Technical considerations for integration of distributed renewables on the grid

A paper by Dr Charlotte Higgins, Dr Bunmi Adefajo & Kumbuyani Chisoro

Kumbuyani Chisoro
Manager Southern Africa
TNEI Services Ltd

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Presentation Overview

- Introduction to TNEI
- Renewable Energy in East and Southern Africa
- Technical challenges for renewable generation
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  - Grid Code Reactive Power Capability
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Introduction to TNEI Services Ltd

- Well known and respected provider of specialist services to the energy sector, particularly in integration of renewables
- Two main consultancy groups:
  - Power Systems & Technology
  - Planning & Environmental
- Manchester, Newcastle, Glasgow and Cape Town
  - Approximately 70 staff – 15 Nationalities
  - Increasing international workload
  - Expanding range of design and technical site services
- Acquired by the Petrofac Group in June 2010

Renewable Energy in East & Southern Africa

- New renewable energy connections increasing rapidly
  - Increased investment
  - Diversified generation portfolio; Job creation; Rural development
- Renewable Energy Independent Power Procurement Programme in South Africa
  - Four bidding rounds completed
  - Renewable energy target of 17.8GW by 2030
- GET FiT Program in East Africa
  - Phase I: 125MW small scale renewable generation projects in Uganda
- Ethiopia
  - Adama II 153MW wind farm connected in May 2015 increasing Ethiopia’s total to 324MW
- Kenya
  - Lake Turkana 300MW wind farm when complete in mid-2016 will be Africa’s largest

Technical challenges for distributed renewable generation

- Important to understand and manage the impact of distributed renewable energy on the grid
- Rural and remote connections
  - Weak, low strength network with minimal local demand
- Grid Performance
  - Different types of renewable energy facilities have varying grid support capability
  - Depending on existing network some connections introduce grid performance problems
  - Use of cables to connect can introduce lower order harmonic resonances
- Technical aspects considered include
  - Reactive power or voltage capability
  - Fault level, stability and fault ride-through issues
  - Power quality

- So what to do?

Grid Code Compliance

- Grid code or connection agreement
  - Set of rules for the energy exchange between the different owners and stakeholders of a grid

- Grid Code Compliance
  - Compliance with the different aspects of the grid code should minimise the risk that new connections will result in degradation of grid performance
  - Assessment of grid code compliance is carried out through power system studies including the modelling of surrounding grid characteristics

- Grid code connection requirements include
  - Reactive power capability; Fault level contribution; Fault ride-through capability
  - Stable response to transients over a range of operating conditions and transient events
  - Power quality e.g. Harmonics, voltage unbalance, flicker

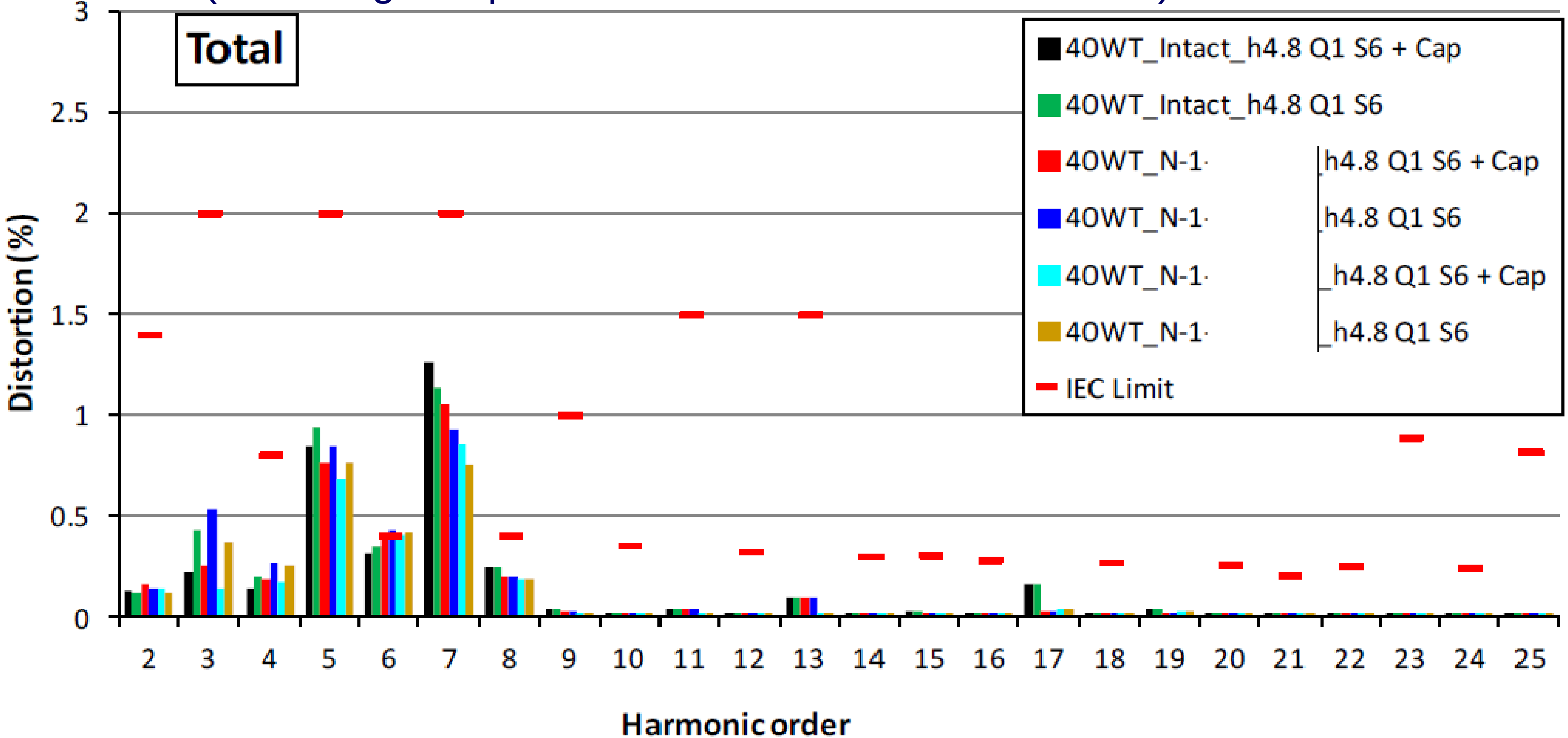
Grid Code Compliance cont'd

- Why early compliance studies are required
  - May indicate the need for mitigation equipment such as reactive power compensation or harmonic filters to achieve compliance or in some cases adaptation of auxiliary controls systems
  - Early identification of potential issues and additional balance of plant required can help to de-risk projects through reducing business case uncertainty and improving definition of construction programme
  - Avoid loss of revenue if generation plant is not fully operational by the agreed connection date

Case Study – Wind Farm Harmonics

- 100MW wind farm
  - Connected at transmission level to a fairly remotely located grid via an 11km underground cable
  - Interaction of the export cable capacitance with the transmission grid impedance caused amplification of existing background harmonics
  - Harmonic impedance and voltage penetration assessments undertaken to establish impact of export cable and wind farm inter-turbine cables
  - TNEI identified that a high-pass harmonic filter was able to damp the resonance and therefore a filter design specification was prepared as shown in **Fig.1**

Fig. 1 – EHV harmonic voltage profile with filter for intact and contingency network conditions (indicating compliance between 5th & 8th harmonics)



Case Study – Grid Code Reactive Power Capability

- 94MW wind farm in Scotland
  - Connected at transmission level
  - Reactive power capability studies indicated the wind farm was not fully compliant with the grid code reactive power requirement at the lower voltage terminal of the grid transformer
  - Studies showed that the addition of two 9MVAr capacitors to be switched in above 60% & 80% active power output respectively, enabled the wind farm to be compliant at all active power outputs (0% to 100%) (Shown in **Fig.2**)

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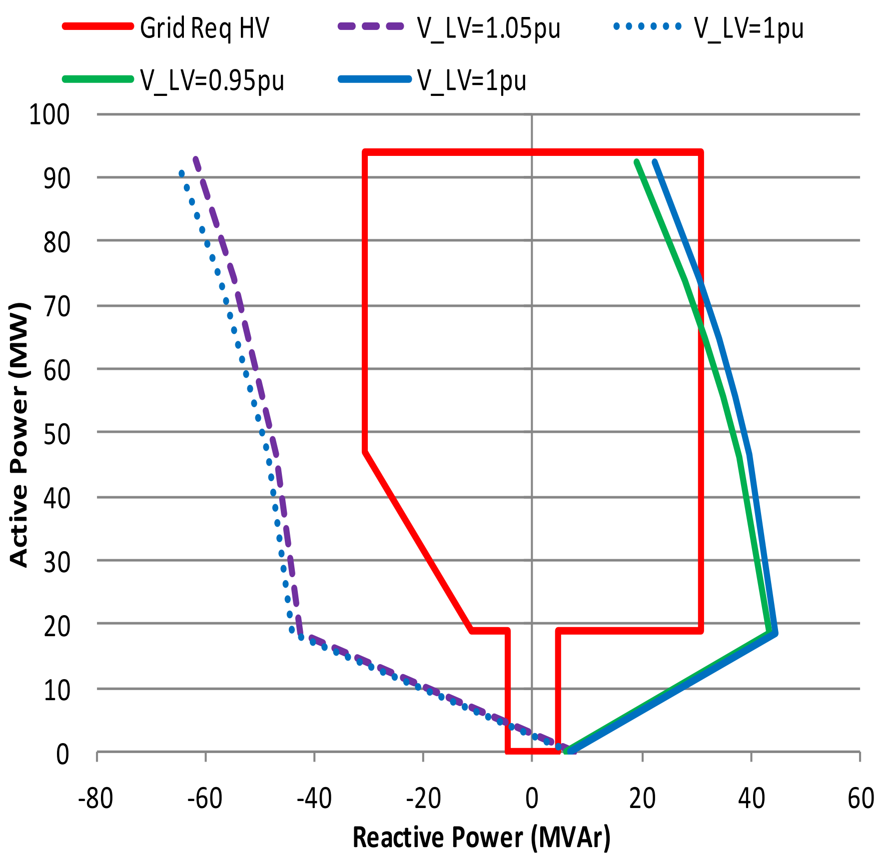
Reactive power capability **with no** reactive power compensation



Reactive power capability **with** reactive power compensation

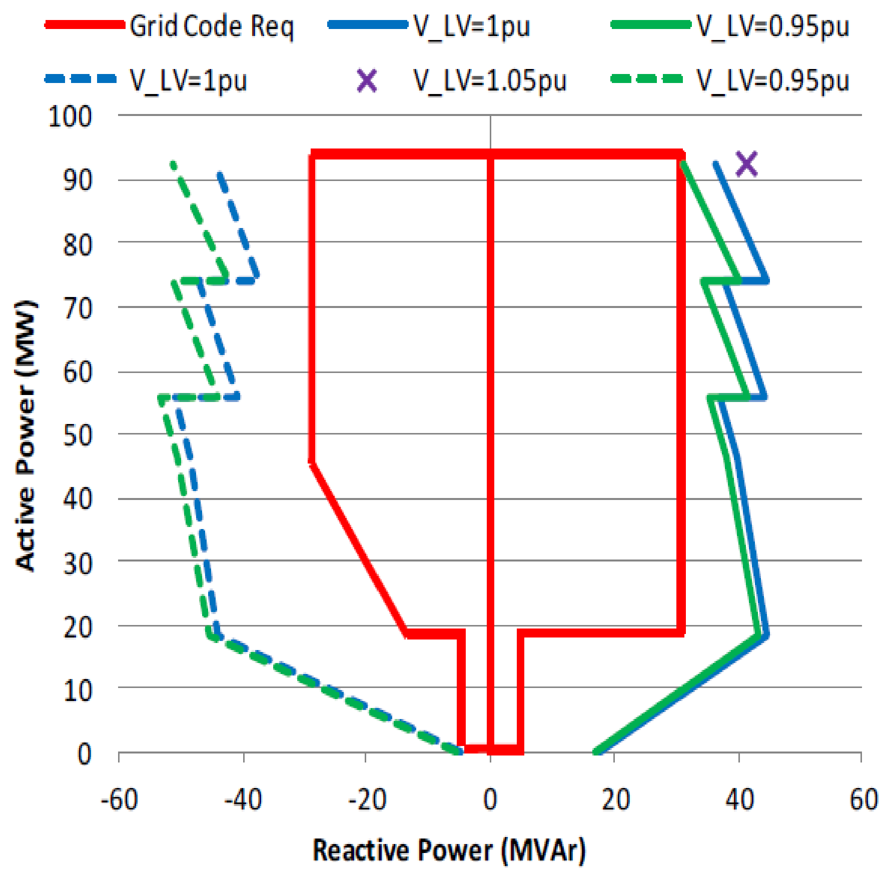


Fig 2.

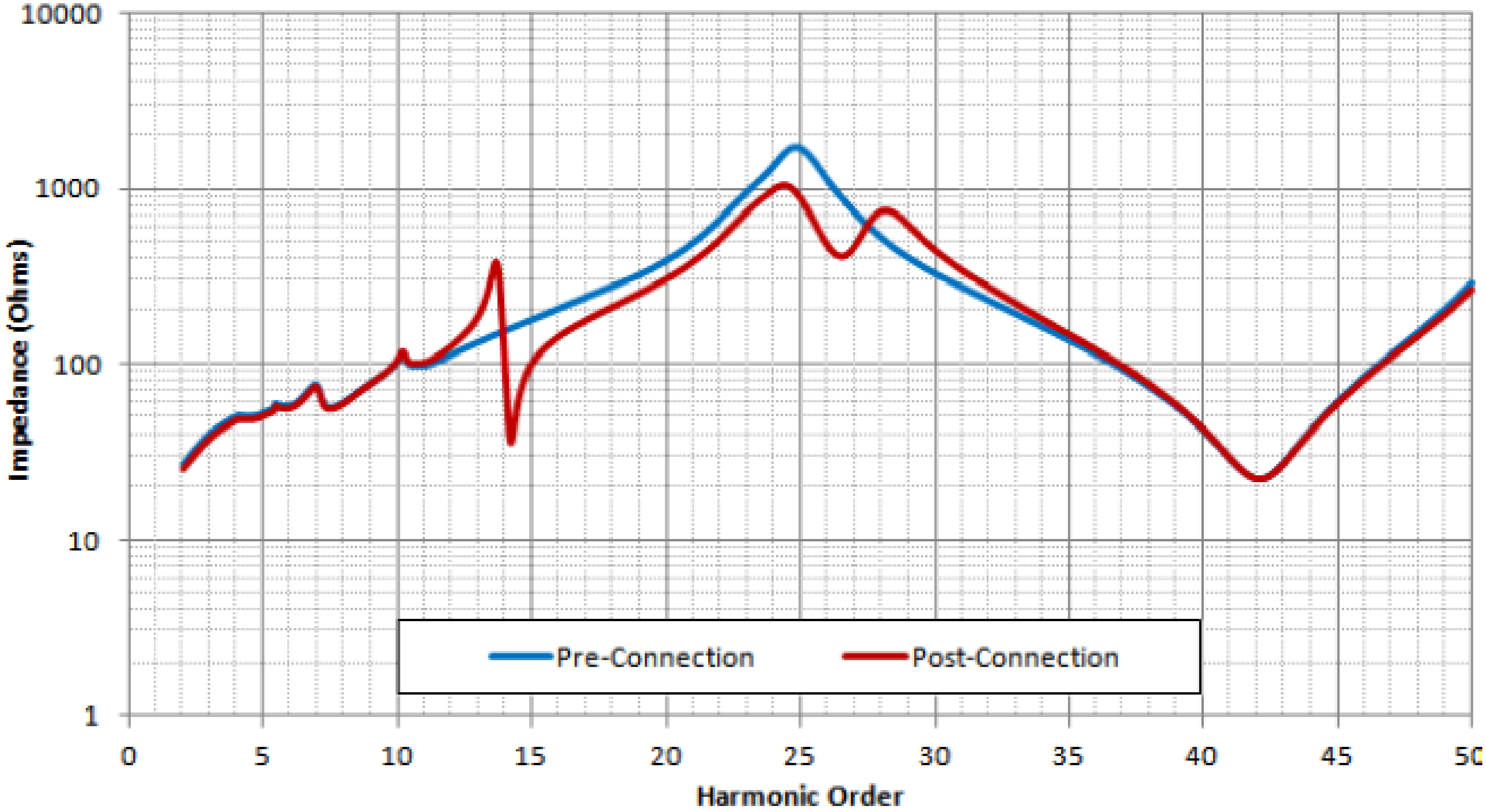
Case Study – Transmission Network Voltage Stability

- Transmission System Operator
  - Voltage recovery issues concern for connection of ten wind farms to a transmission busbar on a weak network in the timeframe 2020-2025
  - Short term voltage stability studies carried out with all proposed wind farms connected while simulating the worst case scenario
  - Eight network contingency configurations were investigated
  - Steady state studies previously showed that 120MVAr reactive compensation would be required
  - Voltage found to be stable and post-disturbance voltage was within the transmission system operating limits when using a STATCOM of 120MVAr

Case Study – Solar PV Harmonics

- 33MW Solar PV
  - Planned to be connected to transmission network
  - Detailed stage 3 harmonics study carried out to ensure connection of renewable generation complies with network standards
  - Significant change in impedance profile observed at 13^{th} harmonic order beyond statutory limits likely due to amplification of existing background harmonics **Fig.3**
  - Harmonic voltage exceedance not significantly beyond statutory limits; Site measurements then undertaken to confirm solar park influence
  - Possible to obtain an exemption from distribution network operator else a harmonic filter could be installed

Fig. 3 – 33kV harmonic impedance profile at point of connection



Conclusion

- Electrical integration of distributed renewable generation should be considered carefully to ensure grid performance is not significantly impacted.
- Achieved through compliance with technical aspects of a grid code and verified through detailed network modelling at concept design stage and testing at commissioning stage.
- Understanding and addressing grid challenges at the early stage will avoid costly retrofits and delays to ensure grid compliance. In short, de-risk the project and save money.

END

Questions?

Kumbuyani Chisoro
Manager Southern Africa

Tel: +27 21 410 8913
Cell: +27 79 225 5872
Email: Kumbuyani.Chisoro@tnei.co.za