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**Topic of Research:** Power Quality Issues and Solutions in Power System -with High Penetrations of Renewable Energy Sources.

### **FINDINGS**

The main findings of the thesis are listed as below:

**1. The Renewable Energy Source (RES) power is quite useful:**

The RES Power has been found to be the most useful due to its ability to be regenerated, non-depleted, easily renewed according to human requirement and other benefits like, no greenhouse gas emissions, reduced air pollution, diversity in energy supply and reduced dependence on imported fuels, creating economic development and jobs in manufacturing, installations and energy sector. These sources are constantly available for use because they are replenished in tandem with exploitation.

**2. The Renewable Energy Source (RES) power has some limitations:**

The RES power initiates poor power quality when penetrated to the power grid because of its intermittent nature and increased penetrations into the power system which is a big challenge as it may lead to voltage variation, frequency shift, and the presence of harmonics that impair system performance contributing to decreased power quality. The majority of power system issues are brought on by interconnections between various generators, transformers, transmission lines, distribution lines, and loads. After a slight system disruption, the loading effect of the transmission line has an impact on the stability of the power system. The technical issues with the RES power integrations are found to be voltage fluctuation, frequency

fluctuation, harmonics, short time power fluctuations, long time/seasonal power fluctuations, power storage issues, power protection issues and optimal placement of renewable energy source in addition to some non-technical issues like, non-availability of technical skilled workers, less availability of transmission line to accommodate renewable energy sources, RES technologies are excluded from the competition which discourages the installation of new power plant for reserve purpose etc.

### **3. The RES Power integration can have improved power quality:**

To have improved power quality with RES power integration into the existing power system and increased RES power penetrations many ways are possible. Some of which have been used and found successful out of which the Cascaded Fuzzy Logic Controller (CFLC) based converter used in this thesis found very effective in stabilizing the RES power. The cascaded fuzzy logic controller attained better efficiency of 91% with 100% duty cycle and the gain found to be 1:4. Similarly, the customized Active Power Controller (APC) smart grid model proved its efficacy and attained the regulated voltage and frequency effectively. The use of Multilevel Inverters (9-levels and 31-levels) incorporating Adaptive Neural Fuzzy Inference System (ANFIS) and landsman converter, in addition to improving the RES generated power quality also increased the amount of power integration, high voltage gain, fast speed of response and reduced the power cost per unit for the customers. The use of a landsman converter has removed the need for external filtering and helped to damp out the oscillations occur in the source current from the photovoltaic module. The other converter like zeta converter can also be applied effectively for improving the power quality of RES power system along with mitigating other related issues regarding power quality. In addition, the levels of multilevel inverters may be increased to increase the amount of RES power penetrations, improved power quality and further reducing the energy generation cost for the consumers.

### **4. Green Energy:**

The renewable energy sources are essentially being incorporated to meet the power needs of the customers replacing 'dirty' energy sources like, coal, oil in the power industry while also providing the advantages of lower emissions and pollution levels. The booming expansion of PV and wind energy conversion system-based power production has been necessitated due to

the ever-increasing demand for power, as well as the need to develop decarbonized power generation system to address the climate change.

#### **5. Power Reliability and Stability:**

The introduction of Battery Energy Storage (BES) system along with RES power eliminates the intermittency and uncertainty associated especially with PV and wind energy conversion system increases the power reliability for the customers. In photovoltaic power, Energy Storage Systems (ESS), Maximum power Tracking (MPPT) and use of dump load reduces the power fluctuations. Also, up-gradation of system balance by incorporating the new materials and storage systems reduces the problems in grid integration. Many other suitable techniques and different analyzing tools are possible to apply for more efficient and improved quality of power that can be harvested from the renewable energy sources. The renewable energy source power if utilised with suitable mean and advanced techniques may replace the whole conventional power system in near future.

(Naresh Kumar)