Maseru increased renewable energy penetration

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Renewable energy generation includes non-intermittent generation such as hydropower, biomass and geothermal which are more predictable energy sources and have no major technical issues to connect to the grid [66]. The focus of this paper is on intermittent renewable energy sources. Solar and wind systems constitute a large share of new intermittent renewable generation being installed in the power grids around the world [62, 84].

Power system security refers to its ability to survive any credible system contingencies without loss of supply to customers [52]. The N-1 reliability standard that is commonly used around the world as a criterion of power system security requires that power supply should not be interrupted by any single contingency i.e. loss of any single plant item of any of the N plant items forming a network or subnetwork should not result in loss of power supply [98].

As renewable energy generation penetration increases, it is becoming more difficult to maintain the security and reliability of power networks, leading to increasing necessity for Network Operators to impose operational constraints on generation and use their market direction powers to maintain power system security and reliability as highlighted by the Australian Energy Market Operator (AEMO) [5]. Constraining generation is not desirable in a liberalised electricity market as it increases costs to the market that are eventually borne by consumers.

In a secure power system operating environment, operational criteria as dictated by relevant grid codes must be satisfied for pre- and post-contingency conditions; this includes steady state and transient voltage and frequency variations, electrical plant thermal loading and power system stability [55]. Power system faults are often unpredictable and unavoidable making security assessment an important requirement [11]. A number of researchers have looked at the power system security assessment and analysis problem in the presence of intermittent generation [11, 31, 49, 52, 98, 101].

In [31], Probability Mass Functions (PMFs) based on Monte Carlo Analysis were used to develop a linear model that predicts failure rates relative to wind and solar penetration (where failure was defined as violations of system limits in the load flow studies conducted by the authors), the authors found that there are critical intermittent generation penetration levels for which the likelihood of failure increases significantly.

A detailed review of risk-based power system security assessment is presented in [11]. Recent trends show that power sytem security assessment has changed from a deterministic assessment approach to a risk-based assessment approach, there is need for further research in risk based assessment methods for power systems with a high penetration of distributed generation [11].

Intermittent power production is characterised by large changes in instantaneous electricity production and limited certainty of energy resource forecast [12]. High intermittent generation penetration levels can cause higher ramp up/down-rates, greater variability, and greater generation scheduling errors. As a consequence, the system operator may need to hold a higher amount of generation reserve to ensure power system security [32, 62].

Fluctuations in intermittent generation energy resource can vary with times of the day or seasons, and can be difficult to forecast using historical data [62]. Continual development of sophisticated resource forecasting techniques is required to effectively schedule generation and reserve requirements to cater for intermittent resource variability.

Several research groups have analysed the impact of large-scale solar and wind generation on reserve requirements and assessment methods for generations reserve requirements for power systems with high levels of renewable power penetration [32]. This is expected to be a continued area of research activity as the world becomes more reliant on intermittent renewable energy sources of generation.