Performance Aanlysis of Unity Power Factor Converter-Inverter Fed Switched Relcrctance Motor Drive

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Abstrack This paper presents the analysis of a new converter-inverter topology for Switched Reluctance Motor (SRM) drive. The SRM is fed fmm s eonvwter4nvertw system The cunent controlled converter dmws sinusoidal ac curronts fmm supply mins and maintains tbem in phase witb the supply voltages, thereby facilitating unity power factor operation.

I. DJTRODUCTION

A four phase SRM rotates by successive exdtatioti of four phase windings through an inverter. The inverter feeds power to SRM by appropriately closing the semiconductor devices at accurate instants of rotor position signal. Normally, the inverter is fed from a single phase or a three phase diode bndge rectifer, which suffers from the operating problems [1] such as poor power factor, injection of harmonics into the ac mains and fluctuations in the dc link vcltage with fluctuations in supply frequency and voltage. Further, diode bridge rectifier inhibits regeneration of enew. Attempts to improve the pow' factor and to meet the IEC 555 harmonic requirements are being nlade in industries. The main thrust of this investigation is to analyse the unity power factor converter operation feeding the highly non-linear SRM drive. ,

The problems at input ac mains are overcome by using a current controlled converter in place of a diode bridge rectifier. The undesirable harmonics are eliminated and converter has unity power factor sinusoidal currents at its input. Moreover, the converter empluys hi& frequency ti-directional power switches which facilitate bidirectional. power flow through the converter lea- to the four quadrant operation 121 of the drive. With this arrangement, the energy can be easily extracted from or supplied to the ac mains [3-41 thereby facilitating regeneration. The current controlled converter operates at an adjustable pOwer fixtor and hence the system could offer the possibilities of VAR compensation. Experimental work on a chopingless converterforthe SRM with unity power Edctor andsinusoidal input current [5] is based on a converter fedby single phase ac mains. However, this paper presents a detailed andysis of a converter fed by three phase ac mains.

n. CONTROL PHILOSOPHY

Fig. 1 shows the schematic of the proposed unity power factor converter-inverter fed SRM drive system. The fast changing currents are maintained through the motor windings with the help of an IGBT based Rurent controlled invener. The current controlled inverter is prxyered with an IGBT based current controlled converter through a filter in the dc link. The input port of unity power factor current controlled converter is connected with the ac mains, controlled converter is connected with the ac d.

In the closed loop control of the converter, & link voltage and current are sensed and the dc Iink power is estimated in the feedfomd control loop [4] and a control command I, is generated. The dc link voltage is kept within permissible hiit so that for agiven ac input voltage, the current distortion and current control limits are not exceded For this purpose, a dc link voltage control loop is incorporated. Here, the reference value of the dc link voltage (V,,> is compared with the sensed voltage V, and the resulting error is processed in the PID voltage regulator which results in a cOmmand current I,. Both the current commands (I, and I>) are summed up and form the peak magnitude *(I,)* of three phase reference currents at the input of the current controlled converter. In order to oWam the unity power factor operation of the current controlled converter, unit curren; templates ($u_{\sim}$, u_b, u) are derived from the three phase ac input voltage (e_a, e,,, e) and current templates are in phase with the ac input voltages. The current templates are multiplied with I_m and three phase reference currents (i^m_a, i" i'$_c$) are generated. These are the ideal (sinusoidal) currents to operate the converter with unity powr factor.

The control of SRM is achieved by sensing the rotor position @, the derivative of which gives the motor speed. The actual speed is compared with the reference speed and the speed error is processed in the slidng mode speed controller. The speed controller produces the speed loci and switching along the speed loci is dependent upon the speed error and acceleration. The limiter Limits the maximum value of the output of the speed controller and is considered as the reference torque r) . This limit is dictated by the maximum motor rated current and current rating of devices used in inverter circuit In response to the speed error, SMC generates the control signal so that the dynamics of SRM follows certain specified trajectory. For smooth control it is desired to obtain a fast response without overshoot. The reference torque signal is used to obtain the reference current magnitude. The tum on and turn off angles are fixed and depending upon the present rotor position g, the reference current generator generates the reference cnrrent signal for each of the four phase windings of the SFUvl. The stator winding current of a particular phase is compared with its reference counterpart in a hysteresis current controller. The current controller then decides the switclmg (odaff, instants of IGBT of the inyerter.

m. MODELLING OF THE SYSEM

Each block of the above control scheme is systematically modeled for computing the transient and steady state behaviour of the SRM drive. This knowledge of instantaneous current, voltage and torque is required for the design of controller for optimum performance of the drive wrking under wide operating conditions.

A. (Irtmziit ('ontrolled Coiiverrer

The mathematical equations [4] governing the current controlled converter is represented by the following set of four equations (refer Fig 1):

$$pi_a = -(R_{sc}/L_{sc})i_3 + (e_a - v_a)/L_{ac} \quad (1)$$
$$pi_b = -(R_{sc}/L_{sc})i_b + (e_b - v_b)/L_{sc} \quad (2)$$

$pi_c = -(R/L i_+ + (e - v_J/L$ (3)

$pv_, -= (i.f_A d-^{'}+_L SB\& + i_- SEC-i_>/C$ (4)

wfiere, R, \nd L^ "are per" phase resistance and inductance, respectively,of the ac source. e,, e_b and e_c are three phase voltage applied at the input of converter. SAC, SBC and SCC are the switching functions stating the odoff positions of three phase converter'switches, v,, v_b yd v are three phase PWM voltage reflected on ac input side of the converter as a result of switching 4 is the load current a! converter output and p is the differential operator (ddt).

R. Modeling of SR Molor

Since SR motor is highly non-linear in nature, the basic volt-ampere equation goveming its current profile is

d'Y,ld' = v, - hj (5)

j=number of the phase (1 to 4). Here, v. is the instantaneous voltage across the mid-point converter'appliedto the phase winding llaving resistance R andyj is the flux linking the jth phase windng

The electromechanical equations goveming the motor behavior are:

dddt = (T, -T,)/J (6)

d8/dt = *w'* (7)

where T_I is gwen by T_e = dW/dp (8)

C. Inverrrr .\fodrlItig

The excitation of the stator windings of SRM is provided by the mid-point inverter. This inverter offers the advantage of requiring only one semiconductor switch (IGBT) per phase thereby considerably reducing the number of devices and their a d & control complexity. The hysteresis current controller contributes to the generation of switching pattern for the converter devices.

(i) Enewse Phase-1

If i, < i" Then T,ON

i, > (i," + hb) T,OFF (9)

i, < (i' - hb) T,ON.

(ii) &energise phase-1: T, OFF, D, OFF

where hb is the hysteresis band around the reference current i',. Similar switching topology can be written for other phase windings. The stator winding currents i,, $, i, and i, are regulated in magnitude as per their reference current magnitudes. The IGBT switch is dosed by an advance angle 8 such that the winding current rises to the desired current fat the start of the rising inductance region of the particular phase.

$\theta_{on} = IL_{min} w_{sc} TV_{dc}$ (10)

rw forwardmotion, the winding excitation Seauence is 1-2-341 with winding excitation Tn the rising inductance region. Reversal of direction of rotation is obtained by exciting the stator windings in the sequence 4-3-2-1-4. This is achieved by advancing the current rotor position e by IJ, (stator pole arc).

D. Sliding Mode Speed Confml

The action of sliding mode speed cantroller is based on the switching function S_I and S, whose values are decided [4] as follows!

S,I= +]ifrx,>O; S,=-1ifm,<O;

S, = + 1ifrx,>O0; S, = -lifrx,'O (11)

where$x_1$gspeederrorw_n-w_n-,: x,=px,,andr(=kx,+x,) is the switching hyperplane, k being the adjustable parameter.

The output of the sliding mode speed controller is the reference torque magnitude

T + S x (12)

Dependmg upon the turn off, turn on angles, present rotor position? and the sign of reference torque, the commutation logic decides the excitation of a particular phase, thereby giving the reference current for individual phase winding,

IV. RESULTS AND DISCUSSIONS

The developed model is simulated for transient and steaiy state behaviour of SRM. The model is solved using Fourth Order Runge-Kutta method. The simulated results of the proposed unity power factor control of SRM drive scheme are shown in Fig.2. Fig. 2a shows the starting response of the motor. The actual motor speed reaches the reference speed within 40 mSec with practically negligible overshoot. The electromagnetic torque (Fig. 2@)) required by the motor during starting is large and its value reduces as the motor speed reaches its steady state value. The torque wavefon is pulsatin% in nature ~ c h is an inherent ~~ of SRM due to the pulsed current operation. The starting current (Fig 2(c))ofpbl drawn by the SR motor winding is large and is limited by the current rating of the device employed in the inverter circuit. Howver, under steady state, the m n t requtrement of the motor is reduced The current waveforms for other phases (not shown) are similar with time shift. Effect on converter side current is similar to the statorwindingcurrent. Theconverter-largethreephase currents from the ac mains, during starting and the supply current under steady state is considerably reduced. Due to current controlled converter behaviour, the ac supply current is exactly in phase with the mains voltage thereby providing the unity power factor operation (Fig. 2id)). As expected, the m n t is not perfidy sinusoidal due to switching action of the converter.

V. CONCLIMONS

The paper presents the analysis of a three phase converter-inverter fed SRh4 drive system operating under starting as well as under steady state providing unity power fbctor operation at the ac mains thereby relieving the utility of harmful effects of low power factor. The use of current controlled converter at the supply side is found to be effective in maintaining ac current in phase with the supphl voltage. Hence, the proposed scheme is suitable and quite effective for unity power factor operation.

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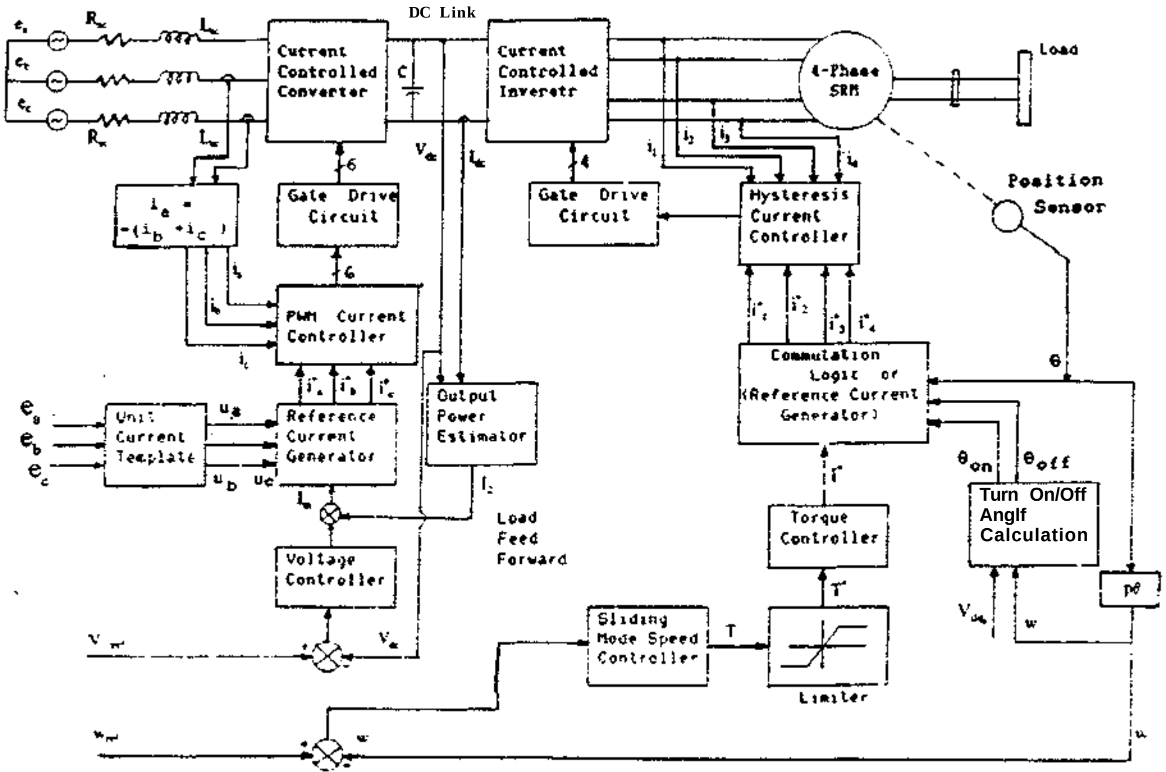
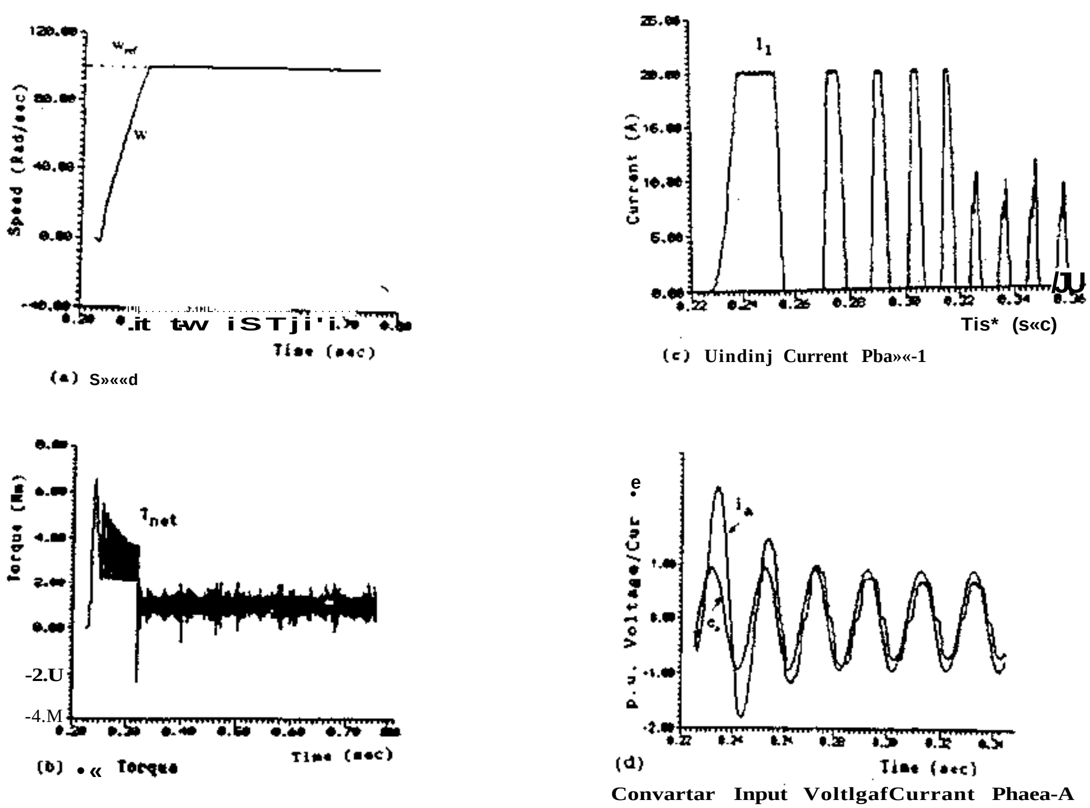


Pfg.1 Schematic Block hagram of UPF Converter-Inverter fed SRM Drive



Rg.2 Starting Performance of UPF Converter-Inv-rtor fed SRM Drive