Dynamic performance of three phase motors fed single-phase source with soft starting circuit using Simulink

Qazem Mah'd Jaber, Hussein Najeeb Alhatamleh

Abstract: The asymmetrical three-phase induction machine fed by a single phase source, already discussed with capacitor connected between two phases, can be make induction motor to produce nominal power at nominal speed with minimization of the oscillating torque, starting time and comparison with a similar symmetrical induction motor . This paper presents the dynamic model of the asymmetrical three-phase induction machine fed by a single phase source with soft starting electronic circuit with triac connected between two phases, the simulated results show that the asymmetrical induction motor with electronic circuit produce a dynamic torque and speed with acceptable starting time and minimum oscillation compared with that of a similar symmetrical induction motor. The suggested circuit and simulated model were designed and building using simulink/matlab.

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Index Terms **Electronic circuit with triac, simulink model, asymmetrical motor..**

I. Introduction

The three-phase supply system is now available worldwide, except in some rural areas where only a single- phase supply is available. Single-phase motors are the most common form in the lower horse-power ranges, but it became uneconomical for ratings above 0.5 kW. Therefore an increasing tendency to use standard three-phase motors supplied from single-phase supply if the three-phase supply is not available [1,2 and3]. In many applications it could be necessary to use three-phase induction motor or permanent magnet motors fed a single-phase supply system. For example, in the recently days the solar and wind energy generation are used for domestics applications where is only single phase source and small power are demanded. Another example is the portable pump sets which be must operated with three- or single-phase supply depending on what is available at the site [4].

The asymmetrical three-phase induction motor with single phase feeding, presents satisfied behavior when the capacitance is designed for nominal condition. But with the same capacitance the motor didn't show a good electromagnetic torque performance in respect to oscillations when outside the normal load condition, It is worth mentioning that the combination of parameters which gives a better performance for the asymmetrical three phase induction motor is slightly more complex. Due to this complicity ,obtaining an asymmetrical induction motor with performance close to symmetrical three – phase induction motor is a challenge [5,6,7]. The asymmetrical three-phase induction motor present some problems when keeping the capacitor in Figure 1 at a fixed value, and it shows also a poorer performance when compared with the ordinary three-phase symmetrical induction motor fed by a three-phase balanced source. Solving some of these problems it has been suggested in the past the possibility dynamically changing the value of Cap as a function of the motor load. However some additional problems as in reference[8], need to be solved. One of the problems, is the undesirable effects in the oscillating torque. Recent investigation on minimization of dynamically oscillating torque, using the reference frame theory has been applied to the analysis of three- phase induction motor, when particularly fed from a single phase source[9].The methodology of analysis when supplied from a single-phase source has been developed in view of the reference frame theory. Transient analysis procedure for both delta and star connections was given. The design and implementation of a controlled capacitor for a three-phase induction motor operating from single-phase supply has been presented, using a fixed capacitor in series with an electronic switch[10], the proposed system eliminates the use of mechanical or centrifugal switches which is located inside the motor. The references are not up to date because the subject is old. In this paper a triac electronic circuit with control signal replacing capacitor will be used. This avoids the possibility that leads to less operational and maintenance cost and improves the system reliability. Dynamic performance analyses of the three phase induction motor fed by a single phase source will be carried out using simulink blocks with pre- selected parameters for motor dynamic model, electronic circuit, comparison with previous investigations in the literature will be carried out**not**.

II. Simulink model

The three-phase asymmetrical induction motor fed by a voltage single-phase system has a squirrel-cage rotor and stator where the three-phase windings are located with each phase spatial displaced of 120o and different turns number in each phase according to design considerations. With the utilization of a capacitance, cap, connected between phases B and C, as in Figure 1.

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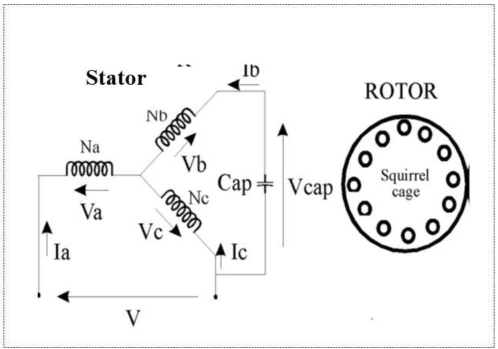

Figure 1. Schematic diagram for an asymmetrical three-phase induction motor.MATH

Figure 1 shows that the capacitor current is ib, and from this figure the expression of the capacitance voltage with respect to time can be derived also,[7] which is given by:

$dVcap/dt = -1/Cap\ i_p$.... .(1)

Analysis the circuit obtained in figure 1, the following two equations can be deduced:

$ic = -(ia + ib)$ ……………………(2)

$V = Va - Vc =$ .... (3)

A 6x6 impedance matrix [L] should bevmade to represent the majority of aspects of the asymmetrical motor, such as the different turns ratio in each phase, the 1200 between the phase2windings A, B and C in the stator and their different number of making the windings asymmetrical. The flux linkage [λ] and current [I] vectors are represented by two 6x1 vectors. So the expression for the flux linkage is:

$[\lambda] = [L].[I]$………………………. (4)

Induction motor voltages could be represented by:

$V = r.\ i + d\lambda/dt$......................(5)

Where, i(a, b, c, A, B, C) and r(a, b, c, A, B, C) are the stator and rotor currents, the stator and rotor resistances respectively. The differential equation for flux can be obtained from equations (5) and (1). The mechanical equations for the motor are given by

$d\omega r/dt = 1/J(Tm-Tl)$………………… (6)

$d\Theta dt = P/2(\omega r)$…………………… ..(7)

$Tm = P/4[I]^T[\partial L/\partial \Theta][I]$……………. .(8)

To have a reasonable simulating conditions, parameters ωr and Tm will be used as state variables, so equations (6) and (8) should be expanded in such a way that the derivative of rotational speed could be obtained as a function of currents and displacement angle (θ). The dynamic model of three phase induction motor fed by a single phase source can be build using differential equations though this is not our mentioned objective yet. In this work the simulink/matlabe blocks will be applied to the dynamic analysis of a three-phase induction motor, furthermore, investigation may be extended to the permanent magnet motors when fed from a single –phase source .The methodology of motors analysis when supplied from a single –phase source with soft starting will be developed .

The three-phase induction motor circuit using a triac-starter that connected between phase A winding and phase B winding instead of capacitor is presented in Fig.2. It is clear from the principle circuit that the triac-starter consists of anti-parallel thyristors with firing currents, i.e. Ig.

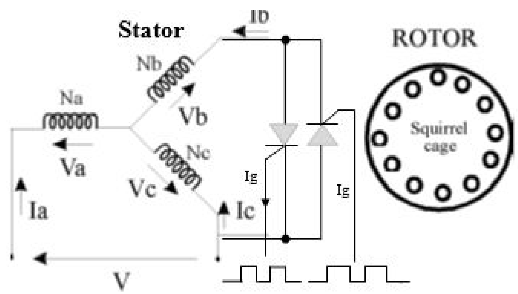

Figure2. Schematic diagram of the asymmetrical three-phase induction motor with soft starting circuit Units

Fig. 2. indicates that the dynamic model of the three phase induction motor triac-starter fed with single phase source building with blocks of Matlab/Simulink software package program, consists of standard toolboxes that enables simulation of an actual engineering systems, The differential equations (1-8) were used to obtain the dynamic model of the three phase induction motor fed by single phase source with soft starter studied system as shown in Fig. 3. In this Figure, the triac-starter was modeled together with motor, hence making it easier to compute motor's characteristics , make analysis, and ease of comparison with other system, i.e. input and output. The inputs include source and output voltage of stator windings with triac-starter, while outputs comprise the d–q axis stator current, motor's torque and speed.

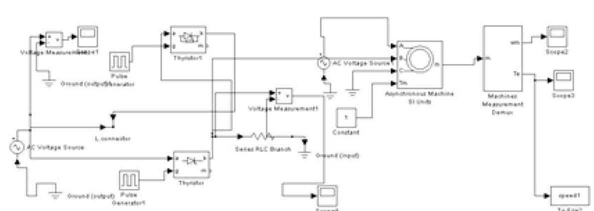

Fig.3. Dynamic model of three phase induction motor fed single phase source with soft starter

The detailed electronic triac-starter connected with the winding of the a asymmetrical induction motor is shown in Fig. 4, and the firing angle has been selected to acquire the maximum starting torque. The pulse generator provides pulses required for firing thyristors, and the delay angle was selected from the pulse cycle and delay time of the pulse generator

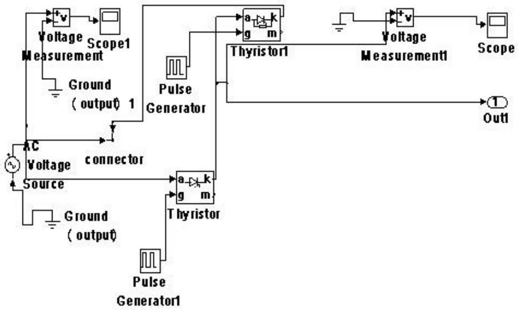

Figure 4. Triac-starter model in Simulink.

III. MOTOR DATA AND SIMULATION RESULTS

Following are the parameters of the induction motor chosen for the simulation studies.

Type : three-phase, wye-connected, squirrel cage induction motor ;Nominal power :Pn = 3*746(va) ;Nominal stator voltage :Vs= 220v;Frequency:f=50Hz;Number of poles= 4

Stator resistance: Rs =0.435ohm;Stator leakage inductance :Lls =0.002 H; Rotor resistance referred to stator: Rr =0.816 ohm; Rotor leakage inductance referred to stator: Lr = 0.002 H; Mutual inductance :Lm =0.06931 H ;Mass moment of inertia of the rotor: J = 0.089 kg.m^2; Coefficient of friction = 0.

To illustrate the application of the dynamic model of the asymmetrical induction motor to transient operation, a simulation study of direct-on-line starting is demonstrated at the initial

instant of time, t = 0, the motor, previously de-energized and at standstill, is connected to a 220 V, 50Hz supply. The load torque, TL, is assumed to be % of the rated torque of the motor, and independent of speed. The mass moment of inertia, JL , of the load equals that of the motor.

Fig.5; 6 and 7 show the results of computer simulation using the SIMULINK model. The torque oscillations of the three phase induction motor fed single phase source with soft electronic starter in the torque characteristic are reduced and damped more rapidly, but the run up time of the motor is longer as shown in fig.7

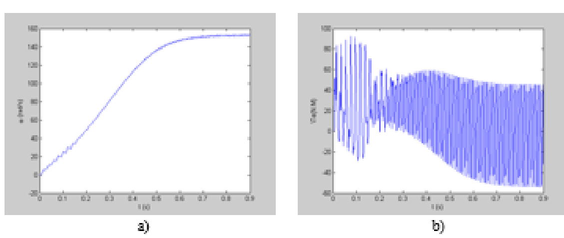

Figure5- Asymmetrical three phase induction motor transient state at 1N.M load torque.a) speed ; b)torque

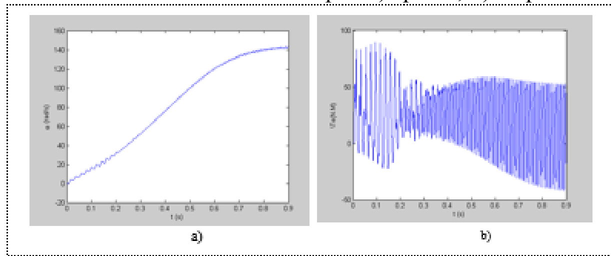

Figure 6 – Asymmetrical three phase induction motor transient state at 4N.M load torque. a) speed ; b)torque

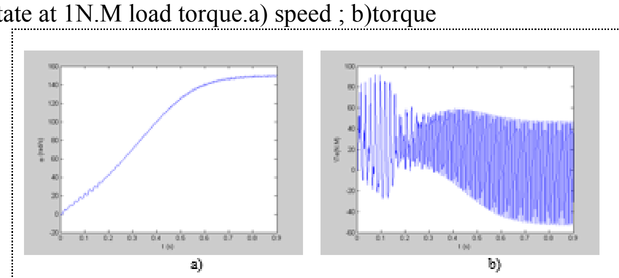

Figure 7 – Asymmetrical three phase induction motor transient state at 9N.M load torque.a) speed ; b)torque

The simulated model of asymmetrical three phase induction motor fed single phase source with capacitor shown in fig.8.The simulated result for speed and torque for three phase asymmetrical induction motor transient state shown in fig.9

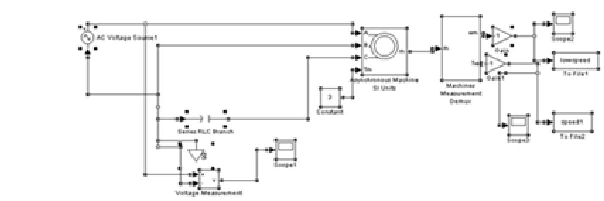

Figure8. Dynamic model of three phase induction motor fed single phase source with capacitor starter

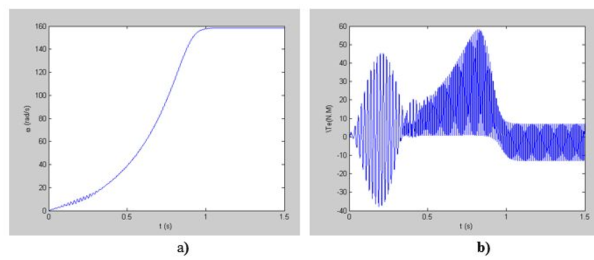

Figure 9 - Asymmetrical three phase induction motor with capacitor (30 mf) transient state at 3 N.M load torque.

a) speed ; b)torque

CONCLUSION

A dynamic simulation of three phase asymmetrical induction motor fed single phase source with electronic triac-starter has been investigated and presented in this theoretical investigation. It has been shown that it is possible to obtain the maximum torque by using electronic triac-starter as compared to conventional capacitor without any difficulty. In this study, it is concluded, that in the case of asymmetrical three phase induction motor with electronic triac-starter the transient state is smoother, than the transient state of the asymmetrical three phase induction motor with conventional capacitor at 3N.M load. Such finding could be attributed to the fact that the start time required by the electronic traic-starter is slightly greater than that when starting capacitor was used. It is believed that such a new starting system would improve the performance of these motors, hence consumers and industry may benefit from the obtained results and advantages. translation journals, please give the English citation first, followed by the original foreign-language citation [8].

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