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BOTTLING COMPANY EQUIPMENT WOUND ROTOR INDUCTION MACHINE DRIVES SPEED AND STALL CONTROL USING EXTERNAL RESISTANCE

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Abstract: The bottling company equipment wound rotor induction machine drives speed and stall control using external resistance is presented. A bottling plant is a specialized facility that is fitted with bottling equipment that provides service of filling of bottling of beverages with the product and other services for customers. Stalling is *the slowing and stopping of a process b*ottling plant wound rotor induction machine, which includes power-off, power-on, and accelerated. These have constituted a negative threat to the plant's smooth operation. A wound-rotor induction machine is an induction machine whose rotor windings are connected through slip rings to external resistance and allows control of the speed and torque characteristics of the machine by resistance adjustment. The rheostat was used for starting, changing, and disconnecting the machine speed by changing the rotor resistance with the rheostat. The bottling plant wound rotor induction machine now operates under constant load conditions when an external variable resistance is applied. Wound rotor induction machines are mainly used in a variety of industrial applications such as crushers, plunger pumps, cranes and hoists, elevators, compressors, and conveyors. Speed variation and stalling issues constitute a challenge and a negative threat to the smooth operation of bottling plant equipment, and the needs call for this negative threat. There was a variation in the bottling company wound rotor induction machine operational speed of as much as 75% as a result of varying the resistance in the rotor circuit. The greater the resistance inserted in the rotor circuit, the lower the speed below the synchronous speed. When the bottling company wound rotor induction machine resistance was adjusted to the lowest value, the speed was less because of the internal resistance of the rotor windings, which is appreciably higher due to winding and rheostat tolerances. The bottling company wound rotor induction machine rotor stalls while operating in an overload condition at low speed. An external resistance was connected to the circuit, and the speed and stalling issues that constitute a challenge and threat to the smooth operation of the bottling plant equipment were eliminated. The results of the no-load characteristics of the wound rotor induction machine are as follows: average current = 0.62, apparent power = 223 VA, real power = 72w, reactive power = 211 var, and power factor = 0.323. The results of the characteristics of the wound rotor induction machine when the external resistance was set at zero ohms and at a torque of 91 bf.in are as follows: average current = 1.08 AC, apparent power = 378 VA, real power = 290w, reactive power = 242 var, power factor = 0.772, horse power = 0.220, and efficiency = 56.6%. The results of the characteristics of the wound rotor induction machine when the external resistance was set at 16Ω and at a torque of 91 bf.in are as follows: average current = 1.03 Aac, apparent power = 377 VA, real power = 283w, reactive power = 240 var, power factor = 0.768, horse power = 0.117, and efficiency = 30.8%. With the external resistance in the circuit, the input power supplied not only the actual output power but also the iron, copper, windage, and frictional losses, including the power dissipated by the external resistances. However, below the full speed operation means that the machine is operating at reduced efficiency and horse power. The machine is susceptible to variation in speed as the load changes because it has a high rotor resistance. This is recommended for bottling company engineers, technicians, and operators.

Keywords: Rotor, Stator, Rheostat, external resistance, Synchronous speed, Susceptibility, Stalling

1.0: Introduction

The bottling company equipment wound rotor induction machine drives speed and stall control using external resistance is presented. A bottling plant is a specialized facility that is fitted with bottling equipment that provides service of filling of bottling of beverages with the product and other services for customers. Stalling is the slowing and stopping of a process [1,5, 6] *of a bottling* plant wound rotor induction machine, which includes power-off, power-on, and accelerated. These have constituted a negative threat to the plant smooth operation

A wound-rotor induction machine is an induction machine whose rotor windings are connected through slip rings to external resistance and allows control of the speed and torque characteristics of the machine by resistance adjustment. The rheostat was used for starting, changing, and disconnecting machine speed by changing the rotor resistance with the rheostat. [2. 3, 10]

The bottling plant wound rotor induction machine now operates under constant load conditions when an external variable resistance is applied. Wound rotor induction machines are mainly used in a variety of industrial applications such as crushers, plunger pumps, cranes and hoists, elevators, compressors, and conveyors. Speed variation and stalling issues have constituted a challenge and a negative threat to the smooth operation of bottling plant equipment, and the needs call for this negative threat.

The three ends of the three-phase rotor windings were brought out to the three slip rings mounted on the rotor shaft. The brushes bearing on the slip ring play a crucial part in realizing the maximum advantage of the wound rotor induction machine. The development of a high starting torque becomes possible by connecting the brushes through rheostats. The full resistance of the rheostats was maintained and the maximum starting torque was obtained. [2, 4]

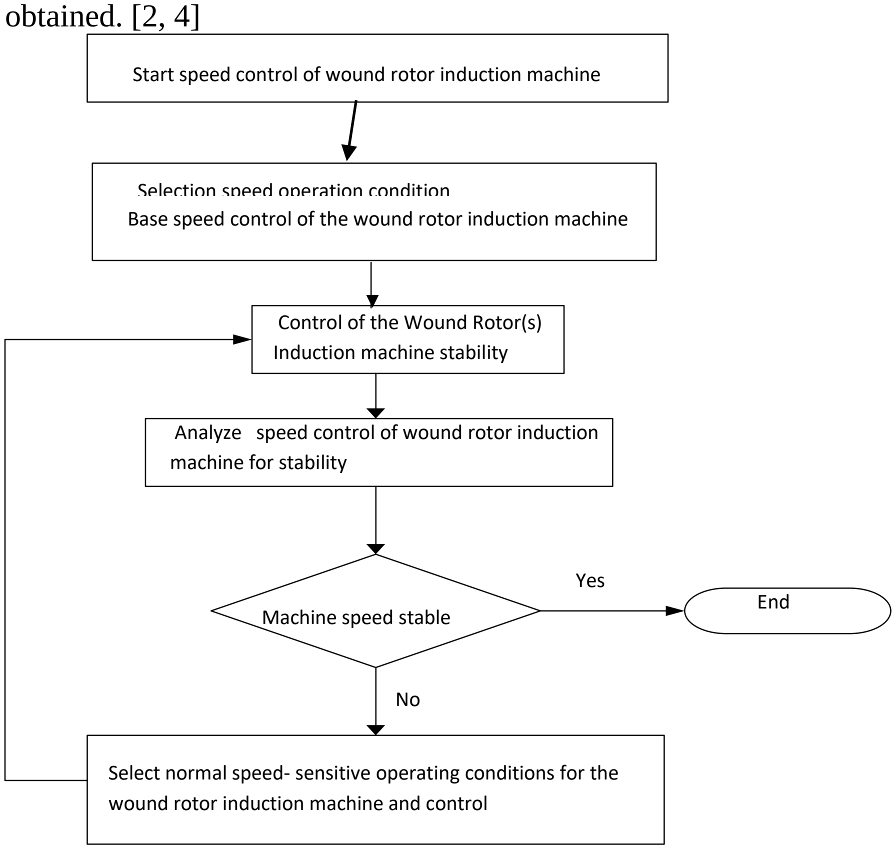


Figure 1: Bottling Company wound rotor induction machine speed control flow chart

2.0: Mathematical Modeling of the Bottling Company Wound Rotor Induction Machine

Mathematical modeling of a bottling company wound rotor induction machine is essential in industrial setup. The representation of mathematical characteristics helps to model the bottling company wound rotor induction machine by setting its component transients to zero and sufficiently obtaining the complete reduced system transients. [2, 5, 9] The mathematical equations that show the relationships between the bottling company wound rotor induction machine and the equivalent diagram of machines are shown in Figure 1. [2, 3, 8]

3.0: ELECTRICAL MODELING

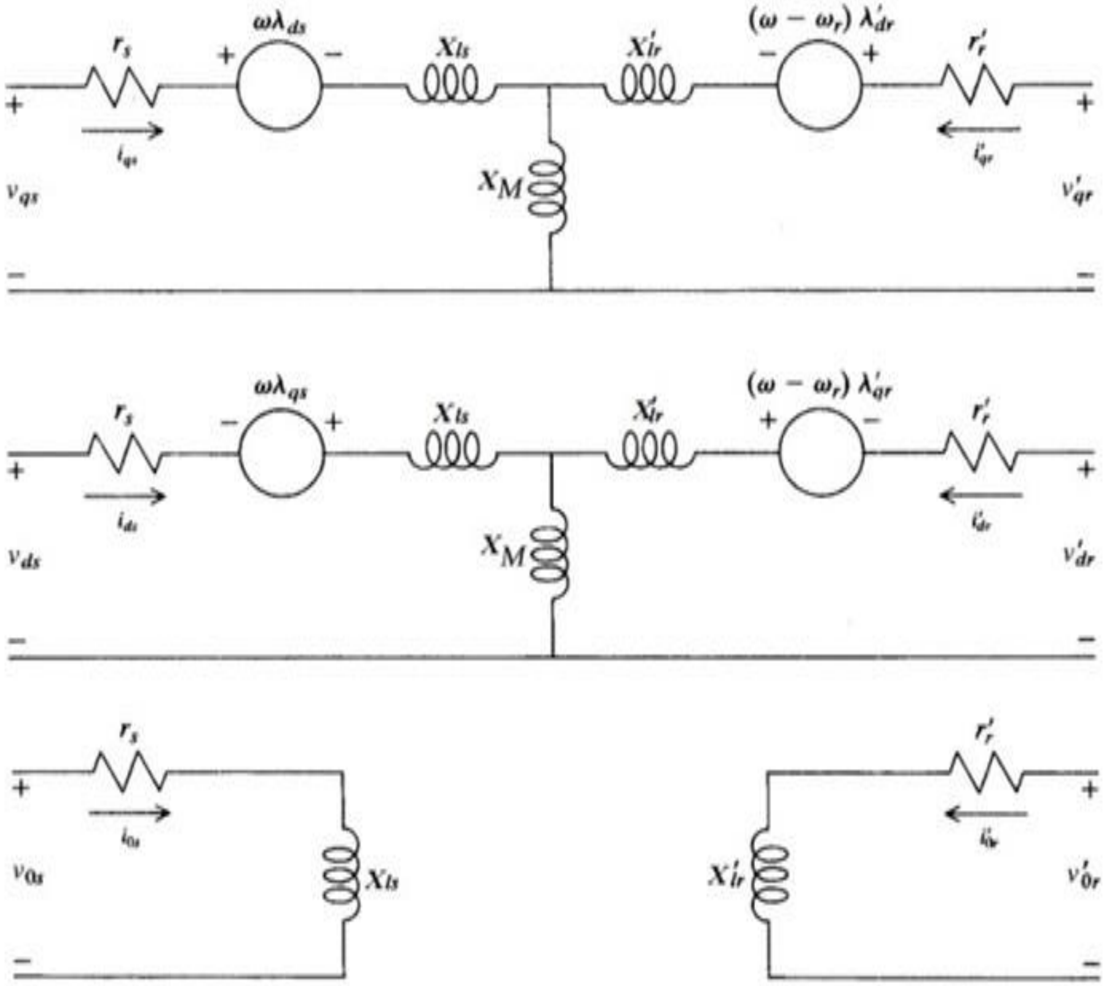


Figure 2: Equivalent circuit diagram of the machines.

$$V_{qs} = r_s i_{qs} + \frac{w_s}{w_b}\psi_{ds} + \frac{p}{w_b}\psi_{qs} \quad (1)$$

$$V_{ds} = r_s i_{ds} - \frac{w_s}{w_b}\psi_{qs} + \frac{p}{w_b}\psi_{ds} \quad (2)$$

$$V_{0s} = r_s i_{0s} + \frac{p}{w_b}\psi_{0s} \quad (3)$$

$$V_{qr} = r_r i_{qr} + \frac{w_s - w_r}{w_b}\psi_{dr} + \frac{p}{w_b}\psi_{qr} \quad (4)$$

$$V_{dr} = r_r i_{dr} - \frac{w_s - w_r}{w_b}\psi_{qr} + \frac{p}{w_b}\psi_{dr} \tag{5}$$

$$V_{0r} = r_r i_{0r} + \frac{p}{w_b}\psi_{0r} \tag{6}$$

Equation of the flux

$$\psi_{qs} = X_{ls}\, i_{qs} + X_m(i_{qs} + i_{qr}) \tag{7}$$

$$\psi_{ds} = X_{ls} i_{ds} + X_m(i_{ds} + i_{dr}) \tag{8}$$

$$\psi_{0s} = X_{ls} i_{0s} \tag{9}$$

$$\psi_{qr} = X_{lr} i_{qr} + X_m(i_{qs} + i_{qr}) \tag{10}$$

$$\psi_{dr} = X_{lr} i_{dr} + X_m(i_{ds} + i_{dr}) \tag{11}$$

$$\psi_{0r} = X_{lr} i_{0r} \tag{12}$$

Thus, the set of equations becomes

$$X_{ss} = X_{ls} + X_m \tag{13}$$

$$X_{ss} = X_{ls} + X_m \tag{14}$$

When these equations are expressed in matrix form,

$$\begin{bmatrix}\psi_{qs}\\ \psi_{ds}\\ \psi_{0s}\\ \psi_{qr}\\ \psi_{dr}\\ \psi_{0r}\end{bmatrix} = \begin{bmatrix} X_{ss} & 0 & 0 & X_m & 0 & 0\\ 0 & X_{ss} & 0 & 0 & X_m & 0\\ 0 & 0 & X_{ls} & 0 & 0 & 0\\ X_m & 0 & 0 & X_{rr} & 0 & 0\\ 0 & X_m & 0 & 0 & X_{rr} & 0\\ 0 & 0 & 0 & 0 & 0 & X_{lr}\end{bmatrix}\begin{bmatrix} i_{qs}\\ i_{ds}\\ i_{0s}\\ i_{qr}\\ i_{dr}\\ i_{0r}\end{bmatrix} \tag{15}$$

(16)

$$\begin{bmatrix} V_{qs} \\ V_{ds} \\ V_{0s} \\ V_{qr} \\ V_{dr} \\ V_{0r} \end{bmatrix} = \begin{bmatrix} r_s + \frac{p}{w_b} X_{ss} & \frac{w_s}{w_b} X_{ss} & 0 & \frac{p}{w_b} X_m & \frac{w_s}{w_b} X_m & 0 \\ -\frac{w_s}{w_b} X_{ss} & r_s + \frac{p}{w_b} X_{ss} & 0 & -\frac{w_s}{w_b} X_m & \frac{p}{w_b} X_m & 0 \\ 0 & 0 & r_s + \frac{p}{w_b} X_{ls} & 0 & 0 & 0 \\ \frac{p}{w_b} X_m & \frac{w_s - w_r}{w_b} X_m & 0 & r_r + \frac{p}{w_b} X_{rr} & \frac{w_s - w_r}{w_b} X_{rr} & 0 \\ -\frac{w_s - w_r}{w_b} X_m & \frac{p}{w_b} X_m & 0 & -\frac{w_s - w_r}{w_b} X_{rr} & r_r + \frac{p}{w_b} X_{rr} & 0 \\ 0 & 0 & 0 & 0 & 0 & r_r + \frac{p}{w_b} X_{lr} \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{0s} \\ i_{qr} \\ i_{dr} \\ i_{0r} \end{bmatrix}$$

Mechanical model of the bottling company wound rotor induction machine torque equation was expressed as [2, 7]

$$T_e = \left(\frac{3}{2}\right)\left(\frac{P}{2}\right) L_m \left(i_{qs} i_{dr} - i_{ds} i_{qr}\right) \tag{17}$$

Thus, equation becomes:

$$L_m = \frac{X_m}{w_b} \tag{18}$$

$$D = X_{ss} X_{rr} - X_m^2 \tag{19}$$

The mechanical torque equation becomes

$$T_e = \left(\frac{3}{2}\right)\left(\frac{P}{2}\right) \frac{X_m}{D w_b} \left(\psi_{qs} \psi_{dr} - \psi_{ds} \psi_{qr}\right) \tag{20}$$

Reduced bottling company wound rotor induction machine component transient model

Machine component transients are set to zero; thus,

$$\frac{d\psi_{ds}}{dt} = \frac{d\psi_{qs}}{dt} = 0 \tag{21}$$

As a result, equation (1-3) become

$$V_{qs} = r_s i_{qs} + \frac{w_s}{w_b} \psi_{ds} \tag{22}$$

$$V_{ds} = r_s i_{ds} - \frac{w_s}{w_b} \psi_{qs} \tag{23}$$

$$V_{0s} = r_s i_{0s} \tag{24}$$

4.0: Experimental Investigation of the Bottling Company Wound Rotor Induction Machine

The bottling company equipment wound rotor induction machine experiment was carried out in a standard research laboratory. The materials and instruments used included a wound rotor induction machine, an electro-dynamometer, a speed control rheostat, a three-phase wattmeter, a power supply, an alternating current meter, a hand tachometer, connection leads, and a timing belt. Safety was highly considered during this investigation. Connection was not made when power was "ON" because of the presence of high voltage.

The arms of the three rheostats were separately brought out to terminals 1, 2, and 3, while the remaining ends of the rheostat were connected internally and to the neutral terminal. The three rheostats were ganged together for simultaneous variation. The resistance was 0Ω when the machine rheostat control knob was turned full counterclockwise and 16Ω when the machine rheostat control knob was turned full clockwise.

Experimental Investigation before Couple the Electro-Dynamometer to the Machine

With the use of materials and instruments, the circuit was connected as shown in Figure 3. For the initial investigation, the machine was not coupled to the electro-dynamometer. The machine's rheostat control knob was turned full counterclockwise for zero-ohm resistance. The machine started turning when the power supply was switched "ON", and the voltage was adjusted to 400 V. The machine's right direction was observed, and the line current and wattmeter indications were taken as shown in table1. Thereafter, the power supply voltage was returned to zero and the power supply was switched "OFF".

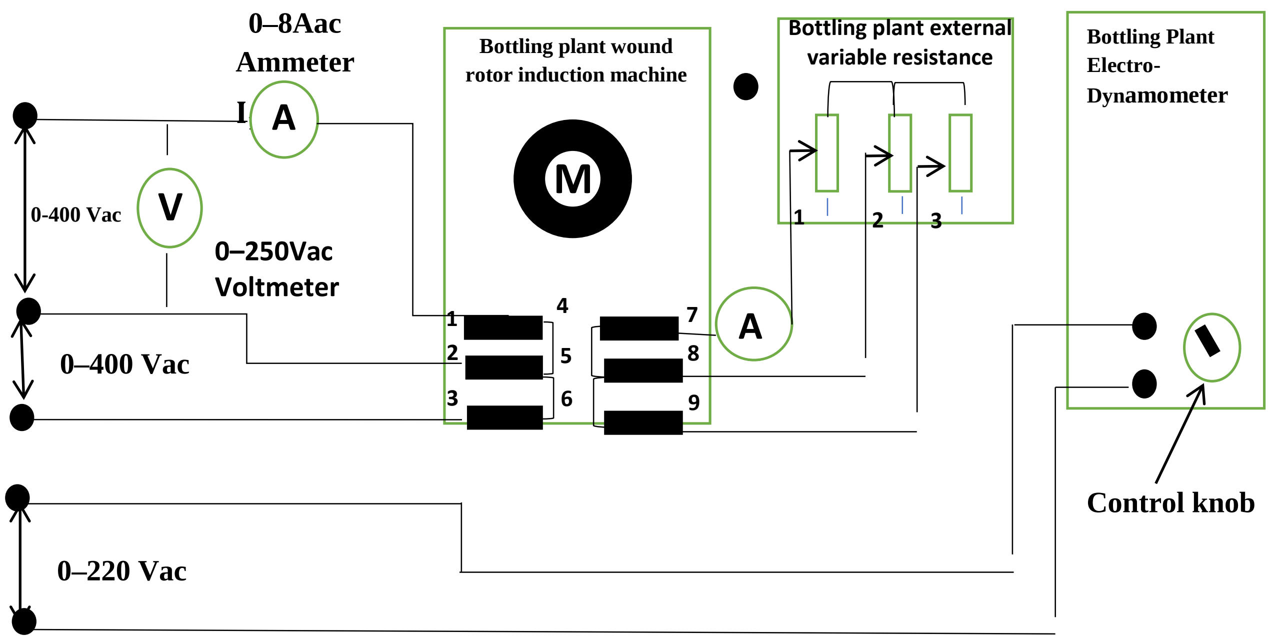
The bottling company equipment wound rotor induction machine was coupled to an electro-dynamometer with a timing belt, and the electro-dynamometer control knob was set to the full counterclockwise position. The procedure was followed as before for the toque, and the record was taken as shown in Table 1 while maintaining the input power supply of 400 V. The power supply voltage was returned to zero and the power supply was switched "OFF".

Experimental Investigation after coupling the electro-dynamometer to the machine

The rheostat speed control knob was set to the full clockwise position for maximum resistance, and the bottling company equipment wound rotor induction machine was uncoupled from the electro-dynamometer. Then again, the machine started turning when the power supply was switched "ON" and the power supply voltage was adjusted to 400 Vac. The machine's right direction was observed, and the three-line current, wattmeter indications, and bottling company equipment wound rotor induction machine speed were recorded, as shown in Table 2. The power supply voltage was returned to zero, and the power supply was switched "OFF".

The bottling company equipment wound rotor induction machine was coupled to an electro-dynamometer with a timing belt, and the electro-dynamometer control knob was set to the full counterclockwise position. The procedure was followed as before for the toque, and the record was taken as shown in Table 1 while maintaining the input power supply of 400 V.

The bottling company equipment wound rotor induction machine speed rheostat control knob was set at 91 bf.in, from full clockwise to full counterclockwise, and the bottling company equipment wound rotor induction machine speed and development torque were changed. The power supply voltage was returned to zero, and the power supply was switched "OFF". The circuit was connected as shown in figure 4. The electro-dynamometer control knob was set at its full clockwise position to provide the Bottling Company equipment wound rotor induction machine maximum starting load, and the machine speed control rheostat knob was set at its full clockwiseposition. The power supply was turned "ON" for a quick record, and the machine power supply was turned off.



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

Figure 3: circuit diagram of bottling plant wound rotor induction machine before electro-dynamometer coupled

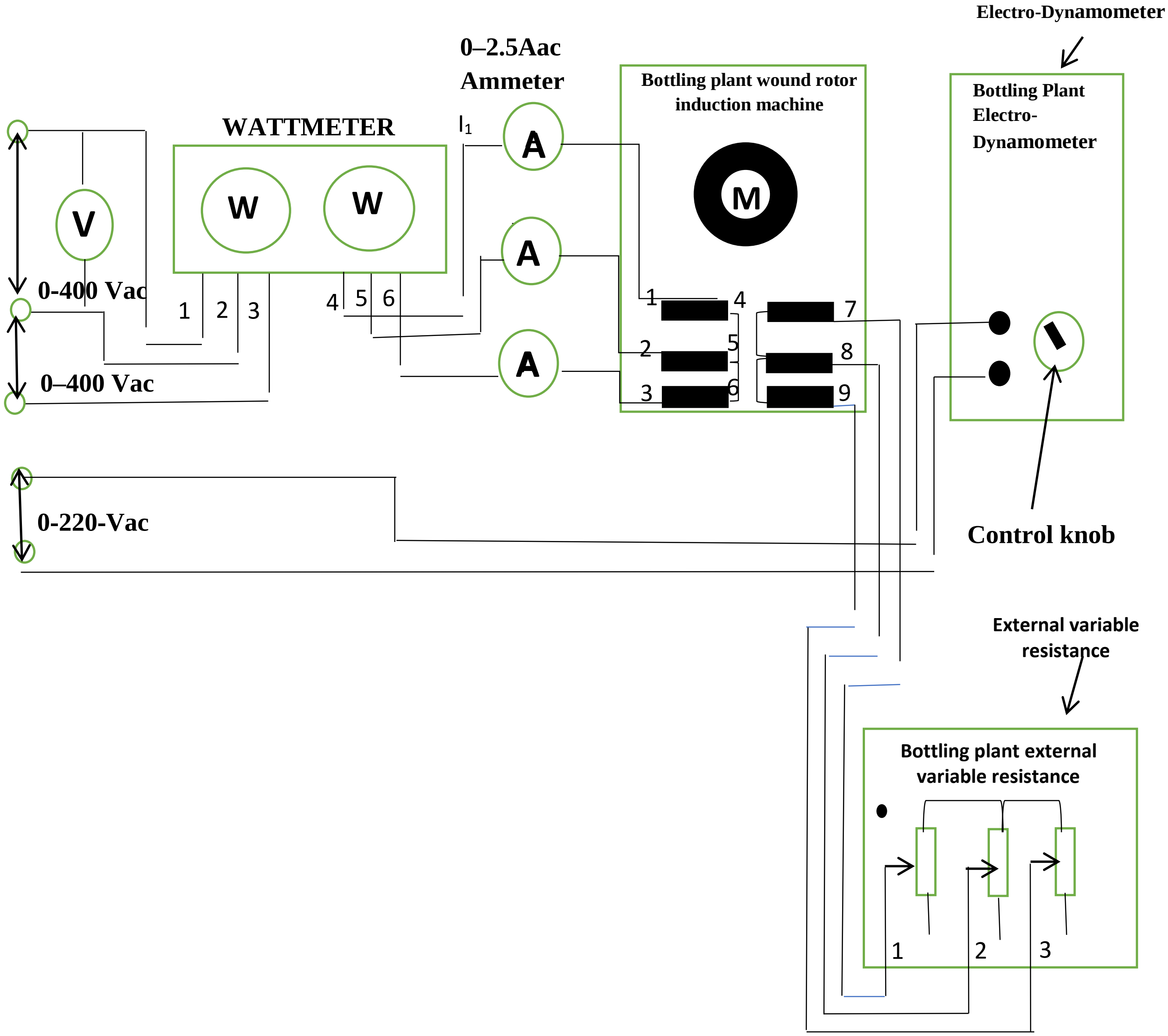


Figure 4: Circuit diagram of bottling plant wound rotor induction machine after Electro-Dynamometer Coupled

TABLE 1: Experimental results of the bottling plant wound rotor induction machine before electro-dynamometer coupled

S/No.	I_1(amps)	I_2(amps)	I_3(amps)	W_1(watts)	I_2(watts)	SPEED(r/min)	TORQUE(Ibf.in)
1	0.70	0.74	0.72	-30	102	1775	**0**
2	0.80	0.88	0.80	22	143	1680	**3**
3	0.84	1.03	0.94	55	180	1620	**6**
4	1.14	1.22	1.10	90	220	1550	**9**
5	1.38	1.46	1.35	155	265	1435	**12**

TABLE 2: Experimental results of the bottling plant wound rotor induction machine after electro-dynamometer coupled

S/No.	I_1(amps)	I_2(amps)	I_3(amps)	W_1(watts)	I_2(watts)	SPEED(r/min)	TORQUE(Ibf.in)
1	0.70	0.76	0.71	-30	100	1750	**0**
2	0.80	0.86	0.79	20	140	1420	**3**
3	0.94	1.00	0.92	50	178	1140	**6**
4	1.12	1.18	1.10	86	217	800	**9**
5			MACHINE	STALLS			**12**

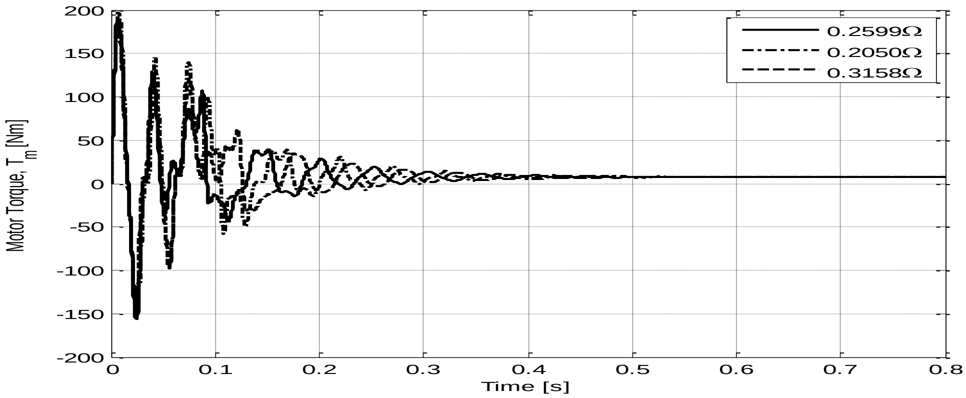


Figure 5: Graph of the bottling company wound rotor induction machine motor torque against time For Varying Stator Resistance.

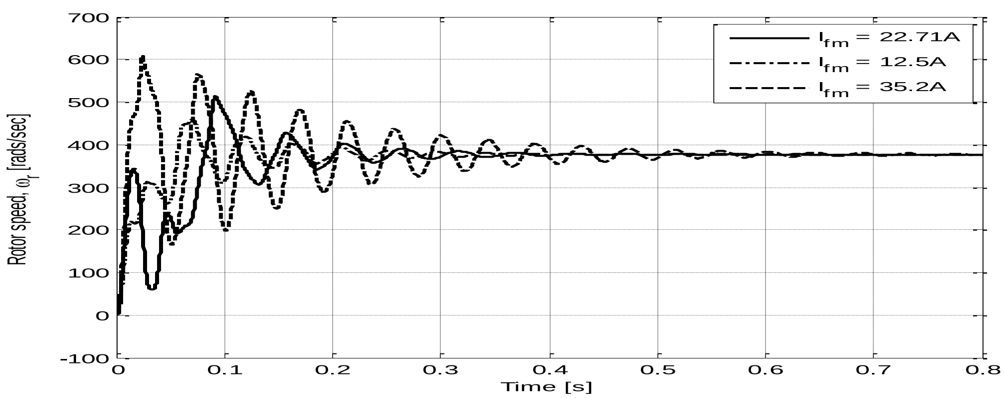


Figure 6: Graph of the bottling company wound rotor induction machine Rotor speed versus time for Varying Equivalent Field Current

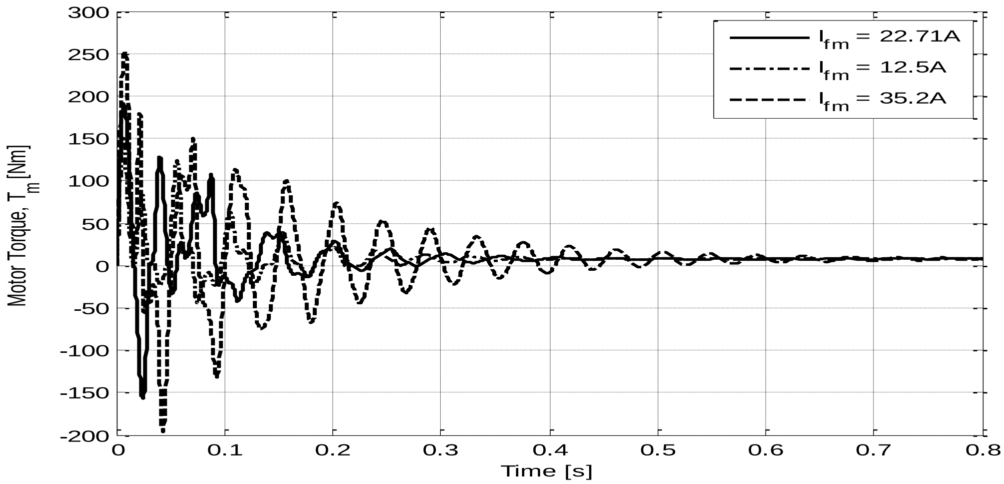


Figure 7: Graph of the Bottling Company Wound Rotor Induction Machine Motor Torque Against Time for Varying Equivalent Field Current

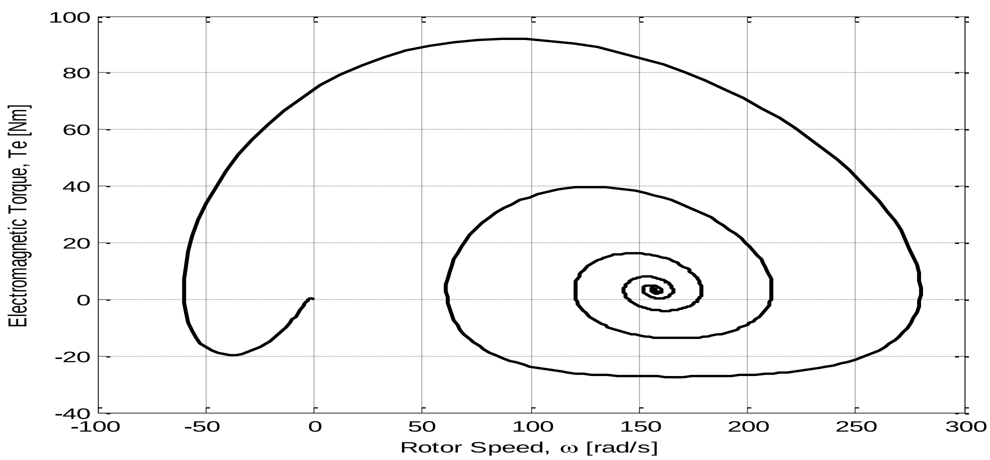


Figure 8: Graph of the bottling company wound rotor induction machine electromagnetic torque Versus Rotor Speed.

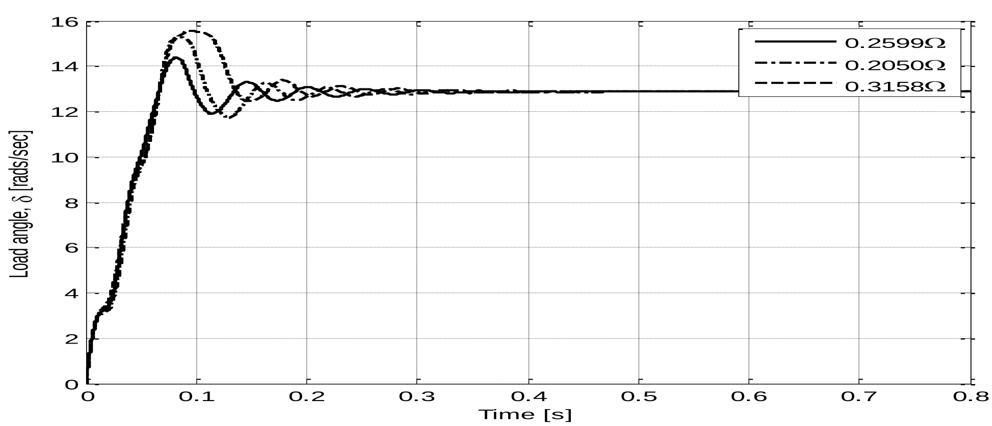


Figure 9: Graph of bottling plant wound rotor induction machine load angle versus time for varying stator resistance.

The power factor improves with loading as loading increases, the machine delivered power, and the real input power increases proportionately; however, the reactive power required for the magnetic field remains relatively constant. Varying the equivalent field current above or below the rated value forces the load angle to drop considerably. When the external resistance was in the circuit, the input power supplied not only the actual output power but also the iron, copper, windage, and frictional losses, including the power dissipated by the external resistances.

The quick record results are: I_1 = 1.43 AAC, I_2 = 2.23 AAC, E_1 = 400 V, the machine toque was 15.8 1bf.in, and apparent power =522 VA.

The results of the no-load characteristics of the bottling company equipment wound rotor induction machine are as follows: average current = 0.62, apparent power = 223VA, Real power72w, Reactive power = 211 var, power factor = 0.323

The results of the characteristics of the bottling company equipment wound rotor induction machine when the external resistance was set at zero ohms and torque of 91 bf.in are as follows: average current = 1.08 AC, apparent power = 378 VA, real power = 290 W, reactive power = 242 var, power factor = 0.772, horse power = 0.220, efficiency = 56.6%.

The results of the characteristics of the bottling company equipment wound rotor induction machine when the external resistance was set at 16Ω and at a torque of 91 bf.in are as follows: average current = 1.03 AC, apparent power = 377 VA, real power = 283w, reactive power = 240 var, power factor = 0.768, horse power = 0.117, and efficiency = 30.8%.

The results of the no-load and full-load characteristic ratio of the bottling company equipment wound rotor induction machine when the torque was set at 91 bf.in are as follows: average starting current to full load current = 1.42 Ac, starting torque to full load torque = 1.76, full load current to no load current = 1.70.

5.0: Conclusion

When the bottling company equipment wound rotor induction machine approaches the normal operating speed, the rheostat resistance is gradually reduced and out of the circuit entirely at full speed. The starting torque of the wound rotor induction machine was very high because of the rotor winding resistance. The bottling company equipment wound rotor induction machine has a variable speed capability as a special future for varying rheostat resistance, which makes it possible to vary the percentage slip and the bottling company equipment wound rotor induction machine speed. The power factor improves with loading as loading increases, the machine delivered power, the real input power increases proportionately, and the reactive power required for the machine magnetic field remains relatively constant.

The quick record results are: I_1 = 1.43 AAC, I_2 = 2.23 AAC, E_1 = 400 V, the machine toque was 15.8 1bf.in, and apparent power =522 VA. The results of the no-load characteristics of the wound rotor induction machine are as follows: average current = 0.62, apparent power = 223VA, Real power72w, Reactive power = 211 var, and power factor = 0.323. The results of the characteristics of the wound rotor induction machine when the external resistance was set at zero ohms and at a torque of 91 bf.in are as follows: average current = 1.08 AC, apparent power = 378 VA, real power = 290w, reactive power = 242 var, power factor = 0.772, horse power = 0.220, and efficiency = 56.6%. The results of the characteristics of the wound rotor induction machine when the external resistance was set at 16Ω and at a torque of 91 bf.in are as follows: average current = 1.03 Aac, apparent power = 377 VA, real power = 283w, reactive power = 240 var, power factor = 0.768, horse power = 0.117, and efficiency = 30.8%. The results of the no-load and full-load characteristic ratio of the wound rotor induction machine when the torque is at 91 bf.in are as follows: average starting current to full-load current = 1.42 AC, starting torque to full load torque = 1.76, full load current to no-load current = 1.70.

When the external resistance was in the circuit, the input power supplied not only the actual output power but also the iron, copper, windage, and frictional losses, including the power dissipated by the external resistances. However, below the full speed operation means that the machine is operating at reduced efficiency and horse power. The machine is susceptible to variation in speed as the load changes because it has a high rotor resistance. This is recommended for bottling company engineers, technicians, and operators.

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