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Nonlinear controller design for IPC using feedback linearization method

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ABSTRACT

This paper establishes a mathematical model in the d–q frame for the conventional interphase power controller (IPC) in series with a transmission line connecting two power systems. The IPC model is nonlinear. Based on this model and the theory of feedback linearization, a MIMO nonlinear controller is proposed. This controller can independently adjust active and reactive powers of the transmission line and maintain the voltage of the capacitor and the current of the inductor in the branches of IPC at the prescribed values. The simulation results, carried out by Matlab/Simulink® software, show the effectiveness of the proposed controller.

1. Introduction

The interphase power controller (IPC) is a series connected device, which is equipped with the phase shifting transformer (PST). It can potentially control the power flow and mitigate the fault current [1–3]. This paper contributes to carrying out the nonlinear control design for the conventional IPC via feedback linearization method (FLM). This method has been utilized for controlling different quantities and devices in the power systems like AC and DC machines [4–10], convertors and FACTS devices [11–20], transient stability enhancement and voltage regulation [21], multiple HVDC links [22] and interconnected power systems [23].

The complexity and coupling of equations of the IPC system, prevents the efficient application of the linear control methods. So, the nonlinear methods like feedback linearization should be utilized to control the system. This approach is to algebraically transform a nonlinear system dynamics into a fully or partially linear and controllable system, so that the linear control techniques can be applied.

In this paper, the ability of the IPC for individually controlling the active and reactive powers in a transmission line has been investigated and for this purpose, the model of the IPC in series with a transmission line connecting two buses is represented in the d–q frame. There are 2 PSTs in the IPC and each PST can vary the magnitude and the phase of its output voltage in relation to its input voltage. It is shown that the order of the IPC's nonlinear equations is 6 and one can consider 4 inputs (2 control inputs for each PST including the voltage gain and voltage phase) and also 4 outputs (active and reactive powers of the transmission line equipped with IPC, voltage of the capacitor and the current of the inductor in the IPC branches). Since the equations are nonlinear and coupled, the linear control methods are inefficient. Subsequently, the FLM is applied to IPC to control the desired outputs including active and reactive powers of the line. Finally, to show the performance of the nonlinear control method, a numerical case study is carried out by using Matlab/Simulink® software.

This paper is principally concerned with the theoretical derivation of a nonlinear control system for the conventional IPC using feedback linearization method and we think it is likely to provide accurate and desirable responses. Unfortunately there is not any attempt for nonlinear control of the conventional IPC to compare the results of our study to them.

2. Conventional IPC

An IPC is a series-connected active and reactive power controller, consisting of inductive and capacitive branches subjected to separately phase-shifted voltages, which are made by phase shifting transformers (PSTs) [24]. Fig. 1 shows the simplified schematic diagram of a conventional IPC in series with a transmission line connecting two buses.

In this figure, R_x and L_x are the line resistance and the line inductance, respectively. The sending and receiving end terminal AC source voltages and AC-side currents are (v_{dS}, v_{qS}), (v_{dR}, v_{qR}) and (i_d, i_q), respectively. The dq components of currents in the inductive and capacitive branches of IPC are (i_{dL}, i_{qL}) and (i_{dC}, i_{qC}). The voltages

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