Speed Control of Three Phase Induction Motor Using Universal Bridge and PID Controller

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Speed Control of Three Phase Induction Motor Using Universal Bridge and PID Controller

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Abstract. Speed control technique are generally essential in adjustable speed drive system. This system requires variable voltage and frequency supply which is obtained from a three phase voltage source inverter. This paper presents the speed control of induction motor fed by a three phase voltage source inverter using pulse width modulation method and universal bridge. To control the peak dc link voltage of voltage source inverter, a PID controller was designed. The performance analysis of open loop and closed loop speed control system is carried out in Matlab/Simulink. The simulation result shows that the speed controller has a good dynamic response and can control the induction motor successfully with a better performance.
Keywords : three phase induction motor, speed control, voltage source inverter, universal bridge, PID controller

1. Introduction

At present, asynchronous motors or induction motors are used in extensive industrial drives because of their simple, inexpensive or inexpensive engine construction and excellent reliability. This engine control is difficult because of the high motor complexity. Several control strategies have been presented to control motor engines. This technique includes PWM speed control. This control has a rapid expansion with the growth of power electronics [1]. They have succeeded in the application of inverter components which made it increasingly popular. In addition, PWM control, in particular, is regretful as one of the well-known techniques for controlling the high complexity of three-phase induction / asynchronous motor systems. This technique is done by adjusting the pulse width and the pulse duty ratio to set the average voltage. PWM technology is accompanied by the development of electronic power devices, has a good development and is now mature. By using the PWM technique, the waveform of the output signal of the inverter can be improved to minimize harmonic and ripple output torque. This technique reduces the design of the inverter, to speed up the level of adjustment and increase the dynamic response of the system. In the field of electric propulsion, the motor is very important to complete the variable speed motor [2].

1.1. Working principles of three phase induction motor

The working principle of a three phase induction/asynchronous motor is slightly different from a single phase. When the stator holds a three-phase winding that is moved in space by 120 degrees, when a three-phase supply is fed to the stator winding, a rotating magnetic flux (rotating at synchronous speed) is created in the stator. [3]

Three-phase stators and rotors are considered as two basic parts of a three-phase AC induction motor. When the stator phase is energized by a three-phase AC power source, current flow is generated in the stator. The magnetic field synthesized by three-phase stator currents always rotates nonstop with variations in current. This rotating magnetic field cuts the rotor and the current produced in it interacts with the rotating magnetic field and thus produces a magnetic torque that makes the rotor spin (Figure 1). The rotational speed of the rotor n must be less than the rotating magnetic field n0. Reverse rotation of the rotor will be realized by the interchangeable three-phase resource position.

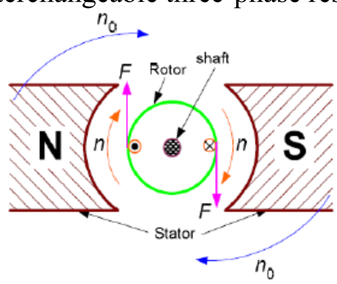

Figure 1. Rotating magnetic flux of asynchronous motor

When the filed is totating, the direction is the same with phase current and speed value is proportional to the frequency and inverse;y wiyh the polar pair number. Calculated per minute, the speed of the rotating magnetic field n_0 can be represented by this equation:[4]

$$n_0 = \frac{120\,x\,f}{P} \tag{1}$$

Where n_o = synchronous rotational speed in rev/min
f = power supply frequency in Hz
p = number of motor poles

The speed which the stator flux rotate is called synchonous speed, depend on the number of poles of the motor and the power supply frequency. In the practical field, the speed value of rotor will be slower than synchronous speed. Induction motors are also called as asynchronous motors because the values of rotor speed is different with stator flux. The slip is differences between rotor speed and rotational of stator flux. The value of slip varies between 1% to about 6% of stator flux speed.

The value of slip is,

$$slip = s = \frac{(n_0 - n)}{n} \text{ p.u} \tag{2}$$

And the value of rotor speed is,

$$n = n_0(1 - s)\, rpm \tag{3}$$

Where n_0 = the speed of stator flux in rpm
n = The value of rotor speed in rpm
s = the value of slip in pu

When the AC power supplied the motor through stator windings,the stator flux rotate the same direction with the the supply .[5]

1.2. Induction motor drives

Induction motors or asynchronous motor have two types of windings. They are stator and rotor winding. These winding are designed for three phase system. Induction motor or asynchronous motor usually operaated in variable speed drives. Three phase AC voltage supplied stator winding with balanced voltage. The stator induced the rotor with magnetic flux as transformer principal. The value of rpm and torque of induction motors/asynchronous motor can be adjusted by :

- Controlling the stator voltage
- Controlling the rotor voltage
- Controlling the frequency
- Controlling stator voltage and frequency
- Controlling the stator current

• Controlling the voltage, current and frequency

To get the rpm and torque, controlling the duty cycle, voltage, current and frequency are very important[5].

The purpose of this paper are controlling the rpm of an induction motor/asynchronous motor by adjusting the stator voltage. This method can be achieved by using sinusoidal pulse width modulation technique method through an universal bridge component and PID controller.

1.3. Three phase dc to ac converter (inverter)

In high power application, Three phase dc to ac converter (inverter) are widely used for adjustable frequency drive applications. A basic priciple of three phase dc to ac converter containing of three single phase switches which connected to one of the three load terminal ports..

Inverter is a circuit that is used to convert a DC voltage source into an AC voltage source. The power semiconductor components used can be in the form of SCRs, transistors, and MOSFETs that operate as switches and converters. Three phase inverter can be shown in fig.6

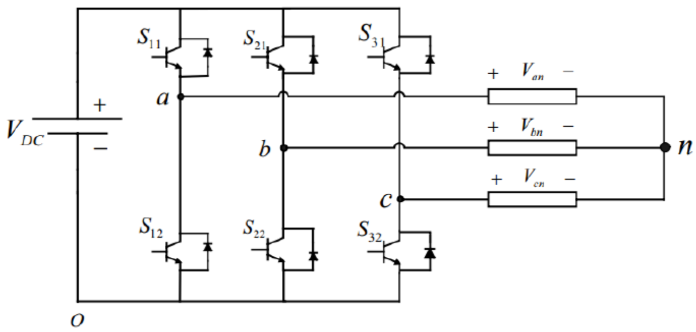

Figure 2. Three phase dc to ac converter cicruit

Judging from the conversion process, inverters can be divided into three types, namely inverters: series, parallel, and bridge. Bridge inverters can be divided into halfwave bridge inverters and fullwave bridges. The resulting output voltage can be in the form of one phase or three phases.[6]

1.4. PID controller

PID control systems are the most widely used in control systems industry. The success of the PID controller depends on its accuracy in determining PID constant (reinforcement). Practically the determination process PID constants are based on human expertise based on rules called rules of thumb. If the right result has been obtained, then this PID constant used for further control. This of course has weaknesses because this constant is the same for every error value that occurs and requires tuning reset if there are changes in plant parameters in the PID constant. For To overcome this, a method is needed to determine the PID constant exactly according to the plant. It is hoped that the performance of the PID control can be improved. In Figure 7 shows the priciple of PID controller.[6]

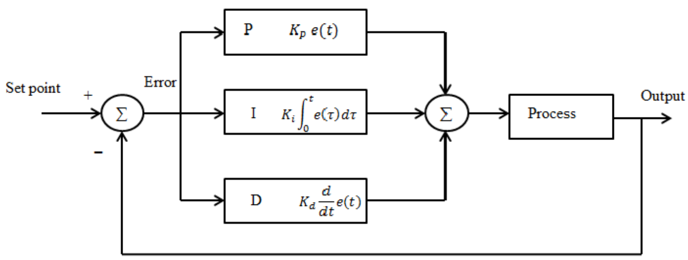

Figure 3. Diagram of PID control circuit [6]

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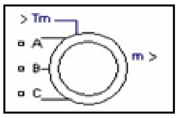
Common characteristics used in the regulation of an intermediate system others include stability, accuracy, response speed and sensitivity. In action proportional control, the output of the control system will be proportional to the input. The output signal is a reinforcement of the error signal with certain factors, This reinforcement factor is a proportional constant of the system, which is expressed by Kp, where Kp has a high / fast response. In integral control, the output always changes during deviations, and the speed at which the output changes is proportional to the deviation, a constant expressed as Ki, where Ki has a sensitivity which is high, i.e. by reducing the error generated from the feedback signal. The greater the value of Ki, the higher the sensitivity, but time needed to achieve stability more quickly, likewise the opposite. Whereas derivative control works by rate deviation changes, so this type of control is always used together with proportional and integral controllers. Constants expressed in Kd, where Kd is affecting the stability of the system, because of this control action able to reduce errors. By combining these PID control actions then expected to get a response that has a level of stability tall one.[6]

2. Methodology
There are tools which will be used for the effective implementation of this project, they include Matlab tool, Simulink tool and Simpowersystem tool.

2.1. Asynchronous machine/induction machine (squirrel cage)
Induction/asynchronous machine block represent of 3 phase asynchronous engine such as wound rotor machine, squirrel cage machine. This machine will have two function, they are motor or generator.. These function is determined by the value of torque from the machine :



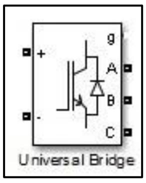
- the machine will acts as a motor when Tm value is positive
- the machine will acts as a generator when Tm value is negative

The instrument value of the machine component is measured in table .

Table 1. Asynchronous/Induction motor paramater

Nominal power, voltage (line-line), frequency	746 VA, 380 V, 50 Hz
Stator resistance & inductance	0.009961 Ω , 0.000867 H
Rotor resistance & inductance	0.005837 Ω , 0.000867 H
Mutual imductance	0.03039 H
Inertia, friction factor, pole pairs	0.4 , 0.02187 , 2

2.2. Universal bridge



The universal bridge block component represents an universal voltage converter for 3 phase power system. This block contaian six switches which connected in a bridge arrangements. The universal bridge can be power electronic devices component [7]

The measurement value of this universal bridge can be described in table 2.

Table 2. Universal bridge componen block measurement value

Power electronics devices	IGBT/Diodes
Number of bridge arms	3
Snubber resistance	1e5 Ω
Snubber capacitance	inf
Ron	1e-3 Ω
Tf , Tt	1e-6 s, 1e-6 s

2.3. Pulse Width Generator

Pulse Width Modulation (PWM) in general is a way of manipulating the signal width expressed by pulses in a period, to obtain a different average voltage. Some examples of PWM applications are data modulation for telecommunications, controlling power or voltage entering the load, voltage regulators, audio effects and amplification, as well as other applications. The simplest PWM signal generation is by comparing the sawtooth signal as a carrier voltage with reference voltage using an op-amp comparator circuit. The workings of this analog comparator are comparing sawtooth voltage waves with reference voltages. when the reference voltage is greater than the carrier voltage (sawtooth), the comparator output will be high. But when the reference voltage is less than the carrier voltage, the comparator output will be low. By utilizing the working principle of this comparator, to change the duty cycle of the output signal is enough to vary the reference voltage. [7]

2.4. System overview

The proposed circuit of the system had been designed and simulated using Matlab/Simpowersystem. Fig. 8 and Fig.9 shows the simulink circuit of the proposed model.

2.4.1. Open loop system

The open loop system consist of four main component. They are DC voltage supply, universal bridge, PWM generator and Asynchronous machine block. In open loop system, there are no feed back to control the speed. So the speed depend on the value of dc voltage supply. The open loop control system is traditionally control that used in several induction motor. Thi control is simple because contain a few component to implemented.(fig 8).

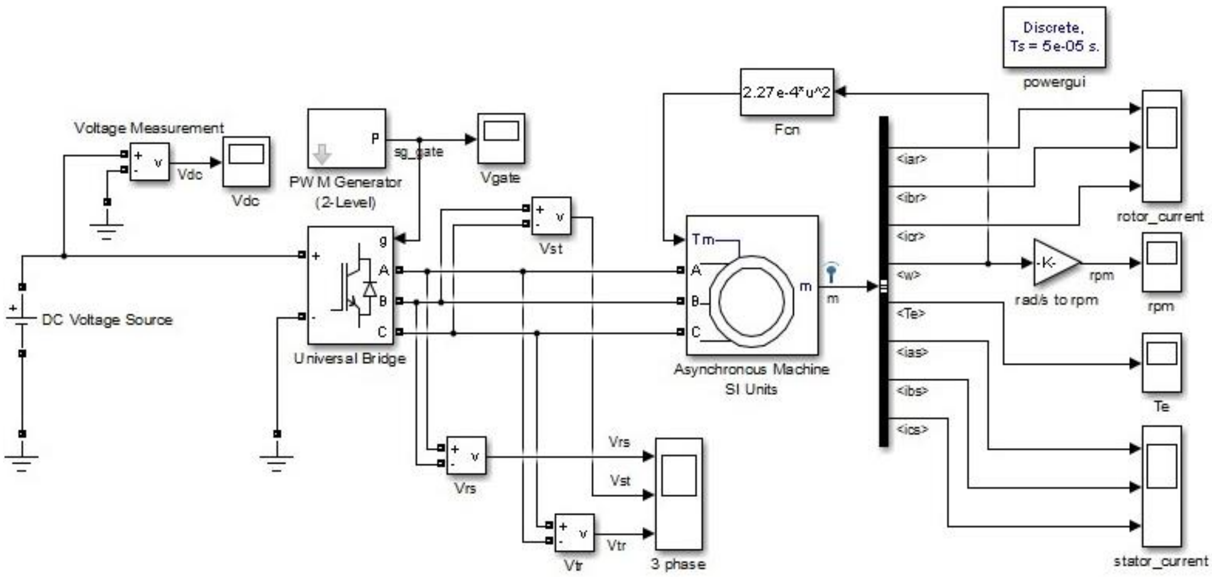


Figure 4. Simulink model of open loop system

2.4.2. Closed loop system

The improvement of open loop is closed loop system. The closed loop system consist of five main component. The component are contolled voltage source, PID controller block, universal bridge block, PWM generator block and asynchronous motor machine block.The circuit diagram of closed loop system shows in fig.8.

In closed loop system, speed sensor used as feed back signal to set point reference. The error is the differences between actual speed and rpm set point. The PID block process this error as signal control to controlled voltage sources.

Controlled voltage source block produce the varied dc voltage output as the input signal for universal bridge.

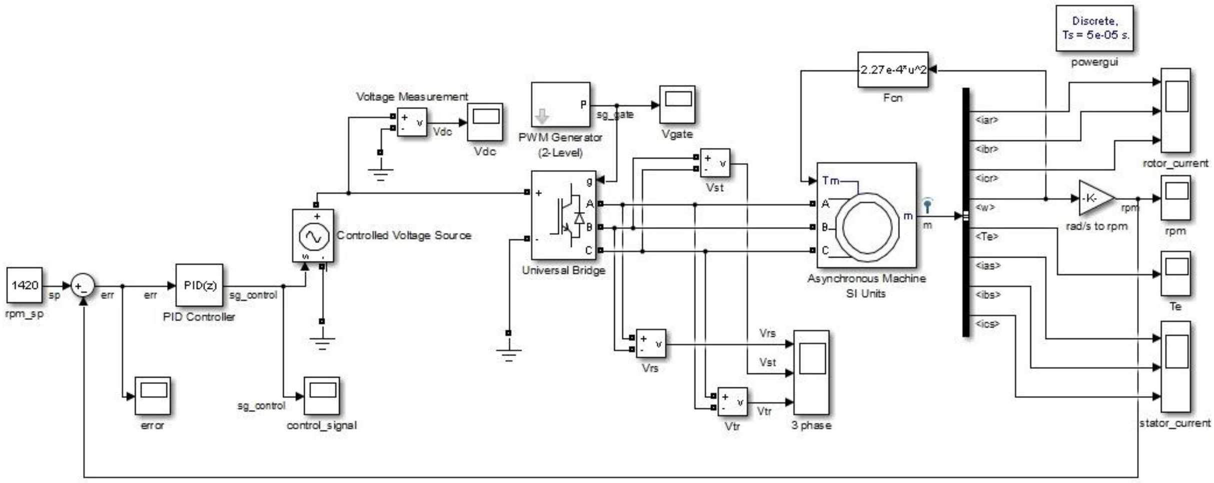


Figure 5. Simulink model of closed loop system

The universal bridge convert dc voltage to ac voltage from controlled voltage source. This bridge generate 3 phase voltage to supply asynchronous motor. The speed of asynchronous motor determined by the value of 3 phase voltage and frequency of the output universal bridge. This speed is adjusting to get the nearest value based on set poin rpm speed.

3. Results & Discussion

Simulation results are obatained from Matlab/Simulink software tools. The results of line voltage, phase voltage, current in the line are listed along with speed and torque results of induction motor in the following figures.

3.1 Results of open loop system

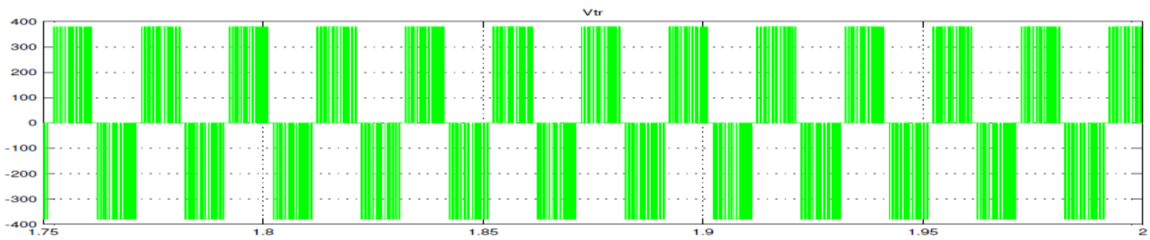


Figure 6. Line voltage output of universal bridge

From fig 6, the voltage value of inverter output are 380 Vac. Induction motor use this voltage for operation according to the nominal voltage rating.

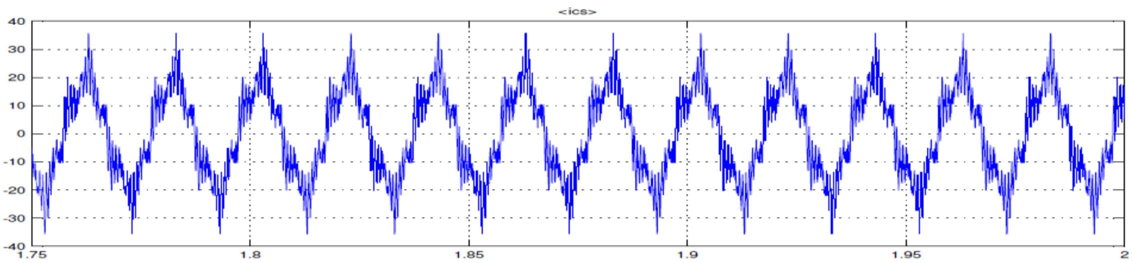


Figure 7. Stator current of induction motor

Induction motor produce 35 A for stator current. This current is equal to every phase because induction motor are a balanced load.

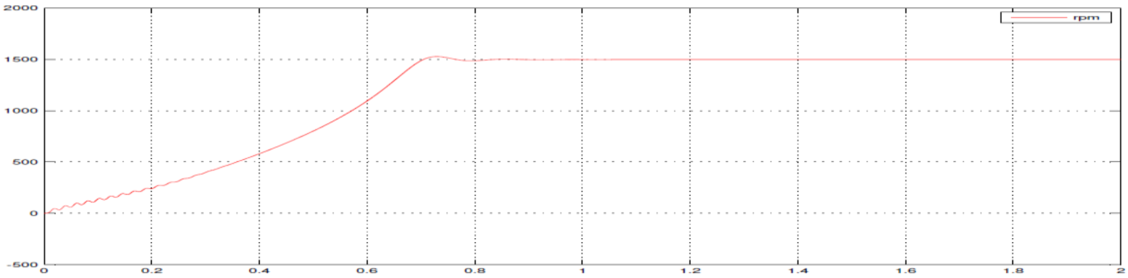


Figure 8. Rpm output of induction motor

From fig 8, the steady state speed of induction motor are 1500 rpm. The respons of open loop system can be shown from this figure. Open loop system respons are rise time (tr) = 0.7 s, delay time (td) = 0.55 s, peak time (tp) = 0.73 s and steady state time (ts) = 0.9 s.

3.2 Results of closed loop system

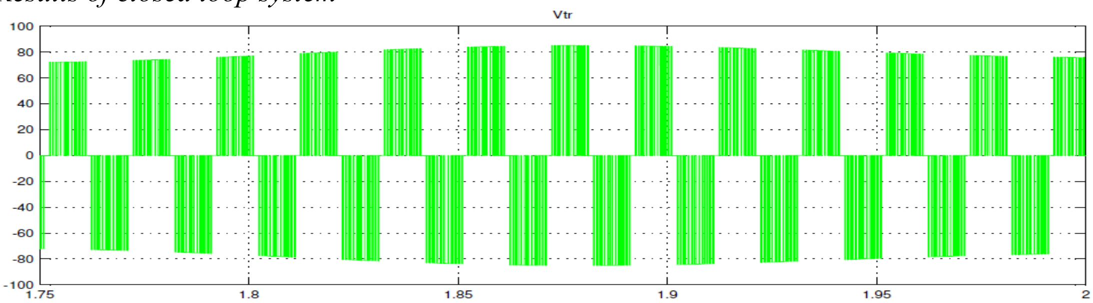


Figure 9. Line voltage output of universal bridge

From fig.9, the voltage value of inverter output are 85 Vac. Induction motor use this voltage for operation according to the nominal voltage rating.

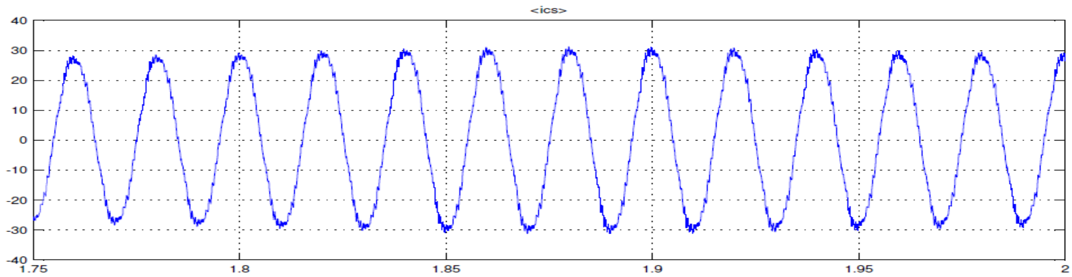


Figure 10. Stator current of induction motor

Induction motor produce 30 A for stator current. This current is equal to every phase because induction motor are a balanced load.

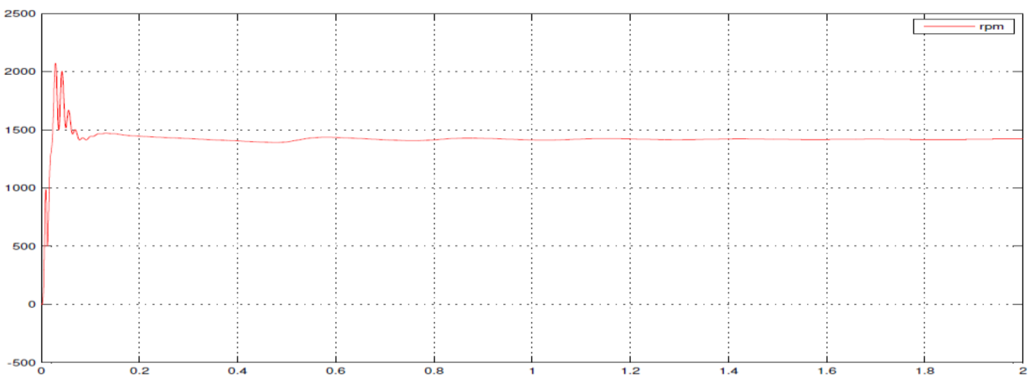


Figure 11. Rpm output of induction motor

From fig.11, the steady state speed of induction motor are 1420 rpm. The respons of closed loop system can be shown from this figure. Closed loop system respons are rise time (tr) = 0.02 s, delay time (td) = 0.015 s, peak time (tp) = 0.025 s and steady state time (ts) = 0.2 s.

4. Conclusion

Simulations have been carried out with Matlab / Simpowersystem. From the simulation results, it is obtained that the control of the induction motor using the PID controller and universal bridge produces a better response than without the PID control. In the open loop system, the time to get steady state speed is 0.9 seconds while in the closed loop system, the time to get steady state speed is 0.2 seconds. This shows that the PID controller obtained a faster response than without a controller. After all simulation we can conclude that the proposed system has a good ability to control the speed of the induction motor.

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