Abstract

The power generation system consists of the usage of non-renewable sources of energy such as coal, petrol, diesel, etc. The supply of these sources are limited, and the demand is ever increasing. This has led to a huge surge in the prices of these resources. Furthermore, power generation from non-renewable sources has led to various environmental issues such as an increase of CO_2 emissions, ozone depletion, global warming, etc. These drawbacks have led to an increased emphasis on power generation from renewable sources such as photo-voltaic panels, wind turbines, tidal energy, etc. The renewable sources are considered to be echo-friendly and efficient compared to the non-renewable sources. The main benefits of using renewable sources consist of remote access to power by microgrids and nano-grids, intermittency, local power generation and consumption, and fewer transmission losses. On the other hand, renewable sources have more power generation and installation cost and are less reliable due to their dependence on environmental conditions. However, the benefits are more compared to the issues in the long run. To ensure this, the sources must be made to operate within safe operating limits.

The renewable sources are often interconnected to form a microgrid. An interfacing converter such as a boost converter is used to regulate the voltage level of the dc bus within desired regulation limits. Furthermore, a smaller interconnection such as nano-grid can also be formed. The traditional power generation system consists of AC loads. These loads are rated to operate at a certain voltage level and frequency. Further, the microgrids are also projected as the traditional grid supporting system. The microgrids are interfaced with the grid system so as to improve the reliability of the power generation system. The grid interfacing of microgrids or feeding AC load requires DC-AC conversion. Traditionally, voltage source and current source inverters are used for DC-AC conversion. However, these are not capable of boosting the AC voltage more than the input DC voltage. Intermediate boost converters are required, or a transformer is needed to step up the AC voltage. Such two-stage conversion leads to reduced efficiency due to power loss, increased weight, and cost. Instead, various single-stage inverter (SSIs) topologies such as- Z-source inverters (ZSI), quasi-Z-source inverters, Switched Inductor ZSI, Trans-ZSI, Inverse Watkins–Johnson topology, DC-link type SBIs etc, which have either a single inductor, capacitor or a pair of inductors and capacitors can be used for feeding power to the AC loads. The source current of the single-stage inverters consists of second-order current ripples. These current ripples oscillate at twice the AC supply frequency of the inverter. Similarly, in terms of DC Microgrid, an AC load connected to the DC bus via an inverter leads to second-order oscillations in the DC bus voltage and source currents. The ripple currents have detrimental effects on the sources, such as heating of sources and depletion of battery electrodes. This degrades the power quality and operating life span of the microgrid. Hence, it must be mitigated. In SSIs, the second-order currents can be mitigated by increasing the impedance LC network used to boost the DC voltage. However, this leads to an increase in the size and cost of the SSIs. On the other hand, the ripples in DC Microgrid may be reduced or mitigated by placing adequate ripple filters at the nodes or the DC bus. However, putting ripple filters at each node may lead to the increased need for maintenance and an increase in the installation cost of the microgrid.

In this thesis, various robust virtual impedance methodologies have been proposed for DC Microgrid and single-stage inverter applications. The proposed methodologies are implemented through control and hence do not lead to the need for additional filters. The proposed methodologies are used to increase the output impedance at twice the AC supply frequency. Furthermore, the cost and component count of the system does not increase. In single-stage

inverter, a sliding mode control based methodology is proposed in which the current reference is provided by passing the inductor current through a low pass filter. The low pass filter is designed to filter out the second-order components in the inductor current. Hence, the control law regulates the voltage and current so as to mitigate the ripple currents. However, the addition of a low pass filter in the control loop may degrade the dynamics of the SSIs. As a result, an integral sliding mode control (ISMC) based dual-loop control of SSIs is proposed. In ISMC the system trajectories start from the sliding manifold right from the beginning, and hence the reaching phase is eliminated. The implementation of ISMC facilitates the integration of classical control with a non-linear ISM control to improve the overall response of the system. The control law of the ISMC is integrated with the dual loop control law. The resultant control law is robust and leads to ripple cancellations even in the presence of the bounded disturbances. The proposed controllers reduce the ripple currents within acceptable limits for various topologies of SSIs. Designing such virtual impedance, to mitigate the ripple currents, in a distributed power generation environment like DC Microgrid may be challenging. The uncertainties in interconnecting components, load variations, and communication between the nodes further increase the complexity of the ripple control design. Furthermore, the designed ripple control must not affect the proportional DC load sharing in DC Microgrids. An inverted notch-inductor current feedback methodology has been proposed for boost converter based DC Microgrids to manage the output impedance of the interfacing converter. The proposed control methodology consists of a linear proportional-integral based control. The second-order component in the inductor current is extracted using second-order general integrator and is compared to the reference ripple. The inverted notch based inductor current feedback leads to an increase of impedance at twice the AC supply frequency. This leads to a reduction of second-order ripples in source currents. The proposed control facilitates ripple sharing. The ripples can be diverted to the nodes, which consists of second-order ripple filters. Hence, the filters can be installed at a node, rather than installing in every node. Furthermore, an adaptive sliding mode control based output impedance shaping (ASMC-OIS) methodology is proposed to mitigate or share the ripple currents. This methodology is robust against uncertainties, and the voltage and current dynamics are not affected by the designed control. In the absence of the AC load, the DC load is shared proportionally. The secondary control in the DC Microgrid plays an important role in proportional load sharing among the nodes. Any uncertainty in communication may lead to instability of the failure of the microgrid. The second-order ripple current leads to ripples in the average load communicated data between the nodes. This leads to erroneous voltage reference generation for the primary control. An integral sliding mode based secondary control is proposed, which is capable of uncertainty mitigation in the communicated data. The uncertainties of low-frequency oscillations to higher-order oscillations can be mitigated, and proportional load sharing can be achieved. A sliding mode control based primary control is integrated with the proposed secondary control to verify the proposed control methodology. The proposed methodologies have been verified using simulations and experiments.

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