Training Content

Stability analysis of converter-dominated power systems

DAY 1

MODULE 1: Introduction

Presentation: Introduction and Basic Concepts — **1 h**

Motivation. Key Characteristics of inverter-based resources (IBRs) vs synchronous generation. Classification. New stability classes resulting from IBRs. Overview of power system dynamic modelling and simulation tools.

Exercise: Power System Analysis in *PowerFactory* — **1/2 h**

Use of quasi-dynamic simulations to identify critical conditions in the network. Execute time-domain simulations for a specific scenario and compare the results of PDT and EMT simulations.

Coffee break

Continue with exercise: Power System Analysis in *PowerFactory* — **1/2 h**

MODULE 2: Simulation Models. Use of Templates

Presentation: Templates — **1/4 h**

Use of Templates form the DIgSILENT Library. Grid-following (GFL) and grid-forming (GFM) converters.

Exercise: Use of Templates in *PowerFactory* — **3/4 h**

Explore the use of templates and compare the use of grid-following and grid-forming (GFM) converters during frequency excursions.

Q&A session

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DAY 2

MODULE 3: Frequency Stability

Presentation: Effects of the IBR generation on frequency stability — **1 h**

Impact of IBR generation on frequency stability. Countermeasures. Simulation models. Analysis tools and procedures. Screening metrics.

Exercise: Frequency Stability Analysis in High-IBR Systems — **1/2 h**

Evaluate the dynamic response of a high-IBR power system to severe MW imbalances using RMS time-domain simulations across critical scenarios identified by frequency-focused screening metrics, quantifying the grid-support impacts of wind farms, Battery Energy Storage Systems (BESS), and HVDC Voltage Source Converters (VSC).

Coffee break

Continue with exercise — **1 1/2 h**

Q&A session

DAY 3

MODULE 4: Subsynchronous Stability

Presentation: Subsynchronous Oscillations — **3/4 h**

Subsynchronous stability. Low-frequency oscillations. IBR control loops. System strength. Tuning of controllers. Synchronous condensers. Grid-forming converters.

Exercise: Multi-Domain WPP Subsynchronous Oscillation Study — **3/4 h**

Investigate wind power plant (WPP) dynamic performance under strong and weak grid conditions to identify subsynchronous oscillations (SSO) in a single-machine infinite-bus (SMIB) network representation. The investigations are conducted in the phasor-domain transient (PDT) and electromagnetic transient (EMT) domains using dedicated simulation models.

Coffee break

Exercise: Multi-Machine Weak-Grid Stability & Mitigation Analysis — **1 1/2 h**

Evaluate the dynamic performance of an IEEE 39-Bus benchmark network where regional synchronous generation is replaced by grid-following (GFL) wind power plants, analysing the resulting weak-grid instability risks from reduced short-circuit power at points of connection, and assessing the deployment of synchronous condensers as a mitigation measure.

Q&A session

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DAY 4

MODULE 5: Impedance-based Stability Analysis

Presentation: IBSA - Single-connection assessment **½ h**

Theoretical background for the IBSA for single-connection assessment based on the stability analysis of SISO systems. Operating point dependency. Coupling over frequency effect.

Exercise: IBSA - Single-connection assessment **1 h**

Develop familiarity with Impedance-Based Stability Analysis in *PowerFactory* by independently analysing the stability of a single wind park.

Coffee break

Exercise: IBSA - Coupling over frequency effect **½ h**

Investigate the coupling-over-frequency effect in the sub- and superharmonic ranges, analysing the inherent interactions between the AC and DC sides of network elements using detailed electromagnetic transient (EMT) models with full DC side representation.

Presentation: IBSA - Multi-connection assessment **½ h**

Theoretical background for the IBSA for multi-connection assessment based on the stability analysis of MIMO systems.

Exercise: IBSA - Multi-connection assessment **½ h**

Apply multi-connection assessment (MCA) techniques to overcome simplified Nyquist criterion limitations when individual subsystem stability is unknown, splitting the network at defined boundaries into multiple verified stable subsystems—such as all converters and a passive system—to evaluate overall grid stability.

Time Schedule (Central European Time)

	Time
First 90 minutes block	9:00
Coffee break	10:30
Second 90 minutes block	10:45
Q&A session	12:15
End of the training day	12:30

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