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A Simulation Study of Inverter Air Conditioner Controlled to Supply Reactive Power

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Abstract

Recently, inverter has been applied in air conditioning technologies. Besides energy saving capability, inverter can also control reactive power by using the dq-axis theory. It separates current into two parts that enable decoupled control of active power and reactive power. This presents a simulation study of an inverter air conditioner controlled to supply reactive power for the installation area without sacrificing thermal comfort. Power factor improvement can reduce loss in transformer and line so power that be saved can be used for others load. Simulation results carried out by MATLAB/SIMULINK showed that reactive power controllability depends on variation of the indoor and outdoor temperature and rated current of equipment.

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Keywords: Inverter air conditioner, Reactive power control

1. Introduction

In recently years, distribution system operators have encountered new challenges to maintain secure and reliable operation with the higher integration of renewable energy sources and increasing electricity demand. Air conditioner is a very essential electric appliances in all sectors (residential, commercial and industrial) in Thailand. Air conditioning technologies can be broadly categorized in two groups. The first is based on the hysteresis temperature control and the motor is turned on/off. The latter uses inverter to adjust infeed power to the motor driving the compressor by adjusting the frequency in order to meet the requirement of the thermodynamic process [1]. The installation of inverter-based air conditioner (IBAC) has been increased quite significantly due to its cost reduction. The use of IBAC not only save energy consumption but also gives possibilities to smart grid functionalities. A smart controller can be developed to adjust active power to maintain thermal comfort in the space as the first priority and to

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supply reactive power if required. Given this capability, IBAC can perform like Static Var Compensator (STATCOM). Reactive power can be locally compensated and could potentially improve voltage stability of the distribution system.

This paper presents a mathematical model of IBAC and associated PI controllers in MATLAB/SIMULINK. Moreover, a control algorithm was developed to reactive power output at its maximum capability without losing its cooling efficiency. The rest of this paper is organized as follows. Section 2 summarizes the theories relevant to this work and shows the developed SIMULINK model. Section 3 gives simulation setting and demonstrate the results. Finally the paper is concluded and the future research direction is outlined in section 4.

2. Developed model

A three-phase induction machine (IM) is generally used as the compressor motor. In an IBAC, inverter is used to control speed of the IM to drive variable refrigerant flow and thereby regulating the conditioned-space temperature. The variable frequency drive is used to achieve the desired frequency and the rotational speed will be proportional to the AC input. To regulate the frequency of AC input to the IM, AC power from the utility is converted to DC by the rectifier circuit. The vector control [3] based on Park's transformation [4] decompose the current in the d-q axes. The DC link voltage V_{DC} , the reactive power Q are measured and used as inputs of the control box. Then the pulse width modulation (PWM) signal is sent to the converter [2]. This allows the separate control of active and reactive power. The diagram of converter and its controllers is shown in Fig 1.

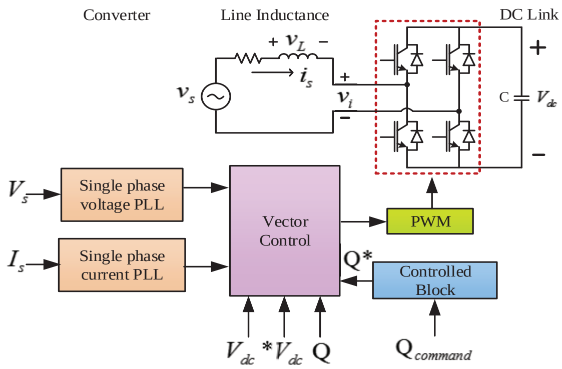

Fig.1 Converter and controllers

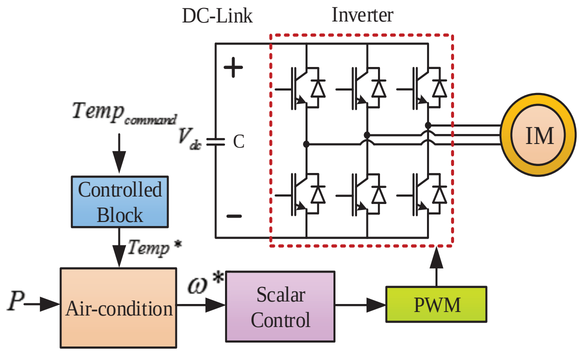

Fig.2 Inverter and controllers

Fig 2 depicts the control blocks of inverter and induction motor. The command temperature $Temp_{command}$ and the active power P required by the air conditioner are used to calculate the scalar control input used to generate PWM signal for the inverter. The model of an IBAC with reactive power control capability developed in SIMULINK is shown in Fig 3.

3. Simulation settings and results

In this work, an IBAC is used to control temperature of a room with the dimension of 10m x 10m x 3m. The only environment factor considered in the simulation is the outside temperature. Realistic measurement data [5] as shown in Fig 4 is used. From the study in [6], thermal comfort of a person can be expressed as a function of temperature and relative humidity inside the control space as shown in Fig 5. In this simulation, humidity is not a considering factor and thereby the comfort temperature is assumed to be within 24 to 27 C.