

Abstract of Ph.D. Thesis

“Analysis, Design and Control of Solar PV- System with Battery for Improved Utilization of Diesel Generator Set”

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Solar photovoltaic (SPV)-battery microgrids in an islanded mode offer versatile solutions for decentralized energy generation. The diesel generator (DG) set based standalone supply systems are also source of electricity in many parts of world. DG sets are backbone of supply in remote areas, hospitals, institutes, telecommunication towers etc. However, 24 hours DG set operation increases overall cost of electricity and pollutes environment, diminishing main purpose of renewable energy-based microgrids. Moreover, a DG set is usually manufactured to work at a 0.8 lagging power factor to cater to the load reactive power demand. However, its power factor reaches around 0.5-0.6 in existing SPV-DG set-based microgrid due to sharing the load real power demand between the DG set and SPV system. However, due to the unity power factor operation of SPVS, the load reactive power burden is fed by the DG set alone. Hence, power factor of the DG set is considerably decreased, especially during the peak solar isolation situation, which reduces fuel efficiency and raises the overall energy cost. Moreover, nowadays many of such loads use power converters and some of them are nonlinear loads. Such loads draw harmonics currents, negative sequence currents and they result in voltage distortion, increased losses, increased fuel consumption and derating of DG sets. Therefore, this work focuses on the power quality improvement of the DG set based standalone supply systems with solar photovoltaic array with and without a battery energy storage (BES) integration.

This work deals with boosting the DG set's utilization by using SPVS power converter available capacity as distribution static compensator. Key highlights of this work are as follows.

- DG set power factor is regulated at unity irrespective of SPV system generation with and without BES or load behaviour, enhancing the efficiency of the diesel engine and electric generator. Hence, the fuel consumption is decreased, lowering the cost of electricity.
- SPV system carries entire burden of the load's reactive power. Hence, the DG set's surplus capacity, which is initially reserved for the load reactive power, is used to commit the additional load on the same rating system.
- Since SPV system utilization factor is raised due to its 24 hours operation, its payback period is less than the existing system.
- The operation of SPV system with and without BES elevates power quality performance of DG set based microgrid without causing any high additional cost to the system. Thus, the IEEE std. 519 is followed at POI, with improved utilization of the microgrid.

Most commonly used machine in DG sets is wound rotor type synchronous generator with automatic voltage regulator. The frequency of supply is controlled by speed regulation of a diesel engine through governor mechanism and load leveling. However, the voltage is controlled using AVR (Automatic Voltage Regulator) with SPV-BES. SPV-BES based DG set based microgrid is used to control the terminal voltage, harmonics elimination, reactive power compensation, power factor correction and load balancing. A battery energy storage (BES) with SPV array is also used to improve fuel efficiency of the diesel engine. SPV array and battery on DC link of VSC (Voltage Source Converter) of this system are used to supply the active power to loads and it stores the energy during light load periods so that the DG set is always loaded with an optimum load of 80% to 100% of the generator rating. An optimum loading of DG set helps in improving the fuel efficiency of the diesel engine. BES also mitigates fluctuations in real power demand of loads. The use of BES helps in better voltage and frequency regulation of the system. Performance of DG systems is tested under steady state and dynamic conditions for linear and nonlinear loads.

Reference source currents are generated using an adaptive algorithm based on least mean $2L_{th}$ (LM2L) to filter nonlinear load currents to investigate performance of single-stage SPV-DG set based microgrids. Performance of adaptive LM2L filter algorithm is compared with N-LMS and N-LMS filters, and it has been demonstrated that LM2L adaptive algorithm has a better steady state and dynamic responses. Moreover, in a two-stage solar PV-DG set based microgrid, an improved variable step normalized adaptive filter (IVS-NAF) control algorithm is used for enhancing power quality of a standalone microgrid. The cascaded generalized second-order integrator (C-SOGI) based phase-locked loop (PLL) is used in single stage solar photovoltaic-BES-DG set based microgrid to improve power quality of this system. Finally, a generalized maximum correntropy criteria (GMCC) adaptive filter based control approach is used to improve power quality in a double stage solar photovoltaic-BES-DG set based microgrid under varying loads and solar PV generation.