An Energy-Saving Scheme of Variable Voltage Control for Three-Phase Induction Motor Drive Systems

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Abstract – This paper presents a control scheme to implement the energy-savings of three-phase induction motors when they operate under long-term light-load or small duty ratio load. The proposed scheme is based on the principle of variable voltage control (VVC) at constant speed. The energy-saving controller for three-phase induction motors is developed. A group of the experiments demonstrate that the proposed scheme gives rise to the considerable energy-savings.

Index Terms – Energy-savings, induction motors, motor controller, variable voltage control

INTRODUCTION

For modern cities, motor drive systems can consume over half of all electricity. Furthermore, those systems can consume over 75% of all electricity in an industrial plant. Motor drives are popularly applied in air-conditioning, fans, pumps, compressors, chillers, escalators, elevators and industrial drives. Common motor drives include induction motor drives, dc motor drives, synchronous motor drives, switched reluctance motor drives, as well as other motor drives. Among these drives, induction motor drives are most popular with real applications and hence are the most electrical devices consuming electricity and applied in industries.

The rated efficiency of an induction motor is high when it runs under the full load. In general, the rated efficiency is larger than 75%. However, the operating efficiency of the induction motor drive system will be low if an induction motor is not selected correctly or does not match its load appropriately. Therefore, even a modest improvement in the energy efficiency of induction motor drives can imply huge energy-savings.

This paper is focused on the issue of energy-savings of induction motor drive systems. The authors propose a control scheme for energy savings of three-phase induction motor drive systems when induction motors operate under long-term light-loads or small duty ratio loads, based on the variable voltage control (VVC). Furthermore, the motor controller for energy savings is developed. The experimental results show that the proposed control scheme can lead to high operating efficiency of the induction motor drive system.

The organization of this paper is described as follow. In the second section II, two kinds of energy-saving methods for induction motor drive systems are summarized. The proposed control scheme and developed motor controller are discussed in the third section. The fourth section shows the experimental results. Finally, the fifth section concludes this study.

ENERGY-SAVING METHODS OF INDUCTION MOTOR DRIVE SYSTEMS

From the view of motor speed, there are two types of induction motor drive systems. One of which is variable speed drive (VSD) system, and the other is constant speed drive (CSD) system.

A. Variable Speed Drives

The implementation of VSD for induction motors is usually carried out by inverters. A typical inverter drive is shown in Fig 1. Many techniques have been developed to implement VSD. They include the variable speed variable voltage (VSVV) drive, variable voltage variable frequency (VVVF) drive and the power factor correction (PFC) method. The principle of energy-savings in a VSD system is to change motor speed according to the load's demand so that the VSD system runs with the high operating efficiency. The common applications of VSD contain fans, pumps, compressors, elevators, and other variable speed loads.

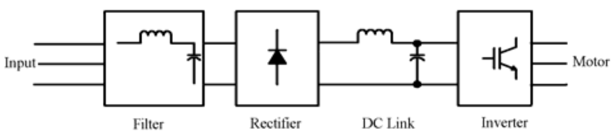

Fig. 1 Typical configuration of an inverter for VSD

B. Constant Speed Drives

The principle of energy-savings in a CSD system is to adjust voltage according to the variation in load in order that the CSD system operates with the high operating efficiency. The proposed control scheme for energy-savings in CSD systems is just based on the variable voltage control (VVC). Fig. 2 illustrates a typical structure of VVC for CSD. The common applications of the VVC include escalators, CSD systems with light-loads, and CSD systems with small duty ratio loads.

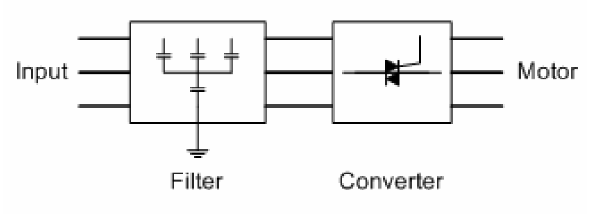

Fig. 2 Typical structure of VVC for CSD

It can be seen that the VVC has the simpler structure than the inverter. A fast sight into the energy-savings of induction motor drive systems is depicted in Fig. 3.

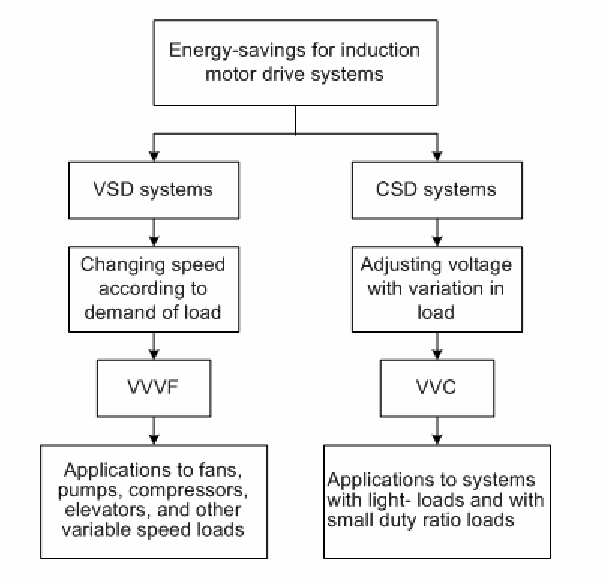

Fig. 3 Classification of energy savings for induction motor drive systems

PROPOSED CONTROL SCHEME AND DEVELOPED CONTROLLER

A. Control Scheme

In general, the design of induction motors ensures that induction motors have high operating power factor and efficiency when they run in the load range from 75% to 100% full load. Thus, high operating power factor and efficiency can be obtained when induction motors run under full load or load near full load. However, induction motors have low operating power factor and efficiency when they run under no-load or light-load [1].

For an induction motor drive system, the selection of rating of the induction motor mainly depends on its maximum load. In real applications, however, the load changes with the actual requirement. Hence, there are often the cases where induction motors with large ratings are used to drive small loads or small duty ratio loads. It will result in that induction motors run with low power factor and efficiency under light-loads or small duty ratio loads.

The proposed control scheme is to automatically adjust the output voltage of the controller with the variation in the load, in order to obtain high operating power factor and efficiency and to implement energy-savings.

B. Developed Controller

From the proposed control scheme, a controller for energy-savings of induction motors has been developed. Fig. 4 shows the schematic diagram of the developed controller for energy-saving of induction motors.

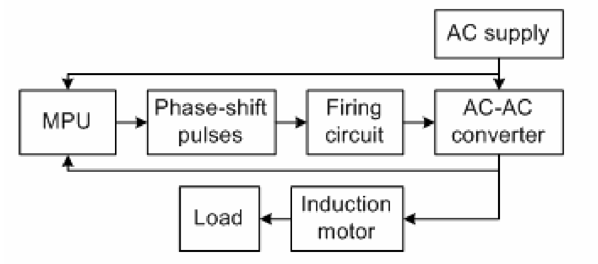

Fig. 4 Schematic diagram of the developed controller

This controller can optimize the output voltage automatically according to the variation in the load and the power factor, so that the induction motor runs with the high operating power factor and efficiency.

VALIDATION

The developed controller was used to drive the 1.5 kW three-phase induction motor connected with the dynamometer. A group of experiments were carried out, in order to validate the proposed energy-saving scheme and developed controller. The changes of the input line-current, power factor and consumed electricity with the load factor are illustrated from Fig. 5 to Fig. 7, respectively. Furthermore, their percents of changes are depicted from Fig. 8 to Fig. 10, respectively.

It can be seen from these figures that the line-current is reduced, the operating power factor is improved, and the consumed electrical energy is decreased, due to the developed energy-saving controller. Moreover, the controller will bring about the larger energy-saving if the induction motor has the lighter load. Therefore, these experimental results validate the proposed energy-saving scheme and developed controller.

CONCLUSIONS

A control scheme to implement energy-savings of three-phase induction motor drive systems has been presented. This scheme is to change the voltage with the variation in the load in CSD systems in order to obtain the high operating power factor and efficiency.

Based on the presented energy-saving scheme, the controller for energy-savings of induction motors was developed. The experimental results have validated the proposed control scheme and developed controller for energy-savings of induction motors.

The proposed VVC scheme can be widely applied in the CSD systems. For long-term operations of induction motors under light-loads or small duty ratio loads, the VVC scheme will bring about huge potentials of energy-savings.

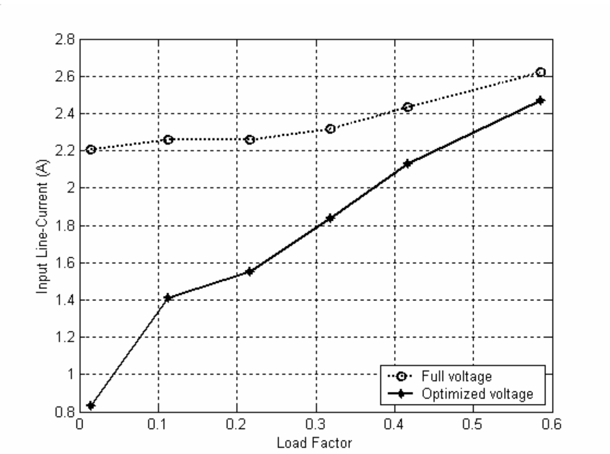

Fig. 5 Input line-current of the induction motor drive system

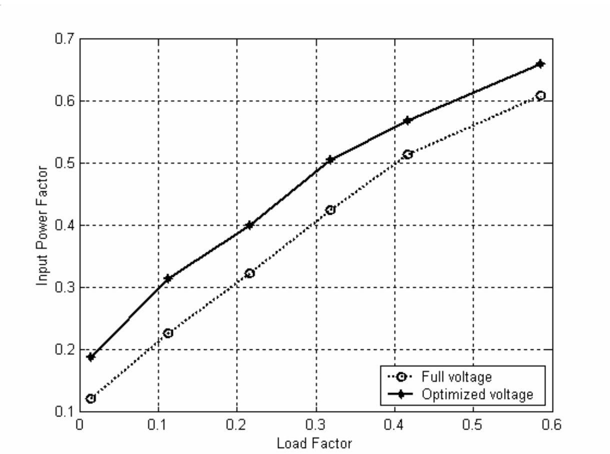

Fig. 6 Power factor of the induction motor drive system

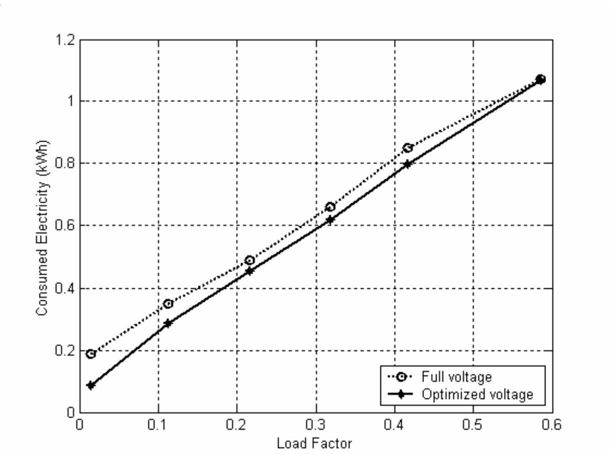

Fig. 7 Consumed electricity of the induction motor drive system

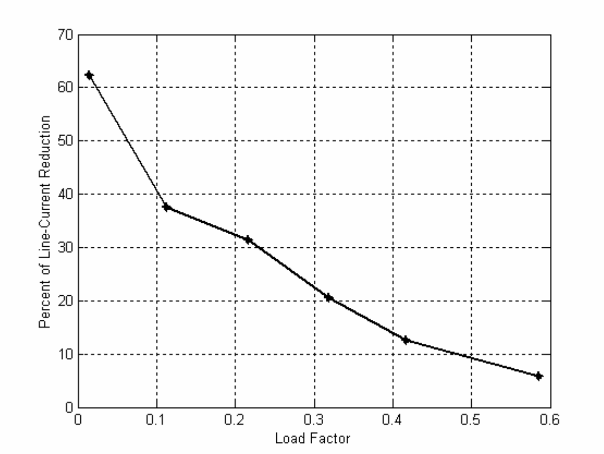

Fig. 8 Percent of the line-current reduction

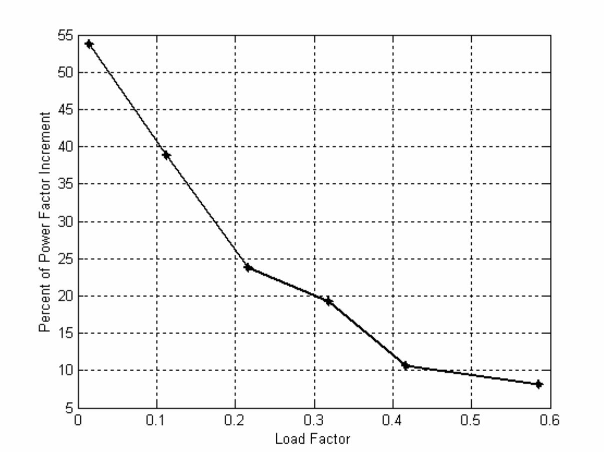

Fig. 9 Percent of the power factor increment

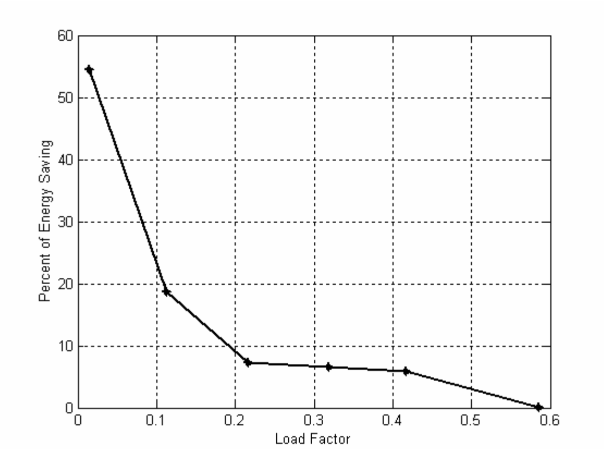

Fig. 10 Percent of the energy-saving

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