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An Analysis Of 3 Phase Ac Motor As A Water Pump Drive In PDAM Tirtanadi Booster Pump

Syahrijal Umri[1], Amani Darma Tarigan[2], Solly Aryza[3]
Universitas Pembangunan Pancabudi, Medan, North Sumatera, Indonesia

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ABSTRACT

Energy efficiency, even though it is small, will have a big impact in terms of power, economy, environment, and others. Many potential energy savings can be explored, one of which is from motor performance. The 3-phase AC motor is the main electricity user in a modern industry. The average electricity consumption for electric motors ranges from 65-70% of the total electricity cost. This study aims to determine the efficiency value of the 3-phase AC motor as a pump driver. The research method used is by means of literature study, measurement, and data processing. The methodology in data collection is carried out with the criteria for sampling the motor, measurement, and output analysis. From the results of the analysis, it is known that the average 3-phase AC motor for the work of Centrifugal pumps on the Booster Pump Tower Water PDAM Tirtanadi work at an efficiency of 47.42% of the load. This result can be called a reduction in improvement considering that maximum efficiency occurs in the range of 75-80%. The amount of energy wasted if realized will have many negative impacts that are detrimental to the company, one of which is productivity

Corresponding Author:
Syahrijal Umri
Universitas Pembangunan Panca Budi, Medan, North Sumatera, Indonesia
syahrizalumry@yahoo.com

INTRODUCTION

Most of Indonesia's energy sources are consumed by the industrial sector. Therefore, energy efficiency in this sector, although small, will be very influential and have a big impact in terms of power, economy, environment and others. There are many potential energy savings that can be explored, one of which is from motor performance. Induction motors are the main users of electricity in a modern industry. The average electricity consumption for electric motors is around 65-70% of the total electricity cost. Three-phase induction motors are one of the motors that are widely used in industry because of their various advantages, including low price, long life, reliability, simple construction and maintenance-free. Recently, problems in a company regarding the use of electric motors have arisen. length is to reduce attention to the value of its efficiency. In fact, in the present and in the future, of course the cost of fuel will continue to increase due to environmental problems and limited energy sources and other things. Therefore, recalculation of the value of the old motor efficiency must be carried out in order to get the maximum value of the performance of the motor. If it turns out to be too far from the manufacturer's efficiency value, it must be recalculated to replace the old motor, add or replace it with the latest energy-saving motor that has the standardization of electric motors in the class based on its efficiency.

Literature Review

Induction Motor

Induction motor is an alternating current (AC) electric motor, it is called an induction motor because this motor works based on electromagnetic induction. Induction motor has a source of electrical energy, namely on the stator side, while the electrical system on the rotor side is induced through the air gap from the stator with electromagnetic media. This is what causes it to be called an induction motor. The use of induction motors in industry is as a driver, such as for compressors, pumps, main drivers of production processes or mills, workshop equipment such as drills, grinders, cranes, and so on. Induction motors rotate at a speed that is basically constant, starting from no load to reaching a load condition. full. The rotation speed of this motor is affected by the frequency, so speed control cannot be easily done on this motor. Three-phase induction motors have several advantages, namely they are simple, sturdy in construction, relatively cheap in price, easy to maintain, and can be produced with characteristics that suit the needs of the industry.

Induction motor efficiency is a measure of the effectiveness of an induction motor in converting electrical energy into mechanical or other energy, expressed as the ratio of the power output of the motor used to its total power output. Efficiency is directly related to the losses of an induction motor regardless of the design of the machine. Losses can vary from less than two percent to 20%. Efficiency is defined as the ratio of the output power to the input power. The output power is equal to the input power minus all losses. Therefore, if two of the three variables (output, input, or losses) have been found, the efficiency value can be determined by the following formula:

$$\eta = \frac{P_{Out}}{P_{In}} = \frac{P_{In} - P_{Loss}}{P_{In}} = \frac{P_{Out}}{P_{Out} + P_{Loss}} x100\% \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:
ηi =i Efficiency (%)
Pouti =i Power Output (Watts)i
Pini =i Power input (Watts)i
Plosion =i Total loss –i loss (Watt)

There is a clear relationship between engine efficiency and load. Engine manufacturers design engines to operate at 50-100% loads and will be most efficient at 75% loads. At small loads, the losses are much larger than the output, and therefore the resulting efficiency is low. As the load increases, the efficiency also increases and is maximized when the core losses and variable losses are equal. The maximum efficiency occurs at about 80%–95% of the rated output of the engine, whereas the higher values are found in larger engines. If the applied load exceeds the load that produces maximum efficiency, the load losses increase much faster than the output, and consequently the efficiency decreases. In induction motors, the measurement of the efficiency of induction motors is often carried out in several ways, such as: a. Measuring the input electrical power and the output mechanical power directly b. Measuring all losses and input power directly. c. Measuring each component of the loss and input power, where the measurement of input power is needed in the three ways above. A simple calculation for measuring the power of a motor to a pump is to calculate the power of the pump shaft first, such as the formula below: Pump shaft power:

$$(P)p = \text{Hydraulic power} / \eta \quad \text{......} \quad (2)$$

Where

η = Pump efficiency

$(P)\rho$ = $(\rho \times Q \times H)/368\times\eta$ ......(kW)

Power from the motor is given to the pump shaft to rotate the impeller mounted on the shaft. Since the pump is driven by an electric motor (drive motor), the working power of the pump is the ratio between the mechanical force given by the motor to the pump. To find the working power of the pump, there are several steps using the formula below:

$$P = \sqrt{3} \times V \times I \times \cos \varnothing \quad \text{......} \quad (3)$$

Where

Pi = i Power given by the motor to the pump

Vi = i Voltage

Ii = i Current

Fluid, Debit, and Head

Fluid is a substance or substance that will undergo continuous deformation if subjected to the slightest force. i Debit or which is often called flow capacity is the amount of fluid volume

$$Q = \frac{V}{t} \quad \text{......} \quad (4)$$

Where:

Qi =i flow debit (m3i /s)i

Vi =i flow volume (m3i)i

ti =i timei (s)

Heat is the energy supplied by the pump per unit weight of the fluid being pumped. The unit of heat is meters or feet. This measurement can be done by measuring the pressure difference between the suction and discharge pipes of the pump, noting that the diameters of the suction and discharge pipes are the same.

Pump Efficiency Estimation

The pump cannot convert all kinetic energy into pressure energy because some of the kinetic energy is lost in the form of losses. Pump efficiency is a factor used to calculate these losses. Pump efficiency consists of

a. Hydraulic efficiency, which takes into account losses due to friction between the fluid and the impeller and losses due to sudden changes in direction in the impeller
b. Volumetric efficiency, which takes into account losses due to recirculation in the ring, bushing, and others

c. Mechanical efficiency, i takes into account losses due to friction on seals, packing glands, bearings, and others. Pump efficiency is the ratio between the hydraulic power of the pump and the pump's porosity power. As can be calculated using the formula below:

$$\eta = \frac{P_H}{P_S} \qquad (5)$$

Where:
PH =i hydraulic power
PS =i pump shaft power

Hydraulic power is the power required by the pump to lift a certain amount of liquid to a certain height. The hydraulic power can be found using the following formula:

$$P_H = \frac{\rho.g.H.Q}{1000} kW \qquad (6)$$

Where:
WHP = Pouti = Output Power (KW)
Qi = Water discharge, capacity (m3 / day)
Hi = Head / height of rise (m)
= Fluid Density (Kg / m3i)
g = Gravity Acceleration = 9.8 (m / s2i)

The individual hydraulic efficiency of the pump is estimated based on the actual operating data of Head (H)i and flow rate (Q). Using the hydraulic efficiency model, the efficiency of the centrifugal pump can be estimated by the following formula:

$$\text{Eff } (\%) = 65.08 \times H^{-0.124476} \times Q^{0.094734} \qquad (7)$$

This efficiency model applies to:
Hi =i (15-100)i mi ,i
Qi =i 20-300m3/ Hours,i
Standardi error = 1.038 %

For each pump, the manufacturer usually provides a characteristic curve that shows the performance of the pump under various conditions of use.

METHOD

This research was conducted in November 2024 at the Water Tower Booster Pump Reservoir, PDAM Tirtanadi Medan (Center). The Water Tower Booster Pump Reservoir functions as a container for distributing clean water to areas in the city of Medan.

Data Collection

a. Data report on operational activities of Booster Pump Tower Tirtanadi.
b. Nameplate or technician data from PDAM Tirtanadi and equipment used in this study in the form of electric motors, pumps, and others.
c. Interview directly with people who are directly related to the study object.
d. Literature study, journals, papers, and previous research reports

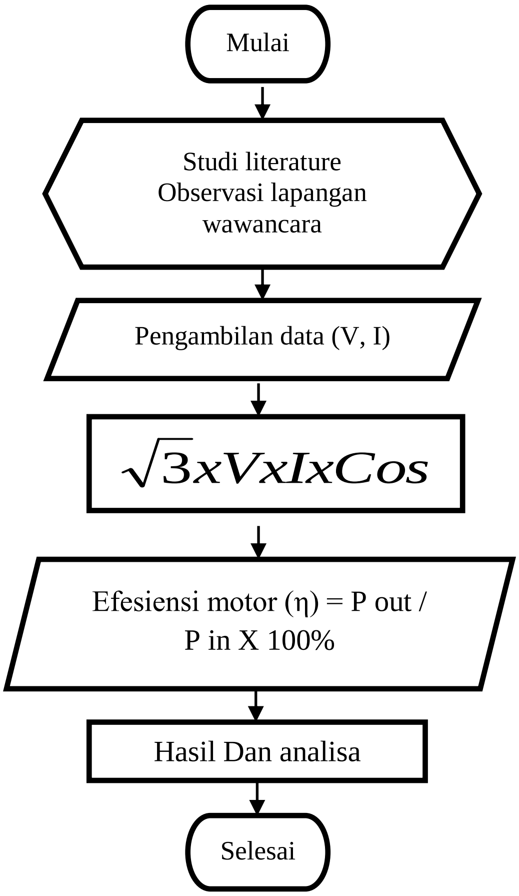

Figure 1 Flowchart of the Research

Data on the source of electrical power to drive the existing electric motors installed on the Booster Pump in Tirtanadii are:

a. Powered by PLNi electricity installed 550i kVA, i Tarifi 2i – i 3
b. Powered by GENSET electricity 600i KVA
c. The efficiency of the four pumps from each manufacturer is 75%.

Table I . Booster Pump Electromotor Specifications

NO. ELECTRO MOTOR	E.01.1	E.01.2	E.01.3	E.01.4	E.01.5	E.01.6
BRAND	MEZ	MEZ	MEZ FRENCH STATE	AEG	GAE	KIRLOSKAR
SYSTEM START	AUTO TRANSFORMER	AUTO TRANSFORMER	AUTO TRANSFORMER	START DELTA	START DELTA	START DELTA
POWER(KW)	90	90	90	55	75	55
FREQUENCY (Hz)	50	50	50	50	50	50
VOLTAGE (V)	380	380	380	380	380	380

CURRENT (A)	165.6	165.6	165.6	102.9	138	102.9
RPM	1480	1480	1480	1480	1480	1480
TYPE	IEC-EN-60034	4AA90-Z-280M	4AA90-Z-280M	M250MV4	VDE 0530	IP 54 CD 25 M
NO. BEARING	6317C3/6317C3	6317C3/6317C3	6317C3/6317C3	-	6314/6314	NU315/6313
HEAVY (KG)	580	580	580	380	520	-
YEAR						
RAFT	2010	2010	2010	1990	1990	1990
OPERATION	2010	2010	2010	1990	1990	1990

The Booster Pump Tirtanadii has 5 units, the specifications can be seen in the table below:

Table 2. Specifications of the Booster Pump Tirtanadi PDAMi Pump

NO. PUMP	P.01.1	P.01.2	P.01.3	P.01.4	P.01.5	P.01.6
BRAND	KSB	KSB	KSB	KSB – TORISHIMA	KSB - TORISHIMA	KIRLOSKAR
TYPE	ETA 150 - 50	ETA 150 – 50	ETA 150 - 50	ETA 150 – 40	ETA 150 - 40	ETA 150 - 40
TYPE	CENTRIFUGAL	CENTRIFUGAL	CENTRIFUGAL	CENTRIFUGAL	CENTRIFUGAL	CENTRIFUGAL
HEAD	70	70	70	50	50	42
CAPACITY (liters/second)	75	75	75	75	75	75
LUBRICANT	OIL	OIL	OIL	OIL	OIL	OIL
OIL SEAL	G. PACKING 10 mm	G. PACKING 10 mm	G. PACKING 10 mm	G. PACKING 10 mm	G. PACKING 10 mm	G. PACKING 10 mm
TYPE	IEC-EN-60034	4AA90-Z-280M	4AA90-Z-280M	M250MV4	VDE 0530	IP 54 CD 25M
NO. BEARING	6411	6411	6411	6412	6412	6412
YEAR						
RAFT	2010	2010	2010	1990	1990	1990
OPERATION	2010	2010	2010	1990	1990	1990

The generator on the Tirtanadi Booster Pump is 1 unit, the specifications can be seen in the following table:

Table 3. Specifications for Booster Pump Genset PDAM Tirtanadi

NO. GENERATOR	G.01.1		
ENGINE		GENERATOR	
BRAND	VOLVO PENTA	BRAND	CRAMACO
MODEL	TAD 164 GE	MODEL	G2R315MB/4
RPM	1500	TYPE	
TYPE OIL	-	PHASE	3 PHASE
RAFT	2012	POWER	500

OPERATION	2012	VOLT	380/400 V
		AMPERE400	

RESULT

Motor Operation as Pump Driver

The analysis in this research was conducted for 3 (three) days. The following is the data on the operation of the Booster Pump for 3 days, as seen in the table below:

Table 4. Pump Operation and Level Height of the Booster Pump PDAM Tirtanadi

Date	Long Operating /Day (O'clock)	Amount pump (Unit)	Amount O'clock	Total O'clock pump operate (O'clock)	Level Water (m3)
Monday, 25 Nov 2024	24	5	120	63	17,071
Tuesday, 26 Nov 2024	24	5	120	60	17,275
Wednesday, 27 Nov 2024	24	5	120	62	17,392
Flat - flat	12.32	1	24	61.6	17,246

From the results of the research and measurements that have been carried out, it is known that the average daily water discharge that is channeled to consumers in Medan City and its surroundings by five pumps from the tower booster pump reaches 17,246 m3 with operating hours in one day 12.32 hours. If combined from the five pumps, it gets 17,246 m3/day. To find out the discharge from one pump, it can be calculated as follows: Total Q = Q1 + Q2 + Q3 + Q4 + Q5 / 5 = 17,246 / 5 = 3449.2 m3/day. One pump produces 3449.2 m3/day of water.

After finding the total discharge of all five pumps and one pump, we can find that the pump capacity corresponds to the maximum unit specifications, namely: ori =i 32,400i m3/day. From the calculation above, the pump capacity according to the pump specification is 32,400 m3 / day. Thus, looking at the reality of the measurements carried out on July 30, 2015, there has been a decrease in capacity of: Total Qi losses = Qi speci – Qi actual = 32,400 - 17,246 = 15,154 m3 / day.

$$Persentase = \frac{Q_{Spek} - Q_{Aktual}}{Q_{Spek}} x100\%$$

$$= \frac{32.400 - 17.206}{32.400} x100\%$$

$$= \frac{15.154}{32.400} x100\%$$

$$= 0{,}468\, x100\%$$

$$= 46{,}77\%$$

From the calculation, the decrease in pump capacity from the specifications to the calculations in the field was 15,154 m3/day or 46.77%.

Calculation of Motor Power for Pump Operation

From the measurement results carried out on the Booster Pump PDAM Tirtanadii to determine the amount of induction motor power as a water pump driver, the data obtained are debit, pressure, specific mass, gravity, input voltage, current, and power factor. This data is data from the water pump and data from the induction motor used in this study.

Table 5 Data on water debit, head, specific mass of water, and gravity from the pumps

No. Pompa	Debit (m^3/hari)	Head (m)	Massa Jenis (kg/m^3)	Gravitasi (m/s^3)
P.01.1	3449,2	70	1000	9,8
P.01.2	3449,2	70	1000	9,8
P.01.3	3449,2	70	1000	9,8
P.01.4	3449,2	50	1000	9,8
P.01.5	3449,2	50	1000	9,8

Tabel 6 Data motor induksi untuk kerja pompa berupa tegangan, arus, dan factor

No. Electromotor	Voltage (V)	Current (A)	Factor Power (because Ø)
E.01.1	380	165.6	0.85
E.01.2	380	165.6	0.85
E.01.3	380	165.6	0.85
E.01.4	380	102.9	0.85
E.01.5	380	138	0.85

Calculation of Motor Power Efficiency for Pump Operation

Based on the data obtained, the calculation of the power value and efficiency of the 3-phase induction motor for the pump can be carried out: Motor 1, motor 2 and motor 3 have the same specifications. It can be calculated using the equation below:

Enter Power (Pin) :

V = 380 V
I = 165,6 A
cos Ø = 0,85

$$P_{In} = \sqrt{3}\, x V\, x I\, x \, Cos\, \varphi$$

$$= \sqrt{3\, x\, 380\, x 165{,}6\, x\, 0{,}85}$$

$$= 658{,}17 \text{ x } 140{,}76$$

$$= 92{,}66 \text{ kW}$$

After knowing the motor input power given to the pump, the hydraulic power output from the pump is also calculated

Hydraulic Power (PH)

Q = 3449,2 m^3 / hari = 0.04 m^3/s = 143,72 m^3 / jam
H = 70 m
ρ = 1000 (kg/m^3)
g = 9,8 (m/s^2)

$$\begin{aligned} P_H &= \frac{Q\,x\,H\,x\,\rho\,x\,g}{1000} \\ &= \frac{2{,}8\,x\,9800}{1000} \quad] \\ &= 27{,}44\,kW \end{aligned}$$

CONCLUSION

Conclusion of this paper are: At the Boosteri Pump, the Tirtanadii Water Pump, every day there are 5 (five) units of motor and pump that are operated and the average daily flow of water that is distributed to consumers by the five pumps is: 32 hours i One fruit pump produces water 3449.2i m3i /i day. 3-phase induction motors for water pumping on Tirtanadii Water Pump Boosters generally work at an efficiency below 50% or more, precisely 47.42%. The efficiency value is still far from the maximum efficiency which ranges from around 75% to 80%. maximum load, or factory efficiency. Calculation of the average value of the power conversion of the kei pump motor can be calculated only about 30% of the electrical power transferred into hydraulic power. The use of motors that are old enough certainly affects the continued efficiency value to some extent increase reduce high operational costs resulting from the age of the motorbike

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