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INTELLIGENCE IN MATHEMATICAL MODELING BASED ON SUBMERSIBLE INDUCTION MOTOR FOR AGRICULTURAL PUMPING

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***Abstract*— Over the last 30 years, induction motors have become more popular. Since for its rugged construction, easy manufacturing, low cost and maintenance free operation. It is preferred for varieties of applications like fan, compressor, crusher, blower etc., currently submersible induction motor is most popularly used for pumping water from open and bore well for agriculture purpose. Performance prediction and routine testing is essential before it installed in agriculture field. The physical testing is currently employed for evaluating the performance of pump and it has become more difficult due to the high labor cost, energy consumption, and time required. When a motor fails in an agricultural field, it results in significant revenue losses and, in some cases re-boring is required. Hence, some simple and reliable alternative testing method is essential for submersible motor to overcome these problems. In this paper, the intelligence in mathematical model is used to predict the problems before it tested into the field and it is validate with dynamic load condition along with the load torque of centrifugal pump characteristics.**

Keywords—mathematical model, dq0 variables, centrifugal pump , non linear systems.

I. INTRODUCTION

Induction motors have been widely used because of its reliable operation, robust construction, low initial and maintenance cost. The most of industrial equipments like elevators, crane lifters, drilling machines, crushing machines, and conveyer belts etc. are operated by induction motor. In induction motor during manufacturing possibility of defects and human error such as unbalanced winding, bubbles and blister in cage bar, improper alignment, eccentricity, defects in materials etc., it cause excess temperature and its associated losses. Finally it leads to reduce the lifetime and reliability of the brand. Once the failure of the motor operating in agricultural field or industry creates substantial revenue losses and in some case damages the whole drive system. In order to provide reliable product to customer, physical testing is often used to assess the performance of induction motors, and it requires a significant financial expenditure in the form of a man power and equipments, power source, and space. Presently submersible induction motor is most commonly used for pumping water from open and bore well. To overcome from these problems, a simple alternative testing method is essential there are various conventional methods are proposed to predict the performance of induction motor such as equivalent circuit and circle diagram based on the results of no-load and blocked rotor testing. But study of motor under dynamic load and supply variation is not possible in these methods. The alternative approach is used to overcome is mathematical model. The proposed mathematical system is tested in under various dynamic load conditions along with centrifugal load torque.

II. LITERATURE SURVEY

This model can do arbitrary qd0-frame analysis and the core loss estimates in line-fed and also inverter-fed instances. Based on a thorough model, estimates of machine copper loss and core loss are presented. The model is then put through its paces on three induction machines (1.5, 3, and 10 HP), indicating that it is scalable and capable of giving good machine loss prediction in both line-fed and inverter-fed conditions, as well as in the flux-weakening area. [1]. The use of a variation integrator to represent induction motors (IMs) in discrete time is discussed in this study [2]. PSTSS systems can use this unique model of an induction motor drive to figure out how to keep them stable. This study is about how to model and run nine-phase induction machines that work with open-phase faults.. This study is concerned with the modeling and operation of nine-phase induction machines with open-phase defects. [3]. The suggested model's development is detailed, including an algorithm that ensures appropriate representation of isolated neutral motors [4]. The proposed technique connects the motor's mathematical model to magneto-static and time-harmonic analysis using finite element simulations. The goal of this method is to include the effect of the slip frequency on the current distribution of the bars as well as the induced currents in the cage caused by stator belt harmonics in a quick calculation for a machine. [5]. The current work concentrates on recalculating the optimum flux component of current using the mentioned methodologies in order to improve the IM drive's overall efficiency. All three methods based IM drive operation show demonstrate a gain in efficiency owing to a decrease in the drive system's core loss. The stator flux vector is employed as the control variable in this research which avoids the problematic stator current prediction at the k + 2 instant. As a result, the weighting component in standard MPTC is abolished, and control complexity is considerably reduced [6] A finite element model-based adaptive ML technique for chip package reliability prediction and design optimization is presented in this paper. To create training data, this machine learning approach uses a tried-and-true multi-scale finite element model. [7].Using the piece wise variable coefficients technique, the suggested model accounts for the effect of the inverter's output voltage harmonics on the motor's iron loss. The suggested technique also induces an a the effect of the slot harmonic component on iron loss [8]. The major purpose of this strategy is to enhance the accuracy of the flux linkage model which based upon least square support vector machine (LSSVM) technology by automatically determining the suitable kernel parameter and regularization parameter of the LSSVM using the grey wolf optimization (GWO) algorithm. [9]. This article presents a bus splitting method to handle the problem and explains how it works mathematically. [10]. Electrical transients and simulations of the analysis software are used in case studies to ensure that the method is accurate. The goal of this study is a robust estimate of the rotor flux and velocity for sensor less motion control of induction motors [11]

III. ESTIMATION OF MODEL PARAMETRS

The estimate parameter is critical before going on to the mathematical model. The model parameters are determined using the resistance test, no-load and loaded rotor tests. These tests are used to identify model properties such as rotor resistance, stator resistance, stator magnetizing inductance, stator leakage inductance, rotor leakage inductance and moment of inertia. The identified model parameters are used for simulating the modeled motor. The induction motor steady state and transient states are then investigated using these parameters. The name plate details of the 3hp submersible induction motor are shown in Table 1.

TABLE I

S.NO	SPECIFICATIONS OF SUBMERSIBLE MOTOR	
1	Motor Rating in kW	3
2	Rated voltage in V	380
3	Rated current in A	7
4	Rated frequency in Hz	50
5	No.of poles P	2
6	Winding connection	S
7	Type of Duty	S1
8	Discharge at duty point in lps	6
9	Over efficiency at duty point (%)	42.50

A. *No Load Test*

In no-load test, motor is operated with rated terminal voltage and frequency under no load condition. The readings during no-load conditions such as voltage, current, power and power factor are measured using appropriate meters. Based on the measured values, model parameters such as are identified. Since the motor is under no-load, power taken by the motor is to overcome mechanical loss, core loss and small negligible amount of copper loss. the total power is equal to the motor's constant core, friction, and winding loss. The power factor of an induction motor is typically less than 0.5 at idle, so the wattmeter shows a negative reading. Therefore, the direction of the current coil connection must be reversed to get the reading. The parameter considered in then no-load test is listed in Table 2.

TABLE II

S.NO	NO LOAD PARAMETERS	
1	Voltage V	380
2	Current A	3.339
3	Power W	445
4	Frequency Hz	49
5	Speed rpm	2984
6	Power factor cos ϕ	0.202
7	Magnetizing current	3.26
8	Core loss branch current	0.674
9	Magnetizing stator impedance Ω	0.641
10	Core loss resistance Ω	975.9

TABLE III

S.NO	PARAMETERS OF LOCKED LOAD	
1	Voltage V	111.0
2	Current A	7.014
3	Power W	824
4	Power factor cos ϕ	0.616
5	Phase angle %	51.97
6	Locked rotor impedance Ω	27.16
7	Stator refereed rotor resistance per phase Ω	13.68
8	Total leakage reactance Ω	21.39
9	Stator leakage inductance Ω	0.034

B. Locked Rotor Test

The rotor of the asynchronous motor is kept stationary then the low level three phase voltage is supplied to circulate rated stator current. The locked rotor test is most comparable to the short circuit test of an transformer which will performed to Calculate the series parameters of the asynchronous machine which means that leakage impedance. The rotor is locked to prevent rotation. The symmetrical voltage and the frequency of 25% is applied to the stator terminals under low voltage and rated current, the core loss and magnetization component of the current will be a very small percentage of the total current. it indicates the parameter included in the locked rotor test. Under normal operating circumstances, the blocked rotor test is carried out. If the rotor current and frequency are the same, the locked rotor test is done under normal operating circumstances. The primary goal is to use unloaded and locked rotors to estimate the magnetization and leakage impedance characteristics of an asynchronous machine.

IV. MATHEMATICAL MODEL

An actual mathematical model is a study of steady-state electrical systems under transient and unbalanced conditions. The link between electrical and mechanical variables is usually represented using mathematical models. When creating a mathematical model for an induction motor, the following assumptions must be made. Asynchronous motors can be thought of rotary transformers whose magnetic circuits are separated by an air gap. The stator is considered as primary winding and the rotor is considered as secondary winding.. The alternating current supplied to the primary side causes a counter current to the short-circuited secondary side when the secondary side is short-circuited due to external resistance. Therefore, the relative

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movement between the stator and the rotor produces a mutual electromotive force. The rotor of an induction motor is called as rotary transformer because it is in a rotating position compared to the secondary side of the transformer. Induction machines differ from other types of electric motors in that induction, like a transformer, produces a secondary current. They are not supplied by DC exciters or anything else likes any other machine, it has an external power supply. The voltage equation of asynchronous motor is complicated because mutual inductance between stator circuit and the rotor circuit changes over time. Changing the variable (reference system theory) solves this problem and allows converting the machine's phase variables to alternative reference system. The idea may be applied to any reference system, however fixed reference systems and synchronous rotating reference systems are the most often utilized. The induction motor equations are applied to these frames using the Clark and Park transformations. The voltage and torque equations may be used to simulate induction motors. These equations may be represented with or without a reference system. By assigning the proper velocity to the voltage equation of any frame of reference and each frame of reference's voltage equation may be found. That is, while stationary, $\omega = 0$; when spinning synchronously, $= \omega_r$ or rotor; and when rotating synchronously, $\omega = \omega_e$. The first stage is to create a mathematical model for an three phase induction motor using machine data (abc). In the following reference frames, the machine is represented using quadrature, direct, and zero (qd0) variables: arbitrary reference frame, stationary reference frame reference frame, rotor reference frame, and synchronous reference frame, to simplify these analysis one these reference frame is used. The synchronous reference frame is one of these reference frames that is used to run non-linear simulations in this model. Based on the Cauchy's equations, the following equations is taken by the inverse Laplace transform. Based on the these equations the following s-domain block diagram is constructed. S-domain block diagram is shown in Fig 1. Based on the no load and locked rotor test the following model parameters is identified. On the following consideration of model parameters the values are feed in to the s-domain block diagram. The model parameters are shown in table 4

TABLE IV

S.NO	PARAMETERS OF LOCKED LOAD	
1	Rotor Resistance, r_r Ω	7.1
2	Stator Resistance, r_s Ω	9.4
3	Stator Magnetizing Inductance, L_{ms}	0.37
4	Stator leakage inductance, L_{ls}	0.32
5	Rotor leakage inductance, L_{lr}	0.32
6	Locked rotor impedance Ω	0.32
7	Moment of inertia,J	0.001
8	Number of poles, P	2

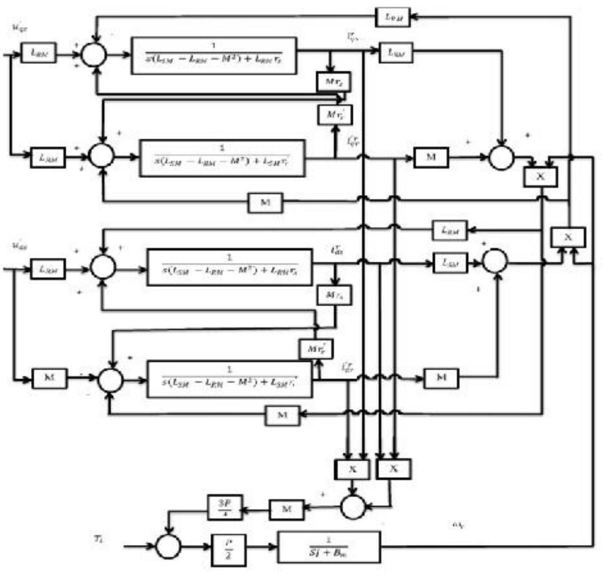

Fig 1 shows the s domain block diagram.

A. *Mathematical Modeling In MATLAB Simulink*

To develop a mathematical model for an induction motor, the understanding of induction motor's fundamental electrical scheme is mandatory. ABC stands for stator phase winding and abc stands for rotor three phase winding in asynchronous motor machine variables. The clarke's transformation is used to simplify machine variables. Despite the fact that the dq0 transformation, i.e. turning clarke's transformation into park transformation of dq0 variables, is conducted for improved clarity and accuracy, The modeling is done in a synchronous reference frame here.

B. *Equations*

$$\frac{}{dt} - \frac{}{L_{SM}L_{RM}-M^2}[-L_{RM}r_s i_{qs}^e - (L_{SM}L_{RM} - \qquad (1)$$

$M2\omega eidse+Mrr'iqr'e-MMidse+LRMidr'e$
$\omega r+LRMuqse-Muqr'e$

$$\frac{}{dt} - \frac{}{L_{SM}L_{RM}-M^2}[(L_{SM}L_{RM} - M^2)\omega_e i_{qs}^e - \qquad (2)$$

$LRMrsidse+ Mrr'idr'e+ MMiqse+LRMiqr$
$'e\omega r+LRMudse-Muqr'e$

$$\frac{di_{ds}^e}{dt} = \frac{1}{Lls}(-r_s i_{ds}^e + u_{ds}^e) \qquad (3)$$

$$\frac{}{dt} - \frac{}{L_{SM}L_{RM}-M^2}[Mr_s i_{qs} - L_{SM}r_r' i_{qr}'^e - \qquad (4)$$

$LSMLRM-M2\omega eidre+LSMMidse+LRMid$
$r'e\omega r-Muqre+LSMuqr'$

$$\frac{di_{dr}^e}{dt} = \frac{1}{L_{SM}L_{RM}-M^2}[Mr_s i_{ds}^e + (L_{SM}L_{RM} - \qquad (5)$$

$M^2)\omega_e i_{qr}^e - L_{SM}r_r' i_{dr}'^e - L_{SM}(Mi_{qs}^e +$

$L_{RM} i'^{e}_{qr})\omega_r - M u^{e}_{ds} + L_{SM} u'^{e}_{qr}]$

$L_{RM} i_{qr}$ [illegible] $- M u^{e}_{ds} + L_{SM} u$ (6)

$\frac{di'^{e}_{or}}{dt} = \frac{1}{L'_{lr}}(-r'_r i'^{e}_{or} + u'^{e}_{or})$

[illegible] (7)

$\frac{d\omega_r}{dt} = \frac{3p^2}{8J} M(i^{e}_{qs} i'^{e}_{dr} - i^{e}_{ds} i'^{e}_{qr}) - \frac{B_m}{J}\omega_r - \frac{p}{2J} T_L)$

(8)

$\frac{d\theta_r}{dt} = \omega_r$

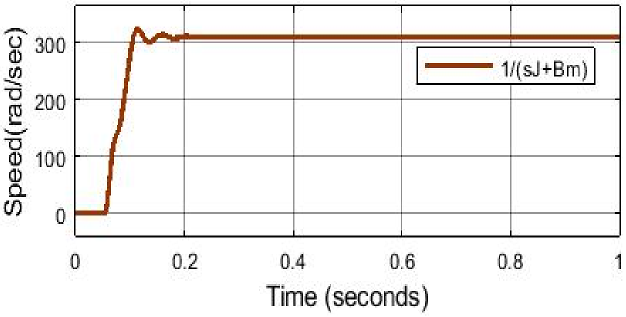

Fig 2 shows the speed of motor at no load

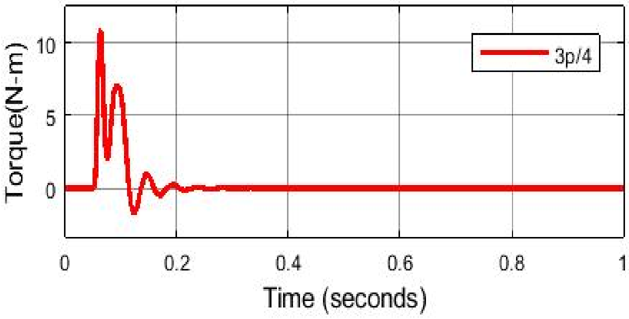

Fig 3 shows the speed of motor at no load

In Fig 2 and Fig 3 shows the transient and steady state of the asynchronous motor. Fig 2 represents the speed of the motor at the no load and in Fig 3 shows the speed of the motor at 0 Nm torque. In the both the case 0 to 0.15 seconds it will in transient state. After 0.15 seconds, it will reach to the steady state.

V. CENTRIFUGAL PUMP

Centrifugal pumps require variable torque depending on the speed. Priming is the initial step in operating a centrifugal pump. Priming is the process of filling the pump's suction pipe casing and direction of fluid with an liquid will be pushed until no air remains in the pump's position. Priming is essential because the pressure exerted at the impeller of a centrifugal pump is directly proportional to the density of the fluid in contact with it. As we disassemble the machine, we can see that the electrical motor has a fan and a protective shell installed on the rear. The stator, which is affixed to the motor's housing and contains the copper coils, is then found within the motor, and we'll go over that in more depth later in this video. The rotor and shaft are parallel to this. The rotor revolves, and the shaft rotates with it. The shaft spans the whole length of the pump, from the engine to the pump. The impeller of the pump is then connected to this. Some centrifugal pumps, such as this one, have two shafts: one for the pump and one for the motor. A coupling is used to link two shafts that are separated by a distance. Coupled pumps commonly feature a bearing house, which houses the bearings, as the name implies. The impeller applies centrifugal force to the fluid, allowing us to transport liquids like water via a conduit. Within the pump casing, the impeller is enclosed. As the impeller pulls and pushes water in and out, the casing confines and directs it. We have a suction intake and a discharge exit as a result. Water has submerged the impeller. When the impeller turns, the water inside it rotates as well. The liquid is radial pushed forth in all directions as the water spins, to the impeller's edge and into the volute. As water travels outwards from the impeller, it generates a low-pressure zone that draws additional water in via the suction intake. The water enters the impeller's eye and becomes caught between the blades. In Simple put,. If you double it, the torque will increase, so if you triple it, the power will increase. When the speed doubles, the power increases eight times ($2^3= 8$). Unlike certain water pumps, the centrifugal pump requires a steady, smooth amount of force with no torque pulsations. Torque is required to drive the pump shaft, which may be computed using HP and N.

T= 5252.11 X HP/N
HP=TN/5252.1 1
T denotes the torque
N denotes speed in RPM.

Based on the centrifugal pump load the load torque of induction machine is tested in dynamic performance have done under the steady state and transient state.

A. Simulations Under Centrifugal Pump

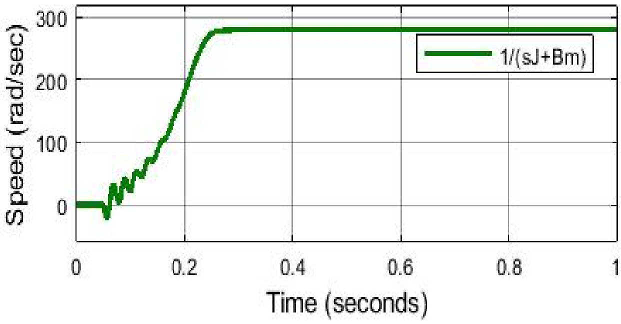

Fig 4 shows the speed of the motor at the load

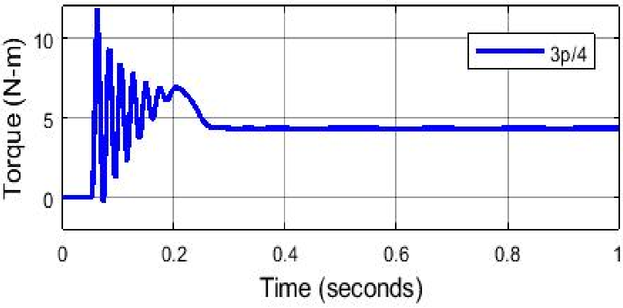

Fig 5 shows torque of the motor at the load

In Fig 4 and Fig 5 shows the transient and steady state of the asynchronous motor. Fig 4 represents the speed of the motor at the load and in Fig 5 shows the speed of the motor at 4.8 Nm torque. In the both the case 0 to 0.15 seconds it will in transient state. After 0.15 seconds, it will reach to the steady state.

VI CONCLUSION

In agricultural and industrial applications, submersible induction motors are often used. Individual motors must be manually tested before being deployed in the field to guarantee reliable functioning. The typical manual testing method necessitates a large investment in terms of money, manpower, and time. In this study, instead of physical testing, a new straight forward mathematical technique is used to anticipate the dynamic performance of a submersible. On the basis of load torque of centrifugal pump the speed and torque of the motor will be identified. MATLAB is used for mathematical modeling. The submersible motor is simulated using a nonlinear dynamic equation derived in synchronous reference frame. The recommended technique's calculated results are proven to be much closer to physical testing. The results of mathematical modeling and practical testing are vastly different. As a result of this work, for submersible pump manufacturers, this strategy will offer lowered capital investment, labor costs, and time.

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