Efficiency Optimization of Induction Motor Drives using PWM Technique

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Abstract -This paper describes the two most efficient, very useful and simple techniques for the efficiency optimization of indirect vector controlled induction motor drives. This is achieved by controlling the flux-producing current, until the power at the dc link is minimum in a synchronously rotating reference frame. The very wide usage of induction motors (IMs) has brought the interest to improve the efficiency of induction motor drives. Out of these two techniques the first one controls the flux producing current in a smooth manner and regularly. In the second technique which combines two important approaches namely the loss model control (LMC) and search control (SC) in a unique way which gives rise to a new method called the Hybrid method, in which the first estimation is from the loss model approach and the subsequent adjustment of the flux is made by search control technique. Both the algorithms are simple easily realizable and offers a great convergence. And also excellent dynamic performance is obtained by the smooth control of the flux. The above discussion shows that even though the availability equivalent circuit for analysis and optimization of losses in an induction motor by hybrid method is the best method.

Key Words: Induction motor, Efficiency boosting, indirect vector control, loss model control(LMC), search control(SC).

I. INTRODUCTION

Induction motors have been widely used in the industrial applications because of low cost, mechanical robustness, and simple maintenance. In general as far as the energy consumption is concerned, the electric motors consume more than 50% of the total electrical energy produced. This is where the efficiency optimization of induction motor drives takes great importance. The induction motor (IM) operates very effectively or efficiently at or near the rated load with rated flux. However, at light loads, no balance in between copper and iron losses, operation with rated flux causes low efficiency. The electric losses of a motor are mainly composed of copper and core losses. If copper losses increase, the core loss will decrease. Therefore, a control technique that maximizes efficiency by adjusting the flux level is required at light loads[1].

For a given motor, operation under rated conditions is highly efficient. However there are certain applications such as electric vehicles (EV), where the motor drive operates far from the rated point. Under such conditions, it is not possible to improve the efficiency by machine design or by waveform shaping techniques. A control algorithm that minimizes the losses is needed in that case.

There are two methods presented in this paper for optimization of efficiency of an induction motor. First one is called the Loss Model Controller (LMC). In this method losses are computed using the machine model, which considers core and copper losses. The flux current is obtained using a loss- minimization algorithm where the total losses from stator copper, rotor copper and iron losses are minimized. This method is considered fast, but obtaining exact parameters is difficult due to dependence on the parameters on parameter sensitivity to operating conditions.

The second method is called as the search control (SC). In this case the flux is searched until the measured power at the input settles down to the lowest value for a given speed and torque. Efficiency improvement using SC is insensitive to model inaccuracies. On the other hand these techniques are reaching the optimum ripple torque in steady state is always present. The control does not depend on the motor parameters and is insensitive to the parameter variations.

A hybrid method combining the Loss Model and the Search Method is proposed for convergence improvement. The first optimum flux was estimated using the LMC method. The subsequent flux adjustments were achieved using the SC method. The operating point for the minimum loss was rapidly computed using a functional approximation of the motor and power converter losses. The loss function parameters were obtained from the measured input power.

II. MECHANISM OF LOSS REDUCTION

The efficiency of a motor is defined as the ratio of mechanical output power to the electric input power. For a given operating point, the mechanical power is constant. The efficiency of a motor can thus be improved by reducing the electrical input power by minimizing the losses.

The losses of Induction Motor (IM) are classified as:

Stator copper losses
Rotor copper losses
Iron losses
Stray losses
Mechanical (friction + windage losses)

Nearly 70% of the losses are mainly due to copper losses and iron losses[4].

Total electromagnetic loss can expressed as

\[ P_{1} = P_{cu} + P_{fe} + P_{cor} \]

2.1 Maximization of efficiency

Two approaches are developed to minimize the losses. In the first approach an objective function is derived based on the modeling of the motor and the losses. The objective function is optimized to yield the maximum efficiency. Therefore this approach is called as feedforward method which treats the situation analytically by properly modelling the losses and is called the Loss Model Controller (LMC). The second method is of a feedback nature where the maximum efficiency is found by adopting a search technique and is called as a search control (SC).

1) Loss Model controller

LMC will vary the flux level so that the losses get reduced and the vector controlled drive will run at optimum efficiency. One of the major advantage of LMC is that this method is fast, however, the accuracy depends on the degree of correct modelling of the motor drive and losses. For the vector controlled drive, major loss saving is possible by considering the system as a whole and employing dynamic programming to select the operating flux. A generalized approach for the loss minimization for different types of motors is attempted. Thus evolution of the LMC is towards developing the controllers for different drive systems by development of the loss model and to include different working situations and applications.

2) Search Control

On the other hand Search control (SC) is based on the exact measurement of power input and do not depend on the machine parameters thus providing optimum efficiency. For a vector controlled drive the flux is reduced in small steps to attain the optimum level. Increased time of convergence and objectionable torque pulsations were the major problem faced during the search process. The optimal slip is searched and the same is stored in the microprocessor memory. The drive system is forced to track the optimal slip from the lookup table.

Performance of a system can be improved but with a cost of sufficiently high complexity of control algorithm. Feedforward compensation technique is used to take care of the torque pulsation problem. However, the major problem exists in selecting the upper and lower limit of the flux producing current before the algorithm starts. It is necessary that one should have to know the drive system very well in order to achieve an acceptable dynamic performance and to increase the speed of search. A comparison between the LMC and the SC reflects that the SC is always slow and the LMC works on the model and not on the actual drives. Performance of the LMC deteriorates when parameters change and online estimation of the parameters makes the method far more complicated even if the modeling of losses is done sufficiently rigorously.

III. SYSTEM LAYOUT

The important factor that has lead to design the system is an application that requires both excellent dynamic performance and maximum efficiency. This, of course, includes the Electric Vehicle (EV), which is one of the main research area. Therefore when an indirect vector-controlled IM drive is considered there exist an additional outer loop for efficiency optimization. The vector control not only has the advantage of excellent dynamic performance, but also, due to the inherent decoupling of d-axis (flux producing) and q-axis (torque producing) currents in the steady state, both flux control and torque control may be thought of separately. This makes the inclusion of the efficiency optimization algorithm very simple.

Fig. 1 shows the configuration of a available general purpose drive system. For the present study, the converter on the left side of the configuration is operated as a rectifier. The vector control part mainly includes speed and current controllers in a synchronously rotating reference frame and also the vector rotators, and reference transformation. Normally the speed can be measured by using tachometer, however, sensors for speed measurement can be eliminated by employing any of the available estimation techniques. The input power to the drive system is measured by measuring and filtering the dc-link voltage and current. Thus due to the ease of measurement of dc-link power, the Efficiency Optimization Control (EOC) is based on dc-link power measurement as in and . This also has the advantage of including the inverter losses in the loss minimization.

IV. PROPOSED BLOCK DIAGRAM

For the hardware implementation we use different components. They are listed below as

1. PIC Microcontroller 16F84A.
2. Voltage Regulators
   a. 7812 voltage regulator
   b. 7805 voltage regulator
3. IC IR2110 for the amplification of the pulses given by PIC16F84A
4.1 FEW SIGNIFICANT POINTS REGARDING THE POWER CIRCUIT:

- A step-down transformer (230/15) V is used to give input supply to the power circuit.
- The 15V AC input is rectified into 15V pulsating DC with the help of full bridge rectifier circuit.
- The ripples in the pulsating DC are removed and pure DC is obtained by using a capacitor filter.
- The positive terminal of the capacitor is connected to the input pin of the 7812 regulator for voltage regulation.
- An output voltage of 12V obtained from the output pin of 7812 is fed as the supply to the pulse amplifier.

- From the same output pin of the 7805, a LED is connected in series with the resistor to indicate that the power is ON.

4.2 PIC CONTROLLER

In this project the hardware is implemented using the Pic- Microcontroller “Pic 16F84A”. The advantages of the Pic- microcontroller is that the instruction set of this controller are fewer than the usual microcontroller. Unlike Conventional processors, which are generally complex, instruction set computer (CISC) type, Pic microcontroller is a RISC processor.

The idea of using the Pic microcontroller is because:

1. To employ the frequently used instructions as the instruction set while using a few instructions to achieve the same function performed by a much more complex instruction in a CISC.
2. The RISC itself has a large number of general purpose registers, largely reduced the frequency of the most time-consuming memory access.
3. In terms of clock rate, the RISC with its much simpler circuits can have a higher clock rate that again increases the performance of a processor.

Overall the RISC processor can provide processing power more than three times of a CISC processor in a particular field of application.

V. EXPERIMENTAL RESULTS

The proposed technique for the efficiency optimization have been developed and tested for maximum efficiency with motor ratings listed below.

The rating of induction motor are:

- Voltage rating : 415V
- Current rating(full load) : 1.9 A
- Power rating : 1HP=0.75KW
- Rev./Min. : 1410

The figures below shows the designed hardware and the experimental results conducted for efficiency optimization.
Fig. 3 Hardware kit with induction motor load

Fig. 4 Input waveform

Fig. 5 Rectified output waveform

Fig. 6 Input pulses to the controller

Fig. 7 Input pulses to driver circuit

Fig. 8 output waveform with Induction motor load

VI. CONCLUSION

Simple technique for efficiency optimization of an IM is presented in this paper. Here we have considered the light load condition for the indirect vector controlled IM drive, where an extra outer loop is added to decide the flux level. The hybrid method which combines the advantages of both LMC and SC in a unique way to extract the best of both.

Thus, the hybrid method possesses the adaptability to variable speed and load conditions. The assessment shows that hybrid method is 1) faster, 2) simpler, 3) easily realizable, 4) gives excellent dynamic performance. Such control schemes are very suitable for applications where high dynamic performance as well as efficiency optimization is desirable.

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REFERENCES


