Abstract of the Thesis

Brushless generation systems are preferred where maintenance is a key issue or where safety is a major concern as brushes and slip-rings are prone to failure. Different brushless generation systems have been reported in literature e.g. permanent magnet synchronous generator (PMSG), self-excited induction generator (SEIG), brushless synchronous generator with separate exciter etc. While PMSGs lack smooth control over excitation, SEIGs suffer from voltage regulation problem with wide variation in load and speed. Brushless synchronous generators employing a separate exciter require more floor area. The drawbacks of these generating systems provide exciting research opportunities to develop new brushless and permanent magnet-less generation systems. This thesis deals with three such topologies applicable for dc microgrids.

The thesis starts with induction generator based approach but with a difference. Instead of following the traditional squirrel cage machine with arrangement for the controlled VAR demand, the investigation looks for multiple windings in the stator. Understanding that the rugged construction of the squirrel cage is a huge advantage, the rotor structure of the machine under investigation did not change. Extensive literature survey indicates that dual stator winding induction generator can be a viable option provided that both stator windings are optimally utilized. Contrary to the available approach in the literature, both the windings are used to support active as well as reactive power demand. Uncontrolled diode rectifier and a suitable small rating converter are used to feed each of the windings. Shunt filters (placed across main winding and optimally tuned to eliminate 5^{th} and 7^{th} harmonic currents generated by the diode rectifier) made the stator current quality acceptable while providing reactive power support at fundamental frequency. This also reduced the reactive power demand from the controlled converter and helped to reduce its rating. At lower speed, the diode rectifier may get reverse-biased and hence no power extraction from the main winding is possible. Under such circumstances the major share of active power takes place through the controlled winding.

The double stator winding induction generators are rugged. However, the reactive power demand of this generator grows with increase in load. Also, the coupling between the two stator windings along with the rotor is responsible for the delay in response corresponding to any change in load/speed. This even can make the system unstable for large change in load. Based on this requirement, series capacitors are introduced those have the ability to self-regulate the system, automatically generating the reactive power in the right direction. New approach to find the magnitude of optimal capacitance is introduced. Eigen-value analysis reveals that addition of series capacitors enhance the stability of the system.

Proposed double winding induction generators are simple in construction and also have overall reduced controlled power-electronics-requirements (i.e. power processed using controlled switches) as it demands a fractionally rated converter in the controlled winding side. However, these generators are either prone to voltage collapse or require more passive components. This motivated to look for synchronous generator based systems. The traditional synchronous generators along with the exciters need more floor area and this is a major reason for these generators to be unpopular in wind energy power extraction. A new synchronous generator is proposed that utilize an inverted synchronous machine to feed excitation to the main machine.

Both the machines are housed in the same mechanical structure and share the same magnetic core. The excitation machine has the armature in the rotor and field in the stator. The armature voltage of excitation machine is rectified using rotating-rectifier to feed to the field-winding of the main machine. As the two machines are wound for different number of poles they are magnetically decoupled. Extensive simulation and analysis using ANSYS MAXWELL-2D and MATLAB/SIMULINK have shown enough promise for this machine for applications in dc grid. Experimental verification using a laboratory prototype confirmed the usefulness of the proposed system.

Keywords: Brushless generators, induction generators, synchronous generators, permanent magnetless generators, dc generation systems, dc grid, micro-grid