PhD Public Defence

Title: WAMS Based Intelligent Operation and Control of Modern Power System with Large Scale Renewable Energy Penetration

Location: Pontoppidanstræde 101, Room 23

Time: Thursday 10 April 2014 at 13.00

PhD defendant: Zakir Hussain Rather

Supervisor: Professor Zhe Chen

Moderator: Associate Professor Tamas Kerekes

Opponents: Professor Stig Munk-Nielson, Dept. of Energy Technology, AAU (chairman)
Professor Keyue Smedley, University of California, USA
Professor Carlo Cecati, Università degli Studi dell'Aquila, L'Aquila, Italy

All are welcome. The defence will be in English.

After the public defence there will be an informal reception in Pontoppidanstræde 101 room 25/27.
Abstract:

Electricity demand worldwide is growing which is mainly driven by growing industrial activities and the widening of access to consumers in the developing world. On the other hand, limitations of conventional sources of energy generation coupled with substantial financial and regulatory incentives for alternative energy systems driven by the pressure to reduce carbon emission has stimulated a renewal of interest in wind power. The combined effect of growing demand and increasing level of intermittent wind energy penetration coupled with deregulated market has pushed the power system to operate close to its security limits. Under such scenario, progressive displacement of conventional generation by wind generation is expected to eventually lead a complex power system with least presence of central power plants. Consequently the support from conventional power plants is expected to reach its all-time low leading the system to be more vulnerable if alternative measures are not sought out. Further, Wide area measurement system (WAMS) which in contrast to traditional SCADA system is able to capture the power system dynamics, has tremendous potential applications including monitoring, control and protection of complex power systems. WAMS is rapidly being implemented in power systems across the globe and is seen a means to realize smart grid at transmission system level.

This thesis proposes WAMS based methods to intelligently control and operate large scale wind integrated power system with least dependence on conventional power plants. An important aspect of WAMS realization in a power system is optimal placement of expensive PMUs in order to realize cost effective and reliable grid state monitoring and control. Coupled with Real time digital simulator (RTDS) based testing and configuration of PMUs, a realistic approach for optimal PMU placement in a power system that takes real life factors into account has been proposed. The proposed method considers pragmatic approach for phase wise deployment of PMUs while accounting for coordination with other ongoing projects, priority of substations and scheduled/unscheduled maintenance. New solution to address few of the practical issues in WAMS experienced on real life Western Danish power system have also been proposed. The overall WAMS has been implemented in DigSILENT and applied to the Western Danish Power system.

Due to intermittent nature and lack of adequate controllability of wind generation, large scale integration of wind energy compromises the security of power system. Therefore, WAMS based security assessment has been proposed to assess the steady state and dynamic security of large scale wind integrated power system. A three dimensional security index accounting for reserve power, voltage stability and overloading of the grid has been proposed to monitor real time steady state security of the system. In order to assess the dynamic security of the system, a WAMS based decision tree approach has been proposed.
The impact of large scale wind energy penetration on system security has been analysed in detail with real life Western Danish power system as a test system. Reactive power support from wind farms, especially from type-3 and type-4 turbine based wind farms has been explored in an attempt to shift the power system voltage control responsibility from conventional power plants to wind turbines. With increased wind penetration and displaced conventional central power plants, dynamic voltage security has been identified as one of the challenging issue for large scale wind integration. To address the dynamic security issue, a WAMS based systematic voltage control scheme for large scale wind integrated power system has been proposed. Along with the optimal reactive power compensation, the proposed scheme considers voltage support from wind farms (equipped with voltage support functionality) and refurbished synchronous condensers. The proposed scheme also improves the overall voltage stability of large scale wind integrated power system.

Danish power system is expected to be the first of its kind where the entire transmission system (excluding existing 400 KV lines) will be replaced by underground HVAC cables. To control the large amount of reactive power generation from HVAC cables, a planning method for optimal shunt compensation determining the optimal location with optimal sizing of shunts has been proposed.