Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 5 (2): 249-252, 2005
ISSN 1812-5654

Development of Single Phase Induction Motor Adjustable Speed Control Using M68HC11E-9 Microcontroller

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Abstract: This study investigates the performance of single-phase induction motor using microcontroller M68HC11E-9. The microcontroller senses the speed's feedback signal and consequently provides the pulse width variation signal that sets the gate voltage of the chopper, which in turn provides the required voltage for the desired speed. A Buck chopper has been used to control the input voltage of a fully controlled single phase isolated gate bipolar transistor (IGBT) bridge inverter. PWM technique has been employed in this inverter to supply the motor with ac voltage. The proposed drive system is simulated using Matlab/Simulink. Its results were compared with the hardware experimental results. The simulation and laboratory results proved that the drive system can be used for the speed control of a single-phase induction motor with wide speed range.

Key words: Single phase induction motor, microcontroller M68HC11E-9

INTRODUCTION

The use of microcontrollers in industrial and domestic electrical devices has become very common over the past decade. Motorola MC68HC11E-9 microcontroller has been chosen for this implementation because it is easy to development, instantly response, high performance, high speed and low-power chip with multiplexed capable of running at up to 2 MHZ. Traditionally, variable speed operation of a single- phase induction motor is suffer from large harmonic injection into the supply and low power factor, in addition to the limited speed.

Correa *et al.*[1] have demonstrated that the operation of start capacitor (SC) and split-phase capacitor (SPC) motors in the two-phase mode provides a significant improvement of the motor performance. In the single-phase mode it is required to use a split-phase capacitor (SPC) motor. It is important to remark that the capacitor is designed for the nominal speed and consequently the performance is not optimized for variable-speed operation. The use of a start capacitor (SC) motor is not recommended for adjustable-speed motor drive systems due to the presence of the centrifugal switch that changes the motor characteristics during the operation. In two-phase mode, as stated before, the single-phase motor is treated as a two-phase motor. The SPC motor has main and auxiliary windings that are used during the entire motor operation. This type of motor can be chosen as the standard choice for designing single-phase adjustable-speed motor drive systems either in single-phase or in the two-phase modes. It must be noted that it is also possible to use an SC motor for implementing single-phase adjustable-speed motor drive systems. Moreover, it is important to evaluate the use of SC motors in the two-phase mode because its use is more widespread and it is cheaper than a SPC motor of the same power. The advantages with respect to the standard single-phase mode are related with reduction of the start-up current and elimination of the torque pulsations. Besides, that is possible to increase up to the double the value of the average motor torque, in the case of the SC motor.

Jiangmin Yao[2] has implemented the PIC17C756 microcontroller in a single phase induction motor adjustable speed drive control with hardware setup and software program in C code. The main feature used in this microcontroller was its peripherals to realize pulse width modulation. in the single phase motor control. Furthermore, one chip and re-programmable ROM replaces the conventional complicated circuit solution. He concluded that this brought low cost, small size and flexibility to change the control algorithm without changes in hardware.

The problem for this microcontroller was that it had no dead band register and only had a three PWM output.

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Therefore, additional logic analog circuits were added to generate their complement signals and to generate dead time in order to avoid the overlapping of turn on for both upper and lower switches.

This work has been implemented using MH68HC11E-9 microcontroller. The microcontroller has been programmed to vary the pulse width variation that controls the duty cycle of the dc chopper. The inverter receives the dc signal from the chopper and converted to ac power to feed the motor.

Miroslav Chomat and Thomas[3], considered a system connected to a single-phase supply, the output portion of the converter consisting of two IGBT switches, generates a pulse width modulated (PWM) output supplying one or both stator windings of a single-phase machine. The variable speed operation is characterized by the fact that the both stator windings are fed from the inverter. The phase shift between the currents in the main and auxiliary windings of the machine is maintained by means of an ac capacitor connected in series with the auxiliary winding. The generation of the triggering pulses for the solid-state switches and the state of the output relay are controlled by a single-chip microcontroller.

The system could be technically possible and economical, but the operation of the drive is not optimal throughout the entire speed range and the significant torque ripple may arise in some operating points.

MATERIALS AND METHODS

The power supply 110 Vac of this circuit was fed from a variable transformer. The full bridge rectifier has been used to convert the ac supply to a dc voltage of an rms value of 155.56 Vdc. The output of the rectifier is the input to the dc chopper which controls the voltage level. The M68HC11E-9 microcontroller has been programmed to vary the PWM that controls the duty cycle of the dc chopper. The last component of this set up is the inverter, which receives the dc signal from the chopper and converts it to ac power to feed the motor under control. Figure 1 shows the hardware circuit implemented for this work.

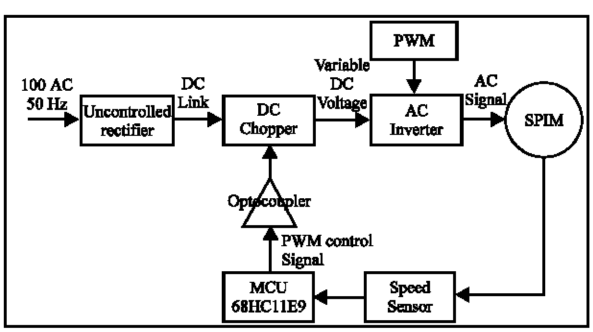

Fig. 1: Block diagram of the circuit

SIMULATION OF THE SYSTEM

Matlab/Simulink software has been used as a tool to simulate, the circuit which consist of a single-phase rectifier, buck regulator chopper and inverter circuit.

In the steady state the motor can be simulated as R-L lumped circuit without loss of accuracy. The resistance R reflects the losses in the stator and rotor cores and the inductance for the winding.

An experiment is carried out to measure R and L and the measured values were used in the simulation on Matlab/Simulink. Figure 2 shows the simulation result for the complete circuit and waveforms at different points in the system.

EXPERIMENTAL SETUP

In this study, the power supply Vac of this circuit was fed via a variable transformer. The full bridge rectifier has been used to convert the ac supply to a dc voltage Vdc. The output of the rectifier is the input to the dc chopper which controls the voltage level. The microcontroller-based adjustable closed loop control system hardware has been implemented and tested in the laboratory. The M68HC11E-9 microcontroller has been programmed to vary the PWM that controls the duty cycle of the dc chopper. The last component of this set up is the inverter which receives the dc signal from the chopper and converts it to ac power to feed the motor under control. Figure 2 shows the hardware circuit implemented for this work.

Dc Chopper performance: Controlling the voltage level of the dc chopper can be obtained by changing the PWM signal through the microcontroller. Figure 3 shows the block diagram for the dc chopper. Via the user interface command, the operator can change the variable command through the keypad. The operator can also select either manual or auto mode.

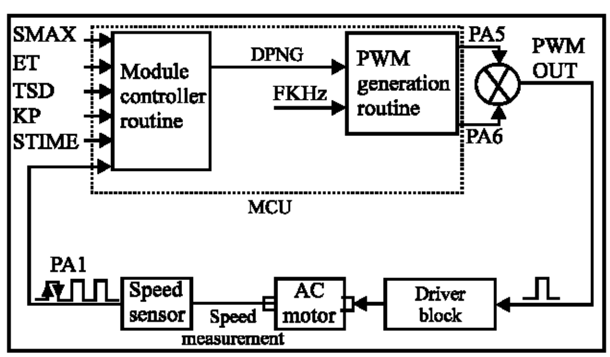

Fig. 2: Block diagram representation of the software routine and speed measurement

The chopper circuit implemented in this work is a buck regulator (step-down chopper). High frequency of variable width is generated by the microcontroller and the XOR gate. Variable width pulse is applied to the gate of IGBT through an Optocoupler, the Optocoupler used to isolate between high voltage of the chopper and low voltage of the microcontroller. A capacitor and an inductor are connected to form a smoothing filter[4].

The M68HC11 Family offers a selection of variable pulse width options to support a variety of applications. Up to six PWM inputs were selected to create continuous waveforms with programmable rates and software selectable duty cycles from 0 to 100%.

The pulse width variation module receives the duty percentage of duty cycle calculated by speed control module (SCM) and frequency in kHz. It adjusts the pulse width accordingly. The pulse width variation module is realized by software codes programmed in the microcontroller. The pulse width modulated signal outputted by this module is fed to the gate of the IGBT chopper.

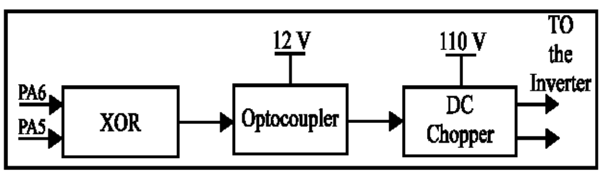

Fig. 3: Block diagram of dc chopper

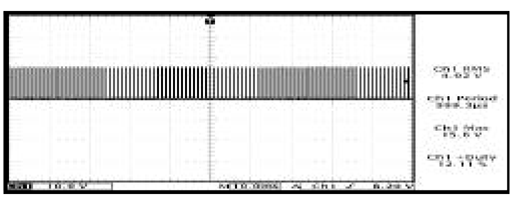

Fig. 4: Dc chopper output at 12% duty cycle

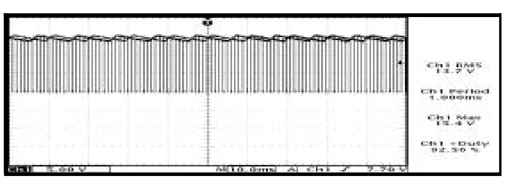

Fig. 5: Dc chopper output at 92% duty cycle

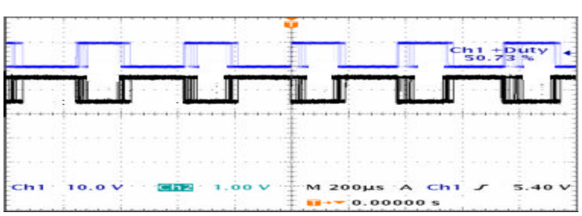

Fig. 6: Firing signal for the bridge inverter

Count is computed from the duty percentage which is the output of the SCM.

At 12% and 92% of the duty cycle the V_{out} of dc chopper is recorded and is shown in Fig. 4 and 5. The duty cycle can be changed automatically by the microcontroller and can be set manually by the user to get the desired speed.

It is clear from Fig. 5 and 6 that the output of the chopper contains harmonics or ripples. The ripples can be reduced by changing the value of the capacitor filter C.

Inverter: In this study four switches have been used to convert the dc to ac voltage. The frequency is fixed and variable output voltage is obtained by varying the pulse width of the chopper switch.

It can be seen from Fig. 6, when IGBT Q_1 and Q_3 are positive voltage signal, Q_2 and Q_4 are OFF by the negative voltage signal and vice versa. These waveforms show that the four IGBT's of Q_1,Q_2,Q_3 and Q_4 will not be ON at the same instant of time.

MOTOR SPEED CONTROL RESULTS

The adjustable speed drive during experiment performed satisfactory and the results are shown in Figure 9-12. Speed Sensing is realized using shaft encoded digital tachometer. It measures the immediate speed (MSD) and feeds it to the speed control module (SCM) block within the microcontroller.

The speed measurements were taken by the microcontroller in hexadecimal units. These data were stored in the microcontroller memory. In order to get the actual Fig. of the curve representing the speed response, these data were plotted on the Excel software, which changes the hexadecimal values to decimal values.

Under no-load the control of the motor speed was smooth and the response of the drive system was as expected. During starting there was overshoot up to 1

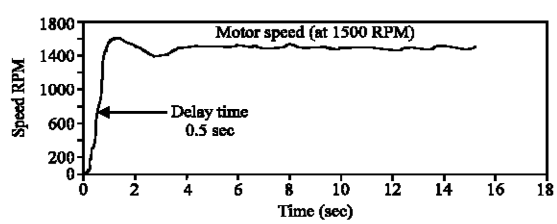

Fig. 7: Motor speed response under no-load

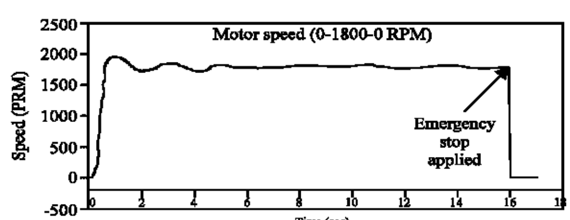

Fig. 8: System's sudden stop command response

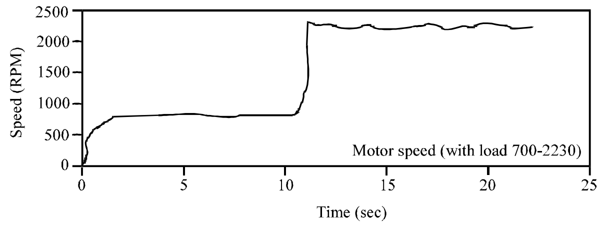

Fig. 9: Motor speed under load condition

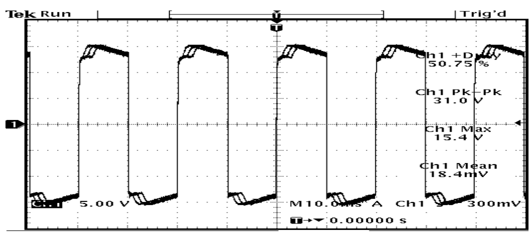

Fig. 10: Load voltage during experimental

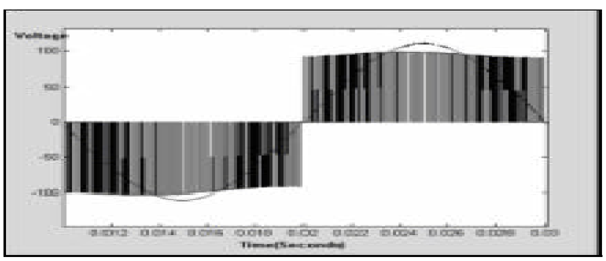

Fig. 11: Load voltage during simulation

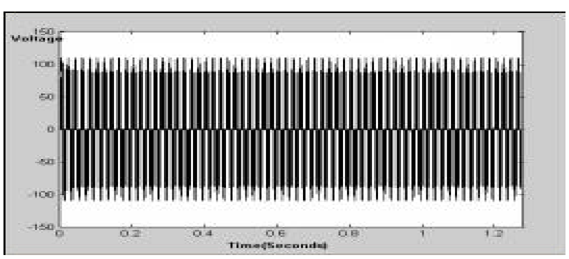

Fig. 12: Detail of figure 11 waveform

second then there was less than 7% oscillation, where the oscillation depends on the system parameters. Then the system reached its steady state speed after 4 seconds as shown on Fig. 7.

Under sudden stop command that initiated manually by the operator using the keypad, the speed of the motor has gone to zero in a very short time. This proves that the drive system's response is quit fast as shown in Fig. 8.

Under load changes and the speed command was changed according to a pre-defined value 700 to 2230 rpm, the drive system performed as shown on Fig. 9.

Comparison between simulation and experimental results: With reference to the results of the drive system for the single-phase induction motor which are shown in Fig. 11 and the Matlab simulation results which are shown in Fig. 12 and considering that the motor at the simulation circuit represented at steady state operation, a good agreement between experimental and simulation results is observed with respect to the voltage value, frequency and the waveform shape. The value of the voltages at the load terminal in both cases was 110 V.

It is shown in Fig. 11 that the load signal is a modulation between the pulse width chopping signal and 50 Hz sinusoidal signal. The signal in Fig. 10, has the same nature but since it has been taken by oscilloscope, the chopping is not visible.

CONCLUSION

The experiments results obtained using the proposed drive system proved the simplicity of the application of the M68HC11E-9 microcontroller kit in the speed control of the single phase induction motor. The simulation results confirmed that the possibility of obtaining of the same results with a representative Simulink block

In general, the AC-DC-AC conversion was successful, on the other side, some overshoot were found due to suspected causes such as the control algorithm used in the microcontroller and harmonic content at the inverter output. However, good results confirming the initial intention for design.

This concludes that the single-phase induction motor can be successfully driven from a variable voltage amplitude control and the motor's speed can be easily adjusted using the proposed drive system. Single-phase AC induction motor controls offer new, low-cost solutions for light commercial and consumer applications.

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