Preface

Voltage stability is a major concern in many stressed power systems as shown by a number of recent blackouts caused by voltage instability. In transmission systems the voltage instability problem is likely to become more prominent because of the integration of renewable generators, mainly induction generators with wind and photovoltaic (PV) solar units. The induction generators are operated in constant reactive power mode and the PV units are operated at unity power factor. Unless the operating mode of the renewable generators is changed, additional devices are required to provide reactive power support to maintain a good voltage stability margin. In distribution systems, with high penetration of distributed generation, the proximity of the generation and dynamic induction motor loads gives rise to new dynamic phenomena that includes voltage oscillation modes. Installing devices for reactive power support in distribution networks and proper controller design can mitigate most adverse dynamic effects of distributed generation. This book comprehensively covers all the topics necessary to increase the voltage stability margin of transmission and distribution systems.

In most cases the integration of higher levels of renewable energy into an existing transmission system does not require a major redesign, provided a thorough analysis before the integration is conducted to check the viability of renewable integration. In some cases the analysis indicates the necessity of additional high-performance control and compensating equipment to enable the system to recover from severe system disturbances. In this book, first dynamic voltage instability problems which are likely to occur in future power systems are presented and then novel robust controllers are synthesised for the enhancement of the stability.

The first part of this book contains case studies for capturing the development of different types of dynamic voltage instability, in both the short- and long-term, caused by the dynamics of wind generators and PV units. In addition, an investigation is presented on the changing nature of systems and their dynamic behaviours giving rise to critical issues that limit the large-scale integration of wind generators and flexible AC transmission system (FACTS) devices.

It is common in the power industry to tune fixed structure controllers, like the proportional-integral controllers, based on single device infinite-bus dynamics. This approach is practical but these controllers do not permit the participation of reactive power support devices and renewable generators to contribute to the fault recovery at their full potential. Novel controllers are required to enable a full participation of all devices in fault recovery so that the ratings of the support devices can be kept low to increase the affordability of the support devices. This book presents detailed design and implementation of robust controllers for stability enhancement and also to reduce the required ratings of support devices for fault recovery.

In robust control design it is important to choose how to capture the knowledge of the unmodelled dynamics in the design process. Partial details such as the 'size' of the unmodelled dynamics are used in the robust control design. It is well-known that smaller 'size' unmodelled dynamics lead to higher performing controllers. The second part of the book presents a method to bound unmodeled nonlinear dynamics and to design excitation control for the enhancement of large-disturbance voltage stability in power systems with significant induction motor loads. A new technique is presented which captures the full nonlinearity of systems in the region of interest. The nonlinear power system model is reformulated with a linear and a nonlinear term. The nonlinear term is the Cauchy remainder in the Taylor series expansion and in this book its bound is used in robust control design.

The third part of the book contains the design of robust controllers which augment the low-voltage ride-through capability of FSIGs during severe disturbances. Control algorithms, using both structured and unstructured uncertainty representations, are developed for the stabilisation of faulted systems under different operating conditions. A method is presented which can be used to design a linear controller for doubly-fed induction generators (DFIGs) which is sufficiently robust to accommodate post-fault low-voltage conditions. An analysis of the possible negative interaction among PV controllers and design a robust controller to mitigate unwanted interactions is also presented. In the proposed robust control design, parts of nonlinear dynamics and control interaction are modeled as disturbances and this ensures a non-interacting robustness of control design.

The performance of the proposed control schemes fulfils the criteria for robust stability and performance, and produces adequate stability margins for a range of test cases. The effectiveness of the suggested control strategies is validated by detailed simulations with complete nonlinear model of the devices. The performances of the designed controllers are also compared with those of conventional controllers. Simulation results show that both the dynamic voltage stability and the transient stability of a power system can be improved by the use of the robust control methods presented in this book.

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