THE STARTING CHARACTERISTICS IMPROVEMENT OF SPIM WITH ONE-CHIP MICROCONTROLLER

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ABSTRACT-A single phase induction motor (SPIM) rated in fractional horsepower is widely used in home and industrial equipment: washing machines, fans, refrigerators, etc. In this paper, authors present the experimental results of the SPIM under controlling of currents of main and auxiliary windings by using a one-chip micro starter (OMS). This new starting method is developed to replace the conventional starting device consisted with a mechanical switch and a capacitor. In mentioned method, the soft-starting of SPIM is simply implemented and higher efficiency is obtained in comparison with conventional condenser type SPIM.

1. INTRODUCTION

A SPIM can not started itself without any starting device because the rotating flux can not generated in a single phase winding. In a conventional SPIM with a capacitor-type starter, a rotating flux is generated by interaction of fluxes between main and auxiliary windings. A centrifugal type mechanical switch and a capacitor are connected in series with auxiliary winding. the flux produced on the auxiliary winding are maintained 90° spatial displacement from that of main winding by the capacitor until the centrifugal mechanical switch break the input power as motor speed approach to the rated speed. If the SPIM start to rotate in a given direction, SPIM can be operated continuously without auxiliary winding[1]. In a conventional starter, the mechanical switch should activated around predetermined speed to prevent damage of the capacitor caused by overheat : if the mechanical switch does not activated over the rated speed, charging and discharging cycle will repeated on capacitor after starting. Or, if the switch activated around rated speed under abnormal condition of switch, a chattering could be occurred on switch and it will cause damage on capacitor and mechanical switch too, because high voltage as much as double may be imposed on circuit by charging and discharging cycle of capacitor at every moment of chattering and arc may be occurred on switch contactor[2]. Arc can be occurred on switch surface, when a motor is operated at a humid or washy area too. To overcome these problems, various type of starter have been proposed. In [3], authors proposed an inverse GTO's set in parallel with a capacitor. The capacitor is shorted periodically and then the effective value of the running capacitor used for maximum torque generation become larger than its actual value. However, they do not explained the algorithm of an electronic switch control. In [4], a new method using a 32 bit DSP and an electronic switch was proposed by authors. to achieve maximum torque control for any speed. However, this method do not compatible with a conventional SPIM due to its higher price expenditure caused by applying a DSP unit. So, in this paper, authors proposed a new simple electronic starter consisted an one-chip microcontroller and two switching elements, TRIAC under the name of One-Chip Micro Starter (OMS). The gate signals of TRIAC are generated by comparing the detected winding currents with predetermined values on the microcontroller. With this new starter, the electromagnetic torque of SPIM is controlled by regulating the magnitude and phase angle of winding currents sequentially during motor starting. In comparison with a conventional capacitor type starter, higher efficiency and soft-start are achieved.

2. THE PROPOSED ONE-CHIP MICRO STARTER

In SPIM, stator has two single phase windings, i. e. a *main winding* and an *auxiliary winding*. When SPIM is supplied from single phase AC source, magnetic flux sinusoidally distributed in space under stationary reference frame is produced on stator. This flux does not rotate itself in stationary reference frame and electromagnetic torque does not imposed on rotor because the rotor flux induced from stator flux by transformational standstill is in-phase with that of stator flux. Therefore, an additional winding is needed to generate another flux kept in different spatial displacement from main flux. It is desired to keep ideally a 90° displacement in space. As a result, a rotating flux is generated from these two fluxes and then electric motive force is impressed on rotor for motor starting. However, there is no need to energize the auxiliary winding after rotor start to rotate on SPIM adapted a capacitor type starter. In a theory, the electromagnetic torque is continuously builded up on SPIM when physical angle of rotor is displaced from that of stator. In order to build up the rotating flux on stator just for the starting period, a centrifugal switch and a capacitor are connected in series with auxiliary winding. Power will be interrupted with a switch when rotor speed reached a certain value predetermined by a manufacture. Fig. 1 show the electrical connection of conventional capacitor-type SPIM.

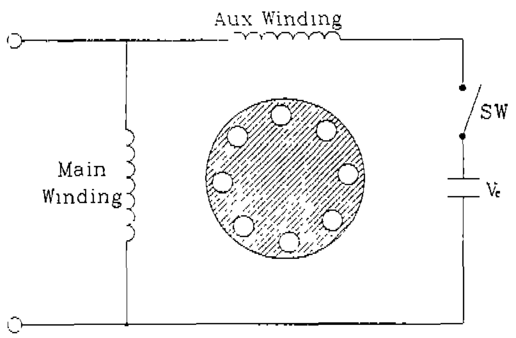

Fig 1 Capacitor type SPIM

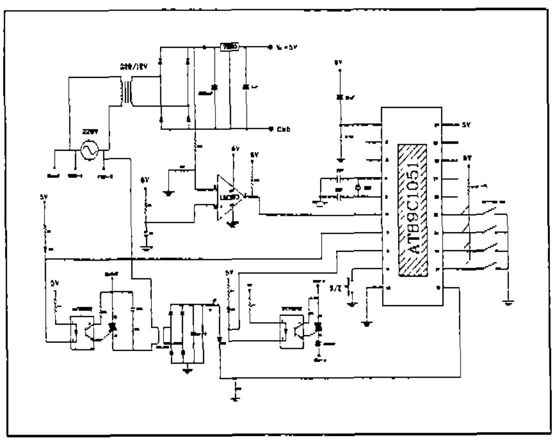

Fig 2 The proposed one-chip micro starter

In this paper, w proposed a new starter based on one-chip microcontroller name as one-chip micro starter(OMS). Fig. 2 show the electrical circuit of proposed OMS of a SPIM. OMS is consisted with a one-chip microcontroller type of AT89C1051, a power supply, a synchronizing unit, a start time selector, a clock generator and two gate drives for TRIACs installed on main and auxiliary windings. The OMS is programed to generate a modulated gate pulses in order to chop the input voltages on both windings sequentially according to programed sequence of starting. The current angle of the auxiliary winding is displaced from that of main winding during the starting. Magnitude of currents of both windings are also regulated to achieve the soft starting. The motor size is greatly reduced in length by replacing the capacitor type stater with an proposed starter, OMS shown on Fig. 3.

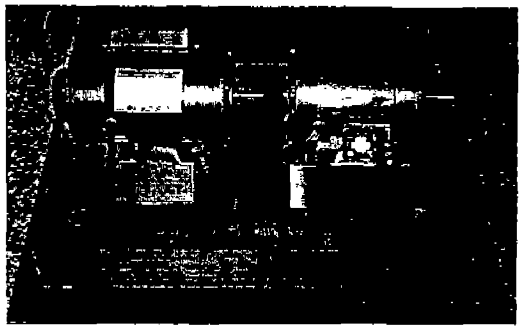

Fig 3. Layout photographs of the SPIM

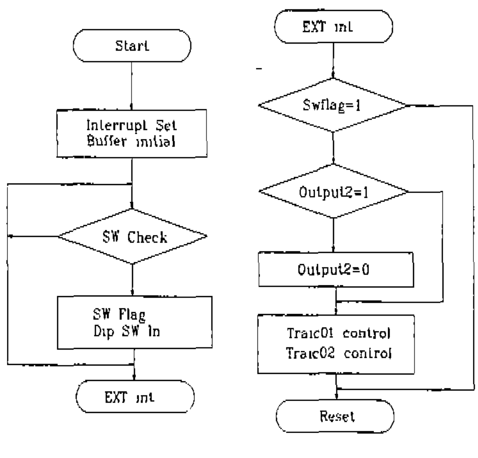

Fig 4 Flowchart of control system

From Fig 2, motor currents are detected with an small current transformer and then feedback to microcontroller, AT89C1051. In microcontroller, magnitude of feedback signals are compared with predetermined references and the errors are supplied to protection circuits to prevent over current due to malfunction of proposed stater.

The phase angle of currents between both windings is always regulated to keep a certain spatial displacement by regulating the chopping angles of supplied power differently with TRIACs. Each chopping angles are calculated in the microcontroller at same time based on the signals from the synchronizing unit. Under the controlling of OMS, the currents of main and auxiliary winding are limited at lower than normal starting currents by maintaining the high chopping angles at first interval and then chopping angles are reduced in next interval according to given time table. The chopping angles are reduced to zero in step as speed approach to the rated speed. When rotor speed reached at rated speed or normal speed, the chopping angle of TRIAC installed at auxiliary winding side increased as speed up over 70% of rated speed again and then power is interrupted at end of starting as final step to prevent the unnecessary energy consumption. The starting time can be adjusted freely and overload can be protected by programing. A flowchart of control algorithm is shown on Fig. 4. Program can be easily changed with a EEPROM writer according to user's application.

4. EXPERIMENTAL RESULTS

Voltages and currents of both windings and torque and speed were measured with a dynamometer type of FR 5ME API. And the starting currents and phase angle of currents were recorded with a test equipment type of LeCroy 9414A DSO. Control algorithm was programmed by an assembler. Table 1 show the motor parameters.

Table 1 The parameter of motor

Rating of Single Phase Squirrel Case Motor (Capacitor Type Starter)			
Power	200 W	Voltage	220 V
Current	3 A	Speed	1741 rpm
Freq.	60 Hz	Poles	4 P
Insulating grading	E	Rated torque	1.16 Nm
Capacitor	200 μF	Maximum torque	3 Nm
Starting current	14 A	Efficiency	53 %

The starting characteristics of the proposed system under rated load is shown in Fig. 5. The starting currents of both windings and gate signals of switching elements are shown on Ch1, Ch2, Ch3 and Ch4 respectively. In order to reduce the starting currents, currents of main and auxiliary windings were controlled individually within at each interval during speed up. Fig. 6 and 7 show starting characteristics of SPIM under rated load taken with the conventional and the proposed starter type SPIM. As shown on the experimental results of Fig. 5 to 7, the starting currents of main and auxiliary windings are 14A and 7.8A in case of conventional capacitor type SPIM, whereas the starting currents of both windings are 12A, 7.5A, respectively, in case of SPIM armed with the proposed starter.

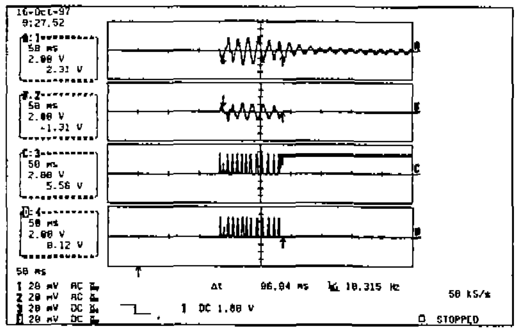

Fig. 5 Stating currents and gate pulse signals on main and auxiliary winding side under no load with the OMS

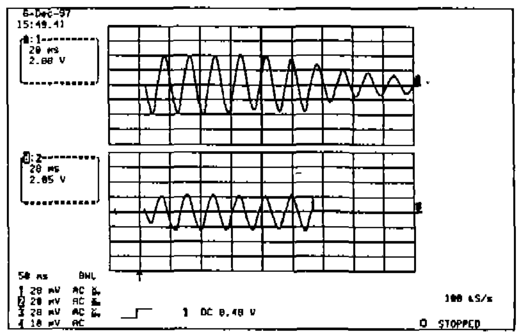

Fig. 6 Starting currents of main and auxiliary windings under full load (Capacitor type SPIM)

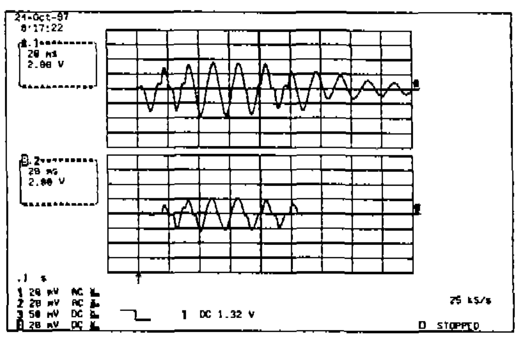

Fig. 7 Starting currents of main and auxiliary windings under full load (One-Chip Micro Starter type SPIM)

Locked rotor test of the proposed type SPIM is shown on fig. 8 : Chl, Ch2, Ch3 and Ch4 are recorded values of main winding current, auxiliary winding current.

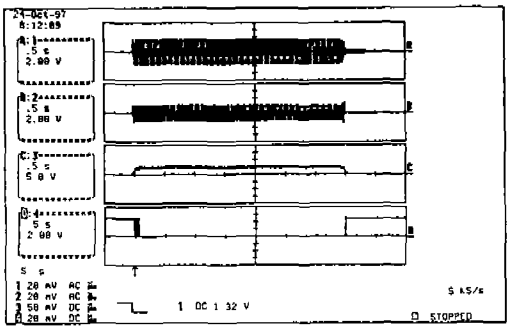

Fig. 8 Locked rotor test of the OMS type SPIM

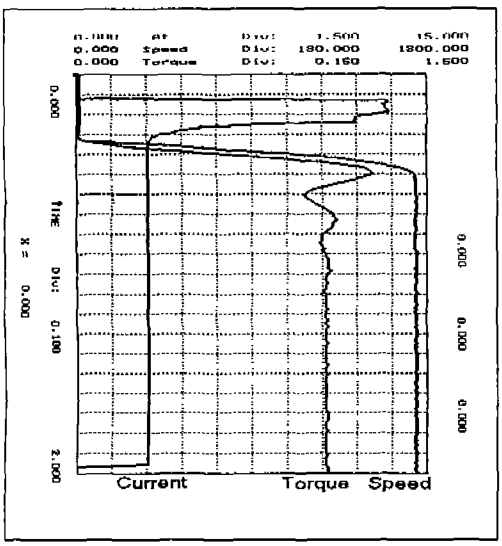

Fig. 9 Starting characteristic curves of the capacitor type SPIM

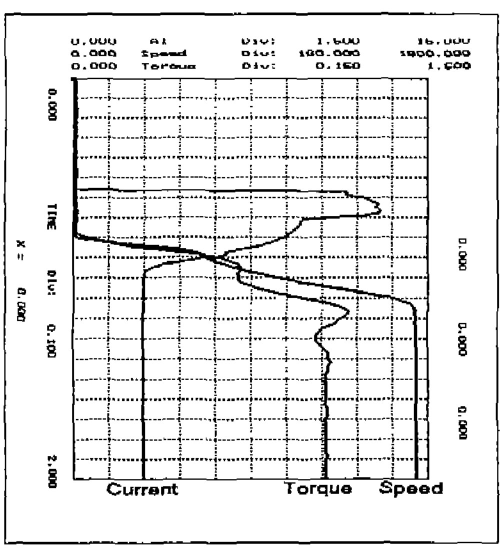

Fig. 10 Starting characteristic curves of the OMS type SPIM

The starting characteristic curves, rotor speed, torque and starting current of main winding taken on both type SPIM under speed-up test to rated speed, 1741rpm are shown on Fig. 9 and 10. From both figures, the maximum torques of both type motor are 1.28Nm and 1.1Nm and the starting currents are 14A· and 12A, respectively.

4. CONCLUSIONS

In this paper, we proposed a new type starter of SPIM named as OMS consisted of a microcontroller and two switching elements, etc. Under the controling with the proposed starter, both currents of main and auxiliary windings of SPIM were regulated respectively by changing the phase angles of winding currents sequentially through TRIACs. With this algorithm, a soft start is achieved and the starting currents of both windings were limited at lower values in comparition with those of the conventional capacitor type SPIM. The speed-up time of SPIM is changable by reprograming on microcontroller. By replacing the mechanical switch and the capacitor with the OMS, the length of SPIM is reduced and higher reliability is achieved by eliminating the possibility of damage may caused on the switch and the capacitor under abnormal condition.

As a further study, it is desirable to extend the proposed system for maximum torque operation of SPIM at any speed.

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