Abstract

In the modern microgrids systems, more and more interconnected renewable energy sources are utilized. They reduce the fossil fuel consumption and the running cost of the systems. However, due to the unstable and intermittency nature of renewable energy sources, power reliability and quality problems are more acute. The voltage sag and swell, and voltage harmonic distortion of the supply, current harmonic distortion of nonlinear load, and low power factor are the most common power quality problems in the power systems. The overload, sudden change of the loads, connection and disconnection of large loads, connection of large capacitor banks, nonlinear loads, and increase of the magnetizing current may cause the aforementioned power quality problems, which will lead to multiple disturbances to the systems. Therefore, it is essential to compensate the power quality problems in the systems to avoid the potential breakdown and damages of power system components.

The existing power quality compensators in the market are capacitor banks, static var compensators (SVCs), dynamic voltage restorers (DVRs), distribution static compensators (DSTATCOMs), etc. These power quality compensators can solve only one or two specific problems. In order to solve all the power quality issues in the microgrids, it is required to install more than one kind of devices. Such a solution is obviously cost prohibitive. Moreover, it is a complex and expensive task to manage and maintain these individual components. Increasing attention has been paid to the unified power quality conditioner (UPQC) system which has the capability of improving power quality at both the source side and load side. The existing state-of-the-art topologies and techniques of the UPQCs can be classified according to their physical structures and compensating techniques. Among the various categories of the UPQC, the voltage source converter (VSC) is the most widely utilized type of converters in the UPQCs; the three-phase three-wire arrangement is the most popular system; the right shunt UPQC is the most common configuration; and the UPQC-P (P for active power) is the most popular compensating technique in the UPQC applications due to the effective compensation capability for both voltage sag and swell of the system. The three-phase three-wire VSC based right shunt UPQC-P is chosen as the basic study case in this thesis.

The first system investigated in this thesis is the UPQC-P. The active and reactive power flows are illustrated in the general block diagram of the UPQC-P. The detailed phasor diagram of the UPQC-P is also presented. The corresponding control method is designed to implement the system. The Matlab/Simulink based simulation results validate that the UPQC-P can provide the superior performance in mitigating almost all major power quality problems. However, during the compensation of the UPQC-P, the series converter only handles the active power, while the shunt converter supports all the load reactive power demand.

In order to coordinate the reactive power between the series and shunt converters, the variable phase angle control (PAC) method is applied in the controller of the UPQC. The series converter can thus be fully utilized during the operation. Based on the variable PAC method, a two-stage algorithm is proposed to optimize the ratings of the shunt and series converters in order to obtain the maximum utilization rates of the power converters in the UPQC. The corresponding control algorithm is developed to reduce the online VA loadings of the proposed UPQC and the safe operation of the system under the different compensating conditions. The mathematical model based analysis, the Matlab/Simulink based simulation results, and the real-time control hardware-in-loop (CHIL) results are provided to validate the performance of the proposed UPQC during all the operating conditions. The results indicate that the proposed UPQC does not compromise the power quality compensation abilities and has the maximum average utilization rate of the series and shunt converters compared with that of other UPQC approaches. The optimal capital cost of the UPQC system is also investigated in this thesis. Based on the compensation requirements, both the ratings of the series transformer and power converters are handled in the proposed generalized strategy, which can determine the minimum total capital cost of the UPQC system. The corresponding control method is developed to implement the proposed UPQC system. The mathematical model based simulation results and the OPAL-RT based real-time simulation results indicate that the proposed UPQC can satisfy the power quality compensating requirements while ensuring that the online VA loadings are within the VA ratings. Moreover, the displacement angle can achieve smooth changeover during the transient states.

Publication

Journal publications

[1] **Ye Jian**, Hoay Beng Gooi and Wu Fengjiang, "Optimization of the size of UPQC system based on data-driven control design," in *IEEE Transactions on Smart Grid* (*early access)*.

Conference publications

[1] N. K. S. Naidu, Hoay Beng Gooi, Tang Yi, **Ye Jian**, Sathish Kumar Kollimalla, Narsa Reddy Tummuru and Pravat Kumar Ray "Coordinated active power control between shunt and series converters of UPQC for distributed generation applications," in *Proc. IECON*, Dec. 2016, pp. 3697-3702.