COMPUTER SIMULATION OF A 3-ϕ SQUIRREL-CAGE INDUCTION MOTOR BY USING VISUAL BASIC 6.0

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ABSTRACT

Computer Simulation is a well-known technique of understanding, testing as well as developing real systems in Engineering and Science. The author has been working on this since 1990-91. Initially, senior members of the research group at the University of Sussex UK did Computer Simulation of a single-phase squirrel-cage induction motor by using FORTRAN 77 as a programming tool [09]. The author accepted the challenge for an interactive simulation of a 3-ϕ squirrel-cage induction motor to cope with the so demanding investigations of systems using 3-ϕ squirrel-cage induction motors. Thorough investigation of the programming languages available was carried out at that time and ultimately Microsoft QBASIC 4.5 was chosen to perform the task. That was later on presented [1] for understanding trends and various operational modes of a thyristor fed, phase controlled induction motor (three-wire) model [2].

In this paper, Computer Simulation of the same model [2] is presented in Microsoft Visual Basic 6.0 by taking advantage of the tremendous growth of the Computer Programming Languages. This simulation extends the author's research work by utilizing the effectiveness of Microsoft Visual Basic 6.0 for its visual as well as graphical representation. This drifts up the researchers for a wider range of investigations and analysis options for research and development in the field.

1. INTRODUCTION

Microsoft Visual Basic 6.0 offers great visual as well as graphical representation which has been effectively utilized for the computer simulation of an induction motor model [2], previously performed by the author in the Microsoft QuickBasic 4.5 [1]. This is presented for a thyristor fed, phase controlled induction motor (three-wire) system. The simulation performed offers a highly effective solution for investigations and analysis of a variable voltage phase-controlled induction motor system by using inherent features of Visual Basic 6.0.

Complete study and graphical representation snap shots are presented. Simulation results presented deliberate their correctness while compared with the previous simulation results.

1.1 BACKGROUND

Modeling and simulation is becoming an important tool in solving and understanding numerous and diverse problems [10, and 11]. Computer programming and its versatility has given it a new trend especially when the computer simulation of real systems is concerned. This is proved as a comprehensive result of the computer simulations carried out by the author. It is a continuous process. This is clearly shown that the simulation in Microsoft Visual Basic 6.0 is more effective as compared to the one in FORTRAN 77 and even the one in Microsoft QBasic 4.5 [1]. This simulation is based on d-q axes model of 3-ϕ squirrel-cage induction motor which is widespread [1, 2, 6, and 07] for the machine analysis.

2. INDUCTION MOTOR MODEL ILLUSTRATION

Keeping in view the fact that; the squirrel cage induction motor inherently being less expensive and robust is extensively used in a variety of systems for various applications [3, 4, 08 and 12]. Thyristor, phase controlled induction motor system shown in figure -1 is simulated. In which voltage is applied to the motor stator windings by using back-to-back connected thyristors as controlled switches in series with the stator.

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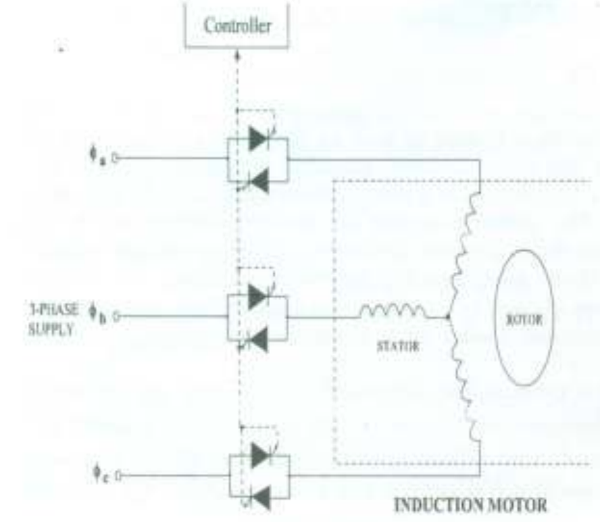

Figure 1: Induction Motor System

An equivalent scheme Figure-2 replaces thyristor pairs with switches S_1, S_2, S_3 in series with the 3-ϕ supply voltages at ϕ_a, ϕ_b, ϕ_c and a three-phase star-connected motor stator with phases as, bs, cs respectively.

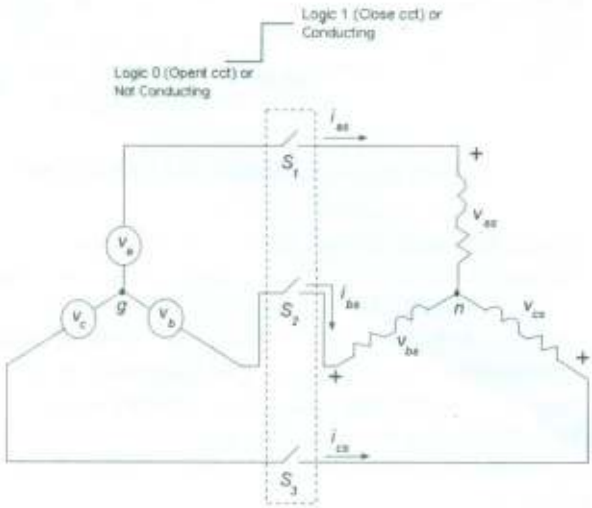

Figure 2: Stator Circuit with Switches

2.1 MATHEMATICAL REPRESENTATION

Chattopadhyay A [2] suggests d-q axes for phase control configuration for computer simulation of the squirrel-cage induction motor model. This along with generalized motor performance equations and their transformation to d-q axes representation and vice versa [5], for calculating instantaneous real values of the induction motor operational parameters is used as a base in the simulation. Five operational modes are worked out for a system figure-2, given as:

Mode	S_1	S_2	S_3	S	Φ-a	Φ-b	Φ-c	i_{as}	i_{bs}	i_{cs}
I	1	1	1	1	Conducting	Conducting	Conducting	Non-Zero	Non-Zero	Non-Zero
II	0	1	1	1	Open	Conducting	Conducting	Zero	Non-Zero	Non-Zero
III	1	0	1	1	Conducting	Open	Conducting	Non-Zero	Zero	Non-Zero
IV	1	1	0	1	Conducting	Conducting	Open	Non-Zero	Non-Zero	Zero
V	0	0	0	0	Open	Open	Open	Zero	Zero	Zero

During the analysis of this system, core losses, space harmonics and magnetic saturation are neglected.

Generalized set of equations [2, 5] are given below. Putting an appropriate state of the switches can drive equations for an individual mode of operation.

$$\frac{\rho}{\omega_b}\bar{i} = \overline{X_g}^{-1}(\overline{v_g} - \bar{R}\bar{i}) \qquad (1)$$

Where $\overline{v_g}$ is generalized voltage vector and $\overline{X_g}^{-1}$ is an inverse generalized reactance matrix, and are written in terms of the logic variables S_1, S_2, S_3, and S as below;

$$\overline{v_g} = \begin{bmatrix} S_1\left\{\dfrac{(S_2 - S_3)v_a - S_2 v_b - S_3 v_c}{(1 + S_2 + S_3)}\right\} \\ \dfrac{1}{2\sqrt{3}}\{S_1(S_2 - S_3)v_a - S_2(1 + S_3)v_b + S_3(1 + S_2)v_c\} \\ 0 \\ 0 \end{bmatrix}$$

and $\overline{X_g}^{-1} = \dfrac{1}{x_s x_r - S x_m^2} \times$

$$\begin{bmatrix} x_s - S_2S_3(1-S_1)\frac{x_m^2}{x_r} & 0 & -S_1(S_2S_3+3)\frac{x_m}{4} & S_1(S_3-S_2)\frac{\sqrt{3}}{4}x_m \\ 0 & x_s & S_1(S_3-S_2)\frac{\sqrt{3}}{4}x_m & -(S_2+S_3+2S_2S_3)\frac{x_m}{4} \\ -x_m+S_2S_3(1-S_1)\frac{x_m^2}{x_s x_r} & 0 & x_r-(S_2+S_3+2S_2S_3-4S_1S_2S_3)\frac{x_m^2}{x_r} & S_1(S_2-S_3)\frac{\sqrt{3}x_m^2}{4x_r} \\ 0 & -x_m & S_1(S_2-S_3)\frac{\sqrt{3}x_m^2}{4x_r} & x_r-S_1(1-S_2S_3)\frac{3x_m^2}{4x_r} \end{bmatrix}$$

and S in terms of the logic variables S_1, S_2 and S_3, is given as $S = S_1 * S_2 + S_3(S_1 + S_2 - 2S_1S_2)$

Equations for any of the five operational modes can be obtained from the generalized form by substituting the appropriate values of S_1, S_2 and $S3$. Where as the electromagnetic torque in terms of d-q variables, and Per unit rate of change of synchronous speed are calculated as;

$$T_E = x_m\left(i_{qs}i_{dr} - i_{ds}i_{qr}\right) \quad (2)$$

$$\rho\omega = \frac{T_E - T_L}{2H} \quad (3)$$

ω is the per-unit rotational angular speed and is equal to $\frac{\omega_r}{\omega_b}$; where ω_b is the base angular speed $(2\pi f)$ and ω_r is the rotating angle speed i_{qs}, i_{ds}, i_{qr}, and i_{dr} are the respective d-q axes stator and rotor currents, ρ is the operator $\frac{d}{dt}$. Equations above are used to compute the performance of Induction Motor.

3. SIMULATION DETAILS

Input / motor parameters [1, 2, 09].;

Stator and rotor resistance and reactance (R_s, R_r, *and* X_s, X_r, X_m) are;

$Rs_{=0.0386}$

$R_{r=0.0541}$

$X_{s=2.1440}$

$X_{r=2.1440}$

$X_{m=2.20400}$

Inertia ($H = 0.2200$),

Number of pole pairs (P),

Supply frequency (FS),

Load torque (TL),

Integration step time duration ($TINCRT$),

Data display time length ($JPRINC$),

Time to apply the load torque (TLS),

Type of operation i.e., direct-on-line operation ($DOL = 1$),

First firing time ($TFFP$),

Width of notch (γ) i.e., thyristor hold-off time,

Motor speed (WPU),

Time and total duration to store the data into appropriate files on a disk (*TDT and TDATA*),

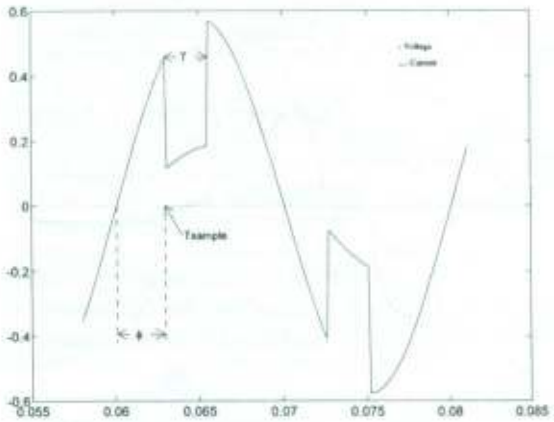

Figure 3: Definition of Various Terms on VI

Time range for graphical display ($TRANGE$), and maximum simulation run time ($TMAX$)

The simulation program run for a 3-ϕ, 415 V, 50 HZ, 4.1 A, 2.5 hp, squirrel cage induction motor with the basic per unit values as mentioned above.

The program flow chart is given below in Figure 4.

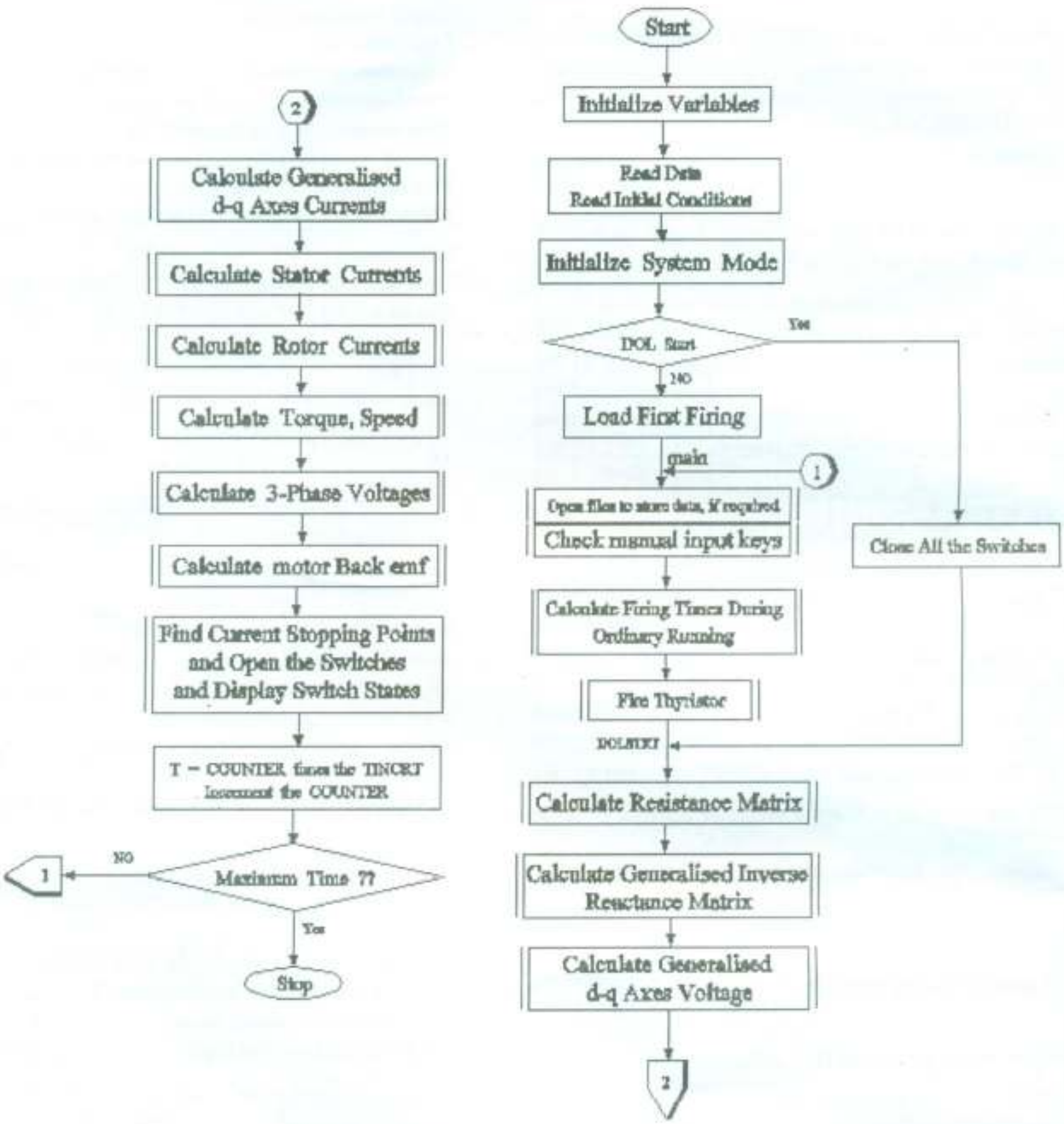

Figure 4: Main Program Flowchart

The program is fully interactive, specifically utilizing the visual as well as graphical features of VB 6.0.

3.1 SIMULATION RESULTS

Investigation of direct-on-line start (i.e., $S_1 = S_2 = S_3 = S = 1$ figure-5) as well as setting up the soft start figure-6 is an interesting feature of the author's computer simulation [1]. This can now be studied and researched more effectively with this new simulation in VB 6.0 Visualization feature and real time graphical representation of the transient behavior of the simulated system that eases in developing the required application oriented systems.

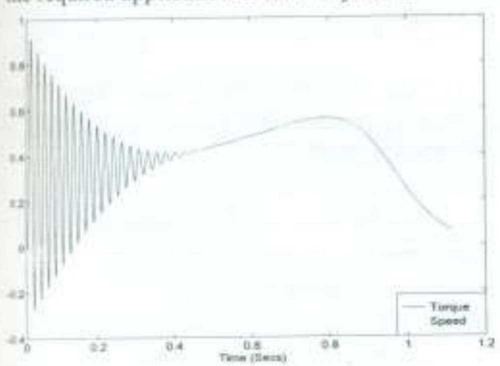

Figure 5: DoL Motor Torque, and Speed [1].

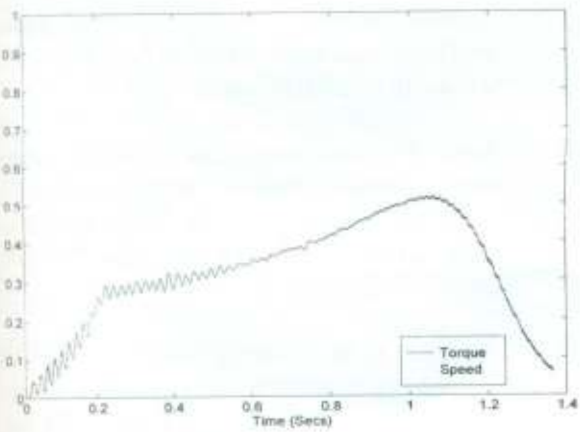

Figure 6: Motor Torque, and Speed, during soft start [1].

Figures below compare the Motor terminal voltages and currents at a certain rate of γ (gamma). Figure -7 is the simulation already presented In Microsoft QBASIC 4.5 [1] for comparison and measurement of the exactness of new simulation. Where as Figure -8 shows the new simulation results in Visual Basic 6.0.

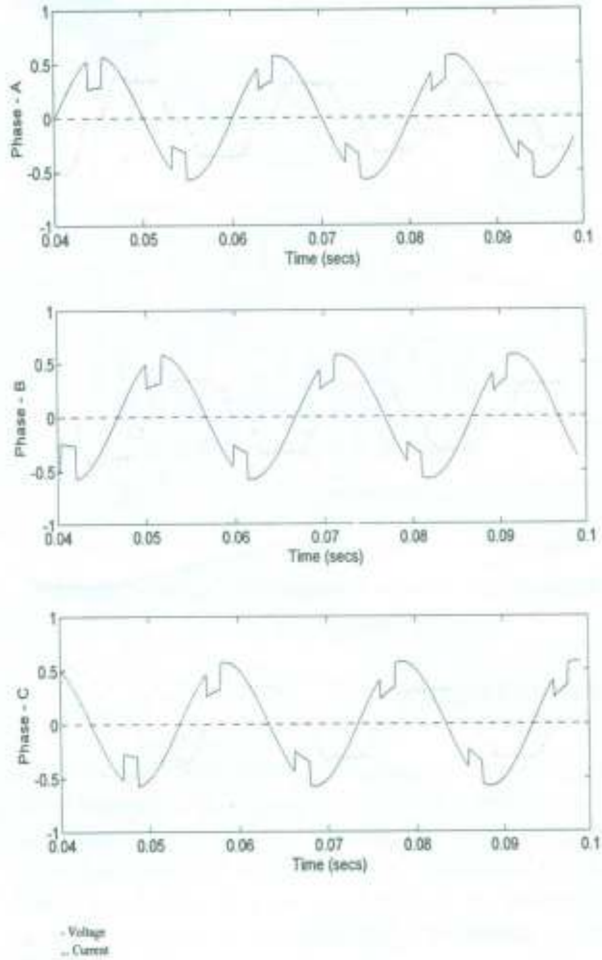

Figure 7: Three Phase Voltages and Currents ($\gamma = 30^0$, Per Unit Speed = .97) [1].

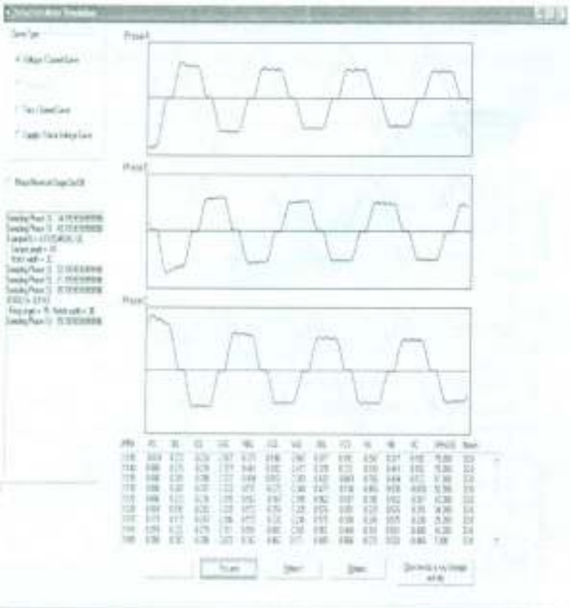

Figure 8: Three Phase Voltages and Currents ($\gamma = 30^0$, Per Unit Speed = .97)

4. CONCLUSIONS

Conclusively, computer simulation based research and development is a continuous process. Development of the programming paradigms gives it a new shape each time. That is accordingly incorporated for a thyristor fed, phase controlled 3-ф squirrel-cage induction motor based system for a variety of applications as a competitor for an expensive system based on DC motors. Simulation results of the Visual Basic 6.0 model have been accordingly tested for various operational modes of the simulated system and exactness of this new simulation has been verified. 3-ф Voltage and Current waveforms have been presented in this paper.

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