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Speed Control of Induction Motor by Rotor Position Feedback over an RF Link

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Abstract

There are different types of speed control of Induction motor. But all the speed control methods are with wire based position feedback. In this paper, we demonstrate the feasibility of controlling the speed of an induction motor using a wireless position feedback over an RF link and compare its performance under dynamic and steady-state conditions with those obtained using a wire based position-feedback control. Due to this wireless position feed back over an RF link minimizing the feedback noise pickup and cost for some applications. This wireless position feedback has the possibility to uses the low resolution and low cost sensors. which, along with the use of simple estimation algorithms, may potentially provide an alternative to or backup support for conventional position sensor less control for a wide range of motors and speeds.

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1. Introduction

Speed control of an induction motor usually requires position feedback information from an encoder, a resolver, or a Hall sensor to a controller unit. These feedback signals, which often pickup noise due to electromagnetic interference, can affect the performance of the motor control system. As such, the feedback cable is shielded and the signals are provided in differential form, which increases the sensing cost.

Therefore, motor-drive manufacturers have been focusing on position sensor less control. However, universal applicability of the position sensor less algorithms for speed control, especially at or near-zero speed and at full-load torque, has not been fully achieved yet. In this paper, we outline a technique for implementing a Volts/Hertz (V/F) (i.e., constant flux) induction motor control using real-time wireless feedback of rotor position over an RF transmission link.

Today, several commercial and defence applications have addressed health monitoring and RF identification (RFID) of motors using a wireless link. The proposed scheme can use the same RF channel (via hopping) to transmit the position feedback (typically over a 300-ft transmission range). This eliminates the need for a multiwire cable, which can be expensive, especially for harsh and extended operating conditions, and much costlier than a miniaturized RF transmitter. The proposed wireless position sensing scheme can also be extended to other vector control schemes for induction and other motors.

Conventional position sensor less control schemes require complex estimation algorithms, and have limitations regarding the speed range and applicability. However, such schemes save the cost of an expensive position sensor. So, if a low-cost, low-resolution position sensor is used that transmits information over an RF link (thereby precluding the cable cost), then a simple position-estimation algorithm operating along with the lower resolution but discrete-time-interval position updates can be potentially as powerful as the complex position sensor less control (which has no position feedback).

Because the cost of the high-resolution sensor is higher to begin with, the proposed wireless information-exchange-based scheme, which can potentially use cheaper low-resolution sensors, can be a more cost-effective approach. However, because wireless transmission over an RF link is susceptible to channel disruptions, it is important to investigate the impact of time delay on the stability and performance of the overall system, so that controllers can be designed to ensure operation within the desired bounds..

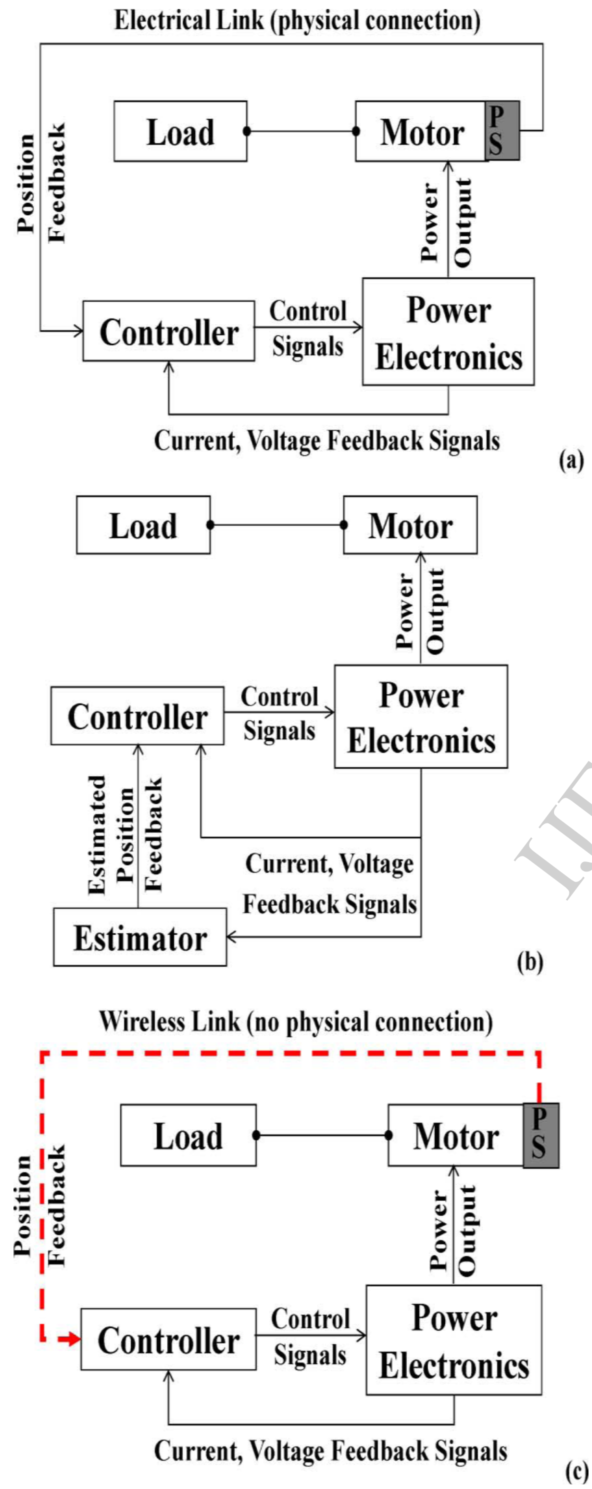

Fig. 1. Illustration of motor-control system (with internal control reference) with: (a) wire-based position feedback, (b) position estimation, and (c) wireless position feedback. PS stands for position sensor.

2. Description of the Scheme

The proposed system consisting of an induction motor, a pulse width-modulated inverter, and a V/F feedback controller that receives the motor position feedback over a wireless channel. We use frequency-shift-keying (FSK) for RF transmission. The square-wave output of the position encoder is first multiplexed and then fed to an RF transmitter. The RF receiver antenna is tuned to a transmission frequency of 900 MHz The receiver demodulates and amplifies the broadcast signal, such that the output of the receiver matches the pattern of the original encoded digital signal. Finally, the demodulated signal is fed to the motor controller. In the absence of channel disruptions, the (position-sensor-to controller or end-to-end) time delay (τd) is negligible, but it increases with deteriorating channel conditions or for reduced data rates. The RF receiver of the controller demodulates the received signal to extract the digitally encoded position feedback (θop). It is then transformed θ which represents the angular resolution of the encoder. The position feedback (θ) is fed to the controller that derives the velocity using $\omega = d\theta/dt$, which is Then compared with the velocity reference. The error between reference velocity and ω is fed to a proportional–integral (PI) controller to obtain the slip, which is then added to ω to obtain the drive frequency (ωCF). Subsequently, using ωCF, a desired voltage reference magnitude (VCF) is generated to maintain a V/F operation of the induction motor. Voltage reference VCF and its instantaneous electrical position (i.e., $\theta e = p\theta/2$, where p represents the number of motor poles) are fed to a space-vector modulation (SVM) block to obtain the switching signals of the inverter.

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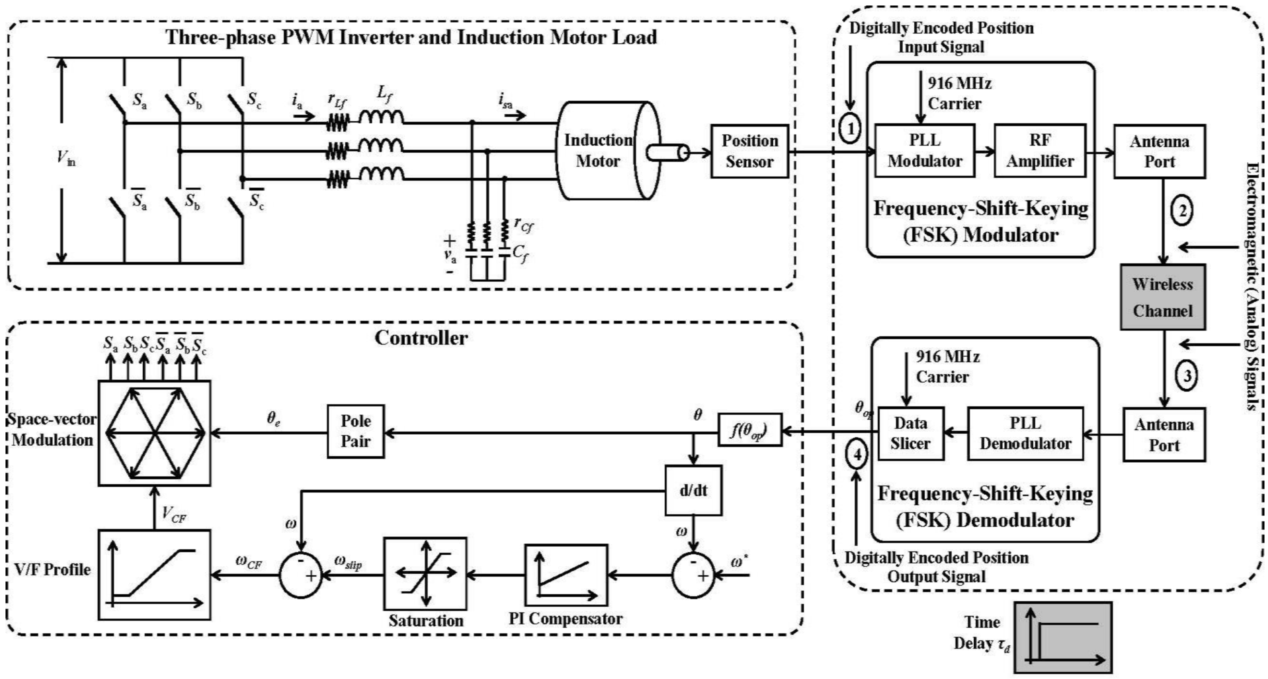
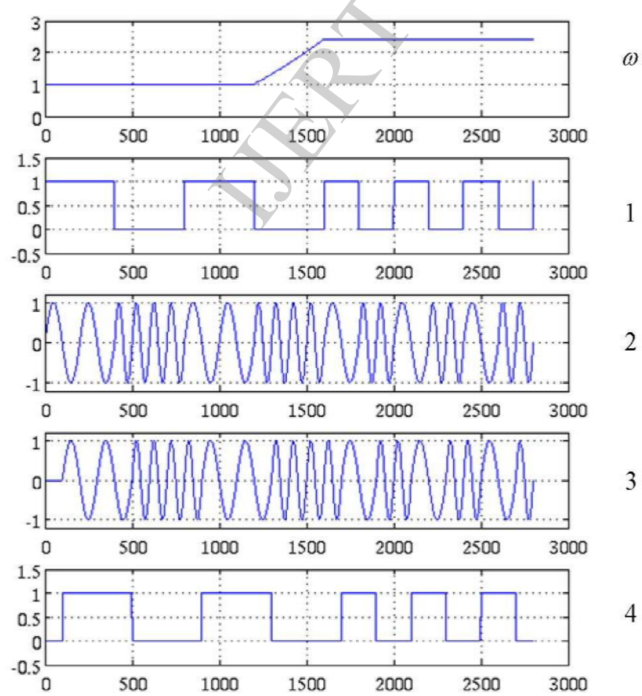


(a)



(b)

Fig. 2. (a) Block diagram of the overall system. (b) Wireless transmission scheme for position feedback along with key waveforms at points marked "1"–"4" and illustration of the end-to-end time delay (τd).

3.1. Modelling of Induction Machine

3. Modelling of Induction Machine

The steady-state model and equivalent circuit are useful for studying the performance of machine in steady state. This implies that all electrical transients are neglected during load changes and stator frequency variations. Such variations arise in applications involving variable-speed drives. The dynamic model considers the instantaneous effects of varying voltages/currents, stator frequency and torque disturbances. The dynamic model of induction motor is derived by using a two-phase motor in direct and quadrature axes. This approach is desirable because of the conceptual simplicity obtained with the two sets of the windings, one on the stator and the other on the rotor.

A wide variety of rotating machines are polyhase a.c. machines constructed in a different manner than the primitive machine. In such cases, the primitive machine can also be employed in the analysis, provided the rotating polyphase winding on the rotor and the stationary polyphase winding on stator. The process of replacing one set of variables by another related set of variables is called winding transformation. The equivalence between the three-phase and two-phase machine models is derived from the simple observation, and this approach is suitable for extending it to model an n-phase machine by means of a two phase machine. The concept of power invariance is introduced: the power must be equal in the three-phase machine and its equivalent two-phase model. The required transformation in voltages, currents, or flux linkages, is derived in generalized way. The reference frames are chosen to arbitrary and particular cases such as stationary, rotor, and synchronous reference frames, are simple instances of the general case. Derivations for electromagnetic torque involving the currents and flux linkages are given. The space-phase model is derived from the dynamic model in direct and quadrature axes. The space-phasor model powerfully evokes the similarity and equivalence between the induction machines and DC machines from the modeling and control points of view.

3.2 D-Q Stationary and Synchronous Reference Frames

As mentioned earlier, there is seldom a need to simulate an induction machine in the arbitrary rotating reference frame. For power system studies, induction machine analysis about some operating condition, a synchronously rotating reference frame which speed drives, it is usually more convenient to simulate an induction machine and its converter to a stationary reference frame. And for small signal-dynamic stability yields steady values of steady-state voltages and currents under balanced conditions is used.

4. Results and Discussion

4.1 Introduction

Speed control of an induction motor usually requires position feedback information from an encoder, a resolver, or a Hall sensor to a controller unit which increases the sensing cost. To overcome this problem RF link is used in place of wire feedback. Speed control with wire feed feedback and with RF link has been stimulated and rotor speed, stator currents are observed

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4.2 Simulation with wire feed back

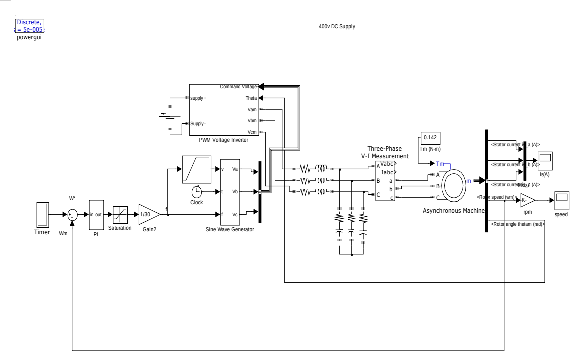

Figure 4.1 Induction Motor Control with Wire Feed Back

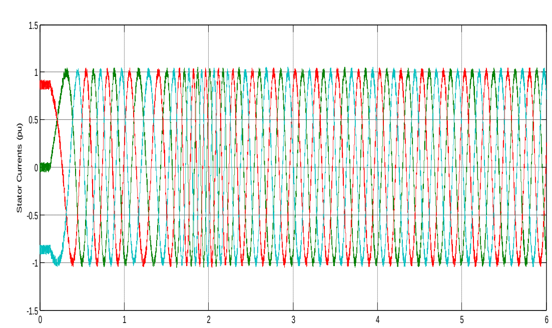

Figure 4.2 Stator Currents with Wire Feed Back

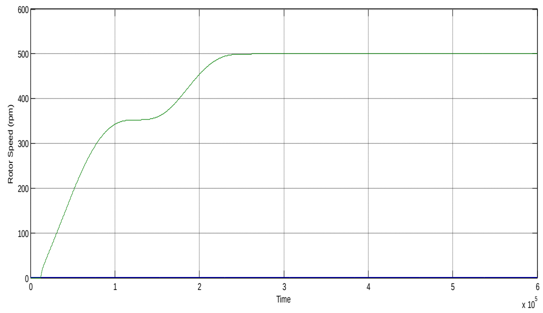

Figure 4.3 Rotor Speed with Wire Feed Back

The graphical diagrams fig 4.2 and fig 4.3 illustrates the stator currents and rotor speed obtained by simulating the speed of induction motor with wire feedback. The rotor speed is limited to 500 rpm.

4.2 Simulation with RF feed back

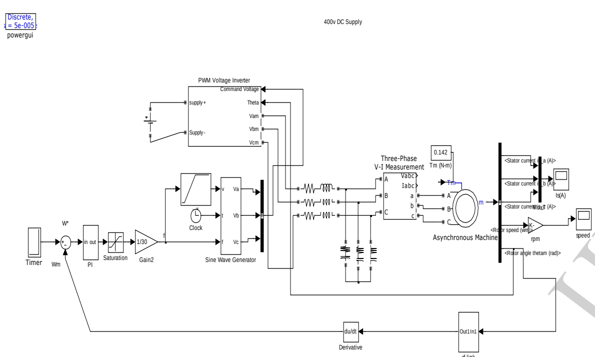

Figure 4.4 Induction Motor Control with RF Link Feed Back

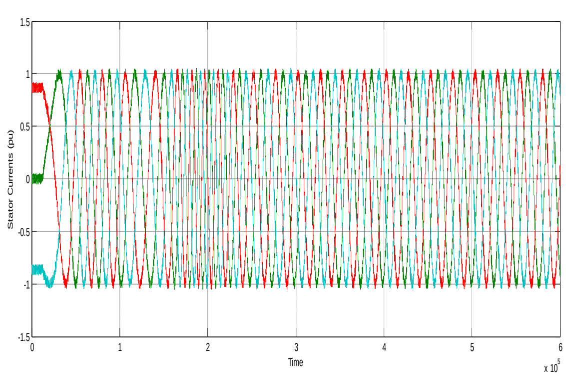

Figure 4.5 Stator Currents with RF Link Feed Back

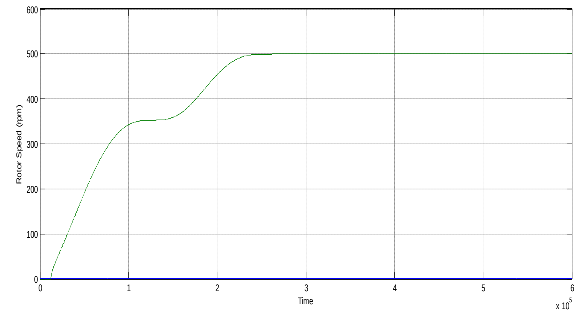

Figure 4.6 Rotor Speed with RF Link Feed Back

The graphical fig 4.5 and fig 4.6 illustrates the stator currents and rotor speed obtained by simulating the speed of induction motor using RF link. The graphs obtained are similar to that of wire feedback. By this we can conclude that instead of electric link, we can use RF link for speed control of induction motor.

5. Conclusion

By simulation results we can conclude that we can use RF link feedback instead of wire feedback to control the speed of induction motor. The advantages of using RF link feedback are as follows:

- This eliminates the need for multi wire cable.
- The proposed scheme can be extended to other vector control schemes.
- Speed control of the motor especially at or near-zero speed and at full-load torque can be achieved.
- Performance of the motor can be improved

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