Wide Area Monitoring, Protection, and Control

(Spring Semester, 2023)

Instructors: H. Golpîra and H. Bevrani

Course Description and Objectives

Wide-area monitoring, protection, and control (WAMPAC) is an important issue in modern electric power system design and operation; and is becoming more significant today due to the increasing size, changing structure, the introduction of renewable energy sources, distributed smart/microgrids, environmental constraints, and complexity of power systems. The wide-area measurement system (WAMS) with phasor measurement units (PMUs) provides key technologies for monitoring, state estimation, system protection and control of widely spread power systems. A direct, more precise and accurate monitoring can be achieved by the technique of phasor measurements and global positioning system (GPS) time signal. A proper grasp of the present state with flexible wide-area control and smart operation address significant elements to maintain wide-area stability in the complicated grid with the growing penetration of distributed generation and renewable energy sources. In response to the existing challenge of integrating advanced metering, computation, communication, and control into appropriate levels of PSMC, this course provides comprehensive coverage of WAMPAC understanding, analysis, and realization. It presents both theoretical knowledge and a practical foundation for understanding WAPSMC. Different aspects, current challenges and research directions will be examined in detail.

The topics given in this course covers the most important issues in WAMPAC. After successful completion of this course, the students will learn the fundamentals of WAMPAC, relevant topics, as well as some methodologies for measurement-based control analysis and synthesis. They will be able to conduct a new research in this area, and will complete and present a research project in one of given main subjects in the contents.

Main References

1- Hêmin Golpîra, Arturo Román-Messina, and Hassan Bevrani. *Renewable Integrated Power System Stability and Control*. Wiley-IEEE Press, 2021.

2- Bevrani, H., Watanabe, M., and Mitani, Y. *Power system monitoring and control*. Wiley-IEEE Press, 2014.

- ## Course Content

Week 1 (H. Golpira)

Introductio

Power system stability and control

Power system engineering

Control Engineering

General overview

Power system elements

Power system layers

Phasor and states

Security and adequacy

Stability and categories

Conventional power systems

Modern power systems

Infrastructure

Advantages and disadvantages

Roadmap

Week 2 (H. Golpira)

Signal processing and application in power system

Measurements vs states and variables

What are measurements?

From where?

PMU vs RTU

Denoising

Why denoising?

Advantages and disadvantages

Methods and example

Extracting of features using

Prony method

Music method

ESPRIT method

Real signal investigation

- *Homework: Breif definition of PMU classes (P and M)*

Week 3 (H. Bevrani)

SCADA and WAMS structure and components

SCADA

Components and structure

Advantages and Disadvantages

Application examples

WAMS

Concept

Components, PDC and SPCS

Roadmap

Structure and application examples

Homework: Write a short report on a real application of PMUs

Week 4 (H. Bevrani)

Frequency stability and control

Definitions and concepts

Basic frequency control loops

New frequency control options comparison

Frequency response model analysis

Local frequencies

Concept

Estimation

Application in power system stability

Case studies

Frequency stability indices

Nadir

RoCoF

Delta-frequency deviation

Parameter estimations

Online

Off-line

WAMS-based frequency control

- ➢ *Homework: Regenerate single-area frequency control system in SIMULINK*

Week 5 (H. Golpira)

Simple simulation

Effect of inertia on power system dyanmics

Inertia: good or bad?

- ➢ *Homework: Doing the same on a simple system*

Inertia constant

Synchronous

Virtual

Case studies

Frequency response model

Parameters

Model derivation

- ➢ *Homework: Extracting SFR model for a system*

UFLS

Model-based methods

Measurement-based methods

Case studies

Week 6 (H. Bevrani)

Oscillation mode

Definitions

Damping, amplitude

Critical mode

Oscillation monitoring

Japan example

Mode extraction

Model-based methods

Measurement-based methods

Case studies

Small-signal stability

Definitions

Oscillation model identification

FFT and DWT filtering

Week 7 (H. Golpira)

Simple simulation

Effect of PSS and AVR on power system dyanmics

PSS: good or bad?

➢ *Homework: Doing the same on a simple system*

PSS design

On-line tunning

Off-line tunning

Coordination with AVR

Wide area damping controller

Model-based methods

Measurement-based methods

Case studies

Week 8 (H. Bevrani)

Voltage stability and control

Introduction and *concepts*

Instability

Effective factors on voltage stability

Bifurcation analysis

Load flow Jacobian

Voltage stability analysis

Sensitivity analysis

Voltage control

Week 9 (H. Golpira)

Clustering and application in stability assessment

Excitation system and control loops

Case studies

- *Homework: implementation of a clustering approach*

Week 10 (H. Bevrani)

Dynamic impact of DGs and Microgrids

Impact of DGs on power grid stability

DGs modelling

An updated frequency response model

Maximum penetration level

Week 11 (H. Golpira)

Simple simulation

Data driven vs model driven

What to be derived?

Data driven: good or bad?

Advanced data-driven control and protection

Advanced power system modelling

Flexible inertia

Ancillary services

Practical considerations

Case studies

Week 12 (H. Bevrani)

Wide-area protection

Literature review

Advanced protection schemes

Wide-area protection backup

○ Grading

- Homework/Short-report: 40%
- Final Exam: 25%
- Final Project and Presentation: 35%

○ Homework/Short-report (Assignments)

The course assignments will be performed along the semester.

Note: Students may discuss the problems with other students, but are not allowed to share solutions (MATLAB m-files, etc.).

○ Final Project

Each student must work on a special project based on his/her interest. This will give students a chance to deepen their knowledge in a specific area. You will provide a detailed written report and simulation files. Detail will be discussed in the class.