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Time–optimal current control with constant switching frequency for STATCOM

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ABSTRACT

In this paper a time–optimal current control algorithm with constant switching frequency for a STATCOM is presented. The method enables a fast transient response of the device limited only by its output voltage rating. The main idea behind the time–optimal current control is to find such control voltage that enables us to reach current reference values in a pre-determined minimal length of time. This control approach utilizes the mathematical model of the STATCOM and computes the exact required output to move the system state to the reference waveform. The algorithm is tested by means of simulations using the STATCOM mathematical model and a detailed model. The performance of the control algorithm is validated for reference current tracking and balanced and unbalanced network voltage sags. Simulations were carried out in PSCAD.

1. Introduction

The main goal of electrical power networks is to provide continuous supply and high power quality. The term power quality usually denotes voltage quality which is affected by harmonics caused primarily by nonlinear loads, uneven distribution of loads, faults resulting in voltage sags and intermittent power generation (e.g. wind) [1].

To improve the continuity of supply and voltage quality, Flexible AC Transmission System (FACTS) devices [2] may be used, as they enable fast control/compensation in static and dynamic network conditions. One of the most viable FACTS devices is the static compensator (STATCOM) which basically generates controllable ac voltage using a voltage source converter (VSC) with a dc capacitor connected to the dc side. The power flow between the STATCOM and the network is defined by the difference between network and generated voltages occurring on the coupling inductance of the device.

STATCOM control in general includes two controllers. The first one controls the STATCOM output current and/or voltage which needs to be fast to provide a quick response in dynamic conditions. The second controller regulates the dc voltage across the dc-side capacitor. Both traditionally use a proportional-integral (PI) controller and are included in many different control strategies [3–6]. Speed of PI controllers can be set by gain and time constants of the controller. However, accelerating PI controllers can easily lead to excessive oscillation of control output variables. Also the nonlinear characteristic of a STATCOM can cause the detuning of the controller at different operation points. In Ref. [5] a method enabling autotuning of PI constants is proposed. With optimization the transients are short and overshoot is minimal. Some control schemes deal with nonlinear models of a STATCOM where the direct feedback linearization (DFL) technique is used to transform the nonlinear model into a linear one [7–9]. In Ref. [9] one of the two presented control schemes enables fast performance and subcycle current responses, but operation under unbalanced conditions is not discussed.

The control algorithm should provide a fast response when reference values change, and stable operation during network transients (e.g. network voltage sags). Unbalanced network voltages and unbalanced sags must therefore also be taken into account in controller design and enable STATCOM operation under such conditions. This means that the positive and negative sequence of the current must be controlled simultaneously. With conventional PI controllers this is achieved with two separate controllers; one for the negative and one for the positive current sequence [3,10,11].

In all mentioned control schemes the operation under unbalanced conditions and fast control responses are treated separately.

In this paper the STATCOM control algorithm is based on the time–optimal current control enabling stable operation under unbalanced network voltage conditions and providing the fastest possible current control taking into account the device's limitations at constant switching frequency. The algorithm is derived in α–β reference frame and is therefore not decoupled as in Ref. [3]. In transient conditions the optimal tracking of reference current is achieved with iterative calculation of the output voltage vector, forcing the STATCOM output current to reach the reference value by an optimal path and in minimum time.

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