Frequency Control and Inertial Response of Power Systems with wind Power Penetration

Introduction

The frequency of a power system depends on real power balance: generation-demand. In the standard operation of a power system, the frequency is regulated within strict limits by adjusting the electrical supply to meet the demand. If the balance between generation and demand is not reached, the system frequency will change at a rate initially determinate by the total system inertia. The total system inertia comprises the combined inertia of most of spinning generation and load connected to the power system. The contribution of the system inertia of one load or generator depend if the system frequency causes change in its rotational speed and, then, its kinetic energy.

The power associated with this change in kinetic energy is fed or taken from the power system and is known as the *inertial response*. During a system frequency event the total system inertia response of all electrical machines connected to the system is the main factor that determine the initial rate of frequency change (ROCOF). For a robust power system (system frequency is not overly sensitive to the power imbalances), it is extremely important that a large proportion of generation and load connected to the power system contribute to the total system inertia and then provide inertia response.

The increasing penetration of wind power into the power system introduces new challenges in the frequency control and stability. Wind generators provide small or even no inertia response, not contributing to the frequency stability. Therefore frequency control schemes are required to be well designed for the system with wind power to maintain the frequency deviating inside the appropriate region.

During a frequency event, the imbalance is initially covered from the kinetic energy stored in the rotating machines; it is the inertia response, as consequence the system frequency will change. Subsequent changes in the system frequency are done by the control frequency and power generation controls, which is referred to as *load-frequency control* (LFC), which is a major function of *automatic generation control* (AGC).

Worldwide, electricity generation from renewable energy is increasing rapidly; it is especially true in terms of the increasing of the wind power penetration. This situation arise some issues regarding the system frequency control because wind turbines provide small or even none response to frequency changes. Power electronically controlled and/or power electronically connected generators such as DFIG and FPC wind turbines do not naturally provide inertia response. However inertia response can be emulated by adding a supplementary control signal proportional to the rate of change of frequency, this is named the *Synthetic* or *Artificial Inertia*. This approach imposes some challenges about control and protection systems.

The course is designed to provide a solid understanding of the frequency control and inertial response of power systems with wind power penetration.

Course Outline

1. Introduction: Electromechanical Concept involved in Frequency control
2. Active Power and frequency control in classical power systems
3. Wind Power Integration
4. Synthetic or Artificial Inertia
5. Wind Power Active Power Control

Scope and objectives

The course is designed to give both industrial practitioners (technicians, engineers and managers) and a solid understanding of the frequency control and inertial response of power systems with wind power penetration.

Course Objectives

1. To introduce the main electromechanical concept and operating principles and main features involved in frequency control
2. To introduce the main principles of the active power and frequency control in classical power systems
3. To provide the attendees a general overview of the implication of the wind power integration on the system frequency response.
4. To introduce the concepts of synthetic or artificial inertia and explain the main implications, challenges and issues regarding this concept.
5. To introduce the classical and advanced operating principles and implications regarding active power control in power system considering wind power.

Who should attend

This course is intended for all technical staff, engineers and managers from electrical power utilities, independent generating companies, electricity regulator, industry, manufacturing and consulting companies and educational and research institutions who deal with the frequency control issues in power system and wind power.

Course duration

Two-day course.

Course Program

Day 1

10:00 - 10:30	Registration
10:30 – 11:10	Welcome and introduction. Course overview
11:10 – 12:00	**I. Introduction: Electromechanical Concept involved in Frequency control** 1. Inertia: a. Concept: Cause and Consequences 2. Frequency a. Definition: Continuous versus Discrete b. Calculation: Estimation, Measurements, c. Standards
12:10 – 13:00	3. Swing Equation: Electromechanical system a. Simple machine system b. Multi-machine systems c. Effect of the generation controllers: Governors: Steam, Hydro. 4. Frequency Response: a. Concept b. Requirements: Why frequency response is needs? c. Providers: Who will provide the frequency response? Generator-side, Demand-side.
13:00 – 14:00	Lunch
14:00 – 15:00	**II. Active Power and frequency control** 1. Fundamentals of speed governing: Classic system, Flywheels. 2. Control of generating unit power output: Droop a.
15:00 – 15:20	Coffee break
15:20 – 16:20	3. Composite regulating characteristic of power systems 4. Response rates of turbine-governing systems 5. Fundamentals of automatic generation control 6. Implementation of AGC a.
16:20 – 17:20	7. Under frequency load shedding a. Classic UFLS schemes b. New approaches based on ICT: Adaptative, Intelligent, etc

Day 2

10:00 - 10:50	**III. Wind Power Integration** 1. Status of Wind turbine technologies a. Types of Wind Turbines concepts commercially available b. Wind Turbine Generators (WTGs) c. Fixed Speed and Variable Speed Systems
10:50 – 11:10	Coffee break
11:10 – 12:00	2. Generator concepts a. Asynchronous Generator: single squirrel cage induction, doubly fed b. Permanent magnet synchronous generator c. Other types of generators. 3. Power electronic solutions in wind turbines/wind farms.
12:10 – 13:00	4. Basic integration issues related to wind power. a. Consumer requirement perspective. b. Requirements from wind farm operators. c. Integration issues. 5. Operation requirements for wind power a. Overview of technical regulations b. Frequency control: wind power production: short, medium and long term.
13:00 – 14:00	Lunch
14:00 – 15:00	**IV. Synthetic or Artificial Inertia** 1. Concept and implementations 2. Requirements of Synthetic Inertia 3. Implications of Synthetic Inertia
15:00 – 15:30	4. General Electric concept: WindINTERIA® 5. Enercon concept: WINDBLATT®, simulating inertia
15:30 – 16:00	Coffee break
15:20 – 16:20	**V. Wind Power Active Power Control** 1. Wind turbine level control a. Inertial control: (i) “Hidden” inertia emulation, (ii) fast power reserve emulation b. Droop control c. Deloading control: (i) Pitch angle control, (ii) Rotational speed control.
16:20 – 17:20	2. Wind farm level control a. Local control: (i) Wind turbine deloading control, (ii) Energy Storage system (ESS) control b. Central Control 3. Power System level control