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Operating Point Optimization of a Poly-Phase Asynchronous Machine for Energy Saving

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Abstract

In this paper, a simple algorithm has been developed to choose the optimum operating point keeping the system stable and saving power as much as possible. It has been proved that optimum use of supply voltage saves power to a great extent. The developed algorithm is advantageous with respect to energy saving, optimum sacrifice of speed and flexibility to change its characteristics as desirable.

Keywords
Component; Asynchronous machine, optimization, power saving, stability.

1. Introduction

Use of poly-phase asynchronous machine both in motor mode and in generator mode is ever increasing. So, present day scenario demands a deep study on this machine to analyze the behavior and performance of the machine in different operating condition. In different drives applications, asynchronous machine as ac drives are dominating over dc drive because of its wide range of operational characteristics. It has already been proved that ac drive is advantageous both in respect of supply and load sides. But, ac drive has some major limitations like production of harmonics, excessive drawl of reactive power and high power loss. Research is going on to cope with the ever increasing power demand and modern energy structure looks for different energy saving methods [1], [6], [9-11]. Different electricity acts and rules have been introduced for assessment of energy saving. Different standards have been introduced by IEEE, IET and IEC. Research is going on to model and simulate different power saving problems involved in induction motor application. Electric machine designers are trying to optimize the use of power and materials and hence to save energy [2], [5], [6], [7], [8], [12]. Different PWM based closed loop control systems have been proposed for optimum use of energy in drive applications. Many ANN and fuzzy based algorithm have been introduced for time based optimization of drive operation. In some modern application vector control are also being used [3], [4]. In some previous work, authors of this paper also tried to make a study the power saving which is obtainable during no load operation of poly-phase asynchronous machine. They found that the power saving 70-90% energy can be saved be reducing voltage up to 60 % keeping operation in stable [13]. In this paper, authors have taken an attempt to choose the track of change of operating point for power saving in respect of stability and transients occurred in the system

2. Power and Voltage

Torque of a poly-phase induction machine depends on slip (s) and applied voltage (V). Mathematically,

$$T = f_1(s, V) \tag{1}$$

Power consumed by the machine depends on the torque to be produced. Hence,

$$P = f_2(T) = f_3(s,V) \tag{2}$$

Equation (2) suggests that power consumed by the machine can be optimized by changing voltage, where, slip (s) is to be assessed in each step and consequently stability is to be confirmed.

In [13], voltage is gradually decreased until the slip or the speed does not change to a great extent so that the system remains stable in operation. Power consumed by the machine has been measured and power saving has been assessed. Some simulated and experimental data are presented in Table 1 and Table 2. The specifications of these motors are presented below.

3- Φ Squirrel Cage Induction Motor

Rating	:	1HP (0.75 KW)
Phase	:	3- Φ
Voltage	:	415V
Current	:	2.1A
Speed	:	1500 RPM
Power Factor	:	0.8 (lag)

Table 1: Simulated result of power saving and reduction of voltage

% reduction of supply voltage	10	15	20	25	30	35	40	45	50
% Power saving	22.5	41.6	58.3	70.83	76.6	81.25	85.4	91.8	95.0

Table 2: Experimental result of power saving and reduction of voltage

% reduction of supply voltage	10	15	20	25	30	35	40	45	50
% Power saving $(P_0-P_i)/P_0$	32.5	47.3	56.1	65.1	72.9	77.9	82.8	87.8	90.1
N (RPM)	1475	1479	1470	1455	1470	1420	1435	1430	1425

3. Optimization

Figure 1 shows that the change of power saving with the reduction of supply voltage is non linear in nature. After obtaining this characteristic, operating point can be optimized. If no reduction of supply voltage is considered, then the operating point is "O". By reducing supply voltage operating point can be shifted to P_1, P_2, and so on provided the system remains stable in all respect. Thus operating point can be shifted following any of the lines like OP_1, OP_2, OP_3 and so on.

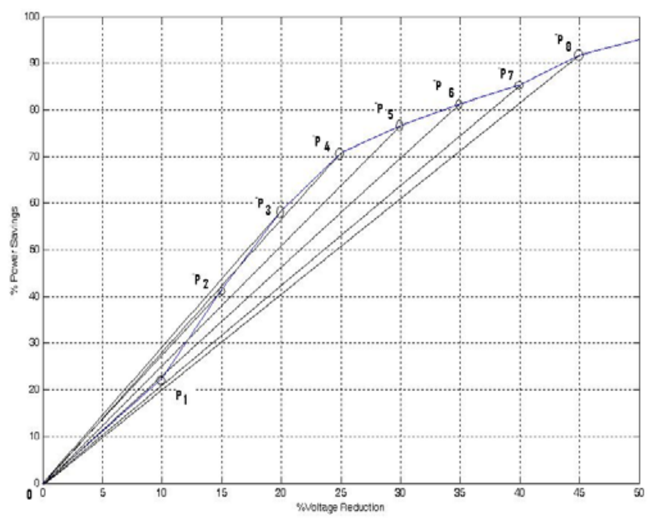

Figure 1: Power saving versus percentage reduction of supply voltage

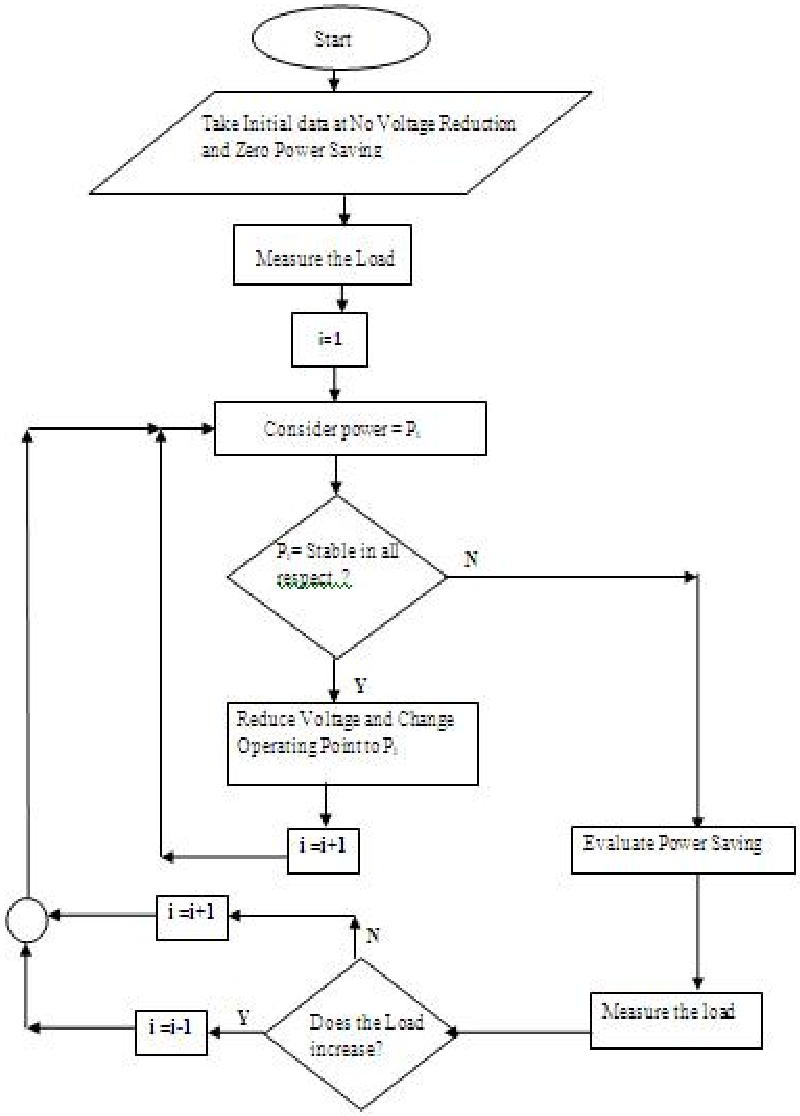

Figure 2: Algorithm for optimum power saving

Supply voltage is to be regulated changing the operating point by step keeping the operation stable. The schematic diagram of the overall optimization technique is shown in Figure 3.

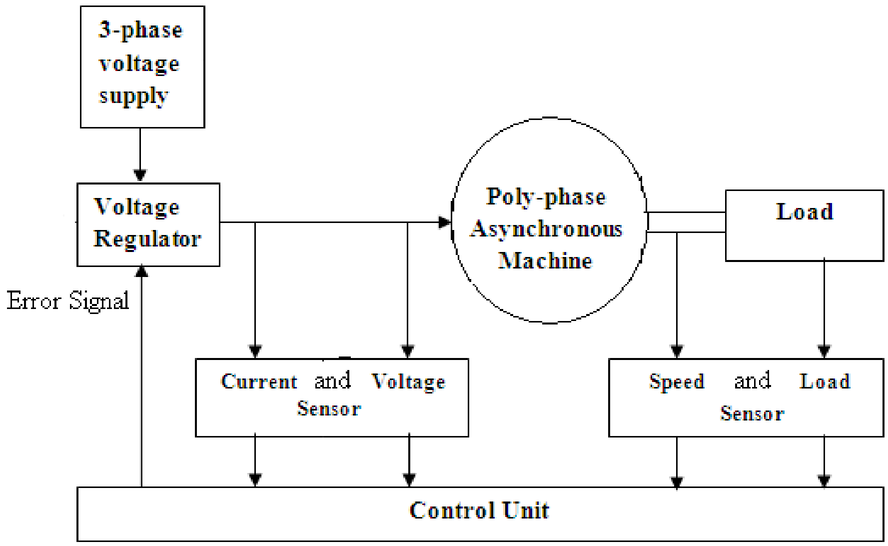

Figure 3: Schematic diagram of voltage controller

After assessing the system performance in respect of system stability and power saving optimum path should be followed avoiding other paths as shown in Figure 4.

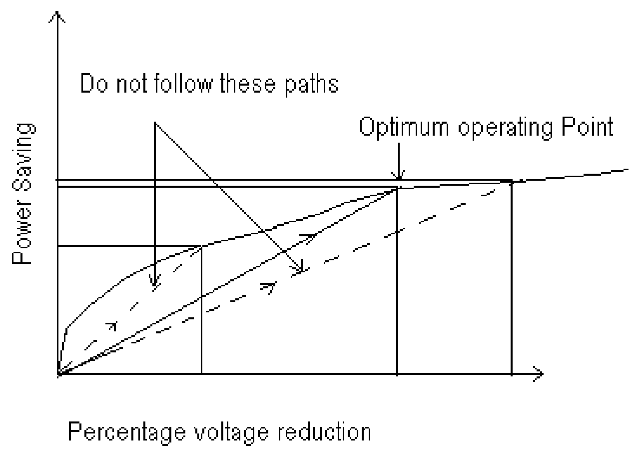

Figure 4: Optimum path to choose operating point

4. Conclusion

An algorithm has been developed to choose the optimum operating point keeping the system stable and saving power as much as possible. It has been shown that Optimum use of supply voltage can save power to a great extent. The algorithm is meritorious with respect to energy saving, optimum sacrifice of speed and flexibility to change its characteristics as desirable.

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