Dynamic Modelling Of Single-Phase Permanent Capacitor Induction Motor and Study of Non-Linear Phenomenon

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Abstract:

This paper presents a non-linear dynamic model of a permanent capacitor single-phase induction motor. The D–Q axis model of the permanent capacitor induction motor, based on the state vector analysis of the system is conducted; revealing the periodic and chaotic phenomenon under different system parameters. Accordingly, a chaotic-speed fan can be achieved by appropriately varying the motors' internal parameters or the operation condition. Mathematical analysis and computer simulations are attached to testify the proposed non-linear model of the permanent capacitor single-phase induction motor.

Keywords: bifurcation, chaos, non-linear, permanent-capacitor, periodicity, phase-plot, single-phase.

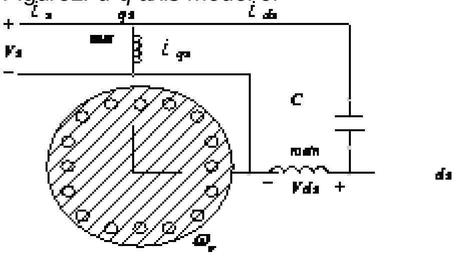
Introduction:

Permanent capacitor single-phase induction motors (SPCIMs) are commonly found in the drive systems of fans, compressors and pumps etc. Here in these particular modelling performance characteristics of the induction motors circuit of lumped parameters are used; offering simplicity and fast computation. Assumptions of the mathematical linearity of magnetic circuits and negligible slotting of the stator and rotor are considered. Chaos can be defined as an a-periodic long term behaviour in a deterministic system that exhibits sensitive dependence on initial condition. Power systems, power converters, motor drives, telecommunications and medical electronics are few of the electrical systems that have already been identified to exhibit chaotic behaviors; characterized by a noise-like spectrum which has a continuous broad-band nature. As the initial state of a practical system can only be specified with some tolerance, the long-term behaviour of a chaotic system can never be predicted accurately.

D-Q axis modeling of the motor:

The D-Q model a single phase induction machine can be considered to be an unsymmetrical two phase induction machine. Three-phase machines' modeling can be easily be defined by the D-Q axis modeling. The equivalent circuit thus obtained can be represented for the SPIM is shown in alongside figure, and the machine is modeled by the following equations:

Figure1*: d-q axis model of*



$$V_{qs}^{s} = V_s$$

$$V_{ds}^{s} = V_s - \frac{1}{C}\int i_{ds}\,dt$$

$$V_{ds} = i_{ds} R_{ds} + p\lambda_{ds} - \omega_r \lambda_{qs}$$
$$V_{qs} = i_{qs} R_{qs} + p\lambda_{qs} + \omega_r \lambda_{ds}$$
$$V_{dr} = i_{dr} R_{dr} + p\lambda_{dr}$$
$$V_{qr} = i_{qr} R_{qr} + p\lambda_{qr}$$

$$T_e = \frac{p}{2}\left(\lambda_{ds} i_{qs} - \lambda_{qs} i_{ds}\right)$$

$$T_e = T_L + J\frac{d\omega_r}{dt} + B_m \omega_r$$

$$\Rightarrow \frac{d\omega_r}{dt} = \frac{T_e}{J} - \frac{T_L}{J} - \frac{B_m}{J}\omega_r$$

where,

R_{dr} = Direct axis rotor resistance,

R_{qr} = Q-axis rotor resistance,

L_{lds} = Direct axis stator leakage inductance,

L_{lqs} = Q-axis stator leakage inductance,

L_{md} =Direct axis mutual inductance,

L_{ldr} = Direct axis rotor leakage inductance,

L_{lqr} = Q-axis rotor leakage inductance,

L_{mq} = Q-axis mutual inductance,

ω_r = Rotor angular speed and

ω = Speed of the reference frame,

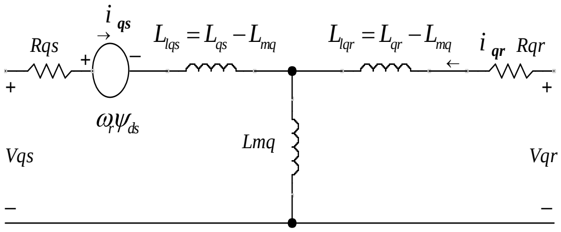


Figure 3: *Equivalent Q-axis model of the induction motor*

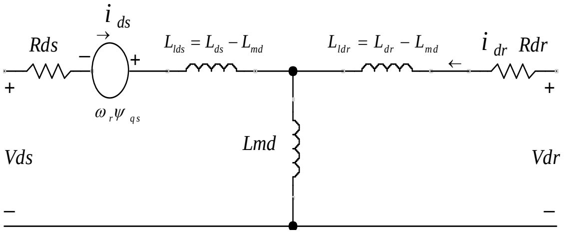


Figure 2: *Equivalent D-axis model of the induction motor*

MATLAB/SIMULINK Modelling:

For a system possessing more than one unique behavior, as a parameter is varied, an abrupt change in the steady-state behavior of the system is called a bifurcation. Here we vary the amplitude of applied voltage. The voltage is varied from zero to 160 volt (r.m.s). The Two (main and auxiliary) stator windings are displaced 90 degree in space. Normally the capacitor is connected with auxiliary winding and the value is selected in such a way that the auxiliary current leads the main winding current by 90 degree for balanced operation. The modeling of the single phase permanent capacitor induction motor projects the non-linear model of the system.

Here to inject non linearity the capacitor is connected to the main winding instead of auxiliary winding and the inductance value of the auxiliary winding is chosen in such a way that the phase difference of currents in the two winding is very less and also different in magnitude. It can be found that the chaotic speed waveforms offer the well-known chaotic properties, namely random-like but bounded oscillations. Also, these waveforms are a-periodic and very sensitive to the initial condition. Physically, these chaotic motions reveal the unbalanced status of the interaction between the magnetic fields by the main winding and the auxiliary winding.

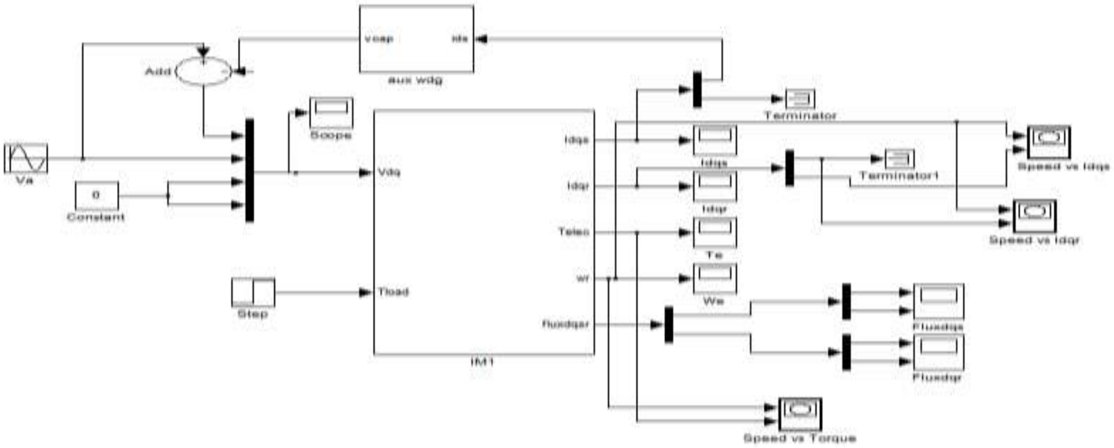


Figure 4: *MATLAB/SIMULINK model of dynamic model of a permanent capacitor single-phase induction motor.*

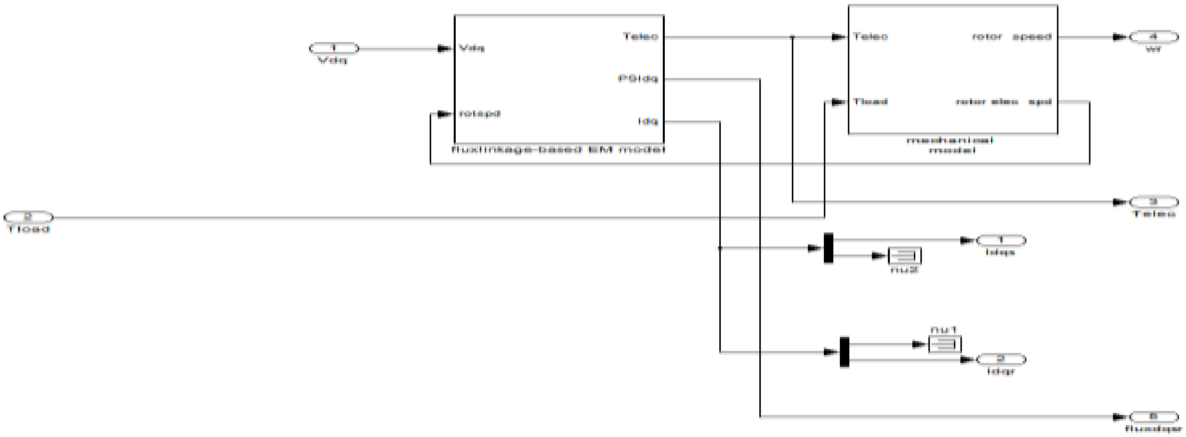


Figure 5: *MATALB/SIMULINK sub-systems for the induction motor*

Parameters	**Value**	**Parameters**	**Value**
Pair Of Poles	1	$L_{\overline{lqr}}$	0.000482 H
R_{ds}	20 Ω	$L_{\overline{mq}}$	0.12 H
$R_{\overline{qs}}$	20 Ω	J	0.00007Kg-m^2
L_{lds}	0.0211 H	B_m	0.001e-2 N.m.s
$L_{\overline{lqs}}$	0.0117 H	C_{run}	211.5μF
$L_{\overline{md}}$	0.2356 H	$R_{\overline{dr}}$	9.5 Ω
$L_{\overline{ldr}}$	0.000482 H	$R_{\overline{qr}}$	4.5Ω
Frequency (f)	40Hz		

Table 1: ***Motor parameters***

Results and simulations:

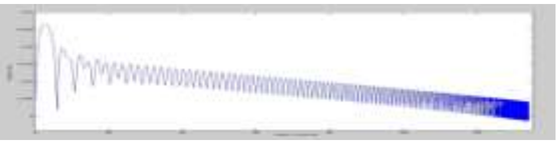


Figure 6: *Speed-Torque Curve for 10 Volt*

Figure 7: *Speed Waveform for 10 Volt (R.M.S)*

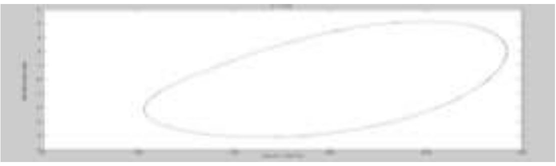


Figure 8: *Idr vs speed for 80 Volt (R.M.S)*

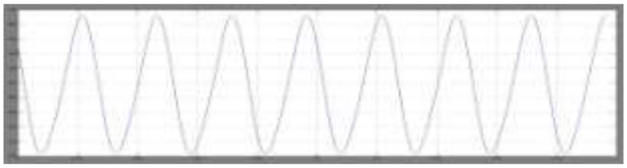


Figure 9: *Speed waveform (Period One) for 80 Volt (R.M.S)*

Figure 10*: Idr Vs Speed for 100 Volt (R.M.S)*

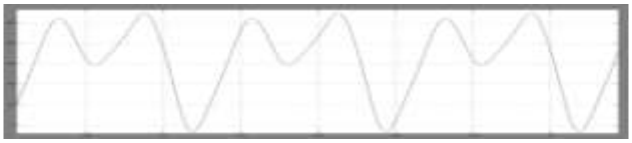


Figure 11: *Speed waveform (Period Two) for 100 Volt (R.M.S)*

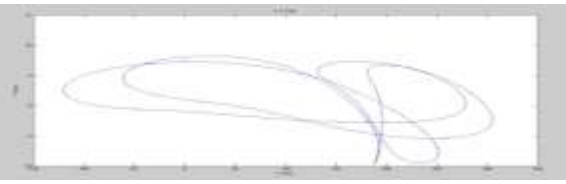


Figure 12: *Idr Vs Speed for 140 Volt (R.M.S)*

Figure 13: *Speed waveform (Period Five) for 140 Volt (R.M.S)*

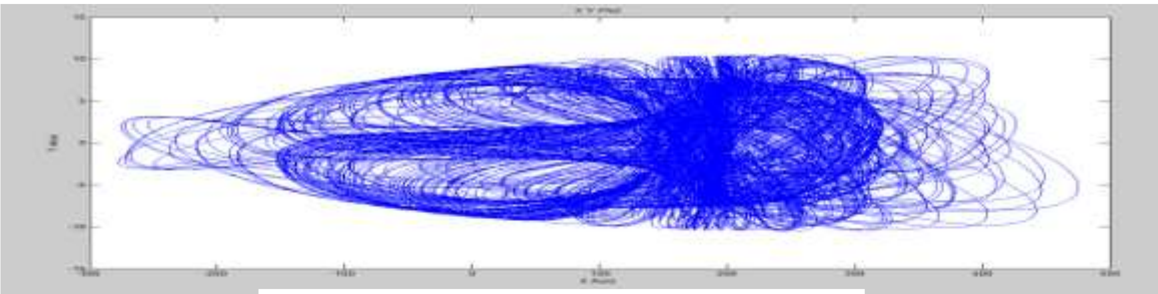


Figure 14: *Idr vs Speed for 160 Volt (R.M.S)*

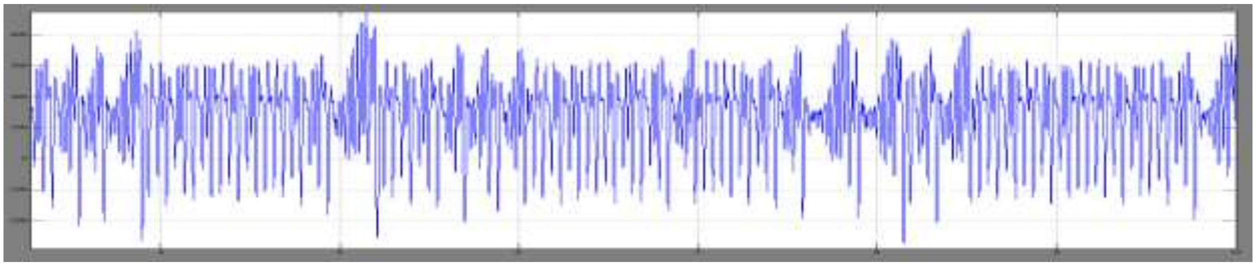


Figure 15: *Chaotic Speed for 160 Volt (R.M.S)*

Conclusions:

The non-linear phenomenon in permanent capacitor single-phase induction motors (SPCIMs) are observed as the input voltage is varied from 0 to 160 Volts. Figures have shown above represents the speed waveforms and the corresponding phase-portraits, at various periodic-speed operations, namely the period-1, period-2 and period-6 operations. These waveforms consist with the well-known phenomenon of inevitable torque pulsation. It should be noted that once the operating condition are known, the motor parameter whose variation bringing chaos may be more than one. Possible candidates are the ratio of *B*m to *J*, main winding resistance, split capacitor and so on.

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