Three-Phase PWM Converter Control of Induction Motor with H-Bridge Cascaded Converter Employing Fuzzy Logic Controller

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ABSTRACT

This study introduces a novel control approach for Power Factor Correction (PFC) in a three-phase PWM AC chopper utilizing the HBCC technique to drive a three-phase squirrel cage Induction Motor (IM) with soft starting and speed control modes. The power circuitry of this strategy stands out for its simplicity, reliability, high efficiency, and cost-effectiveness due to its minimized count of power semiconductor switches. The three-phase PWM AC chopper is constructed with four IGBTs. A new closed-loop control methodology is developed, utilizing only two gate pulses to manage the four IGBTs. The proposed control strategy centers around three key objectives: achieving smooth start-up, regulating speed, and enhancing input PFC. These objectives are met by adjusting the Root Mean Square (RMS) value of the input voltage supplied to the IM terminals. The effectiveness of the proposed control approach is thoroughly examined, analyzed, and validated through simulation experiments conducted under various test conditions.

Keyword : *HBCC, PWM, Converters.*

I. Introduction

AC voltage regulators, also called as AC voltage controllers, are used in various applications that require a regulated AC voltage. Lighting control using dimmer circuits, domestic and industrial heating, speed control and soft starters for the induction motors are examples of such applications [1-2]. Different topologies with different control methods of these regulators in single phase applications and also in three phase applications are presented. The purpose of AC voltage controller is to vary the root mean square (RMS) value of its output that applied to the load circuit. There are three control methods are offered to achieve this objective; ON/OFF method, phase angle (PA) method and pulse width modulation (PWM) method. All three control methods can be implemented in both single-phase and three-phase applications.

In ON/OFF control method, thyristors (i.e. Silicon Controlled Rectifiers) are used as power switches to connect/disconnect the circuit of the load to/from the AC voltage source continuously. Connection is occurred for a few integral cycles and disconnection for the next few cycles of the feeding voltage. Adjusting the number of conducted and interrupted cycle’s controls the RMS magnitude of the output voltage. In ON/OFF method, the generated harmonics by the switching actions are reduced as silicon-controlled .rectifiers (SCRs) are switched ON at zero voltage and switched OFF at zero current. However, undesirable sub-harmonic components may be produced [3].

II. PROPOSED TOPOLOGY

The proposed control strategy has three main control objectives: soft starting, speed control, and input power factor correction (PFC). This strategy is depending on the control of the applied voltage across IM terminals using AC chopper [4]. Fig. 1 illustrates the schematic diagram of the proposed control strategy. It has two control loops. The inner control loop uses HBCC to force the chopper actual current signals to track their command current signals to achieve input PFC, whereas the outer control loop determines the magnitude of the reference currents either from starting mode or speed control mode. As a result, the inner loop controls the phase and the outer loop controls the magnitude of the chopper currents. In the first, the soft starting mode is working, and by giving a switching pulse to the selector switch, the speed control mode is activated and the soft starting mode is turned off.

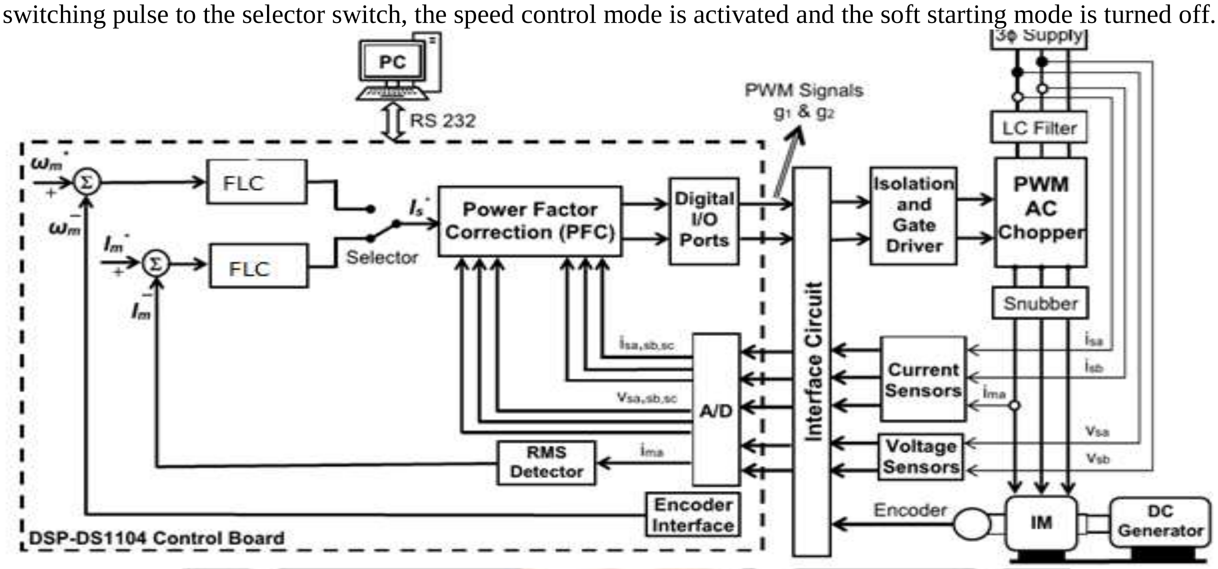

Fig.1 Control Scheme of Proposed topology

III. FUZZY LOGIC CONTROLLER

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection [5].

To understand why use of fuzzy logic has grown, you must first understand what is meant by fuzzy logic.

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalve logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with un sharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of fl. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalve logical systems [6].

In fuzzy Logic Toolbox software, fuzzy logic should be interpreted as FL, that is, fuzzy logic in its wide sense. The basic ideas underlying FL are explained very clearly and insightfully in Foundations of Fuzzy Logic. What might be added is that the basic concept underlying FL is that of a linguistic variable, that is, a variable whose values are words rather than numbers. In effect, much of FL may be viewed as a methodology for computing with words rather than numbers. Although words are inherently less precise than numbers, their use is closer to human intuition. Furthermore, computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution.

Another basic concept in FL, which plays a central role in most of its applications, is that of a fuzzy if-then rule or, simply, fuzzy rule. Although rule-based systems have a long history of use in Artificial Intelligence (AI), what is missing in such systems is a mechanism for dealing with fuzzy consequents and fuzzy antecedents. In fuzzy logic, this mechanism is provided by the calculus of fuzzy rules. The calculus of fuzzy rules serves as a basis for what might be called the Fuzzy Dependency and Command Language (FDCL). Although FDCL is not used explicitly in the toolbox, it is effectively one of its principal constituents. In most of the applications of fuzzy logic, a fuzzy logic solution is, in reality, a translation of a human solution into FDCL [7].

The FIS Editor handles the high level issues for the system: How many input and output variables? What are their names? The Fuzzy Logic Toolbox doesn't limit the number of inputs. However, the number of inputs may be limited by the available memory of your machine. If the number of inputs is too large, or the number of membership functions is too big, then it may also be difficult to analyze the FIS using the other GUI tools.

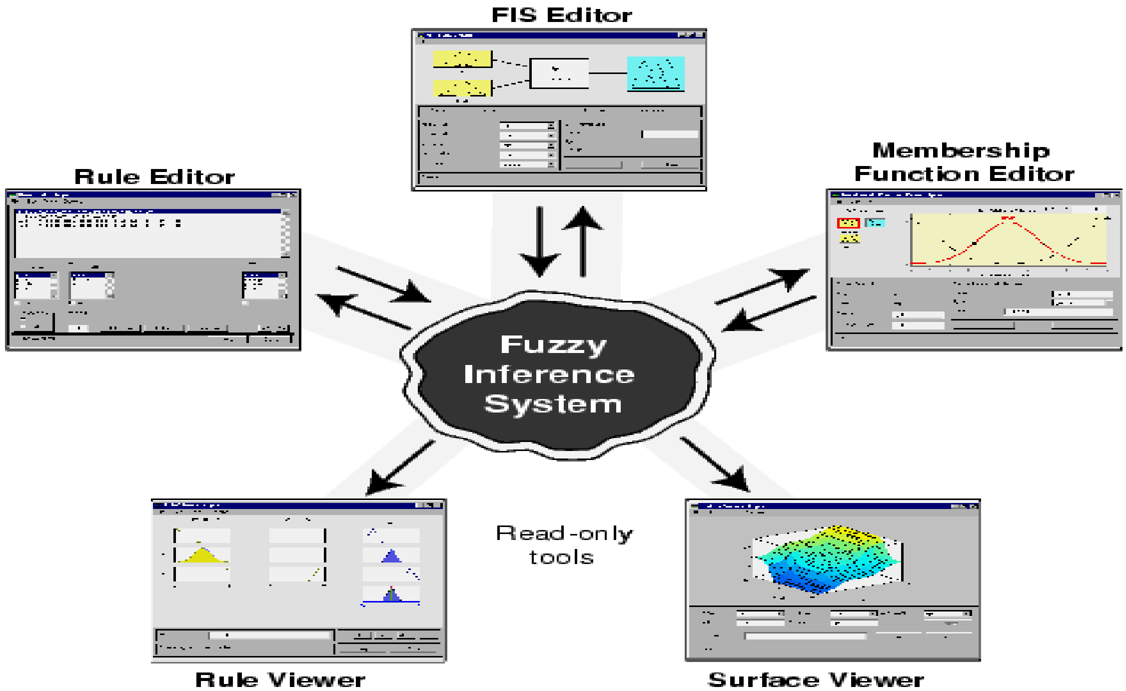

Fig.2 Primary GUI Tools of the Fuzzy Logic Toolbox

The Membership Function Editor is used to define the shapes of all the membership functions associated with each variable. The Rule Editor is for editing the list of rules that defines the behavior of the system.

IV. HYSTERIS BAND CURRENT CONTROL

The current control strategy plays an important role in the development of shunt active filter. The hysteresis-band current control method (Anshuman shukla et al 2007) is popularly used because of its simplicity in implementation. Hysteresis current controller derives the switching signals of the inverter power switches in a manner that reduces the current error. The switches are controlled asynchronously to ramp the current through the inductor up and down so that it follows the reference [8].

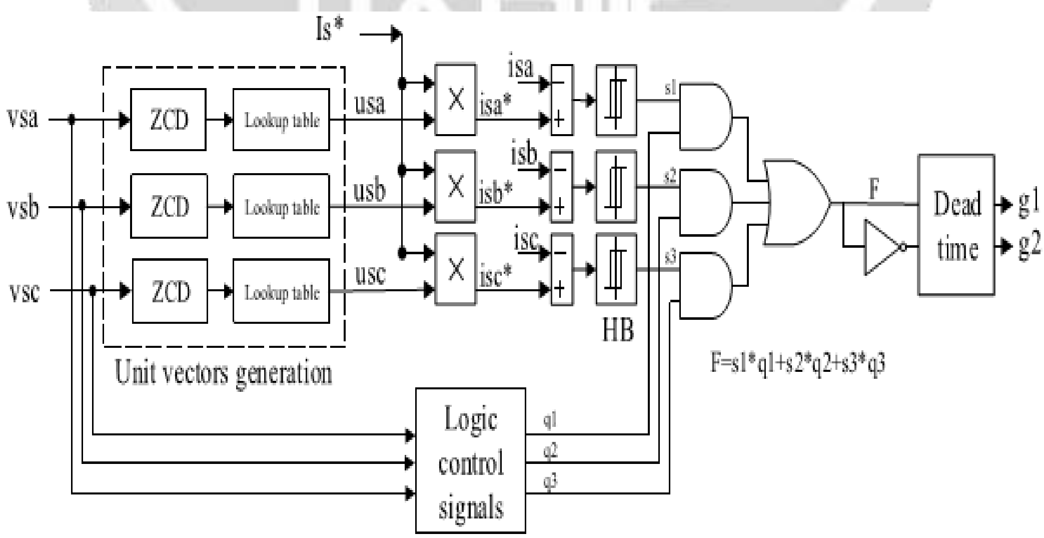

Fig.3 Proposed HBCC technique

When the current through the inductor exceeds the upper hysteresis limit, a negative voltage is applied by the inverter to the inductor. This causes the current through the inductor to decrease. Once the current reaches the lower hysteresis limit, a positive voltage is applied by the inverter through the inductor and this causes the current to increase and the cycle repeats. The current controllers of the three phases are designed to operate independently. They determine the switching signals to the respective phase of the inverter This method has the drawbacks of variable switching frequency, heavy interference between the phases in case of three phase active filter with isolated neutral and irregularity of the modulation pulse position (Simone et al 2000). These drawbacks result in high current ripples, acoustic noise and difficulty in designing input filter. In this chapter, a constant frequency hysteresis current controller is proposed for shunt active filter applications. The details of the proposed current control strategy are presented in the next section [9-10].

V. RESULTS AND DISCUSSION

The proposed AC chopper is simulated in the MATLAB/ Simulink environment and a prototype model is implemented. The simulation was used to confirm the proposed control strategy theoretically. While the experimental prototype has been constructed to confirm the proposed strategy experimentally. Four test cases are examined. Corresponding simulation and experimental results are obtained and compared.

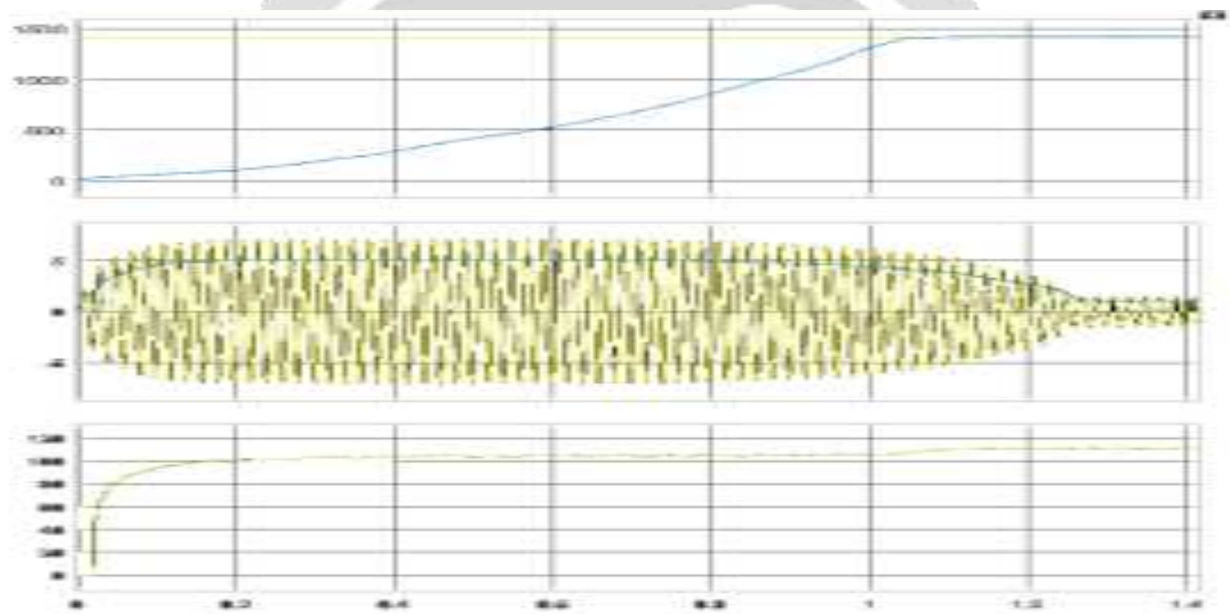

Fig.4.Starting of the motor with Proposed PWM AC Chopper

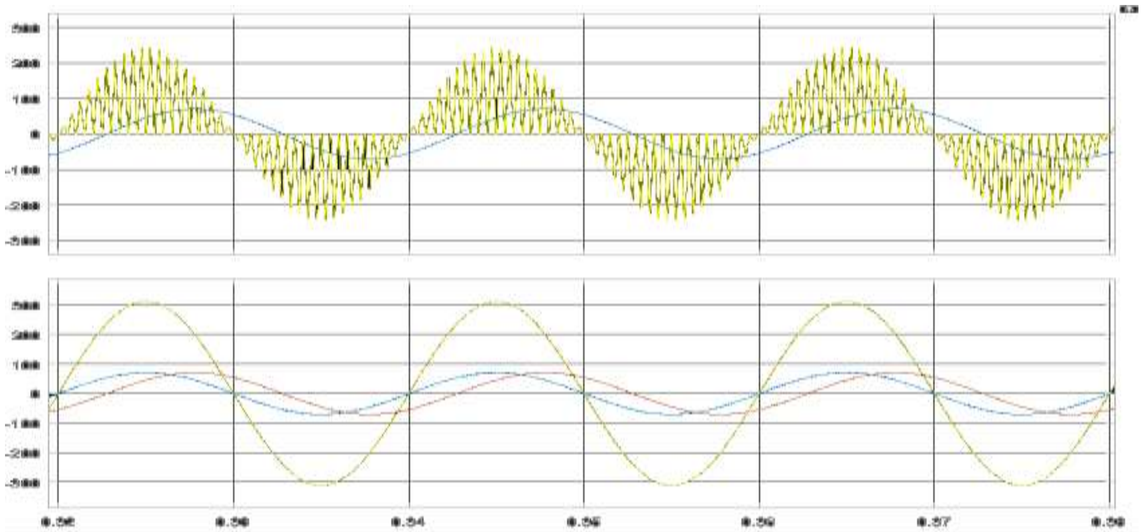

Fig.5. PFC of the drive system during start up of the IM

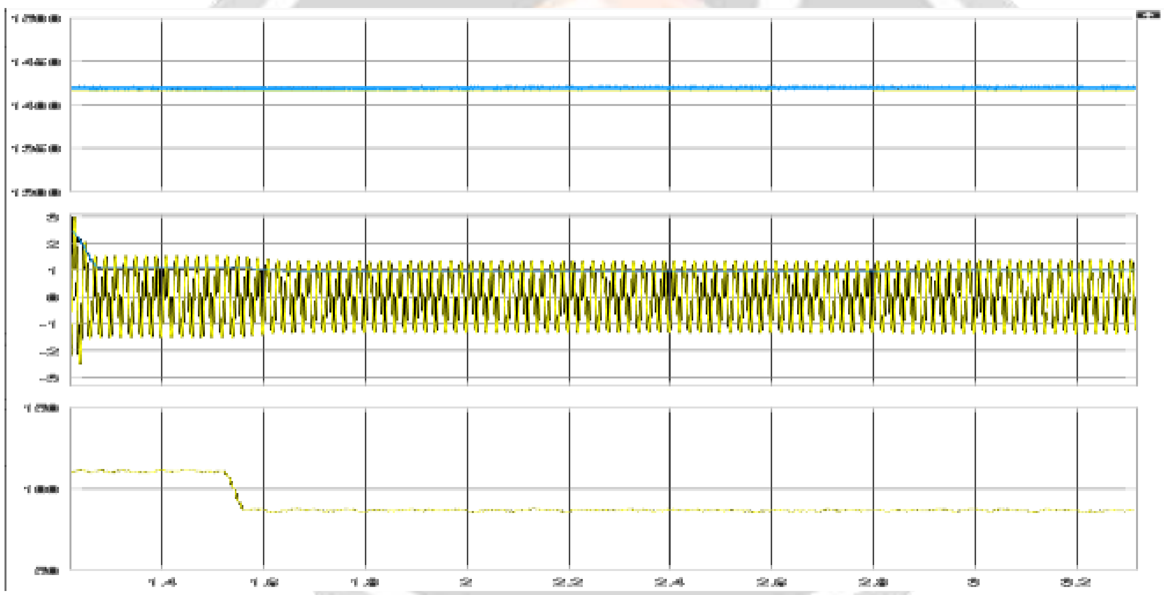

Fig.6. Variation of the motor speed, the current and phase voltage at activation of the speed controller

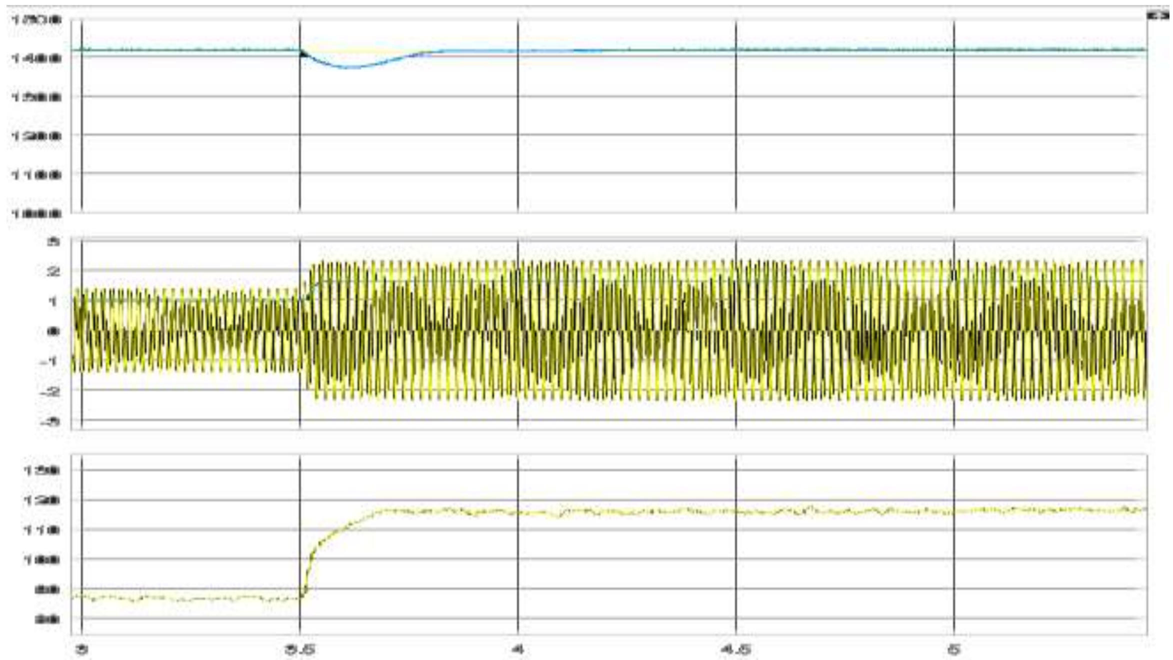

Fig.7. Variation of the motor Speed, Current and Phase Voltage at step change in the load torque

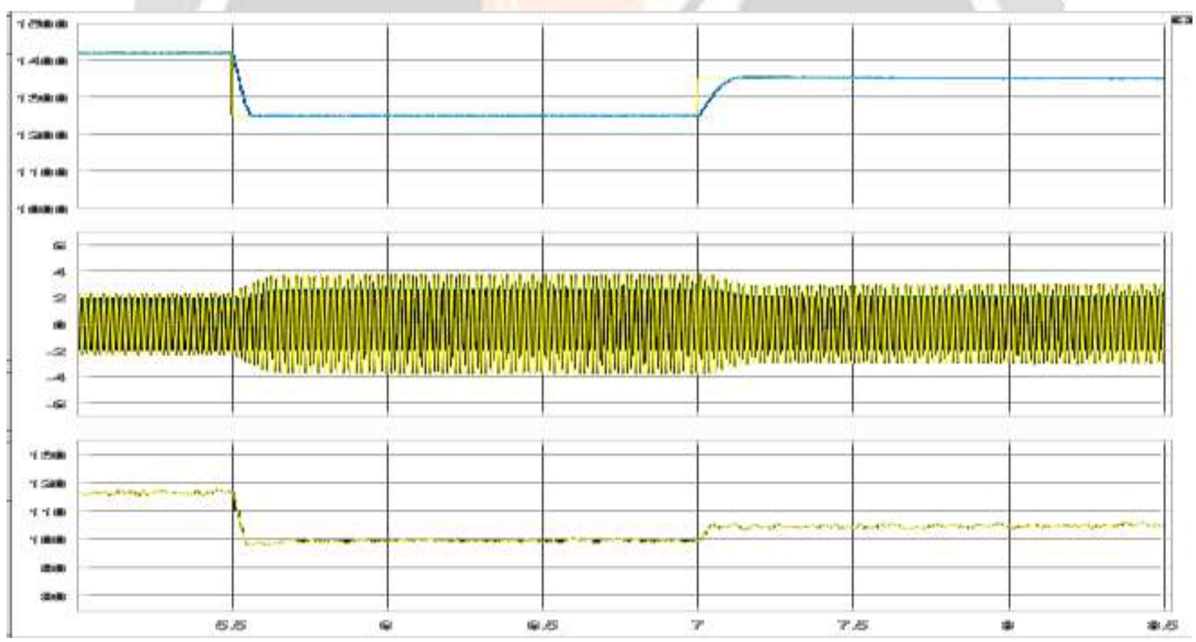

Fig.8 Variation of the motor Speed, Current and Phase Voltage at step change in the reference speed

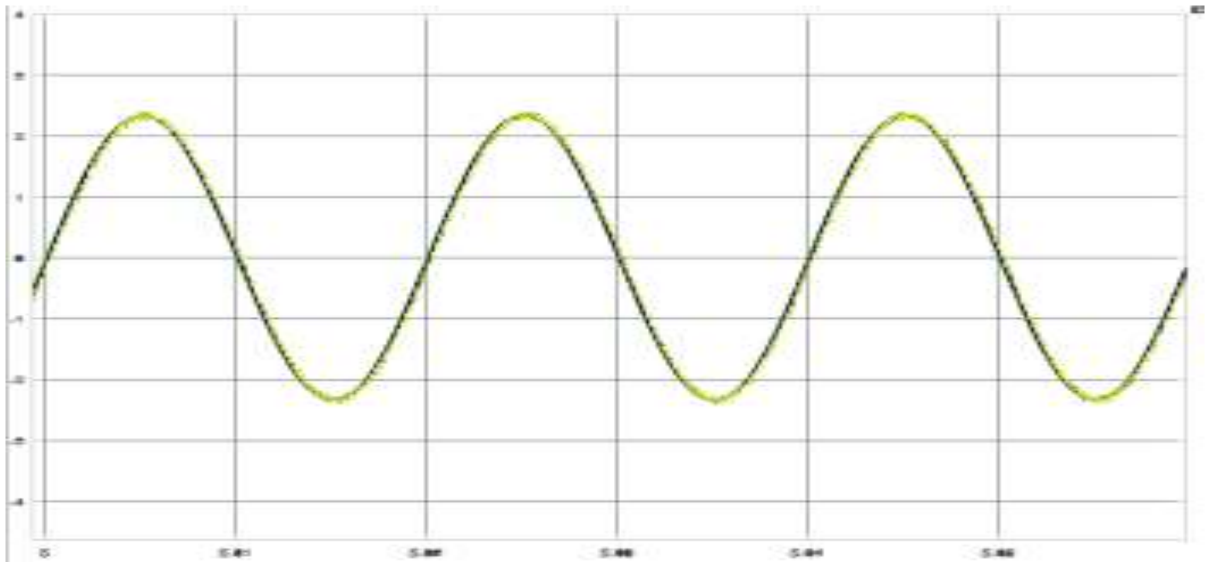

Fig.9.Reference and measured currents supply

CONCLUSION

A new control strategy of three-phase squirrel cage IM fed from PWM AC chopper has been simulated and laboratory implemented using d SPACE (DS1104) control board. The main control objective is to correct the input PF with different operating conditions of the induction motor drive system. Input PFC is achieved by forcing the actual currents of the chopper to track their reference currents that are in phase with the input voltages using HBCC technique. The proposed control strategy uses only two PWM signals for driving the active switches of the AC chopper. The proposed system is simple, reliable and low cost as it has only four IGBT switches. Operation principle and mathematical analysis of the proposed system are introduced. The system was simulated using MATLAB/SIMULINK and a laboratory system was implemented. The effectiveness of the proposed control strategy has been tested at starting, reference speed change and load torque variation. The obtained results from the experimental and computer simulation works verify the validity of the proposed control strategy during all testing conditions. Performance of the system without PFC is roughly compared in accordance with concerning the proposed PFC technique during the three test cases. Comparative results illustrate that the system with the proposed PFC technique has a corrected PF and hence a better performance.

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