SADI International journal of Science, Engineering and Technology
ISSN: 2837-1941| Impact Factor : 6.26
Volume. 11, Number 1; January-March, 2024;
Published By: Scientific and Academic Development Institute (SADI)
8933 Willis Ave Los Angeles, California
https://sadijournals.org/index.php/sijset|editorial@sadijournals.org

PELLET PLANT STARTING TRANSIENT EFFECT AND SPEED CONTROL ON THE CONVEYOR BELT USING A SQUIRREL CAGE INDUCTION MACHINE

Chizindu Stanley Esobinenwu and Lamidi Salihu Owuda
Department of Electrical/Electronic Engineering, University of Port Harcourt, Rivers State, Nigeria.
Email: chizindu.esobinenwu@uniport.edu.ng & owuda@yahoo.com
DOI: https://doi.org/10.5281/zenodo.10639427

Abstract: The pellet plant starting transient effect and speed control on a conveyor belt using a squirrel cage induction machine is presented. A pellet is a *fine-grained iron ore that is converted into balls of a certain diameter, usually 8–20 mm. A pellet* plant is a set of equipment used to produce pellets. Its components consist of crushing, mixing, feeding, granulation, and cooling equipment. Materials used to produce pellets include iron ore and limestone, coke, anthracite coal, quartzite as additives, which are passed through balling disk drum, furnace, and the green pellets so formed rotary kiln as product for steel production. Electrical transient currents are current before reaching steady state and fast rise time, short duration energy pulses that commonly have voltage and current components often transmitted down power lines. This transient is a disturbance that affects the power quality of the pellet plant starting on the conveyor belt and constitutes a negative effect and damage to the pellet plant equipment. Electrical transients occur in pellet plant power systems from a variety of sources and have adverse effects on the equipment and reliability of the power system. These may be electrical transmission faults such as contact of the transmission lines with the tree, lightning, switching, and load changes. This study was conducted to ensure the operational stability of the pellet plant starting facilities after a disturbance while maintaining quality services. The pellet plant conveyor belt is a power-driven belt and is supported by metal plate rollers upon which the conveyor belt rests. It is a wrapped rounded driven pulley driven by an electrical machine. The squirrel cage machine is an induction device that harnesses electromagnetism to generate motion. It is called "squirrel cage" machine because of its rotor shape, and the inner component is connected to the output shaft that looks like a cage. With the introduction of the Squirrel cage induction machine to drive the pellet plant conveyor belt, the pellet plant conveyor belt and its associated equipment were stabilized and the negative effects were eliminated. The experimental investigation revealed that the average current of the pellet plant squirrel cage induction machine at no load characteristics was $0.703A_{ac,}$ apparent power was 220 VA, real power was 80 W, reactive power was 201 VAR, and power factor was 0.286. With the introduction of torque at 12 (12(Ibf.in), the average current at no load characteristics was $1.29A_{ac,,}$apparent power, 412VA, real power ,320W, reactive power ,272var, power factor ,0.785, horse power, 0.260, efficiency, 79.6 %. When torque was introduced at 12(Ibf.in), the starting current to full load current was 4.10, starting torque, 2.27, full load current, 0.603. There was an increase in the power factor and increase in pellet plant conveyor belt squirrel cage induction machine efficiency. When the slip dropped to some value between 2% and 10%, the speed stabilized and remained relatively constant. The operating characteristics of the squirrel cage machine are very efficient, higher full-load speed, and good speed regulation. The squirrel cage induction machine is widely used in a variety of industrial applications and should be introduced for pellet plant conveyor belt operation because its rotor construction is very simple, rugged, and cannot be burnt out. Less maintenance due to the absence of commutation brushes and slip ring. The pellet plant conveyor belt squirrel cage induction machine runs at a rotating field of 1500 r/min at 50 Hz because the excitation current increases because of lower winding impedances. These are recommended for pellet plant engineers, technicians, and operators.

Keywords: Pellet, squirrel cage, limestone, furnace, transient, conveyor belt, torque.

1.0: INTRODUCTION

The pellet plant starting transient effect and speed control on a conveyor belt using a squirrel cage induction machine is presented. A pellet is a *fine-grained iron ore that is converted into balls of a certain diameter, usually 8–20 mm. A pellet* plant is a set of equipment used to produce pellets. Its components consist of crushing, mixing, feeding, granulation, and cooling equipment [1, 8, and 15]. Materials used to produce pellets include iron ore and limestone, coke, anthracite coal, and quartzite as additives, which are passed through balling disk drum, furnace, and the green pellets so formed rotary kiln as product used for steel production. Pellets can be used as fuels for power generation, commercial heating, residential heating, and cooking depending on their heating value.[8,10,15] Electrical transient currents are current before reaching steady state and are fast rise time, short duration energy pulses that commonly have voltage and current components often transmitted down power lines. [12, 13, 14] This transient is a disturbance that affects the power quality of the pellet plant starting on the conveyor belt and constitutes a negative effect and damage to the pellet plant equipment. Electrical transients occur in pellet plant power systems from a variety of sources and have adverse effects on the equipment and reliability of the power system due to electrical transmission faults such as contact of the transmission lines with the tree, lightning, switching, and load changes. The study was conducted to ensure the operational stability of the pellet plant starting facilities after a disturbance while maintaining quality services.

The pellet plant conveyor belt is a power-driven belt supported by metal plate rollers on which the conveyor belt rests. It is a wrapped rounded driven pulley driven by an electrical conventional machine. [8,10] The squirrel cage induction machine is simple and is widely used in a variety of industrial applications such as machine tools, robotics, aerospace generators, actuators, and electric vehicles. This is due to the advent of a high performance squirrel cage induction machine with creativity and residual magnetism, which make it possible for the squirrel cage induction machine to have a superior power density, torque to inertia ratio , and efficiency [10, 11]. The squirrel cage induction machine consists of a laminated iron core that is slotted lengthwise around its periphery. Solid bars of copper or aluminum are tightly embedded into the rotor slots at both ends of the rotor. The short-circuiting rings are brazed to the bar to form a solid structure. It does not have to be specially insulated from the core because its resistance is much less than that of the core. In some cases, the bar and the end ring are cast as a single integral structure for placement on the core. The short-circuiting elements form shorted turns with high currents induced in them by the stator field flux. The periphery of the squirrel cage induction machine is negligible, separating the stator for air gap as a mechanical clearance needed to ensure the strongest possible electromagnetic induction [3, 4, and 10]. When power was applied to the stator of the squirrel cage induction machine, a rotating magnetic field was observed to have been created and the field began to revolve. The line of flux cut shorted turns embedded around the surface of the squirrel cage induction machine rotor and voltage was

generated in them by electromagnetic induction, because of very low resistance of short-circuited turns. Thus, high currents circulated in the rotor bar because of the induced voltage. The circulated current produces strong magnetic fields and magnetic poles. Thus, the rotor revolves with the main field. The squirrel cage machine is an induction device that harnesses electromagnetism to generate motion. It is called "squirrel cage" machine because of the shape of the rotor. The inner component is connected to the output shaft that looks like a cage. [8, 9, 15]
The starting torque of the squirrel cage induction machine was low because, at rest, the rotor has a large inductive reactance (X_L) with respect to its resistance (R), and the rotor current lags the rotor voltage by 90 degree and low power factor. The squirrel cage induction machine was not efficient in obtaining useful energy for this operation of the pellet plant conveyor belt from the power source. [2, 3, 4]

The toque was developed, and the squirrel cage induction machine started turning. The speed between the rotor and rotating slip goes from a maximum of 100 % to an intermediate value of 50 %. The slip decreased, and the frequency of voltage induced in the rotor decreased. As a result, the rotating field cuts conductors at a decreased rate, which in turn caused the overall inductive reactance in the circuit to decrease. As in the inductive reactance decreased, the power factor stated to increase and the speed also increased. The improvement is a result of an increase in toque. The squirrel cage induction machine stabilized as the slip dropped between 2% and 10%. The stabilization occurred because of the tendency for the squirrel cage induction machine speed to increase to where the slip dropped below 2 % and was naturally offset by the fact that as the rotor approached within 2 % of the synchronous speed, the effect of reduced inductance overcame the previous tendency to increase torque as the squirrel cage induction machine was speeded up from the start. Thus, the squirrel cage induction machine exhibits an automatic speed control characteristic similar to that of the DC shunt machine.

2.0: SQUIRREL CAGE INDUCTION MACHINE MATHEMATICAL MODELLING

In a balanced pure sinusoidal three-phase supply, the sum of the three-phase voltages is zero; thus, the zero sequence voltage is zero. [2, 3, 4]

The squirrel cage induction machine has received less attention from researchers, mainly because of the non-linearity involved in the squirrel cage induction machine winding dynamic equation.

The fourth-order ordinary differential equation, which describes the electrical model, and the second-order ordinary differential equation, which describes the mechanical model of the squirrel cage induction machine windings, are generally non-linear. Solutions are usually very difficult; consequently, numerical methods of analysis using Runge– Kutta fourth order were conveniently applied [3,5,7] Accurate knowledge of run-up synchronization and response to sudden load variations of the squirrel cage induction machine winding during dynamic operation is critical, especially when designing the squirrel cage induction machine, and it should be classified into electrical and mechanical models.

3.0: Electrical modeling

The d– q axis representation of a squirrel cage induction machine when the reference frame in the rotor is given by [2, 3, 4]

$$v_q = r_s\, i_q + \frac{d\lambda_q}{dt} + \lambda_d\, \omega r \tag{1}$$

$$v_d = r_s\, i_d + \frac{d\lambda_d}{dt} - \lambda_q \omega r \tag{2}$$

$$0 = r_{kq}\ i_{kq} + \frac{d\lambda_{kq}}{dt} \tag{3}$$

$$0 = r_{kd}\ i_{kd}\ +\ \frac{d\lambda_{kd}}{dt} \tag{4}$$

Equations (1- 4) was expressed in state variable form with flux linkages as state vectors. These imply that [3, 6, 7]

$$\dot{\boldsymbol{\lambda}}_{\boldsymbol{q}} = v_q - \omega_r\lambda_d + \frac{\mathrm{r_s}}{L_{ls}}(\lambda_{mq} - \lambda_q) \tag{5}$$

$$\dot{\boldsymbol{\lambda}}_{\boldsymbol{d}} = v_d + \omega_r\lambda_q + \frac{\mathrm{r_s}}{L_{lx}}(\lambda_{md} - \lambda_d) \tag{6}$$

$$\dot{\lambda}_{kq} = \frac{r_{kq}}{L_{lkq}}(\lambda_{mq} - \lambda_{kq}) \tag{7}$$

$$\dot{\lambda}_{kd} = \frac{r_{kd}}{L_{lkd}}(\lambda_{md} - \lambda_{kd}) \tag{8}$$

Where

$$\lambda_{mq} = L_{MQ}\left(\frac{\lambda_q}{L_{ls}} + \frac{\lambda_{kq}}{L_{lkq}}\right)\square \tag{9}$$

$$\lambda_{md} = L_{MD}\left(\frac{\lambda_d}{L_{ls}} + \frac{\lambda_{kd}}{L_{lkq}} + i_{fm}\right) \tag{10}$$

$$L_{MQ} = \frac{(L_{mq}L_{lkq}L_{ls})}{(L_{lkq}L_{ls} + L_{mq}L_{ls} + L_{mq}L_{lkq})} \tag{11}$$

$$L_{MD} = \frac{(L_{md}L_{lkd}L_{ls})}{(L_{lkd}L_{ls} + L_{md}L_{ls} + L_{md}L_{lkd})} \tag{12}$$

$$L_d = L_{ls} + L_{md} \tag{13}$$

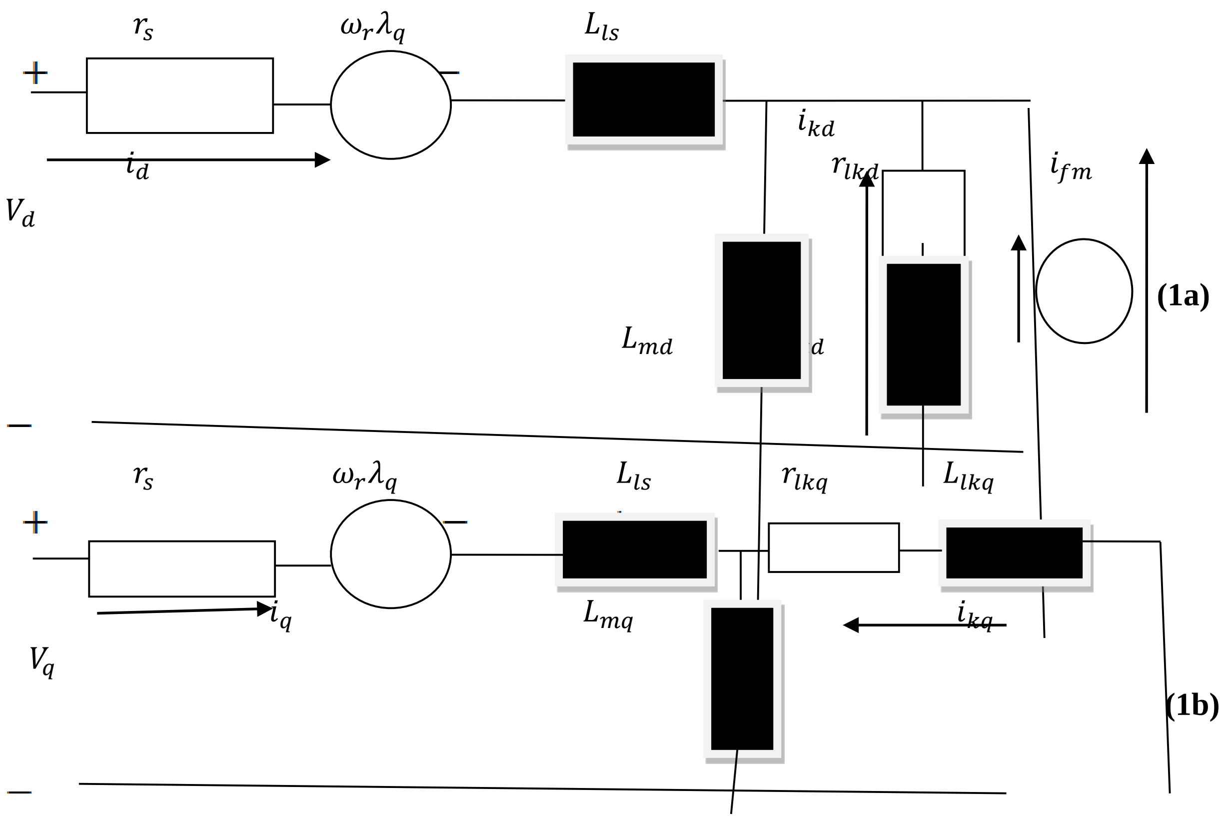
$$L_q = L_{ls} + L_{mq} \tag{14}$$

$$i_q = \frac{\lambda_q - \lambda_{mq}}{L_{ls}} \tag{15}$$

$$i_d = \frac{\lambda_d - \lambda_{md}}{L_{ls}} \tag{16}$$

$$i_{kq} = \frac{\lambda_{kq} - \lambda_{mq}}{L_{lkq}} \tag{17}$$

$$i_{kd} = \frac{\lambda_{kd} - \lambda_{md}}{L_{lkd}} \tag{18}$$



Figures 1a and 1b: Electrical equivalent circuit for squirrel cage induction machine form (1a) Direct Axis (1b) Quadrature Axis used for equation derivation.

4.0: MACHINE TORQUE

Squirrel cage induction machine torque has three main components: reluctance torque, synchronous torque, and excitation torque, similar to wound rotor induction machines [3, 4]

Squirrel cage induction machine torque,

$$T_{em} = 1.5\ \mathrm{p}\ (\lambda_d\ i_q - \lambda_q\ \ i_d) \tag{19}$$

Reluctance Torque,

$$T_r = 1.5\ P\ (L_d - L_q) i_d i_q \tag{20}$$

Synchronous Torque,

$$T_{syn} = 1.5\ \mathrm{P}\ (L_{md}\ i_{kd} i_q - L_{mq}\ i_{kq} i_q) \tag{21}$$

Excitation Torque,

$$T_{ex} = 1.5\ \mathrm{P}\ L_{md}\ i_{fm} i_q \tag{22}$$

where P is the number of pole pairs for the balanced line voltage,
Thus, the d– q voltages in terms of the load angle become

$$V_d = -V \sin \delta \quad (23)$$

$$V_d = V \cos \delta \quad (24)$$

The stator current phase is related to the d– q currents [4, 12]

$$i_{ax} = i_q$$

$$i_{bx} = -\frac{1}{2} i_q - \frac{1}{\sqrt{3}} i_d \quad (25)$$

$$i_{cx} = -\frac{1}{2} i_q + \frac{1}{\sqrt{3}} i_d \quad (26)$$

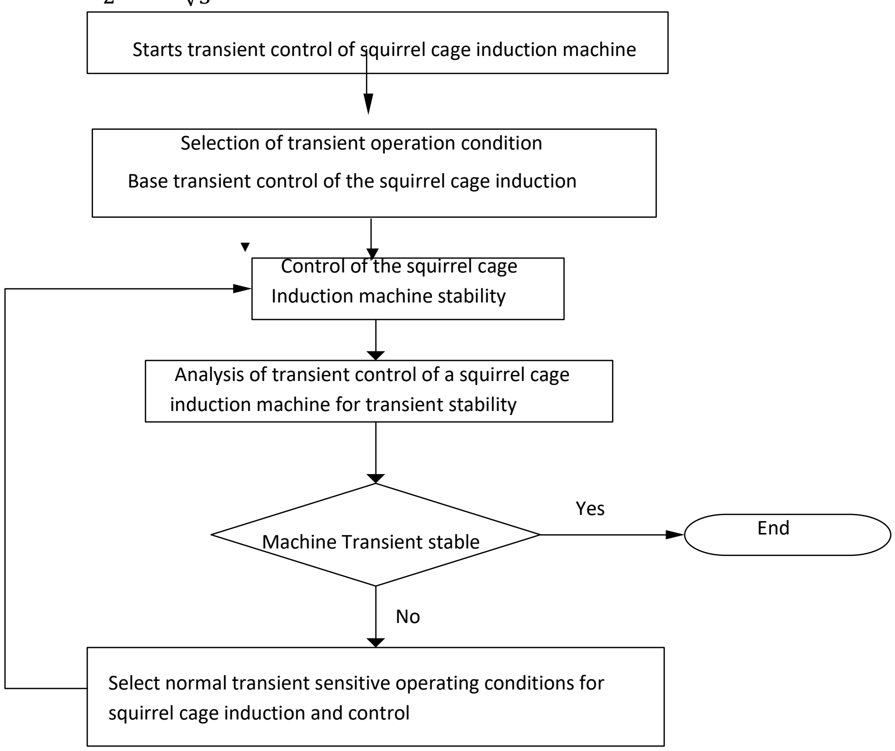


Figure 2a: Flow chart of pellet plant for transient control on conveyor belt using squirrel cage induction machine

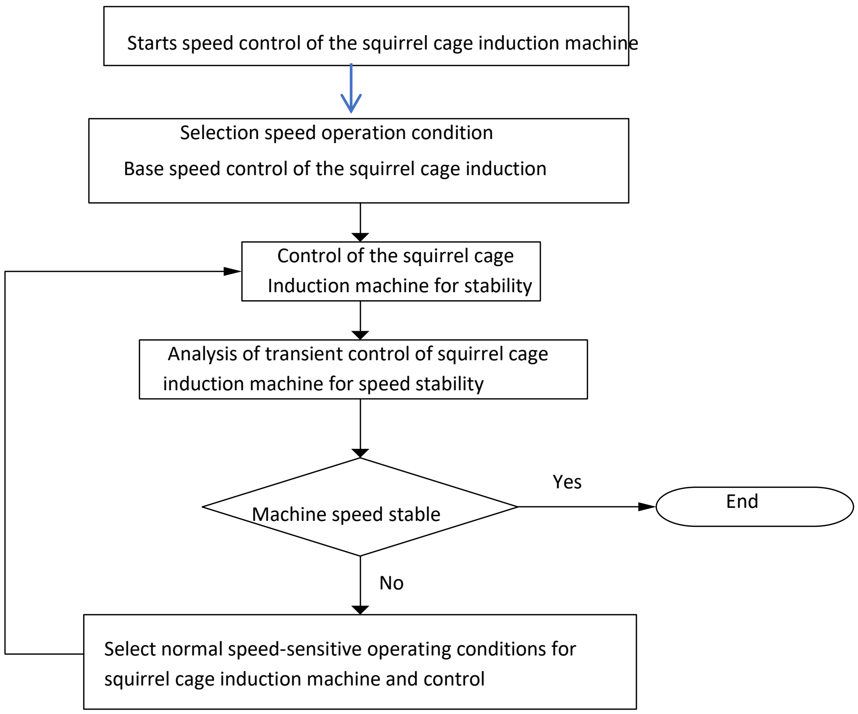
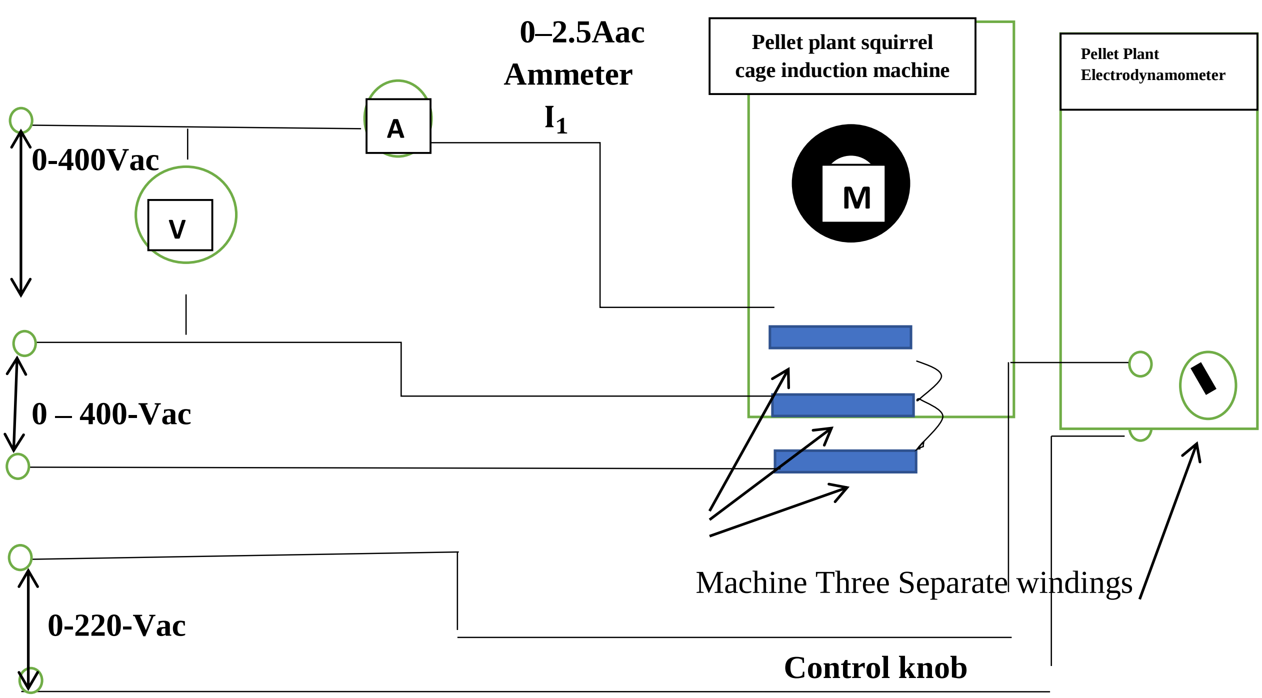
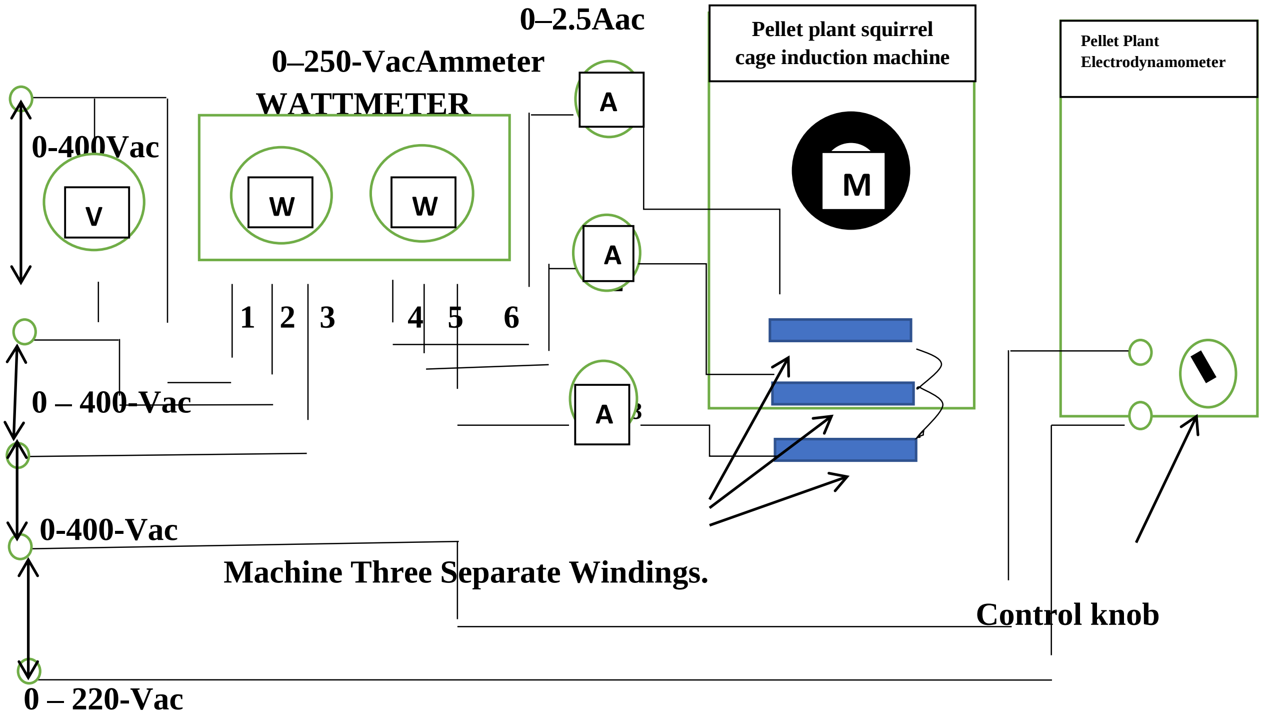


Figure 2b: Flow chart of pellet plant for speed control on conveyor belt using squirrel cage induction machine



Note: The stator windings are wired to the variable three-phase output of the power supply terminal 4, 5, and 6

Figure 3a: circuit diagram of pellet plant squirrel cage induction machine before torque.



Note: The stator windings are wired through the wattmeter to the variable three-phase output of the power supply terminals 4, 5, and 6

Figure 3b: circuit diagram of pellet plant squirrel cage induction machine when connected to an Electro-Dynamometer

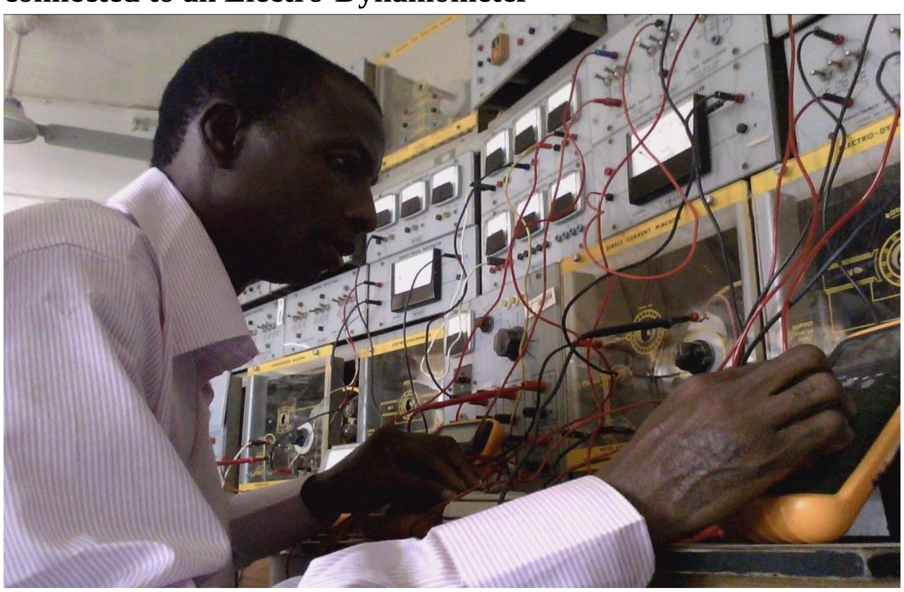


Figure 4a: The author on experiment investigation in a research laboratory [UNIPORT].

Figure 4b: Research Laboratory of Pellet Plant of Transients and Speed Control on Conveyor Belt Using a Squirrel Cage Induction Machine [UNIPORT]

5.0: EXPERIMENTAL INVESTIGATION

The experiment was carried out using a pellet plant squirrel cage induction machine conveyor belt in a standard research laboratory [UNIPORT]. The materials and instruments used are as listed: Squirrel cage induction machine, electrodynamometer, three- phase wattmeter, power supply, alternating current (250 V), Alternating Current (2.5A/2.5A/2.5A/8A), hand tachometer, and timing belt. The pellet plant squirrel cage induction machine consists of many turns of small diameter wire evenly spaced around the stator. It has a cooling fan, an end ring of the squirrel cage induction machine, an air gap between the stator and rotor, an electrical connection, and other parts of the pellet plant squirrel cage induction machine. There are three separate stator windings connected to terminals 1 and 4, 2 and 5, 3 and 6. The rated current of the stator windings is 1.5 A. The rated voltage of the stator windings is 120 V. The rated speed and horse power of the pellet plant squirrel cage induction machine is 1670r/min and 1–4, respectively. Figures (2a and 2b): shows the flow chart of pellet plant of transients and speed control on conveyor belt using squirrel cage induction machine, Figures (3a and 3b): show the circuit diagram of pellet plant squirrel cage induction machine, and Figures (4a and 4b): Research laboratory of pellet plant of transients and speed control on conveyor belt using squirrel cage induction machine [UNIPORT], of Pellet plant squirrel cage induction machine. The stator windings are wired through the wattmeter to the variable three-phase output of the power supply terminals 4, 5, and 6.

When the power supply was turn “ON”, the voltage was adjusted to 400 V by the control knob. The pellet plant squirrel cage induction machine started running. The three-phase line current, two- wattmeter indications, and machine speed were recorded as shown in table 1. The power supply was returned to zero and turned “OFF” Pellet plant squirrel cage induction machine was coupled to an electrodynamometer with a timing belt. The dynamometer control knob was turned anticlockwise. The procedure was repeated as before and recorded as shown in Table 1.

Table1: Experimental investigation results for pellet plant squirrel cage induction machine.

S/No	I_1 (amps)	I_2(amps)	I_3(amps	W_1 (watts)	W_2 (watts)	SPEED (r/min)	TORQUE (Ibf.in)
1	0.78	0.79	0.78	-40	100	1800	0
2	0.90	0.92	0.90	35	150	1770	4
3	1.06	1.10	1.06	65	195	1740	8
4	1.28	1.32	1.28	105	235	1700	12
5	1.54	1.60	1.52	145	290	1640	16

Table2: Squirrel cage induction machine parameters in the simulation model

Stator leakage inductance	2.59Mh
q-axis rotor leakage inductance	40.61Mh
d-axis rotor resistance	0.8113Ω
q-axis rotor resistance	1.6226Ω
q-axis magnetizing inductance	40.69Mh
d-axis magnetizing inductance	19.05mH
d-axis rotor leakage inductance	18.97mH
Load torque	7.63Nm
Motor inertial	0.01986Kgm^2
Rated voltage	230V(208V, 255V)

Source: [3]

Table3: Squirrel cage induction machine parameters in the simulation model.

d-axis inductance,L_d	1.4Mh
q-axis inductance, L_q	2.8mH (1.4mH)
Stator windings R_s	0.6 (1.2 Ω)
Induced flux by the magnet	0.12 Wb
Number of poles, P	2
Rated voltage, V	250 V
Rated frequency, f	50 Hz
Combined rotor and load inertia, J_m	0.83Kgm^2
Shaft mechanical torque, T_l	3.2Nm

Source: [3].

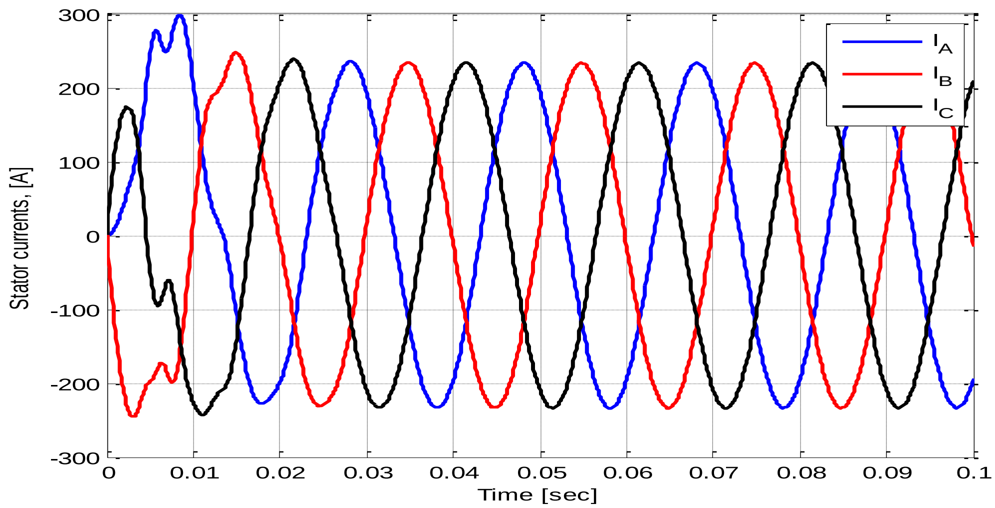


Figure 5: Graph of the Stator Currents against Time.

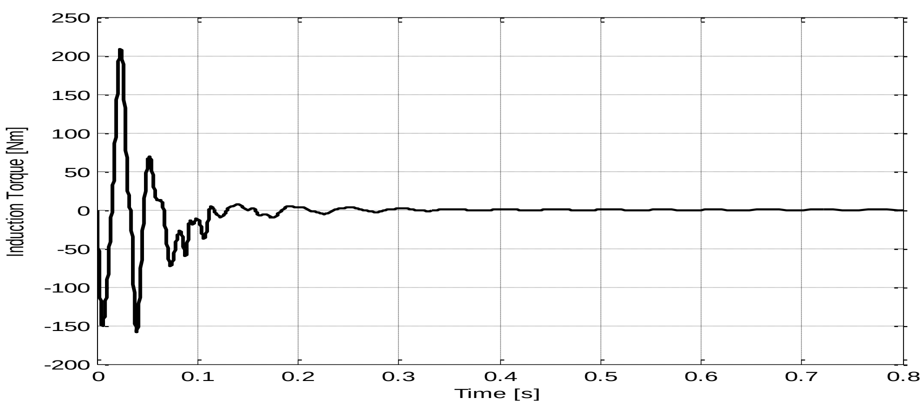


Figure 6: Graph of the induction torque against time under the run-up condition.

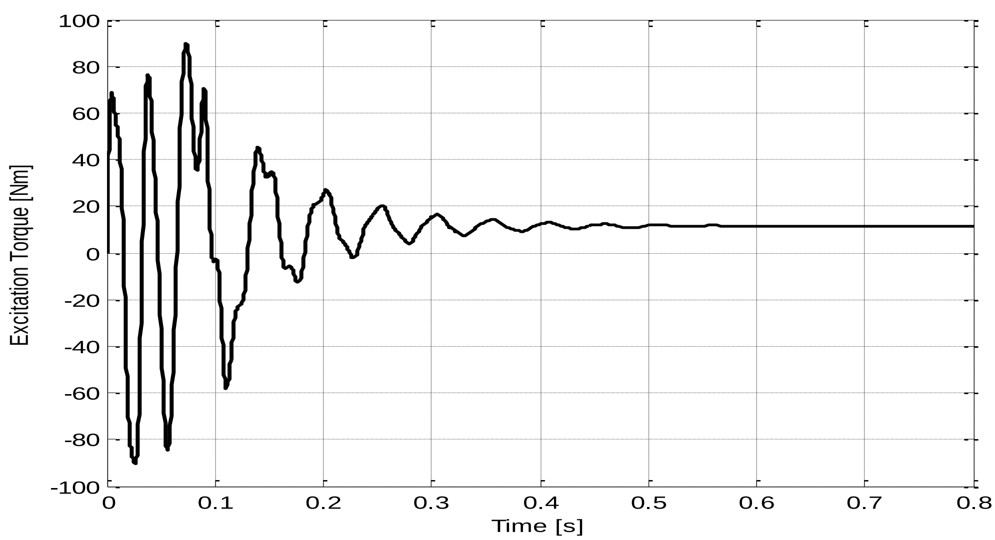


Figure 7: Graph of Excitation Torque against Time at Run-up Condition

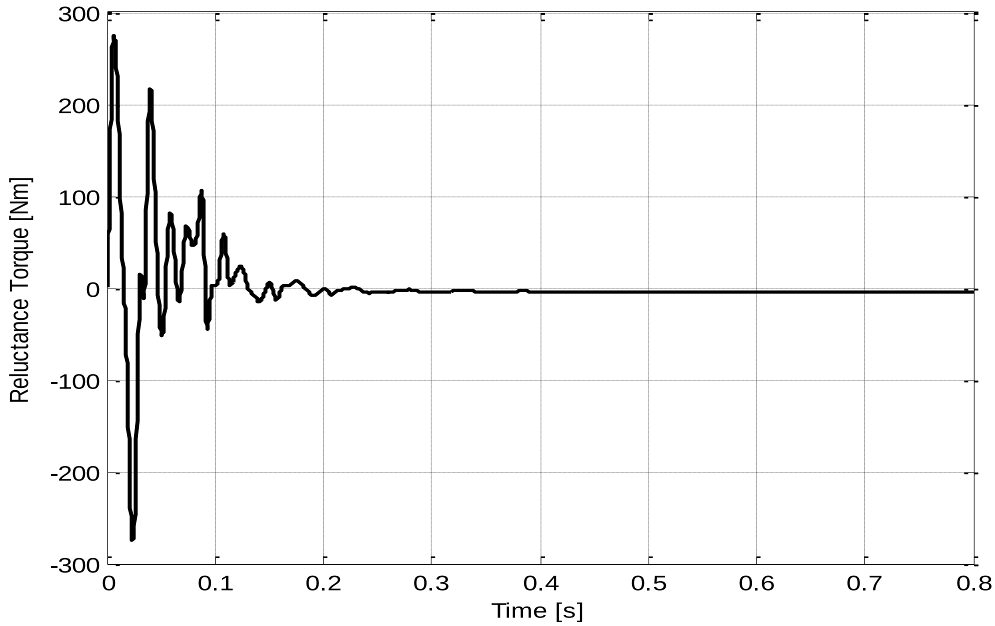


Figure 8: Graph of Reluctance Torque against Time at Run-up Condition

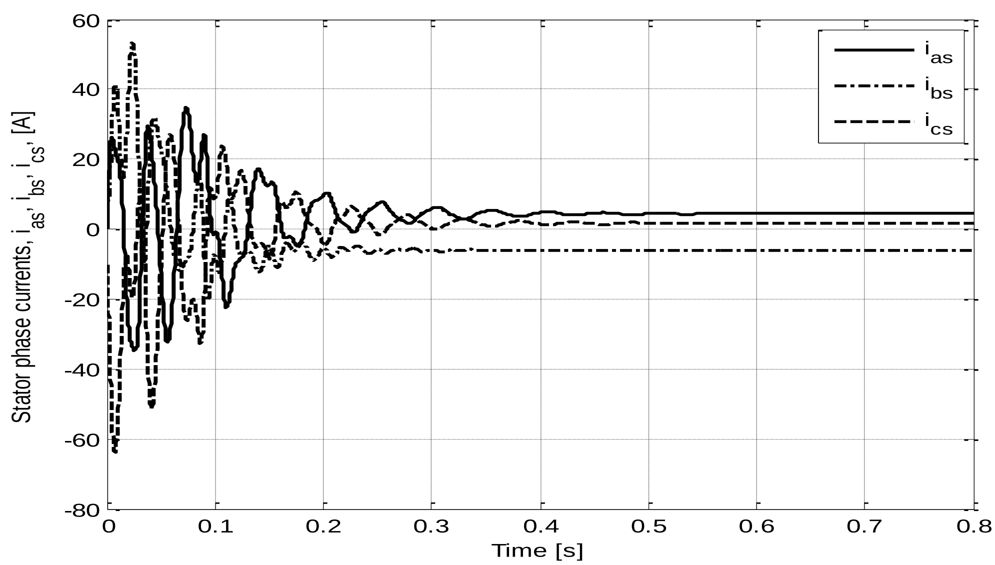


Figure 9: Graph of Stator Phase Currents against time under run-up conditions.

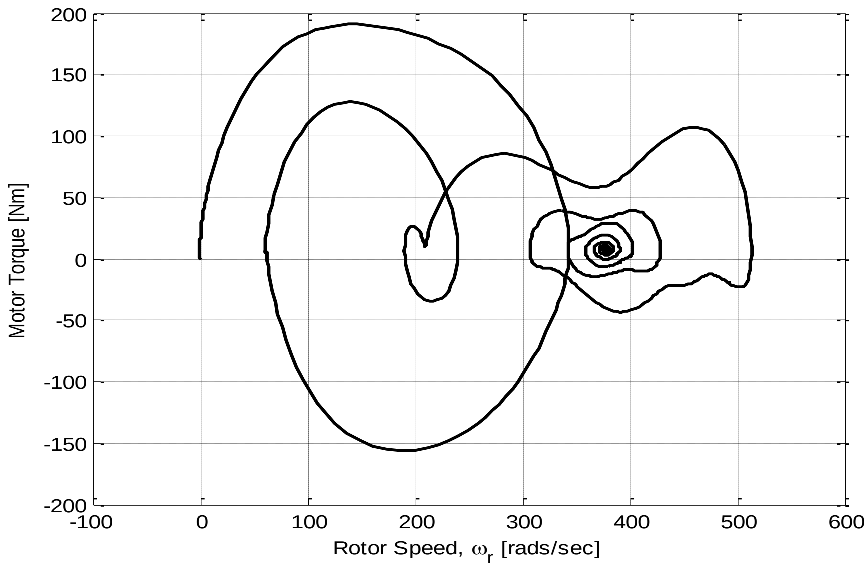


Figure 10: Graph of motor torque against rotor speed under run-up conditions.

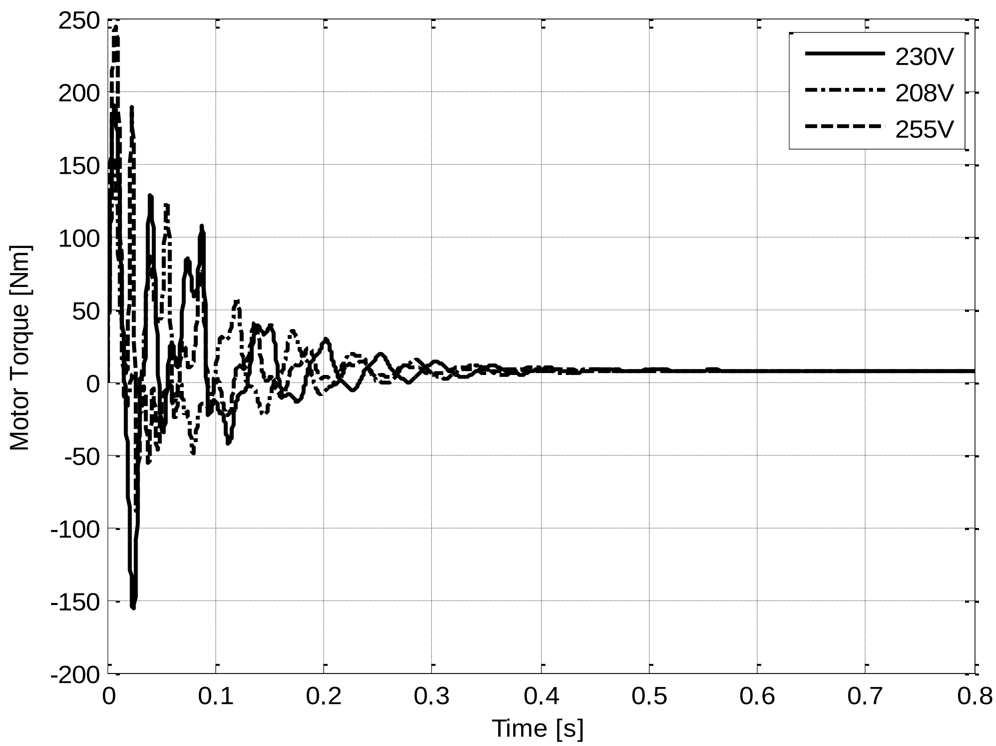


Figure 11: Graph of motor torque against time for varying rated voltage.

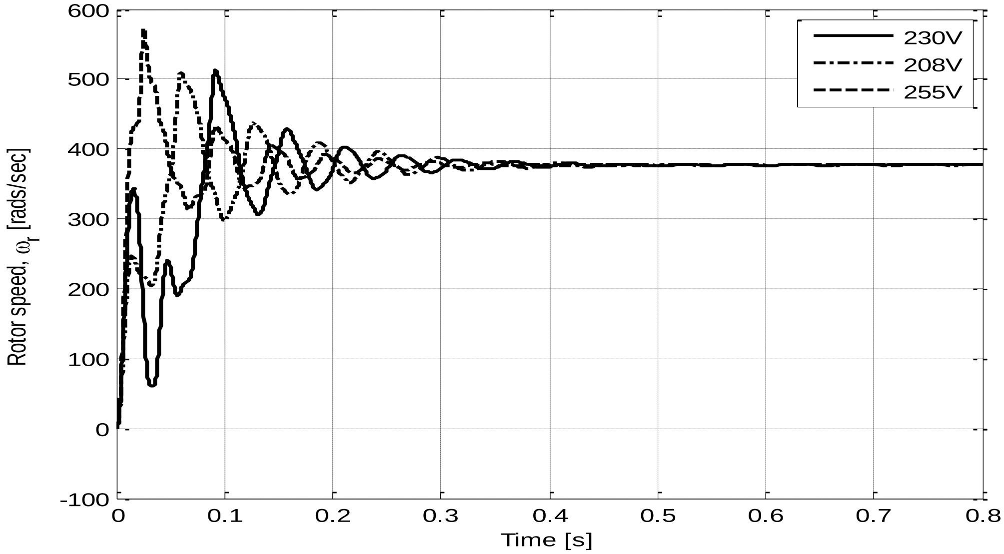


Figure 12: Graph of Rotor Speed against Time for Varying Rated Voltage.

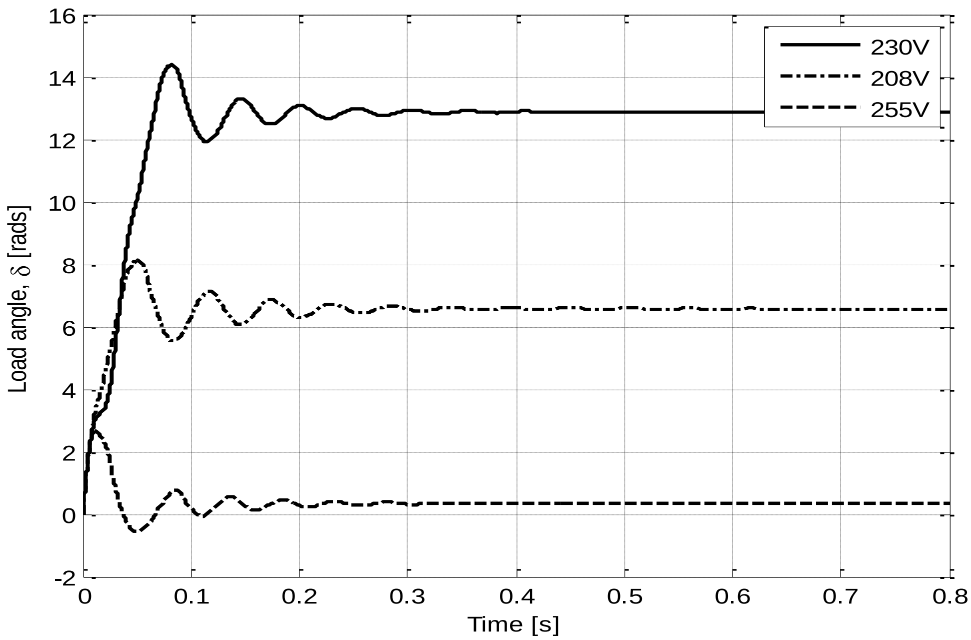


Figure 13: Graph of load angle against time for varying rated voltage.

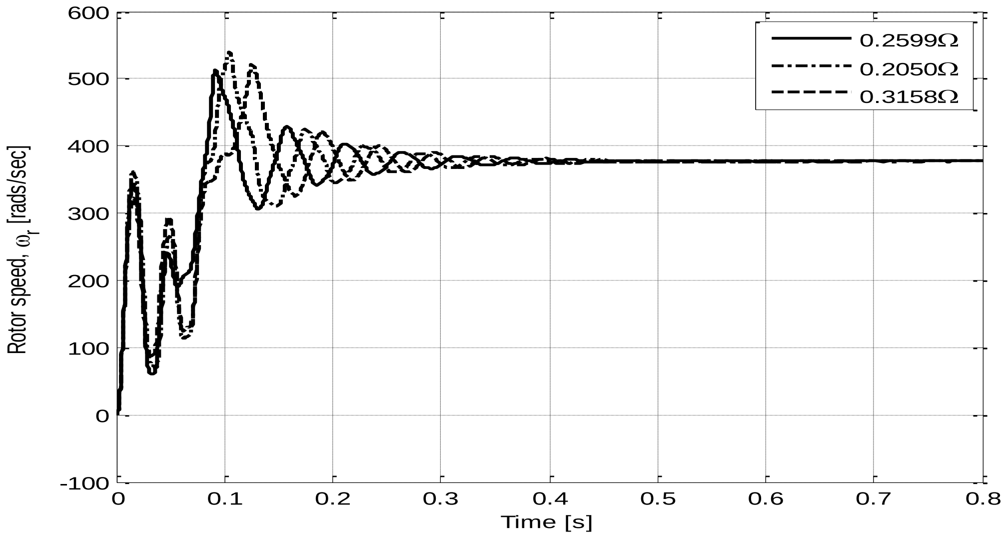


Figure 14: Graph of Rotor Speed versus Time for Varying Stator Resistance.

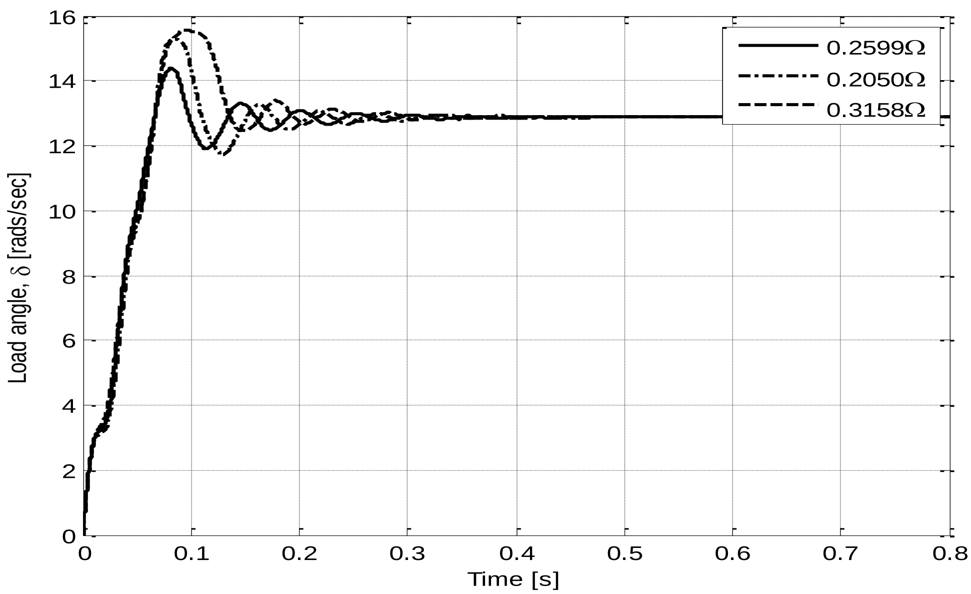


Figure 15: Graph of load angle against time for varying stator resistance.

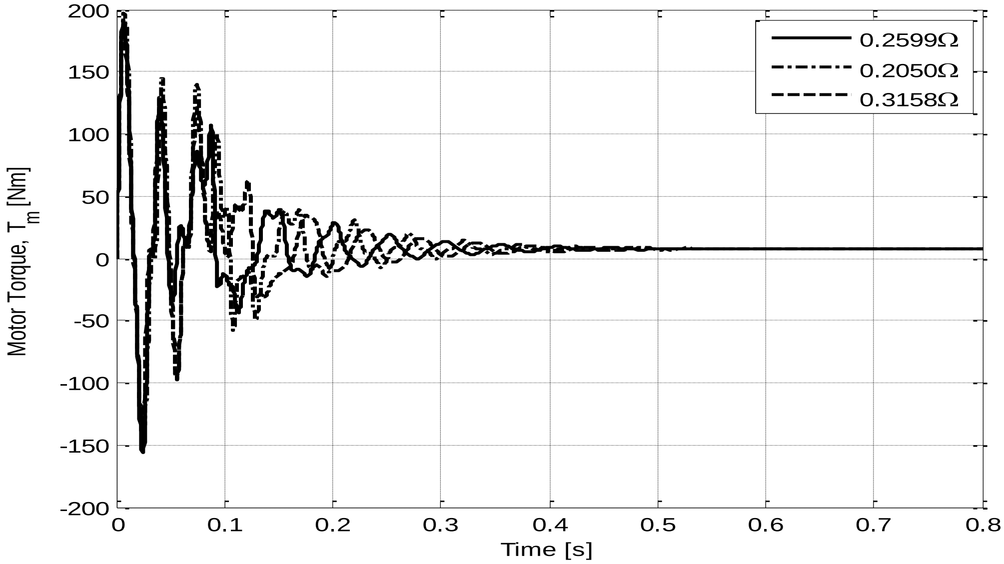


Figure 16: Graph of motor torque against time for varying stator resistance.

The transient of the machine- modeled equations in state variable form with flux linkages as state variables were used. The MATLAB function program, which makes use of the Runge– Kutta fouth-order method, was used to solve the set of equations for both electrical and mechanical models. It was assumed that the rotor and stator flux linkages are initially at zero. Synchronous machine transient responses under run-up conditions are simulated. The depicted graph shows the transients of the simulated machine for the machine torque, machine excitation torque, machine reluctance torque, and stator phase currents as a function of time,.

Varying the machines' stator resistance affects the transient performance of the machines. At lower values of stator resistance, the motor possesses the initial peak magnitude of the rotor speed and motor torque. The maximum load angle is attained at a high value of the stator resistance.

The effect of varying the equivalent field current above and below was investigated and shows that the equivalent field current increases, the rotor speed, and the rotor torque lead to mechanical shock and damage. forces the plant machines to drop considerably.

The pellet plant squirrel cage induction machine torque– rotor speed relationship under the run-up condition is shown graphically. There are three types of torques in the pellet plant squirrel cage induction machine; the initial magnitude of the reluctance torque is greater than the others. The induction torque is as shown. The reluctance transient gradually varnishes after 0.2 s from startup. The transient stator phase currents are very high, especially in phase's c and b. At 0.3 s, the stator phase currents reach their steady state values. The motor torque– rotor speed relationship shows that at run-up, the pellet plant squirrel cage induction machine is highly cyclic.

The average current of the pellet plant squirrel cage induction machine at no load characteristics was $0.703A_{ac,}$ apparent power, 220 VA, real power, 80W, reactive power, 201 var, and power factor, 0.286,

When torque was introduced at 12 (Ibf.in), the average current at no load characteristics was $1.29A_{ac,,}$ apparent power, 412VA, real power ,320W, reactive power ,272var, power factor ,0.785, horse power, 0.260, efficiency, 79.6 %. When torque was introduced at 12(Ibf.in), the starting current to full load current was 4.10, starting torque , 2.27, full load current ,0.603

The operating characteristics were very efficient; it has a higher full-load speed and good speed regulation. The pellet plant squirrel cage induction machine is very reliable because its rotor construction is simple, rugged, and cannot be burnt out. The absence of commutator, brushes, and slip rings reduces the problem of maintenance. When the power line frequency was 50 Hz, the pellet plant squirrel cage induction machine speed was 1500 rpm, and the excitation current increased because of lower impedances.

6.0: CONCLUSSION

The pellet plant conveyor belt is a power- driven belt that is wrapped around a drive pulley and driven by an electrical conventional machine. It is supported by metal plate rollers upon which the conveyor belt rests. With the introduction of the Squirrel cage induction machine to drive the pellet plant conveyor belt, the pellet plant conveyor belt and its associated equipment were stabilized and the negative effects were eliminated. The squirrel cage induction machine has good speed regulation because of its low impedance. Thus, small decreases in slip produce a large increase in the rotor current.

The squirrel cage induction machine has good speed regulation because of its low impedance. Thus, small decreases in slip produce a large increase in the rotor current. The full load is close to 7% of the starting torque, which is lower than that of ordinary conventional machines. At rest, the rotor impedance with its relatively large inductance to resistance ratio has a high induce current that lags the induce voltage by 90^0 at the pick-up speed. As the pellet plant conveyor belt squirrel cage induction machine starts turning, there is a decrease in the slip, frequency of the induce voltage, and rotor reactance. There was an increase in the power factor and increase in pellet plant conveyor belt squirrel cage induction machine efficiency. When the slip dropped to some value between 2% and 10%, the speed stabilized and remained relatively constant. The operating characteristics of the squirrel cage machine are very efficient, higher full-load speed, and good speed regulation. The squirrel cage induction machine is widely used in a variety of industrial applications and should be introduced for pellet plant conveyor belt operation because its rotor construction is very simple, rugged, and cannot be burnt out. Maintenance is eliminated due to the absence of commutation, brushes, and slip ring. The pellet plant conveyor belt squirrel cage induction machine runs at a rotating field of 1500 r/min at 50 Hz. The excitation current increased because of the lower winding impedances. These are recommended for machine designers, engineers, technicians, and pellet plant operators.

REFERENCE

A.B. Kotta, A. Patra, M. Kumar et al., Effect of molasses binder on the physical and mechanical properties of iron ore pellets, Int. J. Miner. Metall. Mater, .pp, 26, 41, 2019

B.B. Silva, E.R. Cunha, R.M. Carvalho, et al, Modeling and simulation of green iron ore pellet classification in a single deck roller screen using the discrete element method, Powder Technol. Pp, 332, 359–370, 2018

O.I. Okoro, “Transient Analysis of a Permanent Magnet Synchronous Machine (PMSM) with Damper windings”, NEJRD, vol.3 No.4. pp 66-69. 2005.

Y. Miyama, M. Ishizuka, H. Kometani, K. Akatsu, “Vibration reduction by applying carrier phase-shift PWM on dual three-phase windings Machine” In Proceedings of IEEE International Electric Machines and Drives Conference (IEMDC), Miami, FL, USA, 21–24; pp. 5998–6004, May 2017.

Z. Zhang, J. Shu, “Matlab-based Machines vector control simulation. In Proceedings of the 2010 3rd International Conference on Computer Science and Information Technology” Chengdu, China, 9 – 11; Volume 9, pp. 539–542, July 2010.

Allan Greenwood, "Fundamental Notions about Electrical Transients", Publisher, John Wiley & Sons, ISBN: 8126527293, 9788126527298. Pp 480-768, 2010

Allan Greenwood, " Electrical Transients in Power Systems”, 2nd Ed" Publisher, John Wiley & Sons ISBN: 8126527293, 9788126527298. Pp367-467, 2010

L.M. Tavares, R.F. de Almeida, Breakage of green iron ore pellets, Powder Technol, pp, 366, 497–507, 2020

M. Javaheri, A. Jafari, G.H. Baradaran et al., Effects of rollers speed regime on the roller screen efficiency, Mineral Process. Extractive Metall. Rev. pp, 1–8, 2021

Vadim I. Utkin, ”Sliding mode control design principles and applications to electric drives”, IEEE Transactions On Industrial Electronics, Vol. 40,No. 1, pp. 23-36, February 1993.

F. J.Al-azzawi, and F. F., Al-Baldaw, “Multi-machines Transient Stability Analysis Method for direct on line studies” King Sa’ud University in Collaboration with IEEE Region 8, pp 345-348, 1987

Allan Greenwood, "Simple Switching Transients", 2nd Ed" Publisher, John Wiley & Sons, ISBN: 8126527293, 9788126527298. Pp, 246-678, 2010

Allan Greenwood, "Abnormal Switching Transients”, 2nd Ed." Publisher, John Wiley & Sons ISBN: 8126527293, 9788126527298. Pp, 456, 674-768, 2010

Allan Greenwood," Transients in Three-Phase Circuits”, 2nd Ed." Publisher, John Wiley & Sons, ISBN: 8126527293, 9788126527298. Pp, 546-768, 2010

D. Cherepakha, J. Johnson, A. Kulchitsky, Examining roller screen performance to categorize iron ore green pellets to optimize pellet induration, in Proceedings of the 8th international conference on discrete element methods (DEM8), 2019