# OPTIMUM EFFICIENCY CONTROL OF INDUCTION MOTOR DRIVES

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## ABSTRACT

The energy conservation is increasing the requirements for increased levels of electric motor efficiency. Controlling motor speed with load change has proven very successful in many applications such as in heating ventilation and air-conditioning. It is therefore important to optimize the efficiency of motor drive systems if significant energy savings are to be obtained. This paper proposes a new control scheme based on artificial neural networks taking advantage of Nola theory which states that at a certain torque and speed operating point there exist only one set of voltage amplitude and frequency that operates the machine at optimum efficiency.

## 1 INTRODUCTION

The high cost of energy provides the incentives to reduce the energy losses and improve the efficiency of electric motors drive systems. Reduced losses not only reduce operating cost but also reduce capital cost of utility systems supplying electric power to their consumers. In hot countries, more than 70 % of the energy consumption is in Ventilation and Air Conditioning. Therefore, it is important to concentrate on optimizing the efficiency of the induction Motor (IM). Recent reductions in the cost of control electronics have made energy savings of 40 % – 60 % possible in numerous applications through the use of Variable Speed Drives. Energy saving is the main reason to use adjustable frequency drives in many applications such as VAC systems. This is because a slight reduction in a fan's or a compressor's speed has a major impact on its energy consumption.

## 2 VARIATION OF INDUCTION MOTOR EFFICIENCY

Although the electricity-to-shaft power efficiency of an IM may be as high as 90 %, the associated control systems and the equipment they drive are often poorly optimized for energy efficiency. However, developments in materials and design have now resulted in a range of motors with significantly higher efficiencies. Such developments have become desirable as the cost of electric power continues to rise. Traditional electrical motor efficiencies could possibly be increased from around 90 % to up to 97 %. An efficient motor not only saves energy but will also generate less internal heat, and run cooler and more quietly. It is also likely to last longer and be more reliable than a less efficient motor. Recently, it will also offer wider speed, torque and power ranges, and shorter response times. Noise and vibration levels of the ventilating equipment will be reduced, although noise at 2 and 4 kHz could develop from the power lines. The improvements are likely to lead to a reduction in maintenance and downtime, and will increase the effective life of the equipment.

## 3 MAXIMUM EFFICIENCY

It is important to define the appropriate values of the applied voltage amplitude and frequency, for any operating point, which maximize the efficiency of the motor.

$$w_o = \frac{2}{p} w = \frac{4\pi f_o}{p} \tag{1}$$

$w_o$ Is the base frequency in mechanical red/sec?

$$a = \frac{f}{f_o} = \frac{w_m}{w_o(1-s)} \tag{2}$$

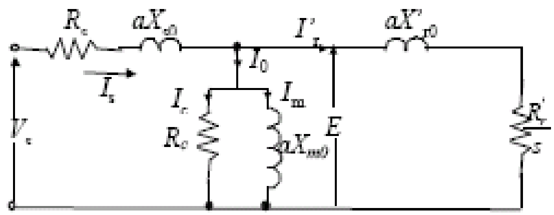


**Fig. 1:** *Induction motor equivalent circuit*

Based on those definitions we can draw the equivalent circuit of the induction motor in (fig. 1) The applied voltage frequencies (f) as well as the amplitude (V) are varied in order to set the induction motor output to the desired speed and torque opera ting point. Fig. 2 shows an example of torque versus speed characteristics obtained for different sets of V and f. It is clear that the same operating point can be obtained with different combinations of V and f (fig. 2). However, only one set will maximize the efficiency of the motor and it is possible to calculate this set for a given operating point.

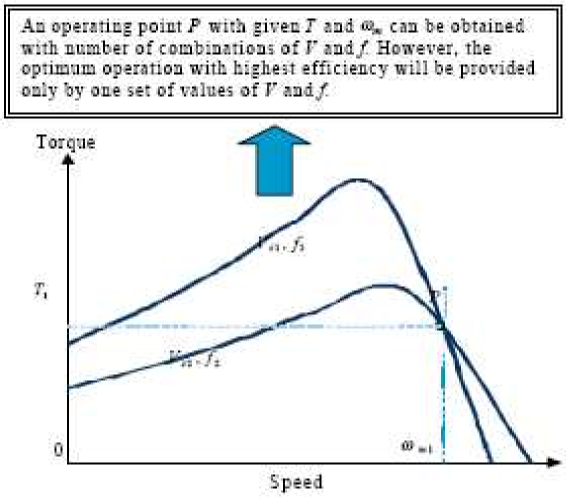


**Fig. 2:** *Torque-speed characteristic under variable voltage and frequency control*

## 4 SIMULATION RESULTS

We use for this simulation the matlab program the technical date of the motor is given in the table .1. Per unit system is used and the reactance and ( $R_m$ ) are valid for $W_1 = 1(50HZ)$, the equivalent circuit of the induction motor for variable angular velocity $W_1$. Show in fig. 3.
Motor parameters:

| $R$ | $R_r$ | $X_m$ | $X_\sigma$ | $X_r$ | $R_m$ |
|---|---|---|---|---|---|
| 0.05 | 0.05 | 1.5 | 0.1 | 0.1 | 29.67 |

**Tab. 1:** *Motor parameters*

The resistance $R_m$ representing the iron losses and can by given as follows:

$$R_m = \frac{W_1}{K_e W_1 + K_h} \tag{3}$$

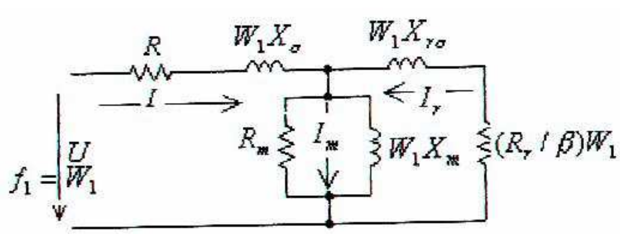


**Fig. 3:** *Equivalent circuit of the IM for variable $W_1$*

When $K_h = 0.0247$. Is a factor representing hysteresis losses?

$K_e = 0.009$. Is a factor representing eddy current losses?

We computed for the M and W the motor stator and rotor currents, voltage, fluxes, and losses for $0.05 \le \beta \le 0.1$ with steps $\Delta\beta = 0.01$. the synchronous speed we can determine by $W_1 = W + \beta$

The rotor current will be real vectors: $I_r = \sqrt{(M * \beta)/R_r}$

And rotor voltage according to equivalent circuit in fig .3. Will be

$$U_m = I_r * (R_r * W_1 / \beta + j * (X_r * W_1)) \quad (4)$$

And the magnetizing current we can determine by

$$I_m = U_m /(j * X_m * W_1) \quad (5)$$

The $W_1$ depending of the slip frequency monotonously increase with the increase of the frequency, the gross mechanical power output, including winding and friction losses, is

$$P_{out} = real((U_m) * I_r) - P_r \quad (6)$$

When

$$P_r = I_r^2 * R_r \quad (7)$$

And rotor efficiency is given by

$$\eta = \frac{P_{out}}{P_{in}} \quad (8)$$

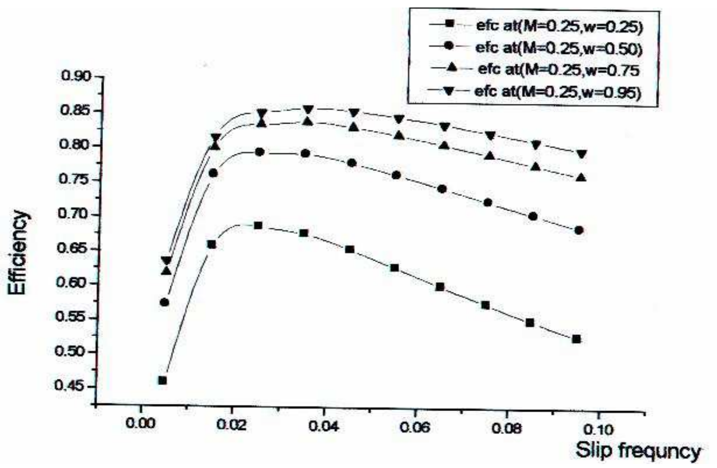


**Fig. 4:** *Relationship between the slip frequency and efficiency*

## 5 CONCLUSION

The investigation has shown that there is considerable potential for loss reduction in adjustable- frequency ac motor drives. inverter losses and saturation parameter changes in the motor will moderate the predicted efficiency improvement, but will not alter this general conclusion when a six step inverter is employed the efficiency improvement is enhanced and undesirable harmonic effects are reduced in an adjustable frequency drive it is usual to employ an induction motor with a low – slip characteristic such motors also offer the greatest potential for improvement in part–load efficiency because of the proximity of the optimum slip to the full-load slip of the motor.

## REFERENCES


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