IMPLEMENTATION OF FUZZY LOGIC SPEED CONTROLLED INDUCTION MOTOR USING PIC MICROCONTROLLER

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Abstract

The speed control of induction motor is more important in order to achieve maximum torque and efficiency. Induction motors have many applications in industries due to its low maintenance and robustness. The purpose of motor speed control is to keep the rotation of the motor at the present speed and to drive a system at the demand speed. In this project a speed control strategy for a single phase induction motor is proposed and implemented in order to obtain the dynamic performance of an induction motor drive using Fuzzy Logic Controller (FLC). A Fuzzy controller is proposed to generate the control rules and thus increases the
effectiveness of the controller. The proposed control rules were successfully implemented to a single phase induction motor fed from single phase inverter. Thus, Simulation result and Hardware implementation in real time has been presented to verify the performance of the proposed speed controller.

**Key Words:** Solar panel, dc–dc boost converter, MATLAB, LC filter, induction motor, Fuzzy logic controller.

## 1 Introduction

AC Induction motors are being applied now-a-days to a wider range of applications which is requiring for variable speed. Generally, variable speed drives for induction motor requires wide operating range of speed and fast torque response. This effects to more advanced control methods tin order to meet a real demand.

The speed of a single phase induction motor is controlled in order to achieve a dynamic performance of the induction motor drives. The induction motor is sturdy and reliable. Induction motors have many applications in the industry because they are simple, cheap, reliable, robust, and durable and they need little maintenance.

In recent years, by the rapid development of microprocessor and power semiconductor technology improved the controlling methods of induction motors. In order to achieve high performance and better controllability, the Fuzzy Logic Control (FLC) has been investigated.

A Fuzzy Logic Controller has been implemented and thus Fuzzy Logic is used to generate the control rules. In a Fuzzy Logic, a rule base is constructed to control the output variable. Logic deals with truth of statements can be derived from the truth values of other statements. The truth value statements may have depended on the particular kind of logic used. In this section, fuzzy logic is derived from the multi valued logic, which in its turn is derived from binary logic. Fuzzy logic is a type of multi valued logic. It deals with approximate reasoning rather than precise.

In this work, MATLAB 2015b software platform is used to implement the speed control of an induction motor using Fuzzy Logic Controller (FLC) and the performance is obtained. Fuzzy controller is an innovative technology that modifies the design of systems with
engineering expertise. Fuzzy logic use human knowledge to implement a system. It is mostly used in systems where there are no mathematical equations for handling system. Common sense, human thinking and judgments are fuzzy rules. It helps engineers to solve non linear control problems. It mathematically emulates human knowledge for intelligent control system and complex applications.

Figure 1 Block diagram of a proposed system.

A DC source is given to dc-dc boost converter. This dc-dc converter boosts up the voltage gradually, which is required to run an induction motor.

2 BOOST CONVERTER

The boost converter is the medium of power transmission to perform energy absorption and injection from solar panel to inverter. The process of energy absorption and injection in boost converter is performed by the combination of inductor, electronic switch, diode, and output capacitor. The process of energy absorption and injection will constitute a energy cycle.

Figure 2 Schematic diagram of boost converter
In other word, the total output voltage is controlled by the switching of on and off time duration. At constant switching frequency adjusting the on and off duration of the switch is called Pulse Width Modulation (PWM) switching. The duty cycle $k$ is defined as the ratio of the ON duration to the switching time period. The energy absorption and injection with the relative length of the switching period will operate the converter in two different modes known as the continuous conduction mode (CCM) and discontinuous conduction mode (DCM).

2.1 Boost Converter Analysis:

Under CCM mode, it is divided into two modes. Mode 1 begins when the switch SW is turned on at $t=0$ as shown in figure 2. The input current which rises flows through inductor L and switch SW. During this mode, energy is stored in the inductor L and load is supplied by capacitor current. Mode 2 begins when the switch is turned off at $t=Kt$. The current flowing through the switch would now flow through inductor L, diode D, output capacitor C, and load R as shown. The inductor current falls until the switch is turned on again in the next cycle. During this time, energy stored in the inductor L is transferred to the load together with the input voltage. Therefore, the output is greater than the input voltage and is expressed as,

$$V_{out} = \frac{1}{1-K} V_s$$

Where $V_{out}$ is the output voltage, $k$ is the duty cycle, $V_{in}$ is input voltage.

When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some amount of energy by generating a magnetic field. Polarity of the left side of the inductor is positive.

When the switch is opened, current will be reduced as the impedance is higher. The magnetic field which is previously created will be destroyed to maintain the current flow towards the load. Thus the polarity will be reversed (means left side of inductor be negative now). As a result two sources will be in series causes a higher voltage to charge the capacitor through the diode D.

FILTER
Need for filter
Filter plays an essential role in the inverter driven loads. It is mainly used for two reasons which are listed below:

1. To convert the inverter output (i.e., square wave) into a pure sinusoidal wave.
2. To eliminate higher order harmonics.

**Elimination of higher order harmonics**

Harmonics are classified into two types. They are higher order harmonics and lower order harmonics. To eliminate the higher order harmonics, we use a filter where the lower order harmonics are eliminated using SPWM technique.

**LC filter**

In this project, a LC-filter and this filter is a second order filter and it has better filtering ability than that of L-filter. This simple configuration is easy to design and it works mostly without any problems. The basic block diagram of a LC-filter is shown below.

![Figure 3 Basic block diagram of LC filter](image)

### 3 SINGLE PHASE INVERTER

The full bridge single phase inverter consists of the DC voltage source, switching elements G1, G2, G3, G4 and the load. The switching element available now-a-days, such as bipolar junction transistor (BJT), gate turn off thyristor (GTO), metal oxide semiconductor controller thyristor (MCT) and static induction transistor (SIT) can be used as a switch.

![Figure 2 Schematic diagram of single phase inverter](image)
4 FUZZY LOGIC CONTROLLER

The need of fuzzy logic controller clearly enables a human being to interface easier with an automated system that in the conventional case.

![Block diagram of Fuzzy Logic Controller](image)

Figure 2 Block diagram of Fuzzy Logic Controller.

The fuzzy logic controller consists of four blocks namely fuzzification, inference mechanism, knowledge base and defuzzification.

Fuzzification: In this stage the crisp variables of inputs are converted to fuzzy variables. The fuzzification maps the error and change in error linguistic labels of fuzzy sets. Membership function is associated to each label with triangular shape which consists of two inputs and one output. The proposed controller uses the following linguistic labels NL, NM, ZE, PM, PL. Each of the inputs and outputs contain membership function with all these five linguistics.

Knowledge base and inference stage: It involves defining the rules represented as IF-THEN rules statements governing the relationship between input and output variables in terms of membership function. In this stage the input variables are proposed by the inference mechanism that executes rules represented in the rule table. Mamdani fuzzy logic algorithm is used for the rule base computation.

C) Defuzzification: This stage introduces different methods which can be used to produce fuzzy set value for the output fuzzy variable. Defuzzification interface performs the following function.

1) A scale mapping, this converts the range of values of output variables in to corresponding universe of discourse.

2) Defuzzification, which yields a non-fuzzy control action from an inferred fuzzy control action.

Each universe of discourse is divided in to seven overlapping fuzzy sets. NL (Negative Large), NM (Negative Medium), ZE (Zero), PM (Positive Medium), PL (Positive Large)
TABLE 1 Fuzzy rule base.

<table>
<thead>
<tr>
<th>Input</th>
<th>Rule 1</th>
<th>Rule 2</th>
<th>Rule 3</th>
<th>Rule 4</th>
<th>Rule 5</th>
<th>Rule 6</th>
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<tbody>
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</table>
Rule statement:
1. If (speed error is NB) and (change in error is NB) then (control is NB).
2. If (speed error is NM) and (change in error is NB) then (control is NB).
3. If (speed error is NS) and (change in error is NB) then (control is NB).
4. If (speed error is ZE) and (change in error is NB) then (control is NB).
5. If (speed error is PS) and (change in error is NB) then (control is NM).
6. If (speed error is PM) and (change in error is NB) then (control is NS).
7. If (speed error is PB) and (change in error is NB) then (control is ZE).
   PM) and (change in error is ZE) then (control is PM).

5 SIMULATION

Figure 7 simulation of speed control of an induction motor
6 SIMULATION RESULTS

Figure 8 Simulation result of solar PV system voltage and current

Figure 9 Simulation result of boost converter as 230V

Figure 10 Simulation result of PWM pulse to inverter
7 HARDWARE IMPLEMENTATION

A 12 V DC supply is given to the DC-DC boost converter, which boost up the voltage. The boosted DC voltage is given to the single phase inverter that converts the DC in to AC voltage. The inverted voltage is given to the load and thus the speed of the induction motor is varied by using the pulse in the inverter.
Figure 14 Hardware configuration of proposed system.

Figure 15 Hardware output voltage of Inverter.

Figure 16 switching frequency for low speed
Figure 17 switching frequency for high speed

Duty cycle for Switching frequency 1 is measured as Ton=3 and Toff=2. Hence Ton+Toff=5 and it has been measured as (5*10=50 HZ). Frequency is inversely proportional to time. F=1/T .. (2) Ns=120F/P.. (3)

Thus, the output voltage of the inverter, gate pulses from the PIC16F877A microcontroller and switching frequency are experimentally analyzed and shown. The speed of an induction motor is controlled by variable frequency method.

<table>
<thead>
<tr>
<th>Output AC voltage (V)</th>
<th>Speed (in rpm)</th>
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<tr>
<td>51.6</td>
<td>577</td>
</tr>
<tr>
<td>55</td>
<td>588</td>
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<tr>
<td>57.6</td>
<td>595</td>
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<tr>
<td>58.5</td>
<td>605</td>
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<tr>
<td>70.6</td>
<td>615</td>
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</table>

8 CONCLUSION

In this project, a single phase induction motor fed PV system implemented on MATLAB has been proposed. Based on the accurate modelling system, Fuzzy Logic System has been studied (FLC). The system consists of speed control strategy. The dc-dc boost converter boost up the voltage, which has been obtained from the solar panel. Thus a DC is converted in to AC using a single phase inverter. This AC source is fed in to single phase induction motor and thus a speed control strategy of a single phase induction motor is done using a Fuzzy Logic Controller (FLC). Fuzzy Logic feedback Controller is used to control the voltage. MATLAB/SIMULINK model of a single phase induction motor fed PV system is useful to understand the designing methodology and speed control strategy of a single phase induction motor. The hardware implementation and results are also achieved.

References


