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New control paradigm for integration of photovoltaic energy sources with utility network

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ABSTRACT

The employment of an inverter to integrate a distributed generation system to the utility network is well known. In such a context, there is an increasing interest in developing an appropriate control strategy to derive a current with less distortion from the inverter. In this paper, a new current controller for inverters of this kind has been proposed. The proposed technique combines the benefits of a proportional–integral controller and a hysteresis limiter. The paper presents the development of such a controller and its structure. Inverter-output current waveforms of the proposed scheme are compared with that of a hysteresis alone and average current mode controllers. A better harmonic elimination and current tracking performance of the proposed controller is thereby established. Filter responses have also been compared to establish the superiority of the proposed approach.

1. Introduction

The contribution of renewable power sources to the total power generation becomes more and more important because of their benign nature to the environment. These sources have become significant because of the steady increase in energy consumption and the deregulation of the utility. Schemes based on photovoltaic (PV) array have also been largely employed for feeding power to the utility network. There are number of benefits for both the utility company and the consumer by integration of photovoltaic resources. These resources have long been proved to be beneficial in peak shaving and in loss reduction of power distribution systems [1]. In such schemes, a three-phase inverter interposed between the photovoltaic source and the utility grid is necessary. The features desirable for such inverters are low line-current distortion with high power factor, high efficiency and high switching frequencies.

As a matter of fact, inverters fed from a PV array are so controlled that it generates an output current which is in phase with the grid voltage. Earlier, proportional (P) control was attempted for such inverters, but such a control has an inherent steady-state error [2]. The steady error found in a P controller was subsequently eliminated with an integral component added to the transfer function [3–5]. The average value of current error can be reduced to zero at specified rate with such an integral component. Nevertheless, the transient response of such proportional–integral (PI) controller is limited by the proportional gain. The gain must be set at a value such that the slope of the error is less than the slope of the carrier saw tooth waveform required for generating the firing pulses of the inverter. This results in an error under transient conditions. Later, an average current mode control (ACMC) was also attempted. ACMC was found to be an improvement of PI control technique because of an additional derivative component, which improves the gain of the regulator at the switching frequency [6]. This method has the problem of high frequency sub-harmonic oscillations with current mode control [7]. ACMC has relatively fast transient response, with a relatively fast removal of steady-state error. However, instability is reported under certain conditions [8].

Current control based on prediction of the required subsequent instantaneous current output was also attempted. Such a control give a better performance only when the mathematical model is accurate, linear and time-invariant. Predictive controller is computationally intensive, and therefore requires a large control loop time-period. This results in low control bandwidth and poor transient response [9]. An elaborate current controller based on *d*–*q* rotating coordinates was also proposed. Nevertheless, this control is not easily amenable to implementation using op-amps [10].

Alongside the development of classical PID current controllers for inverters, hysteresis current controllers were also developed. In earlier hysteresis control, when the line current becomes greater (less) than the current reference given by the hysteresis band, the inverter leg is switched in the negative (positive) direction [11]. Such conventional hysteresis controllers were generally used for their robustness and simplicity and for their very good transient response. In addition, they do not need a triangular carrier signal

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