Abstract

Recent times have witnessed a persistent interest in the remote/local/island/grid-connected power system applications such as DC Microgrid applications, distributed power generation applications and residential power system applications. A typical microgrid has sources especially renewable energy sources, DC and AC loads and storage. Intermittent power generation characteristics of the renewable energy sources and uncertain need of the storage force these sources and storage to connect the load through DC-DC converters in order to match with the load requirements. Furthermore, the DC power is supplied to AC load after the conversion. Therefore, AC-DC power converters are imperative in such systems. The two-stage buck or boost derived DC-DC-AC converters and impedance source converters such as q-SBI, Z-source converters are explored in these applications. The AC-DC converters are also used as inter-link converter between microgrid and the main utility. A very important, inherent and inevitable problem associated with the single-phase inverters is unwanted reflection of Second-order Harmonic current (SHC) ripple at the DC input. This ripple is a low frequency ripple i.e. ripple with comparatively high power and increases with the AC load demand and decrease in the size of DC link capacitance. In the case of two-stage converters or impedance source inverters, this ripple may propagate from the DC-link to DC source through system components in the absence of large electrolytic DC-link capacitor. Existing literature documents several detrimental effects of this ripple on the system components and sources; related to efficiency, life, size, cost, complexity, reliability and stability. In literature, several techniques are proposed to mitigate these problems. However, only few techniques, partially, address the problem using linear controllers. These techniques mitigate the SHC ripple problem, however, adversely affects the system dynamics. This necessitates a trade-off between the ripple reduction and dynamic performance of the system. Moreover, these control techniques do not consider system behavior in the presence of disturbances such as parametric variations, exogenous disturbances, sensor noise and unmodeled system dynamics. Furthermore, with the linear controllers, the intermittent power generation characteristics of renewable energy sources may disturb the operating points; the linear controllers ensure stability at operating points only. The nonlinear controllers such as SMC and ISMC are robust controllers and perform better with the systems having large line-load transients. Therefore, in such applications, the nonlinear controllers are one of the suitable choices.

In this thesis, a comprehensive study is carried-out on the $2\omega-$ripple problem in the single-phase inverters. The SMC and ISMC based controllers are proposed to mitigate the $2\omega-$ripple or SHC ripple problem and to improve the system dynamics in power converters used for microgrid applications. The controllers are verified through a detailed experimentation and simulation studies. In the first work, the proposed technique implements an adaptive sliding mode controller for two-stage boost-derived DC-DC-AC converter. The basic concept of the ripple reduction and improvement in system dynamics is based on the shaping of the output impedance. The proposed controller reduces the SHC ripple in the input current of converter to 1% (approx). At the load transients from no-load to full-load and vice-versa, the undershoot/overshoot in DC link voltage with respect to the reference voltage are $-8\%/+3\%$. The negligible undershoot and overshoot in DC-link voltage are observed at line-transients. In the second work, a quasi-switched boost inverter topology is used. The topology is suitable for the micro-inverter applications. Unlike the voltage source inverter, the q-SBI is capable of the shoot-through operation. A modified version of the controller as proposed in the first work is implemented with q-SBI converter. The SHC ripple in the input current of q-SBI is less than 5%. The size of the capacitor and inductor required are smaller in comparison to the existing work in the literature. In the third work, an integral sliding mode (ISM) based controller has been proposed. The ISM based control approach allows merging of a classical controller with the SMC. The ISM based controller improves the performance of the nominal controller by eliminating the matched uncertainty from the beginning of the system response. The ISM control adds robustness to the system. In this work, an adaptive PI-controller (nominal controller) amalgamates with SMC. The proposed ISM based controller mitigates SHC ripple problem, improve the system dynamics and add invariance property to the system. The nominal controller reduces the SHC ripple in the input current and keep its value less than 7.7%. However, a 50% (approx) reduction in the size of the system parameters (inductance, L and capacitance, C) increases the ripple to 15% (without ISM). With the proposed ISM based controller, the ripple reduces to negligible value. Furthermore, the proposed controller eliminates the effect of the disturbances (experimentation is done with 500 Hz-sinusoidal disturbance) entering through the control input. In the fourth work, an analysis is carried-out on the DC microgrid in the context of the $2\omega-$ripple. A new phase-adjustment technique is proposed to minimize the ripple at the DC bus that feeds two inverter loads. Eventually, the challenges and recommendations for the future research are discussed.

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