DYNAMICAL PERFORMANCE OF A NEW TYPE OF THREE PHASE SYNCHRONOUS MOTOR DRIVE SUPPLTED BY SQUARE - WAVE INVERTERS

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ABSTRACT - In this paper , a three phase voltage source inverter synchronous motor drive is introduced which is capable of producing an approximate to sine - wave currents in the stator windings .
Compare to a conventional current forced ,synchronous machime drive, for the same machine loss , a gain in out put per unit overall volume of 125% at a 5oHz supply frequency has been achieved . In addition, the torque pulsation has been drastically reduced .
These improvements are achieved by introducing new rotor windings which are capable of controlling the stator current waveforms an approximate to sine - wave .
A computer program has been developed which can be used to predict the dynamic performance of this drive/system .
The paper describes the design of rotor windings for cylindrical rotor motor but the theory is equally applicable to salient - pole designs .

1 - INTRODUCTION

The schematic diagram of a conventional current-forced synchronous machine drive is shown in Fig.(1). AS can be seen in this Figure, the synchronous motor is supplied from a naturally commutated converter , [1-3] , which has the advantage of using a simple thyristor bridge circuit. A disadvantage of such a system is that the commutation process must be completed during a particular timeperiod of each cycle when the stator emf's is induced by the airgap flux are in the correct direction .
The commutation process take some time before it is completed which further restricts the time at which commutation can be successeflly accomplished during each cycle . The result of these restrictions is that power factor at which the motor is forced to operate can be considerably reduced . At the same time, the current and voltage wavefarms associated with line commutated inverter drives typically have a high harmonic content resulting increased loss and torque pulsation . In order to reduce the effects of these problems , the theory of design and operation of a new type of voltage - forced synchronous machine drive was proposed in, [5] .
Based on this international patent , the two six phase machine drives were designed and built at University of Manchester in Uk , [5-6] . These designs are capable of controlling the stator current waveforms approximately to Sine-wave and Square wave currents in the stator windings.
The present papers continues that research project with the main objective of designing a

2- THE THEORY OF DESIGN

The schematic circuit diagram of a three phase voltage source inverter - fed synchronous motor drive is illustrated in Fig.(2). As can be seen in this Figure , the dc centere tapped is connected to the machine nuetral point but it can be noted that practically, this connection is not usually exsist . The main aim is to design the two type of rotor windings one of which can induce an approximate to a square wave voltage shape and the other one is capable of circulating an approximate to sine - wave currents in the stator windings . Hereafter, these are named the voltage and current field windings respectively .

Considering the drive/system shown in Fig.(2), the output voltages of the inverter are approximately counterbalanced by the induced voltage shapes due to the voltage field winding .The current field winding has approximately a sinosuidal spatial distribution and is in quadrature to voltage field winding . It is not only capable of compensating the stator magnetic reaction but it can also circulate the approximate sine - wave currents in the stator phases .

With reference to, [5-6] , it is well known that the flux density distribution in airgap of an electrecal machine can be calculated if that distribution of both the rotor and stator amper conductors are known . Considering the cylindrical smooth stator and rotor machine as shown in Fig.(3) , then ,if the arigap is small , the relationship between the airgap magnetic flux density and the stator and rotor current density waves is given by .

$$b(x, t) = \frac{u_0}{g} x [j_s(x, t) + j_r(x, t) dx \qquad (1)$$

Where x is the stator displacement measured from reference point on the inner stator bore and t represents time . Equation (2) is rewritten as follows :

$$\int j_r(x,t)\, dx = \frac{u_0}{g} b(x,t) - \int j_s(x,t) dx \qquad (2)$$

Considerning Equation (2) in the steady state then , for any given stator voltage and current wave from , The b(x,t) and j_s can be calculated from stator windings and core dimentions . Once these are known then ,possible to calculate a rotor field winding to produce an approximate to it .In Equation (2) if b(x,t) is drivided into two components $b_0(x,t)$, which is the flux density resulting from Equation (2) , with no stator current , and $b'(x,t)$ the remainder due to armature reaction , Equation(2) then, be rewritten as follows :

$$\int j_r dx = \frac{g}{u_0} b_0(x,t) + \int j_s(x,t) + \frac{g}{u_0} \int b'(x,t) dx \qquad (3)$$

The soltution of j_r therfore contains two part , one part being proprtional to the first bracket (referred to as the voltage winding) and the other part proportional to the second bracket on the right hand side (reffered to as the current field winding). The voltage field winding term will vary in proportional to the stator applied voltage , and the current field winding will vary in proportion to the stator current .In designing the rotor windings , the following assumptions are mode :

1- Assuming a dc current in the rotor field windings .

2- No damper cage in the rotor and the excitation windings are current forced therefore capable of inhibiting any induced current.

Based on the above assumptions, the required rotor current density patfern will stationary relative to the rotor and an approxmation to this pattern can therefore be formed by a set of dc excited coils in the rotor slots -

3- COMPUTER RESULTS

Based on the mentioned theory, a computerprogram has been developed which can be used to design the rotor field winding arrangments for any given stator voltage and current waveforms .

Assuming a sine-wave current and a squarewave voltage shape for the stator phases then , using the same machine described in [5-6] , (a six pole cylindrical machine with a 225 stator frame , 36 stator slots and 48 rotor slots), the obtaind rotor field winding arrangments are shown in Fig .(4). The firing angle of the machine inverter can be controlled by varying the dc field current flowing into a third rotor field winding which shown in Fig .(4). This winding is in phase with voltage field winding and has a sine - wave spatial distribution .

A second computer program has been developed to predict the dynamic performance of the drive / system .

The obtained computer results are demonstrated in Figs.(5-7). From these results , the following conclusions are summarized .

4- CONCLUSIONS

The paper has described the theory of design and operation of a new type of a three phase machine commutated synchronous motor drive , which is capable of producing of an approximation to sine - wave currents in the stator windings . This therfore, offers the possibility of improving the performance of synchronous motor drives since sine - wave current improve performance parameters such as power factor , specific output power and torque pulsation .Although, a three phase voltage forced system has been described , the windings should be useful for current forced or forced-commutated inverters.

Compare to six phase design built in Manchester, this drive/system,because imploys only one inverter bridge and one stator winding set, therefore is more simple and cheaper .

5-REFERENCES

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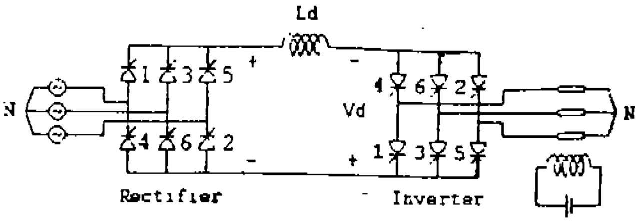

Fig .(1)- The Schematic circuit diagram of current - source inverter synchronous machin drive .

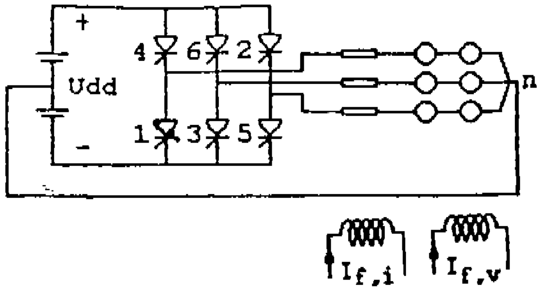

Fig .(2)- The Schematic circuit diagram of voltage - source inverter synchronous machin drive .

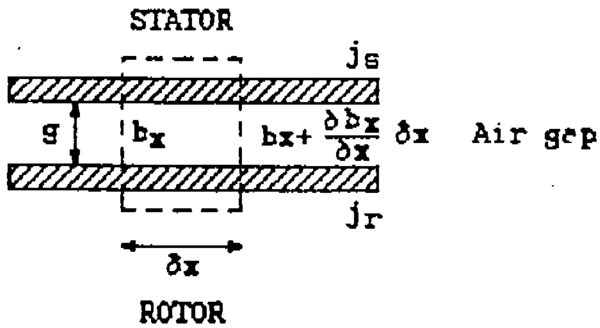

Fig .(3)- The uniform airgap model A.C machine .

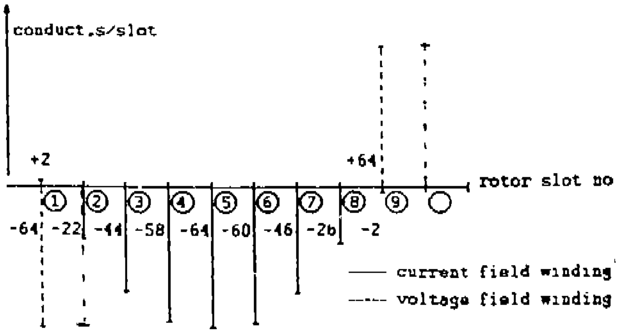

Fig .(4-1)-The rotor voltage and current field winding arrangments .

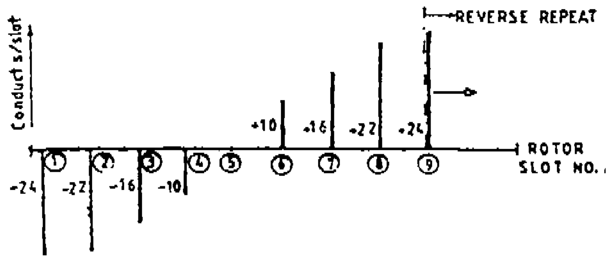

Fig. (4-2)- The third rotor current field winding arrangment .

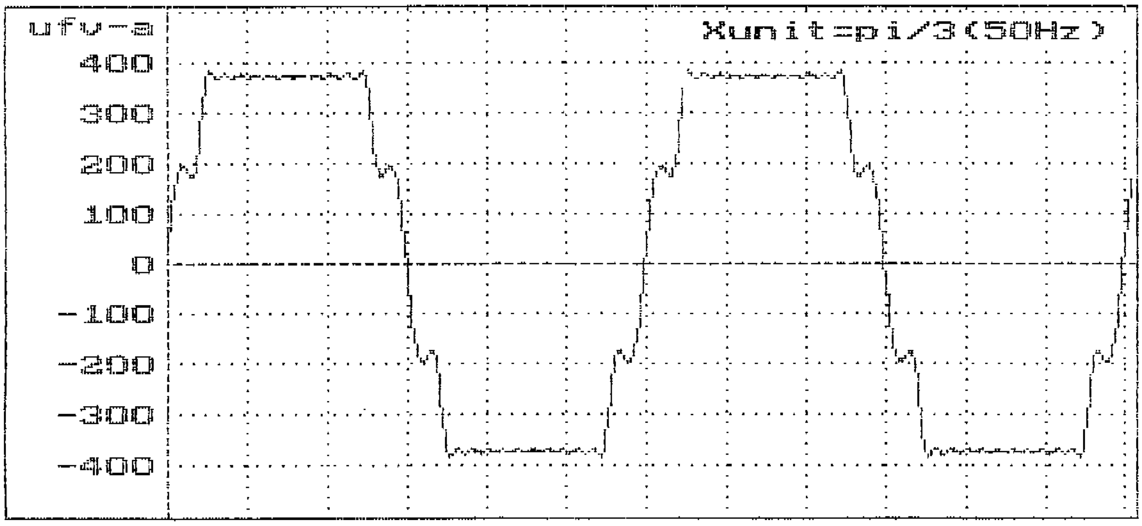

Fig .(5-1)- The induced emf waveform due to the voltage field winding .

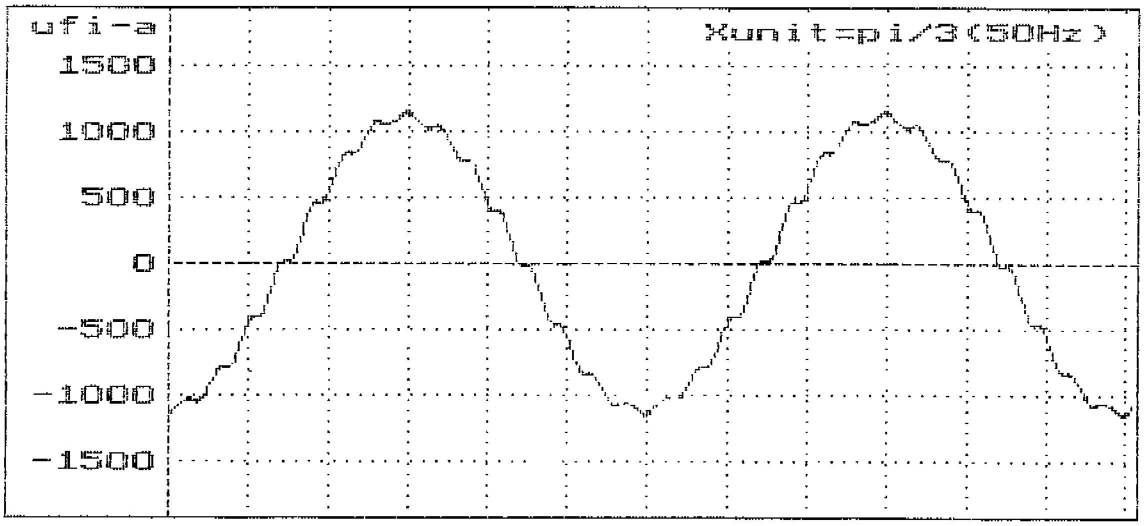

Fig .(5-2)- The induced emf waveform due to the current field winding .

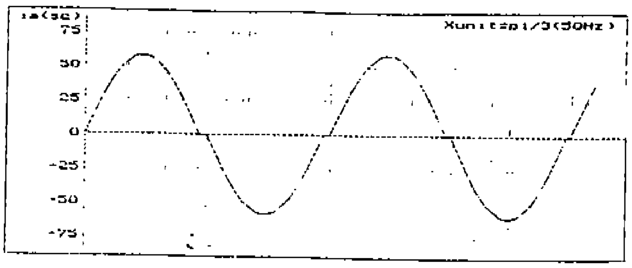

Fig (6-1)-The stator reference phase current waveform with d.c link shorted.

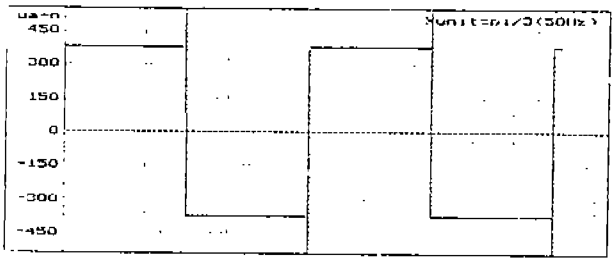

Fig .(6-2)-The motor terminal voltageshape .

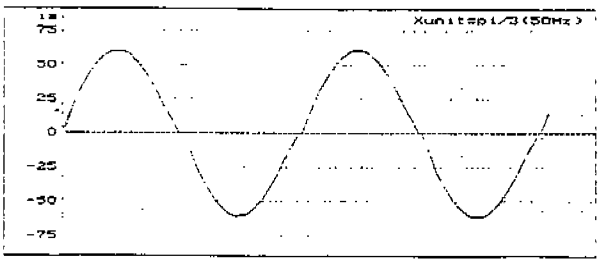

Fig .(6-3)- the stator reference current.

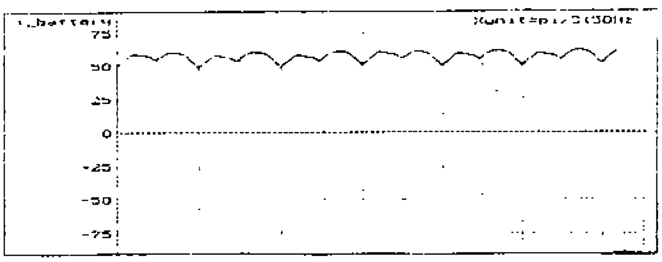

Fig .(6-4)-The d.c link current waveform .

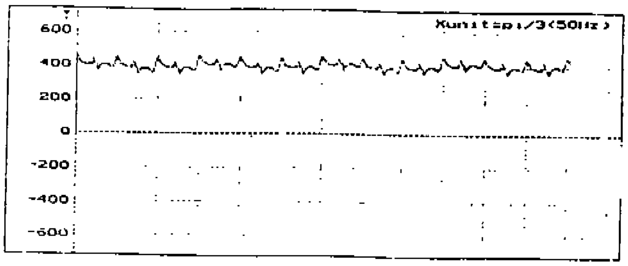

Fig .(6-5)- The motor produced torque waveshape

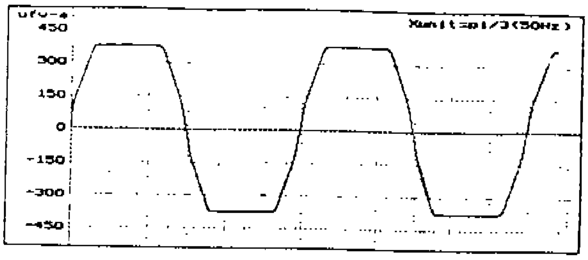

Fig .(6-6)The induced emf waveform due to the rotor volgate field with rotor skewed for one slot .

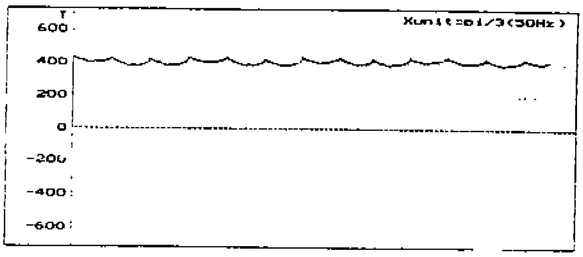

Fig .(6-7)- The motor produced torque with rotor skewed for one slot .