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Experimental Validation of Vector Control of a Matrix Converter Fed Induction Generator for Renewable Energy Sources

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Abstract

Grid integration of induction generators driven by renewable energy sources requires power electronic converters to transform the grid voltage into an output voltage of appropriate magnitude and frequency. This paper presents an experimental validation on vector control of a matrix converter fed induction generator. Operation of a matrix converter is presented. The principle of vector control for induction generators is described. A matrix converter prototype 3 kW, 230V, 50Hz is developed. Rotor speed and flux are digitally controlled by 32-bit microcontrollers TMS320F28069. The experimental results confirm viability of the proposed control method.

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Keywords: Maxtrix Converter; Vector Control; Induction Generator

1. Introduction

Nowadays, power electronic converters play an important role in the integration of renewable energy sources to the grid. They are capable of converting ac voltages with variable magnitude and frequency to desirable ac voltages as recommended by grid requirements. These power converters can be categorized into two types:

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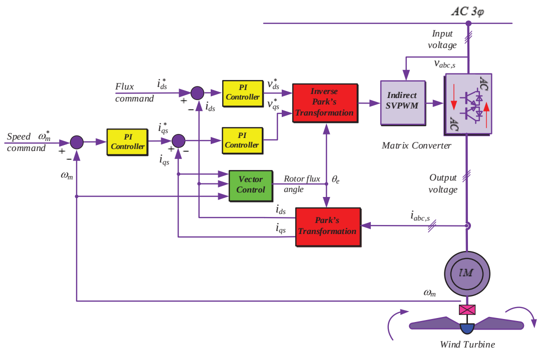

Fig. 1 Grid integration of a variable speed wind turbine using a matrix converter

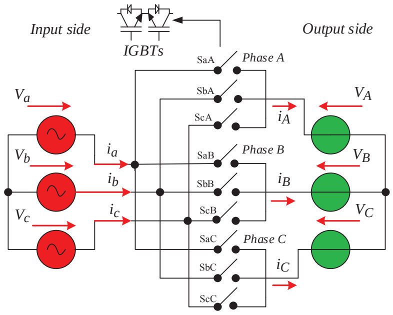

Fig. 2 Matrix converter topology

an indirect ac/dc/ac converter and a direct ac/ac converter; i.e. a back to back PWM rectifier/inverter and a matrix converter respectively [1-2]. Although an indirect ac/dc/ac conversion system has several advantages such as being mature technology, robust and simple to control. The use of a bulky dc-link electrolytic capacitor which has a limited lifetime is a serious drawback. Instead, a direct ac/ac conversion system i.e. a matrix converter has a number of advantages such as sinusoidal input/output currents, bidirectional flow, controllable power factor, compactness, and high reliability due to lack of bulky electrolytic capacitors.

In Fig. 1, a matrix converter is employed to control speed and rotor flux of an induction generator driven by a variable speed wind turbine. The real power converted from wind energy is directly fed into the grid. But the reactive power required by an induction generator and drawn from the grid can be controlled independently.

In this paper, experimental validation of vector control of a matrix converter fed induction generator is presented. Operation of a matrix converter is detailed. Principles of vector control and gain selection of PI controllers are discussed. A matrix converter prototype with ratings of 3 kW, 230V, 50Hz is developed and controlled using 32-bit microcontrollers. Viability of the proposed conversion method is verified by experimental results.

2. Matrix Converter

A matrix converter is represented by a switch matrix as shown in Fig. 2 It consists of nine bidirectional switches with three input phases that can be connected to any of three output phases without an energy storage element. The notations of bidirectional switches are given that small letters *a*, *b*, or *c* belong to the input phase and capital letters *A*, *B* or *C* belong to the input phases. For example, the switching state [S_{aA}] refers to the state where the output phase *A* is connected to the input phase *a*.

The operation of a matrix converter has two restrictions First, three input phases must never be shorted circuits. Second, three output phases must never be opened circuits. It is assumed that an element of a switching transfer matrix is one when a corresponding switch is closed and it becomes zero when a corresponding switch is opened. The switching transfer matrix and its constraint is expressed as,

$$\mathbf{S} = \begin{bmatrix} S_{aA} & S_{bA} & S_{cA} \\ S_{aB} & S_{bB} & S_{cB} \\ S_{aC} & S_{bC} & S_{cC} \end{bmatrix} \qquad \begin{array}{l} S_{ij} = 1; \text{ On state} \\ S_{ij} = 1; \text{ Off state} \\ i \in \{a, b, c\}, j \in \{A, B, C\} \end{array} \tag{1}$$

$$S_{ai} + S_{bj} + S_{cj} = 1 \tag{2}$$

The input currents and output voltages of a matrix converter can be determined by the product of the switching function matrix and the input current vector and the output voltage vector expressed as.

$$\mathbf{V_o} = \mathbf{S} \cdot \mathbf{V_i} \tag{3}$$

$$\mathbf{I_i} = \mathbf{S}^{\mathrm{T}} \cdot \mathbf{I_o} \tag{4}$$

where $\mathbf{V_0}$ is the output voltage vector, $\mathbf{V_i}$ is the input voltage vector, $\mathbf{I_i}$ is the input current vector, $\mathbf{I_0}$ is the output current vector, **S** is the switching function matrix, and *T* denotes transposition of a matrix.

Voltage and current conversion above require advanced modulation techniques. In this reseach, the indirect space vector PWM is adopted for the implementation [4]. This modulation has a significant advantage that it enables control of the input currents and the output voltages to be decoupled. Thus, the reactive power required by an induction generator and unity power factor at the utility side can be controlled independently.