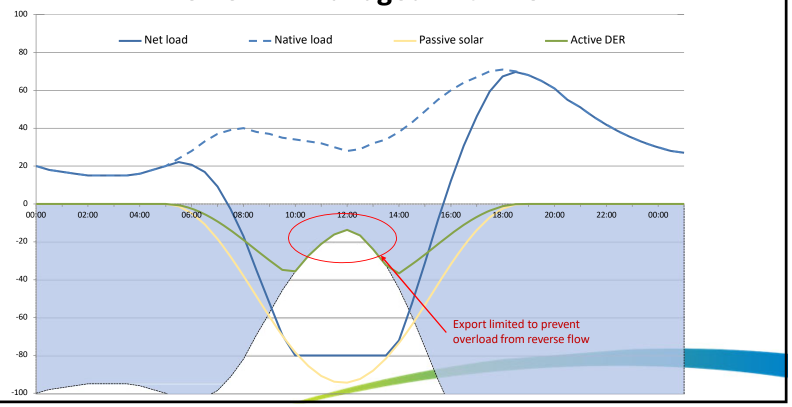
Net Load with significant PV generation Newer PV managed with DOE



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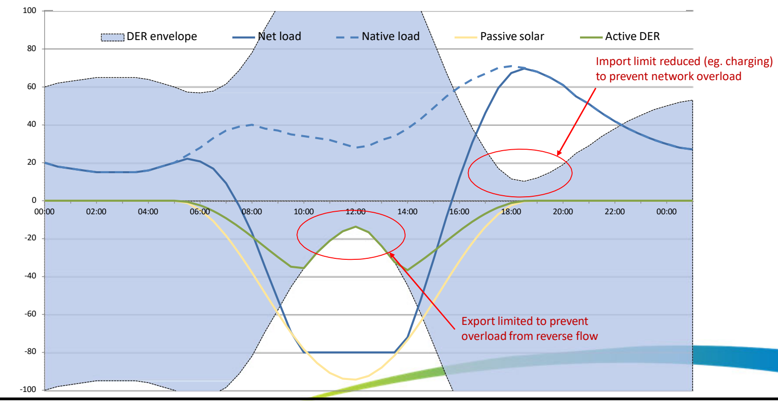
DOE can manage constraints associated with load also



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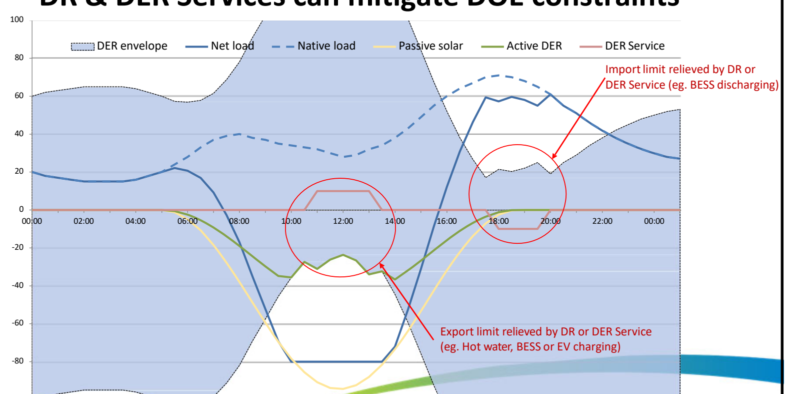
In addition to network augmentation DR & DER Services can mitigate DOE constraints



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From passive PV to active DER

- In just over a decade solar PV capacity in Qld has increased 1000 fold, primarily on the distribution network
- The 230V standard & improved distribution voltage regulation accommodates more voltage rise/PV
- Advanced autonomous inverter GSF mitigate impacts and maximise PV penetration
- DOE enables active DER management & DER service participation to maximise hosting capacity

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References

1) Energy Queensland, “Energy Queensland Annual Report 2020-21.” [Online]. Available: https://www.energyq.com.au/__data/assets/pdf_file/0010/939484/Energy-Queensland-Ltd-Annual-Report-2020-21.pdf
2) Ergon Energy Network, “Distribution Annual Planning Report.” [Online]. Available: https://www.ergon.com.au/network/network-management/future-investment/distribution-annual-planning-report
3) Energex , “Distribution Annual Planning Report.” [Online]. Available: https://www.energex.com.au/about-us/company-information/company-policies-And-reports/distribution-annual-planning-report
4) Grid connection of energy systems via inverters, Part 2: Inverter requirements, AS/NZS 4777.2: 2020.
5) C.G. Kaloudas, L.F. Ochoa, B. Marshall, S. Majithia and I. Fletcher, "Assessing the Future Trends of Reactive Power Demand of Distribution Netzworks", IEEE Trans. on Power Syst., vol. 32, no. 6, 2017.
6) Ergon Energy Network & Energex, “Enabling Dynamic Customer Connections for Distributed Energy Resources,” December 2021. [Online]. Available: https://www.talkingenergy.com.au/dynamicconnections

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Appendices

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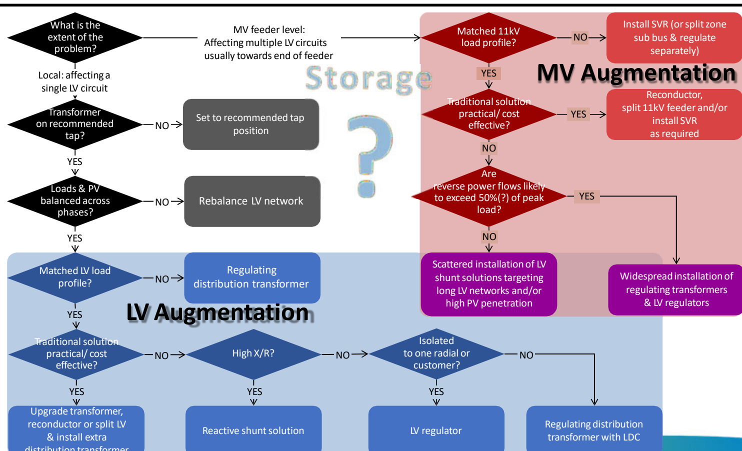
Network Augmentation Options



20 January 2022 Voltage management on distribution networks with high PV penetrations – Peter Kilby, Energex

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Volt-var response and mitigation of voltage rise

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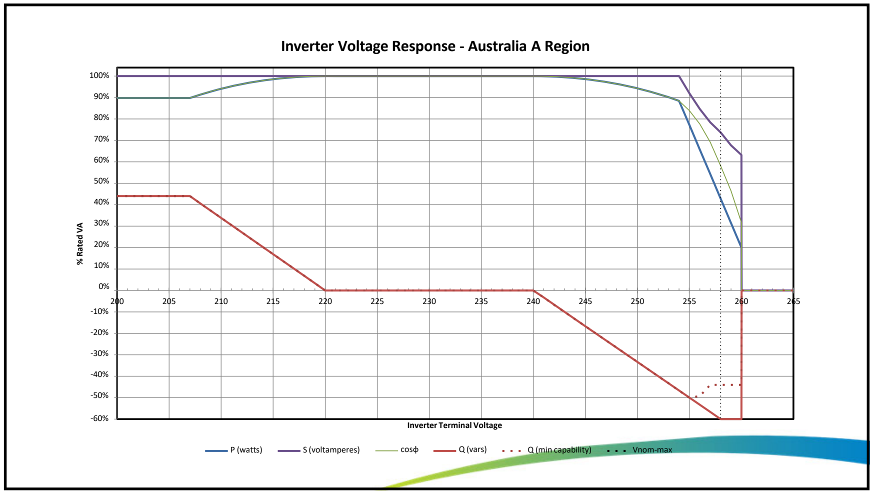
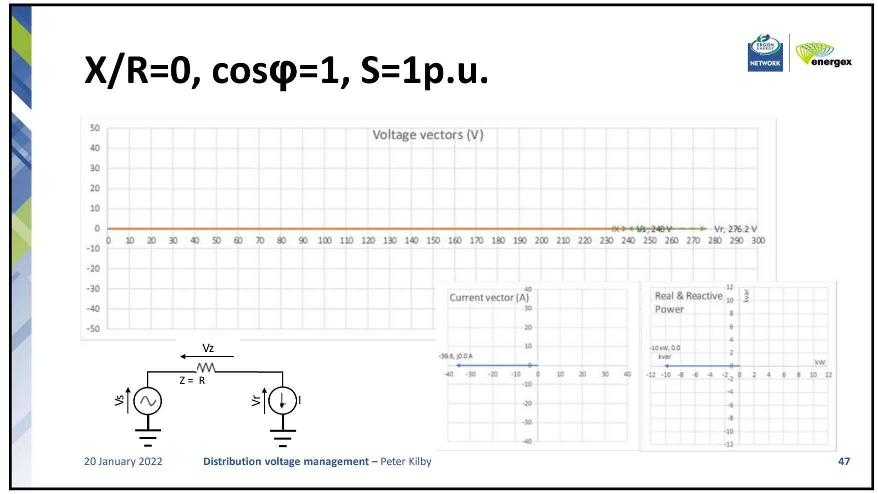

Inverter Voltage Response - Australia A Region
% Rated VA
Inverter Terminal Voltage
P (watts)
S (voltamperes)
cosϕ
Q (vars)
Q (min capability)
Vnom-max

41


X/R=0, cosφ=1, S=1p.u.
Voltage vectors (V)
Vr, 276.2 V
Vs, 240 V
Current vector (A)
Real & Reactive Power
Vz
Z = R
Vs
Vr
I
20 January 2022
Distribution voltage management – Peter Kilby
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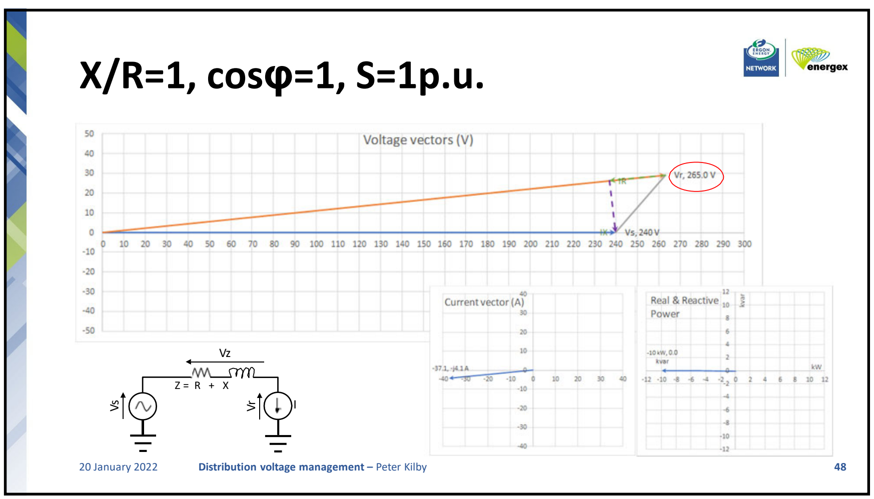
X/R=1, cosφ=1, S=1p.u.
Voltage vectors (V)
Vr, 265.0 V
Vs, 240 V
Current vector (A)
Real & Reactive Power
Vz
Z = R + X
Vs
Vr
I
20 January 2022
Distribution voltage management – Peter Kilby
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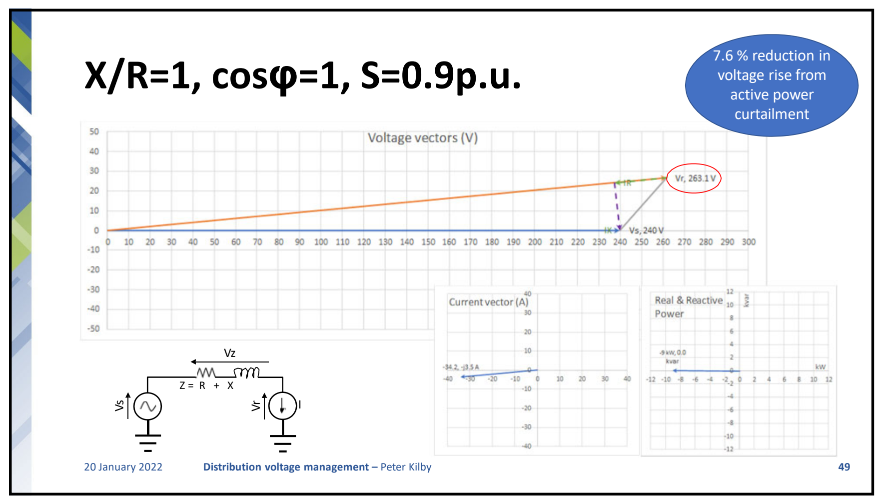
X/R=1, cosφ=1, S=0.9p.u.
7.6 % reduction in voltage rise from active power curtailment
Voltage vectors (V)
Vr, 263.1 V
Vs, 240 V
Current vector (A)
Real & Reactive Power
Vz
Z = R + X
Vs
Vr
I
20 January 2022
Distribution voltage management – Peter Kilby
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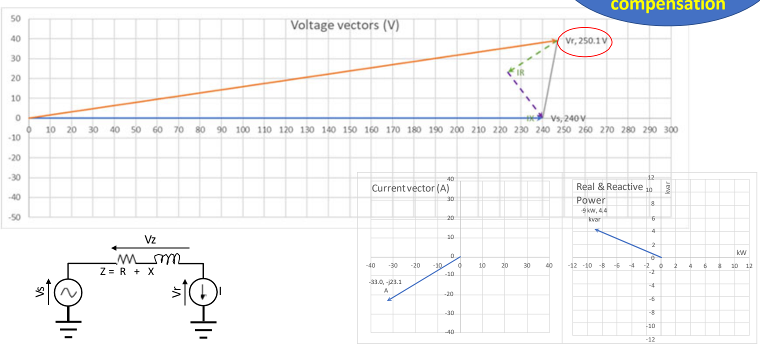
X/R=1, cosφ=0.9, S=1p.u.

60 % reduction in voltage rise from reactive power compensation



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Summary on volt-var

- Reactive power mitigates voltage rise associated with active power generation from DER with much less impact on output than active power curtailment
- This is true even on LV networks with relatively low X/R ratios
- Volt-var response only requires significant reactive power (associated with modest active power curtailment at full output) near voltage limits unlike fixed power factor or reactive power modes.
- Imposing volt-var response sooner (closer to nominal), ensures more DER on a distribution network contribute and mitigate voltage rise, reducing number of customers exposed to higher voltages that require volt-watt response

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