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Two Phase Motor under Control

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Abstract: ***The use of symmetrical two-phase stator windings with time phase control, (leaving the phase voltages eqal in magnitudes), leads to better utilization of machine material. This aidea can be extended to include many methods of control such as amplitude control, time-phase control, frequency control, voltage control and voltage-frequency control methods. If any of these methods is used, either Vc, β, f and/or Vr may be varied with the control signal. For these sugested methods, the reference voltage Vr, changes w.r.t nominal voltage Vrn, the frequency changes w.r.t the nominal frequency fn, the control voltage Vc, changes w.r.t nominal voltage Vrn and the time phase angle β decreases than 90o, respectively.***

In this paper, the operation of 2-phase motor from single-phase supply is carried out by connecting one stator phase directly to the voltage source, and exciting the second stator phase through a phase shifting element.Compared to single-phase operation, good performance characteristics with higher starting torque are achieved. It is necessary to start the analysis by using the known equivalent circuits of both forward and backward components to obtain the relations between the sequence parameters and the phase values.

In this method of control, starting torque and maximum torque values are controlled by changing the stator field from a pulsating field at zero degree to a pure rotating field which must be achieved at 90o electrical degrees.

Keywords:Two-Phase Motor, Phase-Angle Control

I. INTRODUCTION

The single-phase motors with main and auxiliary stator windings are widely used, but with out saving in both iron and cupper materials. This paper suggests exchanging the single phase motor with a modified 2-phase motor and applying the time phase control method, which makes the motor more capable and efficient.The operation of this modified motor is carried out by connecting one of stator phase directly and continuously to the 1-phase source and exciting the second phase through a phase shifting element. The extension into two-phase, enables the motor to be higher power rating, good starting conditions with resenable control and low expensive cost.

In this paper, the gradual change of motor speed is achieved by controlling the phase angle between the applied 2-phase voltages. In addition to the conventional two-phase application, the phase angle control (2, 3) will lead to more development of the motor. Beside that, the cost decrease and both maximum and rating torque increase as a result of balanced windings. Other important benefits are increasing the starting torque through satisfying a principal of rotating field at the motor start and the ability of controlling its speed through changing β from 90o to zeroo.

In order to completely describe the modified motor performance, it is necessary to derive expressions for both stator and rotor phase currents which enable the developed electromagnetic torque to be deriven. By using the method of symmetrical components, the unbalanced stator phase voltages are expressed into balanced components which include positive and negative sequence values. Consequently, the forward and backward current components are introduced and then the motor performance are determined.

Thhis analysis, provide minimum calculation effort for obtaining the stator and rotor currents and the developed torque acting on the rotor. The results can be carried out, plotted and investigated with using thephase angle β as a parameter.

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II. RESEARCH METHOD

2.1 Operation of Two-Phase Motor from Controlled Supply.

Compared to single phase operation, a good utilization of machine material is achieved by supplying the two-phase stator windings from a controlled supply. As known, the conventional single-phase induction motor contains two stator windings, main and auxiliary windings. A required capacitor is placed in series with the auxiliary winding, to give difference in time phase. The best phase angle between the two phases is nearly 90o and it is used only at a period of starting. Finally after starting, the motor, it runs depending only on the main winding with some level of humming noises associated during the running operation. All materials of iron, cupper beside the starting capacitor and centrifugal switch, are cut off through the 1-phase operation.

To run this single-phase induction motor from two-phase supply, simple modification in the stator windings must be done, wherethe starting capacitor and centrifugal switch are then not needed.The auxiliary winding of this modified motor has the same conductor diameter and coil turns as well as the main phase winding.In the modified two-phase motor, the stator 2-phase windings will completely have a new design to be suitable for thesymmetrical two-phase operation. Fig. (1), gives the modification of single-phase motor to be two-phase induction motor.Normally, a variable two phase voltage, variable frequency supply can be obtained from a single phase-two phase inverter to feed the modified and controlled motor.

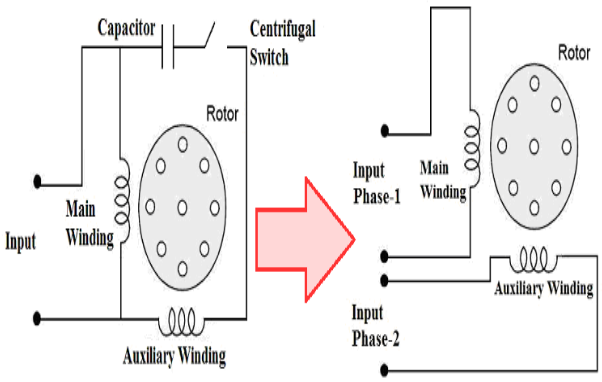


Figure 1. Conversion of single-phase operation to be controlled two-phase operation

1. Mathematical analysis and Motor Performance under Controlled Supply

In order to completely describe the motor performance under general operating conditions of unbalanced supply voltages, it is necessary to use equivalent circuit obtained for forward and backward system. The resulting current I_{s1} and I_{s2} in the first and second stator phase windings produce magneto motive forces, which are proportional to the products $I_{s1}W_{s1}$ and $I_{s2}W_{s2}$, respectively. By using the shown equivalent circuit of Fig. (2), and applying the method of symmetrical components, the motor performance are obtained. The unbalanced stator phase voltages are resolved into two balanced components, the positive and negative sequence values. Consequently, the forward and backward current components, which enable the motor performance to be determined are investigated.

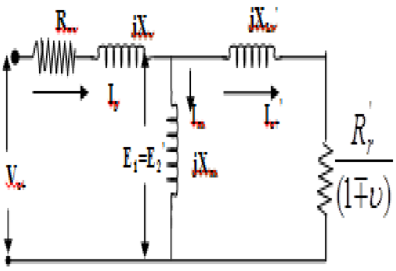


Fig (2) Equivalent circuitfor unsymmetrical two-phase induction motor

1.1 The Mathematical Analysis

Since, the method of time phase control is used, the second phase voltage V_2 is related to the first phase voltage V_1 with a time phase angle β as:

$V_2 = V_1 e^{-j\beta}$ (1)

Starting from the obtained equivalent circuit of Fig. (2), it enables now the calculations of the motor currents, the torque and the efficiency, for the values of the phase angle β. The expressions of positive and negative sequence current components can be written as:

$I_{sf} = (V_1+jV_2)/2Z_f$, $I_{sb}= (V_1-jV_2)/2Z_b$ (2, 3)

Where Zf and Zb are the positive and the negative sequence impedances given from Fig. (2). Therefore, the stator phase currents can be obtained.

$I_{s1} = (V_1/2)\,[(1+\sin\beta+j\cos\beta)/Z_f + (1-\sin\beta-j\cos\beta)/Z_b]$ (4)

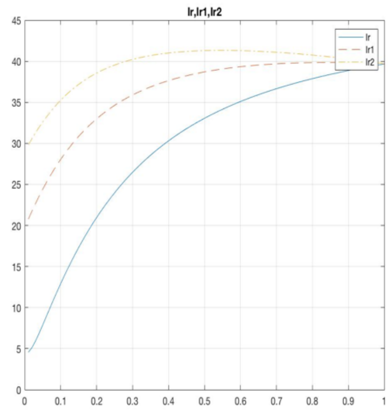
$I_{s2} = (V_1/2)\,[(1+\sin\beta+j\cos\beta)/Z_f - (1-\sin\beta-j\cos\beta)/Z_b]$ (5)

The calculations were carried out on a motor having the following parameters using Matlab Software for three values of the control angle ($0^o, 30^o, 90^o$):

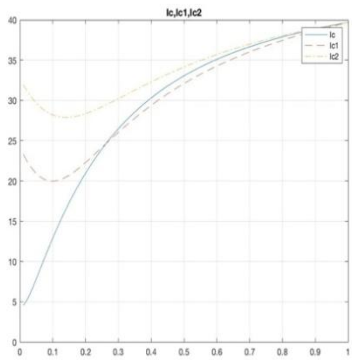
V1= 220 v, f = 50 Hz, Rs = 5 Ω, Xs1 = 2.0 ,Xs2= 2 Ω and Xm = 48 Ω. b=2.,ns= f./b, Zs1 = Rs1 + j.*Xs1,Rs2 = 5 Ω , Xs2 = 2 Ω ,Zs2 = Rs2 +j.*Xs2, Rr =1.5 Ω ,Xr =2 Ω, k1 = 1, k2 = 1.C = 30.*(10.^-6),no=1./1.,B =no.*pi./2.,v1 = k1* V, v2 = j.*v1.*1.,v2 = (cos(B)+ j.*sin(B))* V*k2,Xc = 1./(2.*pi.*f.*C), Zc = 0, zm = j.*Xmag, s=.00:0.01:1,

The following Graphs illustrate the differences of (the stator currents (refrence Ir, the control Ic),the mechanical power (Pm) and the Torque(T)) for the three cases.

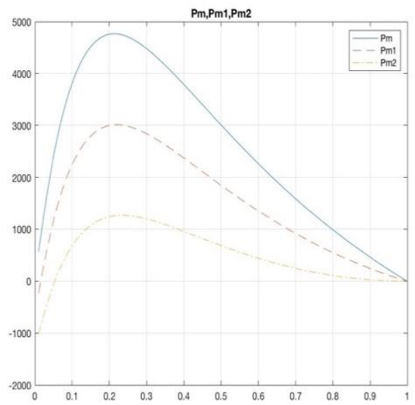
The two phase stator windings are identical, and the stator phase currents are calculated. The results of the control current are plotted as function of the relative speed υ = n/ns, or the motor slip s with different value of dimensionless signal coefficient a1 = sin (β), in Fig. (3,4), with using the phase angle β as parameter.



Fig(3)Relation Between the refrenace current with different values of β with respct to s(from 0 to 1)



Fig(4)Relation Between the control current with different values of β with respct to s(from 0 to 1)



Fig(5)Relation Between the mechanical power with different values of β with respct to s(from 0 to 1)

It is clear from the results, that the stator phase current Ic, has different values, while its maximum value obtained at only $\beta = \pi/2$ at rotating field.

It is evident that the small losses is obtained here and the corresponding high efficiency occurs when the field is a pure rotating.

The stator phase currents are known, then the electric loading may be determined and the motor performance characteristics can be obtained. The air gap power transferred from the stator to the rotor can be given :-

$$Pg = 2\ [\ I^2\ r_f\ (R_r/s) - I^2\ r_b\ R_r\ /\ (2-s)] \quad (6)$$

The mechanical power is calculated and plotted as function of the relative speed υ or the slip s in Fig.(5)

With Irf, Irb are the forward and backward components of the rotor currents. The electromagnetic torque may be then expressed as

$$T = P_g\ /\ (2\pi f/p) \quad (7)$$

The developed torque is calculated and plotted as function of the relative speed υ or the slip s in Fig. (4), with different value of coefficient a1 = sin (β), for the phase angle β is taken as parameter.

It is evident that the phase angle control gives a wide control range for the motor developed torque where β changes from 900 to 0.00.

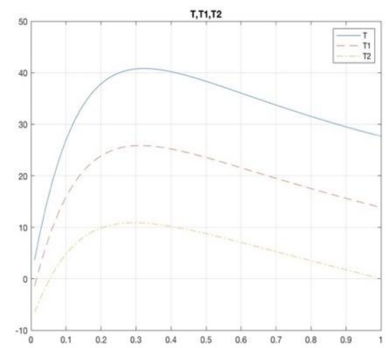


Fig (4) Relation Between the torque with different values of β with respct to s(from 0 to 1)

The intersections of the constant load torque lines with the developed torque curves, can be determine the motor speed as function of the phase angle β. Fig. (4). Shows the motor developed torque as a function of the slip. Higher starting torque ranges are obtained by changing the field from pulsating into an almost rotating field, by increasing the phase angle.

It is noted that, the reduction in the phase angle control is carried out to obtain a gradual changes in the speed. This is associated with some reduction in the pullout torque which limits the value of rated load torque.

III. CONCLUSION

The better utilization of the motor materials, during all operating conditions can be achieved by operating the single phased motor as two-phase from controlled supply.

The control method is carried out here by using phase angle between the two phase stator voltages.

The speed and the starting torque in a two-phase I.M can be changed over a wide range.

This may be carried out by changing the stator field from pure rotating field at the phase angle $\beta = \pi/2$ to a pure pulsating field at $\beta = 0.0$. The higher starting torque, maximum torque and efficiency are realized with the rotating field operation.

The obtained results are given by using the simplified analysis which expressed the controlled current, power and torque formulas in simple forms.

In order to insure a suitable speed control and a large over load capacity the phase angle must be $\pi/2$ i.e with pure rotating field .

This can be achieved only when the modified motor is supplied from an inverter of output perpendicular two-phase voltages.

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