Electrical Power and Energy Systems 33 (2011) 1631–1637

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Universal method for the modeling of the 2nd generation FACTS devices in Newton–Raphson power flow

Anton Vinkovic, Rafael Mihalic *

Faculty of Electrical Engineering, University of Ljubljana, Trzaska 25, 1000 Ljubljana, Slovenia

ARTICLE INFO

Article history:
Received 21 September 2009
Received in revised form 22 April 2011
Accepted 3 June 2011
Available online 23 September 2011

Keywords:
FACTS
Newton power flow
Power system analysis

ABSTRACT

In this paper a universal approach to the modeling of the 2nd generation FACTS devices for power-flow calculations by applying the Newton–Raphson method for current-based models is discussed. First, the basic principles of modeling 2nd generation FACTS devices using current-based models and the current-based models themselves are presented. This is followed by a discussion about the universality of the proposed model. Next, a definition of the FACTS devices' free parameters, a mathematical description of their type, the problem of the initial conditions and the handling of constraints are discussed. The derived model was then tested on the IEEE 57, IEEE 118 and IEEE 300 bus systems. Finally, the main achievements are summarized.

1. Introduction

In the past two decades FACTS devices [1,2] have been the subject of intensive research work all over the world. However, there are still problems regarding a basic analysis of the electric power systems (EPSs) containing 2nd generation FACTS devices (those applying voltage source converters). Although it is hard to imagine how it could be possible to justify an investment in FACTS devices only for the control of steady-state conditions, their impact on power flows has to be considered in investigations, irrespective of the reason why they are included in EPSs. For this reason, it is very important to incorporate the appropriate models of FACTS devices into power-flow routines.

In the available literature numerous models can be found for the variety of 2nd generation FACTS devices. Depending on the way in which they are modeled, these models may be divided into several groups:

- Power Injection Models (PIMs) [1,2],
- Synchronous Voltage Source Models (SVSMs) [5],
- Hybrid Models (HMs) [6],
- Voltage Source Based Models (VSBMs) [1,2,7–12],
- as well as their various modifications, e.g., [13,14].

As reported in the above references these models more or less satisfactorily represent the impact of FACTS devices in load-flow calculations. However, they differ in their consideration of the losses (some of them consider the losses and some do not), in the initial conditions, in the dependency of the iteration speed on the initial conditions, and in the number of iterations needed to reach a certain mismatch level, etc.

It is a common feature of all these models that they do not exhibit universality, which would enable them to include a universal element for FACTS devices in the program codes and to handle all 2nd generation FACTS devices in basically the same way. Instead of which, for each FACTS device a separate model has been developed.

In contrast to these models, the s.c. current-based models [3,4] seem to be an appropriate basis for composing a universal 2nd generation FACTS model. Furthermore, in tests the current-based models are very unproblematic with regard to the initial conditions, the convergence speed and the handling of constraints [3,4].

2. FACTS devices and their free parameters

In this article the following FACTS devices are considered:

- SSSC (Static Synchronous Series Compensator),
- STATCOM (Static Compensator),
- UPFC (Unified Power Flow Controller),
- IPFC (Interline Power Flow Controller),
- GUPFC (Generalized Unified Power Flow Controller).

In general, 2nd generation FACTS devices consist of series and/or parallel branches composed of a transformer, an AC/DC converter and a DC network, which in the case of the "multi-branch" devices also connects the device's branches.

From this point of view the FACTS devices in question consist of:

* Corresponding author. Tel.: +386 1 4768 438.
E-mail address: rafael.mihalic@fe.uni-lj.si (R. Mihalic).

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doi:10.1016/j.ijepes.2011.06.025