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Power Systems Laboratory

Impact of Time Delays on Stability of Inertia-less Power Systems

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Type: SA or MA (Theory/Modeling/Simulation)

Description

Time delays arises in a wide variety of physical systems and their effects on stability have been carefully investigated in several engineering applications, such as signal processing and circuit design. Nevertheless, little work has been carried out so far in the power system area on the effects of time delays on power system stability. As a matter of fact, time delays are generally ignored. Including time delays in the classical electromechanical model leads to formulating power systems in terms of functional differential algebraic equations of retarded type or, more concisely, Delay Differential Algebraic Equations (DDAE). The study of the stability of DDAE is relatively more complicated than that of standard Differential Algebraic Equations (DAE). Nevertheless, both theoretical tools for DDAE and modern computers are mature enough to allow tackling the stability of large scale DDAE systems. Furthermore, as the share of renewables is growing rapidly, the number of converter-interfaced generation is drastically increasing, leading to so-called low- and no-inertia systems. While various Voltage Source Converter (VSC) control concepts have been proposed in literature, almost none of them analyze the impact of time delays coming from measurement or communication in the PE components, which can play an important role in system stability.

This project aims to analyze in detail the stability properties of power systems with inclusion of signal delays. The conventional mathematical representation of such systems, based on Differential Algebraic Equations (DAEs), must be extended to Delay Differential Algebraic Equations (DDAEs), with the actual time delays adequately represented in the model. Subsequently, the stability margins will be assessed.

Goals and Objectives

Study different control schemes for Voltage Source Converters (VSCs), improve the existing [1] and develop new small-signal models with inclusion of time delays. Furthermore, if decision to look into the low-inertia systems is taken, an adequate time-delayed model of a synchronous machine (with inclusion of the Automatic Voltage Regulator (AVR), Power System Stabilizer (PSS), etc.) should be created. Conduct a stability analysis and study the delay margin of several simple test systems (Single-Machine-Infinite Bus (SMIB), 2-bus and 3-bus systems) according to the provided data.

Tasks

1. Do a literature review on time-delay modelling in power systems.
2. Develop adequate small-signal models in MATLAB based on the existing VSC control schemes (complexity of the model will depend on the size of the observed system).
3. Determine best mathematical methods for solving large sets of DDAEs.
4. Conduct the eigenvalue analysis and derive the stability criterion for no-inertia power systems.
5. (Optional) Derive a synchronous machine model, look into the low-inertia systems, and investigate their stability margins.

Notes

Interested students should have a basic understanding of power systems and control. Experience with MATLAB, as well as good mathematical background are an advantage.
Since the research field of low- and no-inertia power systems is quite new, there is a high potential and encouragement from my side for incorporating the ongoing student project into a potentially published paper. The students who are capable and willing to go the extra mile and get their work published (with the help of the supervisor) are favored.

This thesis will be done within the framework of the MIGRATE project (https://www.h2020-migrate.eu/).

[1] U. Markovic, P. Aristidou, G. Hug, “Stability Performance of Power Electronic Devices with Time Delays” *in 2017 Powertech Conference*, June 2017