Design and Implementation of a New Permanent Magnet AC Contactor with Colenoid Actuator

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Abstract: - This paper focuses on presenting a new permanent magnet with colenoid actuator for the purpose of reducing the energy dissipation during a complete operation. The methodology developed is a hardware based approach. It emphasizes on minimizing the cost of operation over a specified time period rather than a fixed operating point. The practical operating concerns of proposed ac permanent magnet (PM) contactor and the coordination with a new actuator are also addressed. The developed ac PM contactor has been implemented as a prototype grade product. Test results on the experimental prototype and computer simulation model show that the energy-saving performance of this newly developed ac PM contactor is effective and feasible.

Key-Words: - AC PM contactor, permanent magnet, energy saving, simulation model, experimental prototype, actuator.

1 Introduction

In recent years, contactors have been widely used in many industrial applications for making and breaking the load current with the use of their contacts. No matter what ac or dc electromagnetic contactors are used. A great amount electric energy will be dissipated by these contactors. As the energy problem impacts the people life is increasing, attempting to find a new type of contactor with outstanding energy saving performance is devoted to more and more attention.

For a conventional ac electromagnetic (EM) contactor, both the armature and the fixed iron core commonly need to be hold by electromagnetic force during holding process. Therefore, several critical disadvantages, such that consumes lots of energy to hold the armature, produces noise at lower voltage and their coils are easy to be burnt due to continual working state. To overcome above mentioned disadvantages of the conventional ac EM contactor, the newly developed actuator is increasingly applied in the development of the ac permanent magnet (PM) contactor.

As a result of several outstanding benefits with the ac PM contactor, such as energy saving, no noise pollution, and no voltage-sags dropouts, the development related to new type of permanent magnet has attracted many researchers' attention [1-4]. Most of the past researching work is focused on the conventional ac EM contactor, such that making use of the finite element method to analysis the response of the magnetic coupling field [5-8], reduces the average bounce-duration after contacts closing [9-16], and so forth. However, little information is available on the development of new ac PM contactor.

In order to design an newly actuator with high energy-saving performance, its magnetic field and electromagnetic force acts on the armature at any armature displacement should be first accurately analyzed and computed. The main purposes of this paper aims at developing a newly actuator with hardware based electronic control module and comparing the energy-saving performance between the conventional ac EM contactor and the proposed newly ac PM contactor. The computer simulation and experimental results of the proposed ac PM contactor are provided.

2 Principle of Operation

Fig. 1 shows the sketch of the proposed ac permanent magnet contactor. In addition to a permanent magnet, two exciting coils, and a needed electronic control module are included in the configuration; the other mechanisms are almost the same as the conventional ac electromagnetic contactor. After the making course of the proposed ac permanent magnet contactor (abbreviated ac PM contactor) has been completed, in principle, the armature is engaged with the fixed iron core and to be hold tightly. Therefore, during holding process, almost there is no any electrical energy is absorbed by the ac PM contactor. The energy-saving performance of the proposed ac PM contactor is often superior to the other types of contactor. In addition, to satisfy with the operation of the proposed ac PM contactor, an actuator with electronic control module (ECM) is included in the mechanism. The purpose of the ECM is not only provide the controlled ac PM contactor with making/breaking commands, but also need to supply with a breaking voltage during breaking course. Two exciting coils are designed in the central leg of the E-type fixed iron core, one of the coils, coil 1 is called as closing coil and used to be energized during closing process, while the other one coil, coil 2, is called as opening coil and used to be energized during opening process.

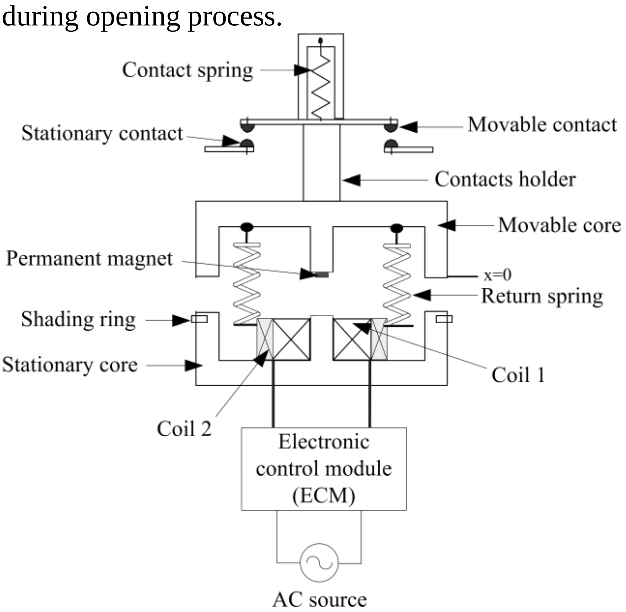

Fig. 1. Sketches the mechanism of the proposed ac PM contactor.

When an ac voltage source is applied to the ac PM contactor, the ac sinusoidal excitation is rectified and converted into a pulse dc voltage source V_o. This rectified pulse dc voltage source is, on one hand, directly used to drive the contactor coil; on the other hand, it is again regulated to be dc voltage source with a fixed voltage, $V_{cc,}$ which is used to supply with the voltage source of the control circuits including in the ECM. As the functional block diagram of the proposed ac PM contactor shown in Fig. 2, during making course, the coil voltage is controlled by switching the power MOSFET M1. The driving signals are generated by a hardware circuit, called as single pulse generator. The maintaining time of signal S_{on} which is obtained from a logical signal V_b is amplified during the power MOSFET M1 switched on is about 30 ms. As the driving signal of the S_{on} becomes low voltage, the power MOSFET M1 is switched off, the electromagnetic flux is removed and the permanent-magnet flux becomes the only remaining magnetic flux in the magnetic circuit. Fortunately, the total reluctance in the magnetic circuit is reduced greatly due to the engagement of the contacts. So that the remaining permanent-magnet flux is sufficient to overcome the spring anti-force and the armature is then to be hold tightly with the foxed iron core. When the ac voltage source is cut off, a breaking information $V_f < V_{cc}$ will be detected by a breaking detector which is built in ECM. There is a logical breaking signal is produced by the breaking detector and again amplified by a transistor driver yields the driving signal of the breaking power MOSFET M2, S_{off} . During power MOSFET M2 switched on, the opening coil is energized by a breaking voltage supplied from an electrolytic capacitor, called as breaking capacitor. Since the spring anti-force is overcome by the electromagnetic force in the reverse direction, the armature disengaged from the fixed iron core and moved back to the opening position.

Compared with the conventional ac electromagnetic contactor, the new design of actuator using permanent magnet excitation needs no electric power in the holding process during the holding force of the permanent magnet. The coil current is required only at the starting and ending transition stages. Fig. 3 shows the current command profiles with the operation in the conventional ac contactor and the newly designed colenoid system with permanent magnet excitation. During closing process, the transition time in the proposed ac PM contactor is shorter than that in the conventional ac electromagnetic contactor due to the permanent magnet excitation. After contacts closing, the armature of the proposed ac PM contactor is tightly engaged with the fixed iron core relies upon the holding force of permanent magnet. Little electric power energy is absorbed by the ac PM contactor. In contrast, the conventional ac electromagnetic contactor needs to produce an electromagnetic force with the use of some electric energy for keeping on holding the closure status between the iron cores of the electromagnetic contactor. Finally, when the maximum releasing voltage is detected by the contactor, the conventional ac electromagnetic contactor as long as relies upon the spring tension force, the iron cores is disengaged from each other. However, the newly proposed ac PM contactor should be first applied an inverse electromagnetic