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COUNTRY : Australia
REGISTRATION NUMBER :

GROUP REF. : B5
PREF. SUBJECT : PS1
QUESTION N° : 7

An Australian Experience of Inverter Based Resource Behaviour and Validation

IBR Model Validation :

- Project MATCH is a collaboration between UNSW, AEMO and Solar Analytics
- Experience shows IBRs can turn off en-masse and exacerbate power system disturbances especially in high IBR penetration areas such as South Australia
- Market Operator AEMO have identified via fault investigations a large proportion of solar arrays disconnect in response to short duration under-voltage events.
- This implies that IBRs are not behaving as expected and validation is required
- AEMO have developed a Short Duration Undervoltage Disturbance Ride-Through (VDRT) Test Procedure. This is to ensure compliance with AU/NZs 4777.2:2015
- Increasingly evident that aggregate behaviour of small-scale PV will pose a power system security threat if left unmanaged
- Many unresolved questions regarding compliance, ambiguity and transitions between the various versions of the standards and with actual grid disturbance events.
- Two recent grid fault excursion events showed of the 376 sites involved, 30-40% of PV generation were lost but individual behaviour of these sites varied markedly

UNSW testing inverters found that with the same settings and control parameters and different behaviours exist from different manufacturers.

Project MATCH builds on ongoing collaboration between UNSW Sydney, market operator AEMO and Solar Analytics:
Power system disturbances can cause voltage or frequency to move outside usual limits. Experiences has shown that IBR can turn off en masse during disturbances and therefore aggravate power system imbalances. IBR can also act to support power system security during some events. Improving our understanding of how IBR behaves can help manage these security risks and realise their potential benefits.

There is a need for high resolution data sets of IBR behaviour under disturbances, analytical tools that can grapple with the complexity of their responses and an improved understanding of IBR performance in the field. Together, these measures can increase the accuracy of power system models and help avoid overly conservative approaches to system operation that adversely impact IBR deployment.

https://www.ceem.unsw.edu.au/project-match

- Naomi Stringer, Navid Haghdadi, Anna Bruce, Jenny Riesz, Iain MacGill (2020) *Observed behavior of distributed photovoltaic systems during major voltage disturbances and implications for power system security,* Applied Energy, Volume 260, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2019.114283

- Naomi Stringer, Anna Bruce, Iain MacGill, Navid Haghdadi, Peter Kilby, Jacqui Mills, Taru Veijalainen, Matt Armitage, Nigel Wilmot (2020). *Consumer-Led Transition: Australia's*

World-Leading Distributed Energy Resource Integration Efforts. IEEE Power and Energy Magazine, 18(6), 20-36. doi:10.1109/MPE.2020.3014720

- Leonardo Callegaro, Georgios Konstantinou, Christian A. Rojas, Nelson F. Avila, John E. Fletcher, "Testing Evidence and Analysis of Rooftop PV Inverters Response to Grid Disturbances", Photovoltaics IEEE Journal of, vol. 10, no. 6, pp. 1882-1891, 2020, doi:10.1109/JPHOTOV.2020.3014873

- Ryan Quint, Lisa Dangelmaier, Irina Green, David Edelson, Vijaya Ganugula, Robert Kaneshiro, James Pigeon, Bill Quaintance, Jenny Riesz, Naomi Stringer (2019). *Transformation of the Grid: The Impact of Distributed Energy Resources on Bulk Power Systems*. IEEE Power and Energy Magazine, 17(6), 35-45. doi:10.1109/MPE.2019.2933071

- AEMO (2019) *Technical Integration of Distributed Energy Resources,* available online at: https://aemo.com.au/-/media/files/electricity/nem/der/2019/operations/technical-integration-of-der-report.pdf?la=en&hash=65EAE8BA3C64216F760B16535CE2D3ED

Need for an international standard to define not only Voltage control, harmonics etc, but how the inverter should behave during fault conditions.

AEMO has identified through analysis of recent power system events, that a proportion of distributed solar PV (DPV) disconnect in response to short duration transmission undervoltage disturbances. Given the levels of DPV installed in South Australia, a severe but credible fault near the Adelaide metropolitan area could cause disconnection of up to half the distributed PV in the South Australian region. Under specific conditions this would leave AEMO with very few courses of action available for secure operation of South Australia. To reduce the potential for disruption and improve power system security, most immediately in South Australia, AEMO has consulted widely to develop a Short Duration Undervoltage Disturbance Ride-Through (VDRT) Test Procedure to ensure inverters compliant with AS/NZS 4777.2:2015, and IBR by extension, respond appropriately during short duration undervoltage disturbance events to mitigate any further potential risks to power system security.

Describe the implementation of SAs approval testing to validate inverters are fit for service. Failure of some even when compliant to AS4777.

The intention of the test procedure is to verify the behaviour of an inverter energy system during a short-duration undervoltage disturbance. The inverter should sufficiently demonstrate the ability to remain in continuous operation through a 220 ms duration voltage dip to 50 V. This test should be applied in conjunction with existing product certification testing for compliance with AS/NZS 4777.2:2015 and has been developed as a supplementary test. All definitions throughout are according to AS/NZS 4777.2. Where possible the undervoltage (V<) trip level from the original AS/NZS 4777.2:2015 certification should be noted. If this value is not available, then the undervoltage (V<) test as described in AS/NZS 4777.2:2015 Appendix G2.2 should be performed to determine the value. This test is used to verify that the undervoltage trip delay and maximum disconnection time for a short-duration undervoltage event, and that the withstand capability for a short-duration undervoltage event that occurs within the trip delay time.

https://aemo.com.au/-/media/files/electricity/der/2021/vdrt-test-procedure.pdf?la=en

Loss of 40% of fleet for a 275kV disturbance. (invalid models / inability to fully test behaviour)

As distributed photovoltaics (PV) levels increase around the world, it is becoming apparent that the aggregate behavior of many small-scale PV systems during major power system disturbances may pose a significant system security threat if unmanaged. Alternatively, appropriate coordination of these systems might greatly assist in managing such disturbances. A key issue is PV behaviour under extreme voltage events. PV connection standards typically specify aspects of inverter voltage behaviour. However unresolved questions remain regarding compliance, ambiguity and transition between versions of these standards. In addition, how major voltage disturbances manifest in the low voltage network is complex, and analysis of operational system data could be particularly useful for establishing the behaviour of distributed PV in the field. The study utilizes 30 s operational PV generation data from 376 sites during two major voltage disturbances in Australia. Australia has one of the highest penetrations of distributed PV worldwide, and as such provides a useful case study. Results show that an aggregate ~30–40% reduction in distributed PV generation occurred during these events, but individual inverter behaviour varied markedly. This is the first time the aggregate response of distributed small-scale PV to voltage disturbances originating in the transmission system has been demonstrated.