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PHARMACEUTICAL INDUSTRIAL PLANT TRANSIENT AND POWER FACTOR IMPROVEMENT USING SPLIT-PHASE MACHINE

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Abstract
Pharmaceutical industrial plant transient and power factor improvement using split-phase machine is presented. Pharmaceutical industrial plant study was carried out to examine transient stability and improve the power factor of the industrial plant so as to maintained quality services. This is because; stress on pharmaceutical industrial plant systems is increasing day by day, due to faults and sudden load change that constitutes negative threat to the industrial. Pharmaceutical industry are apothecaries that engage in wholesale, production of drugs such as morphine, quinine, and strychnine and companies that established research laboratory and discovered medical applications for their products. Electrical transients current is current before reaching steady state and are fast rise time, short duration energy pulses that have voltage and current components often transmitted down power lines. Power line transients are when AC/DC connections are made, broken, short circuit, that constitute negative threat to pharmaceutical industrial plant. Power factor improvements means generating reactive power and common methods are capacitor banks, synchronous condenser and phase advancer. A low power factor increased energy consumption, reduced efficiency, and additional costs. Split phase machine is a single-phase machine, with two windings, one provided with a starting winding, another with running winding and energized continuously. The alternating current circuit of pharmaceutical industrial plant contains pure reactance like capacitive or inductive voltage and current that is 90 degrees out of phase and in most cases no useful real power is developed. Laboratory investigating reveals that this was due to the fact that some reactance and the apparent power (VA) were greater than the real power (W). The difference between the real and apparent was caused by reactance known as reactive power (Var). The capacitance was connected across the machine load to reduce the transient line current and apparent power, the added capacitive reactance suppressed the transient line current to a minimum value

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thereby changed the real power consumed by the pharmaceutical machine. Transient and power factor improved drastically for smooth pharmaceutical industrial plant operation. The stator current decreases as power factor increases, the power factor peak at the stator current null point at 0.14 ampere, and at real power of 50 watts, the power factor is almost at unity (0.99) The experiment on the split-phase machine drives was performance and its various run-up characteristics results were presented graphically for dynamic study and this is recommended for technicians, operators, engineers and machines designers of pharmaceutical industries.

1.0: INTRODUCTION

Pharmaceutical industrial plant transient and power factor improvement using split-phase machine is presented. Pharmaceutical industrial plant study was carried out to examine transient stability and improve the power factor of the industrial plant so as to maintained quality services. This is because; stress on pharmaceutical industrial plant systems is increasing day by day, due to faults and sudden load change that constitutes negative threat to the industry. [2, 3, 5]

Pharmaceutical industry are apothecaries that engage in wholesale, production of drugs such as morphine, quinine, and strychnine and companies that established research laboratory and discovered medical applications for their products. [11, 12, 13]

Electrical transients current is 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. Common causes of power line transients are when AC/DC connections are made, broken, equipment powered down, short circuit that constitute negative threat to pharmaceutical plant facilities. [2, 5,6, 7]

2.0: Pharmaceutical Industry Transient and Power Factor Improvements

Power factor improvements means generating reactive power and commonly methods are capacitor banks, synchronous condenser and phase advancer. A low power factor results in increased energy consumption, reduced efficiency and additional costs. Capacitor was used because they are very cheap, Losses are low in static capacitors, there is no moving part, thus, low maintenance, it works in normal atmospheric conditions, do not require a foundation for installation, and they are lightweight and easy to installed. [9, 10]

Real power is the product of apparent power and the cosine angle while the ratio of real power to apparent power is known as power factor of alternating current circuit and can be found by dividing the real power by apparent power. Power factor value depends on how much the current and voltages are out of phase. The real power is equal to current (I) x voltage (E) when current and voltage are in phase. In pure capacitive or inductive circuit, the power factor is zero when current and voltage are out of phase. This result to actual value of power to be zero, but the circuit that contain both resistance and inductance, the value of the power factor is a value between one and zero. The power factor can be found if the voltage and current value are known.

Split phase machine is a single-phase machine and it has two windings and is provided with a starting winding, running winding and energized continuously. [1, 8] The starting winding is displaced by 90° from the main winding. The product of voltage and current is the apparent power (VA). The device known as wattmeter was used to measured real power supplied to the load. The apparent power is larger than the real power (W) when reactive power (Var) was involved. Reactive power may be capacitive or inductive. [5, 6, 8] In most cases, because of the presence of inductance in electro- mechanical devices, the reactive power is usually inductance and calculated as square root of the square of apparent power minus square of the real power. Real power is calculated when the phase angle is known.

3.0: Mathematical Modeling of Pharmaceutical Industrial Plant Machine

The continuous-time electromechanical model of pharmaceutical industrial machine is second order and non-linear with possible states being the transient current and fluxes. [2, 3]. With assumption that the variation of flux induced by the rotor magnet in the stator must be sinusoidal and the variation of the inductance as a function of the rotor position must also be sinusoidal, the pharmaceutical industrial machine equations expressed in the rotor reference frame become:

$$V_d = R_s i_d + L_d \frac{di_d}{dt} - \frac{L_q}{L_d} P\ \omega_m\ i_q \tag{1}$$

$$V_q = R_s i_q + L_q \frac{di_q}{dt} + \mathrm{P} l_d \omega_m i_d + \omega_m \lambda \tag{2}$$

Equation (1-2) is express in a state variable form with current as state variable, we have,

$$\frac{d}{dt}\, i_d = \frac{1}{L_d} V_d - \frac{R}{L_d} i_d + \delta P\ \omega_m\ i_q \tag{3}$$

$$\frac{d}{dt}\, i_q = \frac{1}{L_q} V_q - \frac{R}{L_q} i_q - \left(\frac{1}{\delta}\right) P\ \omega_m\ i_d - \frac{1}{L_q}\ \mathrm{P}\lambda\omega_m \tag{4}$$

Inductance saliency ratio is defined as,

$$\delta = \frac{L_q}{L_d} \tag{5}$$

d - q axes of the current vector are computed through a state transformation of the stator phase currents as i_{as} i_{bs} and i_{cs} [2, 4].

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\omega & \sin\omega \\ -\sin\omega & \cos\omega \end{bmatrix} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{as} \\ i_{bs} \\ i_{cs} \end{bmatrix} \tag{6}$$

Similarly, the three phase voltages V_{as} , $V_{bs\ and}\ V_{cs}$ applied to the pharmaceutical industrial machine windings are obtained from V_d and V_q voltages by means of the reverse park transformation [2, 5].

$$\begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \cos\omega & -\sin\omega \\ \sin\omega & \cos\omega \end{bmatrix} \begin{bmatrix} V_d \\ V_q \end{bmatrix} \tag{7}$$

The copper loss in the stator windings becomes,

$$P_c = \frac{1}{2}(I^2\ R_s) \tag{8}$$

$$I_2 = i^2\ \mathrm{d} + i^2\ \mathrm{q} \tag{9}$$

The electromagnetic torque of pharmaceutical industrial machine windings gives rise to two types of torques: One is known as reluctance torque, cause by the saliency phenomenon while the second is the hybrid torque due to interaction between rotor and the stator fluxes [2, 5].

$$T_e = 1.5\ \mathrm{P}\ [\lambda\ i_q + (\ L_d - L_q\ )\ i_d i_q] \tag{10}$$

The torque components are derived from equation (10),

Hybrid Torque,

$$T_h = 1.5\ \mathrm{P}\ \lambda\ i_q \tag{11}$$

Reluctance Torque,

$$T_r = 1.5\ \mathrm{P}\ (\ L_d - L_q\ )\ i_d i_q \tag{12}$$

The mechanical model of pharmaceutical industrial plant machine windings is represented as a second-order differential equation [2, 4].

$$J_m \frac{d^2\theta_m}{dt^2} = T_c - T_L \quad (13)$$

If equation (13) is decomposed into two first order differential equation it gives,

$$P\theta_m = \omega m \quad (14)$$

$$J_m (P\ \omega m) = T_c - T_L \quad (15)$$

$$P\ \omega m = \frac{1}{J_m}(T_c - T_L) \quad (16)$$

But

$$\omega r = \omega m\ P \quad (17)$$

$$\theta_r = \theta_m P \quad (18)$$

Figure 1a: Pharmaceutical Machine Research Laboratory [UNIPORT]

The experiment was carried out with pharmaceutical machine in a standard research laboratory [UNIPORT] see figure 1a. The materials and instruments used includes: Split-phase/Capacitor start machine, alternating current metering, single phase wattmeter, power supply module and connecting leads. These instruments and materials were connected as shown in the Circuit Diagram of pharmaceutical Plant, see figure1b.

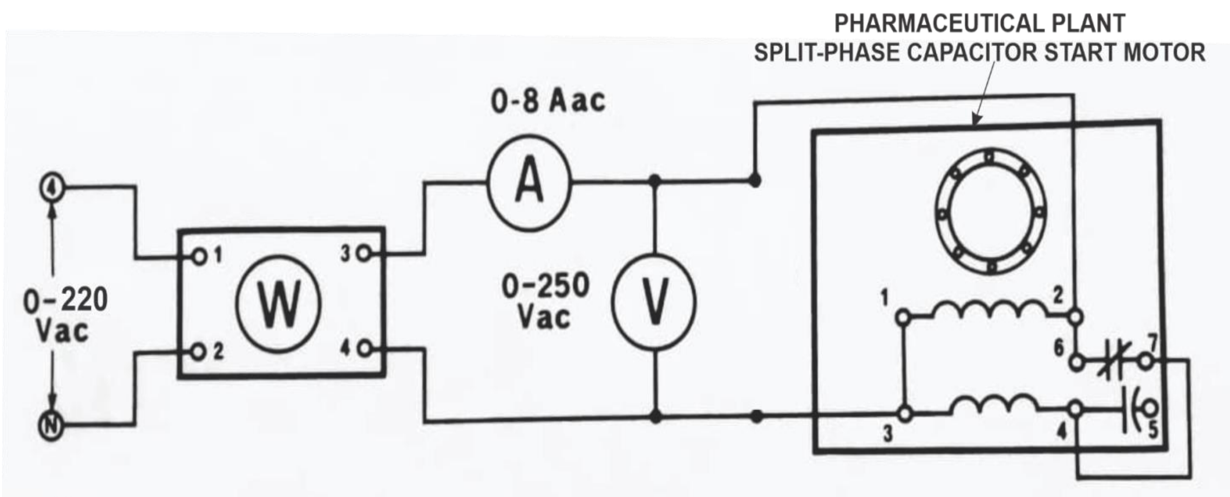

Figure1b: Split-Phase/ Capacitor Start Motor Circuit Diagram for Pharmaceutical Plant

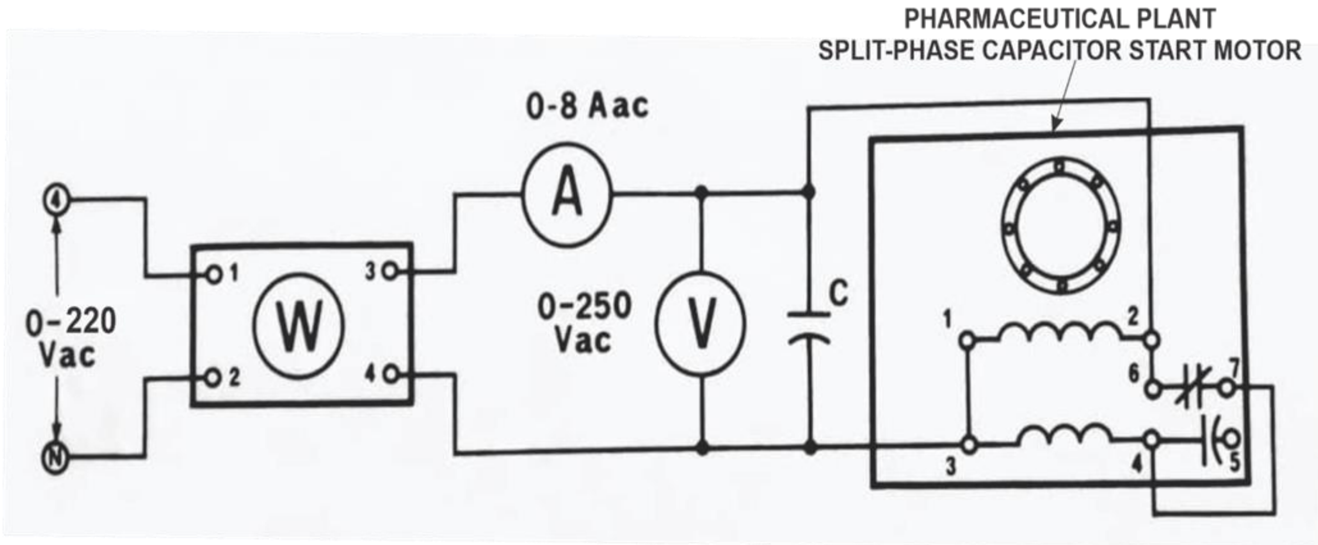

Figure2: Circuit diagram of figure 1b (Split-Phase/Capacitor Start Machine) modify for Transient Suppression and power factor improvement for Pharmaceutical industrial Plant.

Figure2 shows a modify circuit diagram of split-phase capacitor start machine used for transient current suppression and power factor improvement for pharmaceutical industrial plant. The terminal 1 to 3, 2 to 6, and 4 to 7 was connected with a short lead as shown in the figure2. The power supply was turned 'ON' and the machine started running while the voltage was adjusted gradually to 220-volt ac as indicated across the machine.

The line current was recorded as I_L = 3.3Aac

The real Power was also recorded P = 110 W

The voltage was returned to zero and power supply was turned off.

Apparent power was calculated as P_A = Ex I = 120 x 3.3 = 396 VA

PF = $\frac{P}{P_A}$ = 110/726 = 0.278

$P_R = \sqrt{(P_A{}^2) - P^2}$ = 380 Var

After the capacitor was connected in parallel with the pharmaceutical industrial plant machine to suppress the transient current and improved the power factor. The power was turn 'ON' and follows the same procedure of machine operation. It was noted that line current started diminishes to a minimum value as the capacitor was gradually added.

The line current was recorded as I_L = 1.05Aac

The real Power was also recorded P = 110 W

Apparent power was calculated as P_A = Ex I = 126 VA

PF = $\frac{P}{P_A}$ = 110/726 = 0.873

$P_R = \sqrt{(P_A{}^2) - P^2}$ = 61.4 Var

Table 1: Pharmaceutical Industrial Plant Machine Windings Simulation Parameters

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

Source: [2]

Table2: Experimental Result of Pharmaceutical Industrial Plant Machine

I_2 (AMPS)	E1 (VOLTS)	I_1 (Amp)	POWER (VA)	W_1	W_2	POWER (Watts)	PF
0	220	0.80	288	-47	114	67	0.23
0.1	220	0.62	235	-37	93	56	0.25
0.2	220	0.46	166	-17	70	53	0.32
0.3	220	0.24	86.4	10	40	50	0.58
0.4	220	0.14	50.4	25	25	50	0.99
0.5	220	0.20	72.0	40	10	50	0.70
0.6	220	0.35	126	66	-12	54	0.43
0.7	220	0.52	187	80	-24	56	0.30
0.8	220	0.68	245	100	-35	65	0.27

Table 3: Experimental Result of Pharmaceutical Industrial Plant Machine

E (volts)	I (amps)	P (watts)	SPEED(r/min)	VIBRATION
220	4.55	130	1790	Heavy
170	3.25	105	1790	Moderate
120	2.25	50	1790	Light
70	1.45	25	1755	Lighter
20	0.95	10	1750	Lightest

Table 4: Experimental Result of Pharmaceutical Industrial Plant Machine

Torque(Ibf.in)	I (amps)	VA	P (watts)	SPEED(r/min)	Hp
0	3.30	395	110	1795	0
3	3.55	425	225	1770	0.08
6	3.95	473	300	1748	0.17
9	4.45	533	380	1725	0.25
12	5.15	617	480	1685	0.32

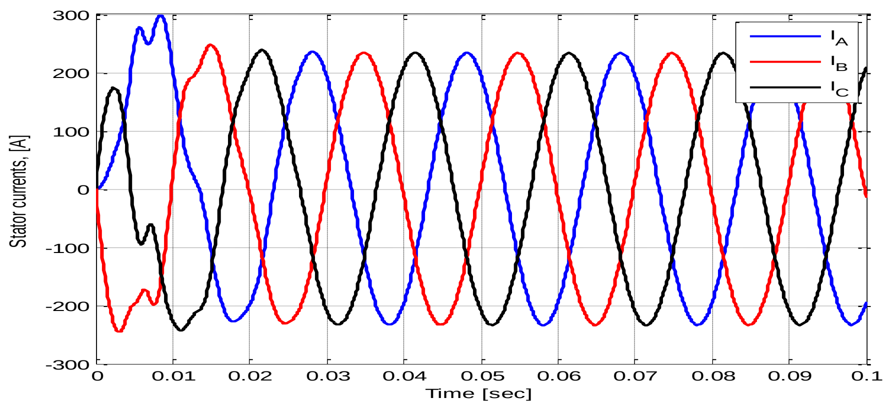

Figure 3: Graph of Stator Currents (amp) /Time (sec) of Pharmaceutical Industrial Plant Machine

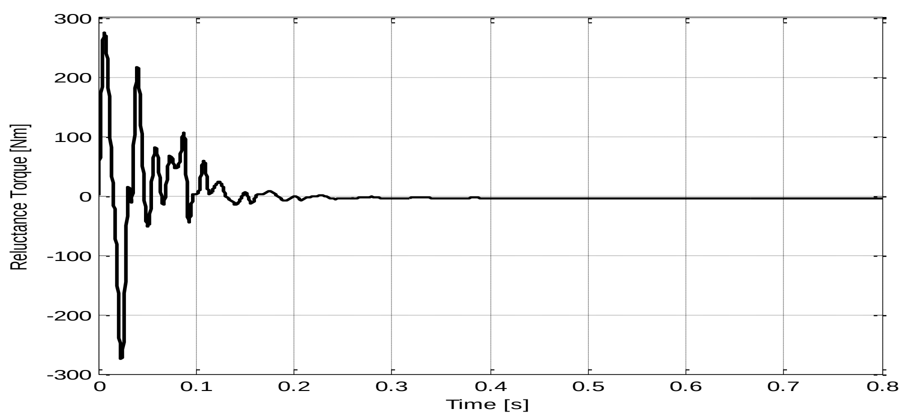

Figure 4: Graph of Reluctance Torque against time of Pharmaceutical Industrial Plant Machine at run-up Condition.

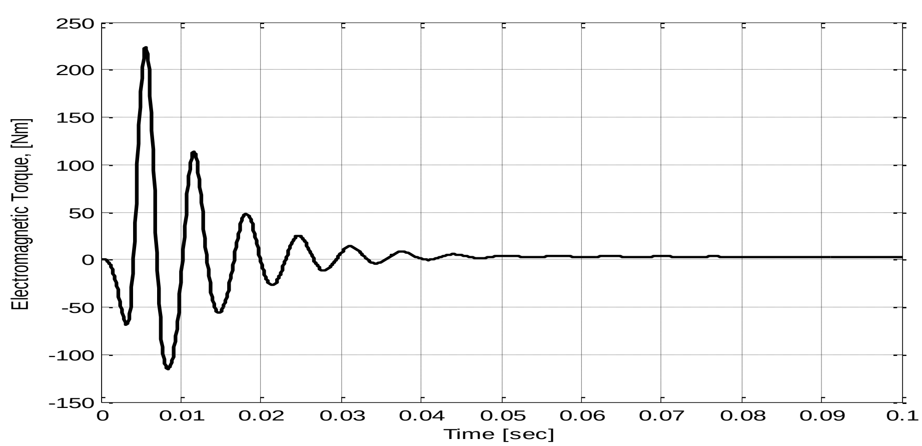

Figure 5: Graph of Electromagnetic Torque against Time of Pharmaceutical Industrial Plant Machine at run-up Condition

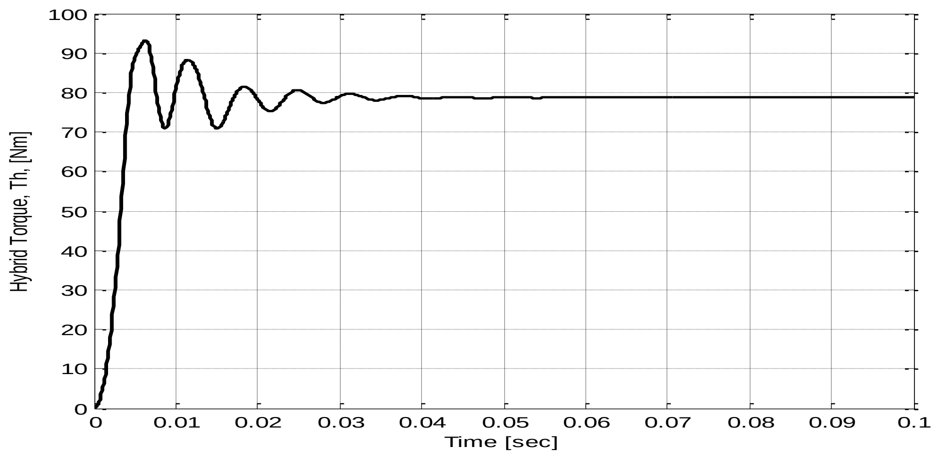

Figure 6: Graph of Hybrid Torque Against Time of Pharmaceutical Industrial Plant Machine at run-up Condition.

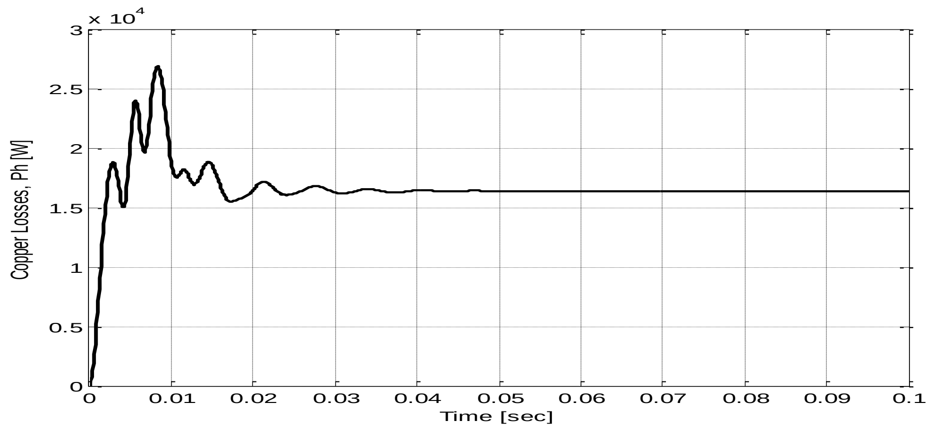

Figure 7: Graph of Copper losses Against Time of Pharmaceutical Industrial Plant Machine at run-up Condition.

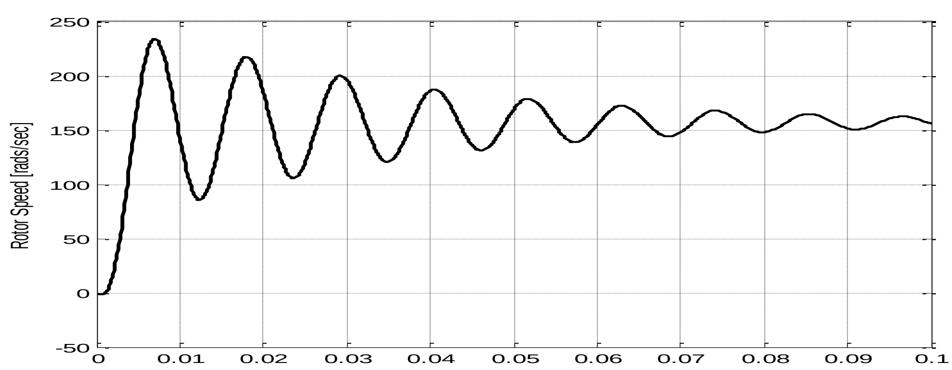

Figure 8: Graph of Rotor speed Against Time before Transient suppression of Pharmaceutical Industrial Plant Machine at run-up Condition.

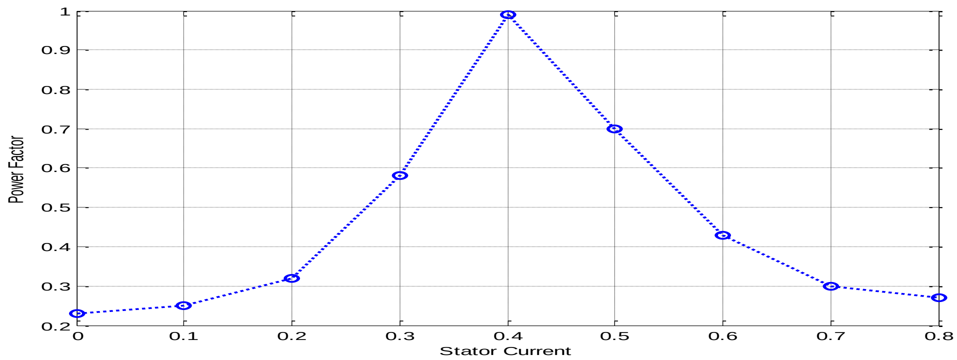

Figure 9: Graph of Power Factor against Stator Current of Pharmaceutical Industrial Plant Machine

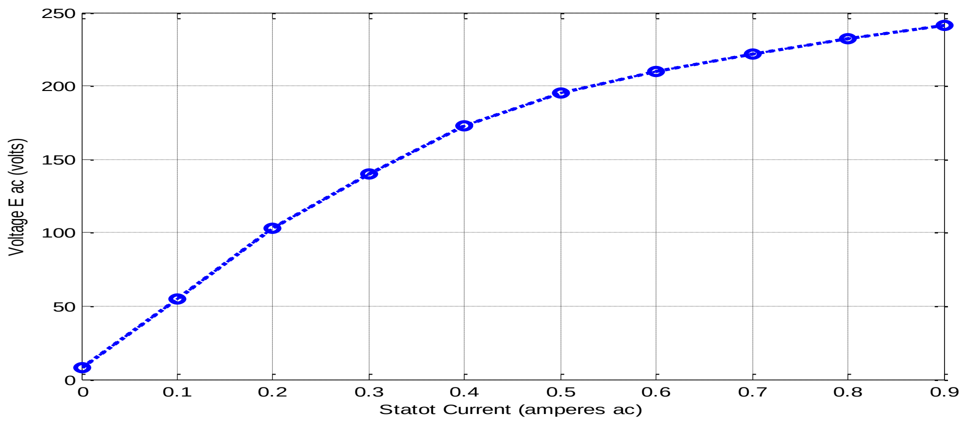

Figure 10: Graph of Voltage (E ac) against Current of Pharmaceutical Industrial Plant Machine,

4.0: Experimental Investigation of Pharmaceutical Industrial Plant Machines

Experimental and analytical investigation show that as more current was supplied to the rotor of pharmaceutical industrial plant machine than it required, the machine was overexcited and took phase-leading current from the power line, like a capacitor connected to the line. When many machine were connected to large pharmaceutical industrial plants, current draw leading current tend to lag the voltage and is common when inductive capacitance is connected to the load circuits. Thus, becomes practically to replace the machines in some of the pharmaceutical plant machine with synchronous motor, to improve the power factor while furnishing useful mechanical power.

When the supply output voltage was fixed at 220volts, Characteristic is “ʌ” machine curves. The line voltage is higher than the 220volts ac at fixed output voltage of the power supply. Characteristic is “ʌ” machine curves also shift to the right or left respectively. This is due to the fact that at higher or lower line voltage, the rotor has to supply more VARS to induce the line voltage than the higher current that flow into rotor windings. The opposite is true for lower voltage line. The reactive power has the disadvantage of producing lower power factor. The stator current decreases as power factor increases, the power factor peak at the stator current null point at 0.14 ampere and at real power of 50 watts. It was noted that the power factor was almost at unity (0.99). Because of the shape of this curve, it is referred to as “V” curves of the machine. By over exciting the rotor, it will have a leading power factor, just like a capacitor used to correct a lagging power line condition.

Real power consumed by the pharmaceutical machine in this case is on the power supply of the copper, iron, friction, and windage losses, since the speed is constant, only the copper losses will vary because of the changing stator current, because of overexcited rotor that create more magnetic field than the machine needs, the power line supply negative reactive power to the stator to keep the total magnetic flux constant. An increase in the rotor current produces an increase in the rotor magnetic strength which luck in more strongly with the rotating stator magnetic field. As a result, the pull-out torque is increased.

The average value of voltage (Eac) against current of pharmaceutical machine result show that voltage increase less rapidly as the current is increase; this is because as the rotor current increase to 0.6A, the iron in the rotor begins to saturate. Therefore, as the excitation current increases above this value, there was a smaller increase in the magnetic flux and generated voltage, because of residual magnetism in the rotor, the flux cuts the stator windings, generating a small voltage. After the capacitor was connected in parallel with the pharmaceutical plant machine to suppress the transient current and improved the power factor. An appreciable power factor was recorded and the pharmaceutical plant machine transient current was suppressed. The smooth operation of the pharmaceutical plant was observed without any negative threat to the plant operation.

5.0: CONCLUSION

There was a significant reduction in the line current after adding the capacitor and it does not affect the pharmaceutical plant machine operation. With capacitor added or not, the real power of the pharmaceutical plant system remains the same. Since the pharmaceutical plant operation did not change, the real power needed to overcome friction, windage copper and iron losses remains.

The power supply was turn 'ON', all the capacitor switches were closed and value was recorded. The line current was recorded as I_L = 1.05Aac and the reactance value was X_C = 37.5Ω.

Machine was observed to draw reactive power from the supply line to create require magnetic field in an alternating current circuit and it was also observed that real power was converted to mechanical power while the rest was dissipated in form of heat. Between the machine and supply, it was observed that, there was a reactive power backward and front movement. This reactive power does no useful work except that it creates a magnetic field for the machine.

Then capacitor was placed in parallel with machine and observed that this reactive power drawn by the capacitor was exactly equal to that drawn by the motor but opposite sign. That is, one reactive power neutralized the other. Power transmission line need not to carry a reactive power at all. As seen in this result, current of transmission line drastically reduced and reduced the need for large diameter of transmission lines wires. That is an improvement to regulation of power transmission line. The power factor of the machine was quite low and as the capacitor was connected in parallel with the machine, the power factor improved nearly to unity. The stator current decreases as power factor increases, the power factor peak at the stator current null point. at 0.14 ampere, and at real power of 50 watts, the power factor is almost at unity (0.99)

The result of the parameter variations show that the dynamic performance of pharmaceutical plant machine is highly sensitive to rated voltage, stator resistance and equivalent field current value of which must be checked and properly regulated during machine design. This is recommended for technicians, operators, engineers and machines designers of pharmaceutical industries.

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