INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

The excessive use of fossil fuels for power generation in the previous decades has led to various environmental concerns. Moreover, such fuels are also with limited availability. These factors have encouraged engineers and scientists to look for alternate renewal energy sources (RES) for power generation. Various RES like solar photo-voltaic (PV), wind, geothermal, etc., have been used for power generation and injection into the electric grid. However, such changing trends come with their own limitations. RES are generally intermittent in nature with widely varying levels of availability throughout the day and round the year. In addition to that, such sources also need power electronic interface for power injection into the electric grid. These factors give rise to various challenges like voltage variations, faults, harmonics in voltages and currents, islanded operation, complexity of control, etc. Various power electronic equipment such as distribution static compensator (DSTATCOM), dynamic voltage restorer (DVR), unified power quality conditioner (UPQC), static transfer switch, static current limiter, etc., are used in the electric grid to address such challenges.

In recent times, solid state transformer (SST) has received considerable research interest for improving performance of electric grid in presence of RES. It is a distribution transformer realized with the help of power electronic converters. In addition to ac voltage transformation and isolation, similar to conventional transformer, SST also provides dc voltage connection which can be used for realizing dc distribution system or interfacing RES to the electric grid. Therefore, the SST is a very attractive solution for the changing power distribution scenario. An SST can be integrated with intelligent control strategies and communication features for voltage control, power quality improvement and power management. Such an SST is termed as a smart transformer (ST).

Many RES generate power in the form of dc. Moreover, modern day loads are also shifting towards the dc side. This has led to the existence of both ac and dc grids in the distribution system, and such grids are termed as hybrid grids.

With multiple ports at different ac and dc levels, the ST has the capacity to provide multiple features in hybrid distribution grids.

This thesis investigates the operation and control of ST based hybrid microgrid and explores the various power management as well as control strategies facilitated by the ST to achieve improved and efficient operation in both the ac and dc grids. A meshed hybrid microgrid with ac and dc grid interconnection enabled by ST is proposed. This is realized by extending the LVdc bus of the ST in the distribution grid and connecting it to the dc buses of the distributed generation (DG) converters already presented in the system. Multiple power flow paths are realized in such a configuration which helps in reducing the line losses. Compared to the ac line, line losses in the proposed LVdc line reduces to 22%. Moreover, reverse power flow efficiency increases by 6%.

Further, the operation of the proposed meshed hybrid microgrid is explored in islanded mode. Islanded operation is achieved by maintaining the LVdc voltage with the help of a battery energy storage system (BESS) and the LVac grid voltage is maintained by the ST LV converter.

The multiple power flow paths offered by the meshed hybrid microgrid are exploited to achieve optimal power flow management in the islanded mode of operation. This helps in reducing the line losses in the system and consequently increases the operation time of the islanded system. It was observed that while in a particular case, the conventional method incurred 1.337 kW losses, the proposed method was able to reduce the line losses to 1.0487 kW. This shows a 22% reduction in line losses with proposed method as compared to conventional method.

The stability of the ST based islanded meshed hybrid microgrid is also investigated while catering to sudden high power demands from electric vehicle (EV) loads. Since a BESS maintains the LVdc voltage in islanded mode, any disturbance or sudden high power demand has to be handled by the BESS. However, owing to the presence of right half plane zero in the transfer function of the BESS converter, the converter's ability to cater to sudden loads is limited. This issue is addressed by exploiting the meshed hybrid configuration. The ST is used to execute an LVac voltage control strategy which reduces the total load on the BESS during EV load transients, and ensures that the system remains stable.

Finally, to establish the reconnection of the ST based islanded meshed hybrid microgrid to the MVac grid, a step-by-step partial start-up procedure is proposed. Since in the islanded operation, ST LV converter is already operational, the partial start-up procedure helps to start the non-operational converters namely the ST isolated dc-dc converter and the ST MV converter without disturbing the operation of the LV grid.

The thesis presents and explores the operation of an ST-based meshed hybrid microgrid and proposes various methods for power management, loss minimization, stability and overall operation of the system in islanded and grid connected mode.