p–ISSN: 2723 - 6609 e-ISSN: 2745-5254
Vol. 5, No. 2 February 2024 http://jist.publikasiindonesia.id/

STRATEGY TO IMPROVE THE PERFORMANCE OF THE NGAGEL I WATER TREATMENT PLANT (IPA) IN PDAM SURYA SEMBADA SURABAYA CITY THROUGH INCREASING PUMP EFFICIENCY

Rezhi Dika Indra[1*], Ade Syaiful Rachman[2], Wafiyuddin[3], Eddy Setiadi Soedjono[4*]
Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia[1,4], Kementerian Pekerjaan Umum dan Perumahan Rakyat, Jakarta, Indonesia[2], PDAM Surya Sembada Kota Surabaya, Surabaya, Indonesia[3]
Email: rezhi.dika@gmail.com[1*], adesyaiful75@gmail.com[2], wavie98@gmail.com[3], soedjonoenviro@its.ac.id[4]
*Correspondence

ABSTRACT

Keywords: Energy Audit; Energy Costs; Energy Efficiency; PDAM Surabaya; PUMP.

PDAM Surya Sembada Surabaya's energy cost in 2021 amounted to Rp 147.654.439.569, with an energy cost ratio of 24.37%, and the electricity cost of production unit accounted for 76% of the total energy consumption of PDAM. The relatively flat topography does not allow gravity-based systems for water supply. Ageing equipment has decreased overall pump efficiency (ηpt) and increased energy consumption, particularly in Ngagel I WTP, built in 1922, necessitating an energy audit. Energy audit includes measuring pump flow rate and pressure, voltage, current, power factor, pump and motor pump rotation, and temperature. Analysis shows that raw water pumps U2, U3, U5, and S1 and distribution pumps U1, U3, and T4 are still in good condition. However, raw water pump U6 and distribution pumps U6, S1, and S2 require reconditioning and impeller adjustment due to declining efficiency. Furthermore, PDAM must inspect the distribution pump T1 with the lowest efficiency value (49.77%) to determine the appropriate repairs. The research results are action recommendations expected to serve as input and considerations for PDAM in their efforts to improve energy efficiency.

Introduction

Surabaya City is a lowland with an altitude of 3-6 meters above sea level at a slope of less than 3%. This relatively gentle topographic condition does not allow PDAM Surya Sembada Surabaya City to use a gravity system to provide drinking water, thus burdening large electricity consumption and increasing from year to year (Octavia et al., 2022). PDAM uses a pumping system at six water treatment plants (IPA) and a gravity-pump combination at two raw water sources to distribute treated water. The use of electrical energy to drive all water pumps in PDAMs is estimated to account for more than 80% of electricity consumption, and the cost can reach more than 30% of all operational costs (Taebe & Slamet, 2023). Energy cost is the energy load, which is the load of electricity, diesel, gas, and other fuels released by PDAM to produce 1 m3 of water. Energy costs are expenses calculated from PDAM's operational electrical energy consumption consisting of raw water units, treatment plants, transmission and distribution networks, and office buildings (Ramadani & Devanti, 2021). The energy cost of PDAM Surya Sembada Kota Surabaya in 2021 reached Rp 409/m3, exceeding the national average energy cost of Rp 356.34/m3 (Biantoro & Permana, 2017).

The energy cost of PDAM Surya Sembada Kota Surabaya in 2021 is IDR 147,654,439,569. The ratio of energy costs to operational costs reached 24.37%, and electrical energy costs in production units reached 76% of PDAM's total energy consumption. The high cost of electricity is generally (Prarestu, 2022) caused by inappropriate energy consumption due to increased production capacity, equipment life, and inefficient energy use. The age of ageing equipment leads to decreased total pump efficiency (ηpt) and increased energy consumption. IPA Ngagel I was built in 1922 by the Government of the Dutch East Indies with a capacity of 60 L / sec; it has experienced 6 (six) times uprating to reach 1,800 L / sec in 1996; it is necessary to analyse the performance and efficiency of the pump considering the long time the pump in the IPA has been working (Maharani, Rachman, & Soedjono, 2021).

The energy costs incurred require PDAM Surya Sembada Kota Surabaya to evaluate usage patterns and calculate energy consumption to identify energy-saving opportunities. This needs to be supported by top management, who must start formulating energy efficiency policies and targets within the framework of an energy management system. In the next stage, the company must inventory the instruments and equipment involved in energy use (ANWAR, 2018). The step that PDAM can take is an energy audit, but until now, PDAM Surya Sembada Kota Surabaya has not carried out an energy audit (Wu, 2019).

Energy auditing is inspecting, surveying, and analysing energy flows to reduce the energy consumed by the system without disrupting production output. The purpose of an energy audit is to recommend steps to be taken by management to improve energy efficiency, reduce energy costs, and save on spending on energy bills (Ramadani & Devanti, 2021). An energy audit evaluates energy utilisation and identifies energy-saving opportunities and recommendations for improving efficiency in energy users and energy source users (Kristiyono & Gunarti, 2018) in the context of energy conservation. Energy efficiency must be achieved to support energy conservation policies that reduce energy intensity, reduce production costs, and produce more affordable energy costs (Kristiyono & Gunarti, 2018). Energy audits aim to compare actual energy consumption with design and find opportunities to be more efficient. The energy audit method comprises preliminary, general, and detailed energy audits. Energy audits require collecting valid data to calculate equipment efficiency; obtaining this requires field measurements with equipment whose accuracy can be accounted for (Mahmudi & Kustiawan, 2022).

This study aims to produce output in the form of recommendations for actions needed in the pumping system, especially raw water pumps and distribution at the Ngagel I IPA, which experienced a decrease in total pump efficiency (ηpt) based on the results of the initial energy audit (Mustafidah, 2019). This research is expected to be an input and consideration for PDAM to determine energy-saving measures at the Ngagel I IPA to improve energy efficiency.

Research Methods

Pump discharge measurement

Discharge measurement can be done using several methods, depending on piping conditions and the presence of measuring instruments. The most commonly used measurement is a portable ultrasonic flow meter for piping that does not have a discharge analyser installed.

PDAM Surya Sembada Kota Surabaya uses a Clamp-on Ultrasonic Flow Meter ChronoFLO 2 to measure discharge. When using this tool, one must consider several things, especially the sensor placement (probe). Figure 1 shows several methods of sensor placement based on the user manual. Figure 2 shows how to measure pipes embedded underground.

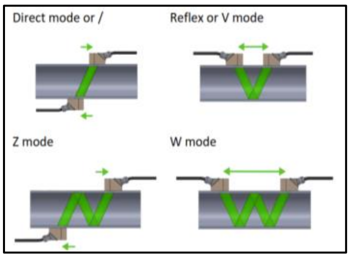

Figure 1
UFM Chrono FLO 2 Sensor (Probe) Mounting Method

Figure 2
Installation of Sensors on Pipe Walls to Measure Discharge

Pump Head/Pressure Measurement

The tool used to measure the size of the head is a manometer. The amount to measure water pressure is shown in bars or kg/cm2 units, which can be converted to m (1 bar = 1 kg/cm2 = 10 m). Head measurement aims to determine the total head, which is the difference between the discharge pressure on the output side of the pump and the suction pressure (suction) on the face of the pump mouth. The equation for the calculation of the total head is as follows.

$$Ht = hd - hs \quad (1)$$

$$hd = hsd + hpd + hfd \quad (2)$$

$$hs = hss + hps - hfs \quad (3)$$

All pressures are calculated by the value of overpressure, not absolute pressure. On the discharge side, the manometer is close to the pump outlet. The hpd value is indicated by the manometer (converted to meters), and the hfd value is small. On the suction side, the hps value is 0, and the hfs value is also small (because the pipe is short with a large diameter). The value of hd is the value of the manometer designation, and the value of hs equals this. Then, the total head calculation uses the principle according to Figures 3 and 4 below.

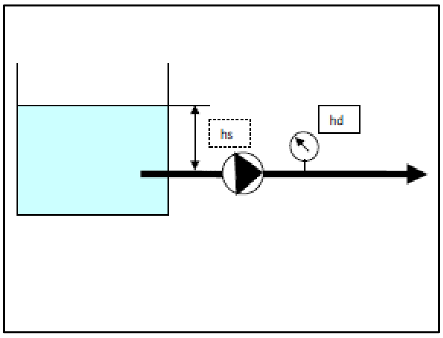

Figure 3
Total Head pada Suction Head Positif

The pressure in terms of positive suction heads, then:

Ht = hd - hs (4)

where

Ht = total head
hd = total discharge head
hsd = discharge static head
had = discharge surface pressure head
had = discharge friction head
hs = total suction head
hss = suction static head
has = suction surface pressure head
has = suction friction head

The condition of the suction head is harmful, being:

Ht = hd + hs (5)

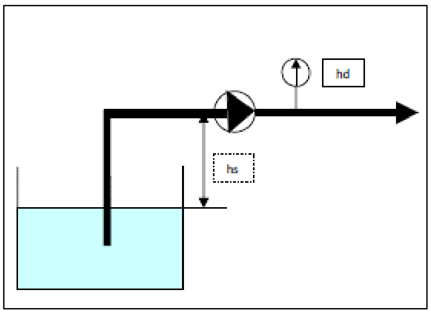

Figure 4
Total Head pada Suction Head Negatif

Measurement of Power, Voltage, Current, and Power Factor

There are 3 (three) types of power absorbed by the pump motor, namely active power (kW), apparent power or real power (kVA), and reactive power (kVAr). Observations and measurements are carried out using a power meter analyser installed on each panel of the raw water pump and distribution pump in the production unit of the water treatment plant. The type of power meter analyser used is shown in Figure 5.

Figure 5
Power Meter Analyzer Schneider EasyLogicTM PM2100

Rotation and Temperature Measurement

Measurement of rotation/speed RPM of an electric motor using a Fluke 820 type stroboscope measuring instrument (Figure 6) and DT-2234B type digital photo tachometer (Figure 7), as well as measuring motor and pump temperature using a Fluke 63 type infrared thermometer measuring instrument (Figure 8).

Figure 6
Stroboscope Fluke 820

Figure 7
Digital Photo Tachometer DT-2234B

Figure 8
Infrared Thermometer Fluke 63

Secondary Data Support

Secondary data that support this study include the following:

1. monthly water production data for the last two years;
2. data on monthly electricity usage and costs of both PLN electricity and electric power for the last two years;
3. technical specification data of pumps and pump motors as mentioned in Table 1.

Table 1
Technical Specification Data of Pump and Pump Motor Required

General Data	Specific Data	
	Pump Date	**Data Motor**
Pump location/pump motor	Pump brand/type	Output power (kW)
Pump function	Pump capacity/flow rate	*Voltage* antar phase (*volt*)
Types of pumps	Speed/pump rotation (RPM)	Electric current (*amperes*)

General Data	Specific Data	
	Pump Date	Data Motor
Number; operation of pumps per year	*Head* (pressure) *discharge*	Speed/pump rotation (RPM)
Year of installation of pump/pump motor	-	Cos φ
-	-	Motor efficiency (η)

Pump Efficiency Analysis

The stages of calculating pump efficiency are:

1. Measuring pump discharge (Q) [m3/min]
2. Measuring head/pressure on discharge pipe [m]
3. Measuring head/pressure on suction pipe [m]
4. Calculating the total pump pressure (b + c) [m], c can be positive or negative (P)
5. Calculate the hydraulic power of the pump (Ph) with the equation:
   Ph = 0,163 x Q x P [kW] (6)
6. Measuring the electrical power absorbed by the pump (Pi) [kW]
7. Calculating the total efficiency value of the pump (ηT) with the equation:
   ηT = Ph/Pi [%] (7)
8. Calculate the efficiency value of an individual pump (η) with the equation:
   η = Ph/(Pi x ηm) [%] (8)

where

ηm = efisiensi motor

Identify High Energy Consumption

nd supuey the enter snd wither: $\frac{\text{Value of energy used}}{\text{Volume of water production produced}}$ [kWh/m^3] (9)

The SEC standard for the clean water industry in Indonesia is < 0.4 kWh/m3. Identification is carried out on mechanical and electrical equipment that use electrical energy as the primary source, especially pump efficiency, real pump power, pump operating hours directly related to total power consumption (kWh), water production volume (m3), and costs incurred.

Results and Discussion

IPA Ngagel I has 8 (eight) raw water pumps and 14 (fourteen) distribution pumps, with technical specifications indicated in Appendix 1. The results of measurements and observations carried out during the energy audit include 5 (five) raw water pumps and 7 (seven) distribution pumps, as seen in Table 2.

Table 2
Results of Measurements and Observations of Pumps and Pump Motors at IPA Ngagel I

No.	Pump Name	Pump Results											
		Pump Capacity (m3/h)	Pump Pressure(m)	Power/Daya			Voltage (V)		Electric Current (A)	Cos φ	Speed (RPM)	Temperature (^{o}C)	
				P (kW)	S (kVA)	Q (kVAr)	Vp (V)	Vunb (%)					
1	U2	1128,24	18	62,15	69,56	31,20	225,70	0,24%	100,80	0,893	1489	37	68
2	U3	1128,24	18	59,38	66,96	30,89	227,70	0,22%	97,19	0,887	1489	38	61
3	U5	1128,24	18	59,93	67,28	30,55	226,60	0,24%	98,85	0,891	1489	40	58
4	U6	1308,24	18	117,90	132,70	60,80	225,40	0,18%	195,90	0,887	1486	61	43
5	S1	2208,24	18	131,00	131,40	9,18	222,60	0,32%	196,80	0,997	1484	36	40
6	U1	1264,58	40	177,10	200,80	94,40	226,90	0,13%	228,10	0,880	1493	58	60
7	U3	1354,58	40	168,60	189,70	86,13	225,80	0,86%	320,40	0,899	1421	43	64
8	U6	904,58	40	189,90	222,40	115,80	228,30	0,31%	325,70	0,853	1490	40	65
9	T1	724,58	40	158,20	185,90	97,67	227,00	0,25%	273,20	0,852	1489	40	72
10	T4	544,58	40	97,97	118,40	66,46	223,80	0,31%	176,70	0,828	1493	40	48
11	S1	740,952	55	216,30	217,30	21,01	222,40	0,32%	325,70	0,995	1491	39	68
12	S2	740,952	56	214,30	215,30	20,80	222,40	0,34%	322,60	0,995	1492	51	66

Analysis of total pump efficiency using equations (6) – (8) and recommendations for actions to take if there is an indication of a decrease in total efficiency (ηpt) in the upper ground pump (Siregar, 2020) are shown in Table 3.

Table 3
Total Pump Efficiency Calculation and Action Recommendations at Ngagel I IPA

No.	Pump Name	Pump Capacity (m3/jam)	(m3/menit)	Pump Pressure(m)	Ph Hydrolis Power (kW)	P input PI (kW)	Total Pump Efficiency ηpt (%)	Recommended Actions [14]
			(a)	(b)	Ph = 0,163 x (a) x (b)		Ph/PI x 100 %	
1	U2	1128,24	18,80	18,00	55,17	62,15	88,77%	Pump in Good Condition
2	U3	1128,24	18,80	18,00	55,17	59,38	92,91%	Pump in Good Condition
3	U5	1128,24	18,80	18,00	55,17	59,93	92,06%	Pump in Good Condition
4	U6	1308,24	21,80	18,00	63,97	117,90	54,26%	Need to Recondition and Adjust Impeller
5	S1	2208,24	36,80	18,00	107,98	131,00	82,43%	Pump in Good Condition
6	U1	1264,58	21,08	40,00	137,42	177,10	77,59%	Pump in Good Condition
7	U3	1354,58	22,58	40,00	147,20	168,60	87,31%	Pump in Good Condition
8	U6	904,58	15,08	40,00	98,30	189,90	51,76%	Need for Impeller Reconditioning and Adjustment
9	T1	724,58	12,08	40,00	78,74	158,20	49,77%	Need Total Repair or Replacement
10	T4	544,58	9,08	40,00	59,18	97,97	60,40%	Pump in Good Condition
11	S1	740,95	12,35	55,00	110,71	216,30	51,18%	Need for Impeller Reconditioning and Adjustment
12	S2	740,95	12,35	56,00	112,72	214,30	52,60%	Need for Impeller Reconditioning and Adjustment

The raw water pump functions to drain water from the sedimentation basin to the aerator for the rapid stirring process (coagulation). Based on analysis, U2, U3, and U5 raw water pumps it proved effective in carrying out their functions with an efficiency of

88.77% each, 92,91%, and 92.06%. Meanwhile, the U6 raw water pump, which has a larger capacity, only produces the same pressure as the previous 3 (three) pumps, with much greater input power. Therefore, it is necessary to recondition the pump and adjust the impeller on the U6 raw water pump because it only produces an efficiency of 54.26%. This can be caused by changes in the distance between impellers that are not as needed due to shifting pads or rubber between impellers due to foreign objects such as garbage or stones carried away when flowing raw water.

The S1 raw water pump is in charge of delivering water from the sedimentation basin from the south; this pump is still in good condition with a pump efficiency value of 82.43%, where the pump capacity is fully utilised to carry out its functions.

The distribution pump at IPA Ngagel I is divided into three directions according to its service area. The northeast side distribution pumps (U1, U2, and U3) serve the Jagir Tirtosari, Marmoyo, Raya Darmo, Raya Diponegoro, and Pasar Kembang areas. At the same time, other northern distribution pumps (U4, U5, and U6) serve the Darmo, Embong Kaliasin, Genteng, Krembangan, and Tambaksari areas. U1 and U3 distribution pumps are still performing well, with efficiency values of 77.59% and 87.31% respectively. Unlike the case with the U6 distribution pump, which has a smaller capacity than the two pumps above, it should be able to produce more significant pressure. The U6 distribution pump produces an efficiency value of 51.76%. PDAM needs to evaluate this pump, even if it is required to recondition the pump and adjust the impeller, because pump efficiency can be affected by the shape of the impeller, the number of impeller blades, and the angle of the impeller outlet [15][16][17][18].

Large middle distribution pumps (T1 and T5) serve Bratang, Kalibokor, and Krukah, while small ones (T3, T4, and T6) serve Jagir Wonokromo, Panjang Jiwo, and Rungkut. PDAM needs to be aware of the performance of the T1 distribution pump because the efficiency value is only around 49.77%. Pumps with a ηpt value of $\leq$ 50% should be performed as a total repair or replacement if needed [14]. The first step is to check the condition of the unit by overhaul, namely component disassembly activities, followed by research inspections so that appropriate repairs can be determined to produce improved engine performance [21]. The T4 distribution pump still performs well, with an efficiency value of 60.40%.

The areas of Ngagel, Bagong, Nias, Wonokromo, Ketintang, Dukuh Menanggal, Ngagel Kebonsari, Ngagel Rejo, Ngagel Timur, and South Kalibokor are the service areas of the southern distribution pumps (S1, S2, and S3). However, the performance of S1 and S2 distribution pumps is still around 51.18% and 52.60%, respectively. The decline in pump performance needs to be analysed, considering that these two pumps were only installed in 2018. Reconditioning steps can be done in the form of [19] initial evaluation, disassembly, cleaning, and inspection of components to make repairs according to the problems. One of the treatments that can be done is to adjust the impeller by increasing the number of impeller blades [18], which can increase pump efficiency.

The SEC calculation in PDAM Surya Sembada Kota Surabaya uses secondary data on PDAM production and PDAM energy consumption during 2021-2022, as shown in Table 4.

Table 4
SEC Calculation of PDAM Surya Sembada Kota Surabaya

No.	Moon	Konsumsi Energi IPA Ngagel 1	
		2021	**2022**
1	January	1.194.480	1.273.400
2	February	1.106.960	1.174.720
3	Maret	1.267.600	1.280.480
4	April	1.077.800	1.315.920
5	From	1.311.680	1.311.600
6	June	1.131.600	1.241.720
7	July	1.281.600	1.322.200
8	Agustus	1.289.360	1.037.640
9	September	1.262.640	1.256.160
10	October	1.284.440	1.296.320
11	November	1.252.880	1.292.800
12	December	1.277.880	1.264.000
Total (kWh)		14.738.920	15.066.960
Real Production Volume (m3)		54.041.746	51.878.025
SEC (kWh/m3)		**0,27**	**0,29**

Based on SEC calculations, the energy consumption index in PDAM Surabaya Surabaya City, according to SEC standards for the clean water industry in Indonesia, is < 0.4 kWh / m3. This shows that the management and use of energy by PDAMs, in general, is efficient and by clean water industry standards, but still considers the efficiency of several pumps that have decreased by the discussion above.

Conclusion

PDAM Surya Sembada Surabaya City needs to identify the T1 distribution pump because, based on the calculation analysis of the entire distribution pump at IPA Ngagel I, this pump has the lowest efficiency value (49.77%). This is done to avoid future disruption of clean water services in the area, considering that the T1 distribution pump is a large pump owned by PDAM. The recommended action for U2, U3, U5 &; S1 raw water pumps, as well as U1, U3, and T4 distribution pumps that have a ηpt value of $\geq$ 60%, is to carry out routine maintenance, which includes regreasing (lubricant), bolt tightening, and electromotor cleaning so that equipment continues to function effectively and efficiently. Future research can analyse the costs required for several action recommendations to improve energy efficiency in the Ngagel I IPA pumping.

Bibliography

anwar, Borris Afdhal. (2018). *Analisis Kinerja Instalasi Pengolahan Lumpur Tinja (Iplt) Dengan Pendekatan Audit Teknologi Di Daerah Istimewa Yogyakarta*. Universitas Gadjah Mada.

Biantoro, Agung Wahyudi, & Permana, Dadang S. (2017). Analisis audit energi untuk pencapaian efisiensi energi di gedung ab, kabupaten tangerang, banten. *Jurnal Teknik Mesin Mercu Buana*, *6*(2), 85–93.

Kristiyono, Antonius Edy, & Gunarti, Monika Retno. (2018). Pengaruh Jumlah Sudu Sentrifugal Impeller Terhadap Kapasitas Dan Efisiensi Pompa Sentrifugal. *Jurnal 7 Samudra*, *3*(1), 26–34.

Maharani, Astri, Rachman, Ade Syaiful, & Soedjono, Eddy Setiadi. (2021). Kajian Penghematan Energi Sistem Pompa Distribusi Jalur Kaum Pandak Kabupaten Bogor. *Journal of Syntax Literate*, *6*.

Mahmudi, Ali, & Kustiawan, Redi Tian. (2022). Rekondisi Alat Uji Turbin Kaplan di Laboratorium Fluida, Termal dan Otomotif Polban. *Providing Industrial Research Workshop and National Seminar*, *13*(01), 395–400.

Mustafidah, HIDAYATUL. (2019). Optimalisasi Tingkat Kehilangan Air PDAM Kota Mojokerto Dengan Penerapan Sistem Distric Meter Area (DMA) Ditinjau Dari Aspek Teknis, Kelembagaan Dan Finansial. *Surabaya: Tesis Jurusan Teknik Lingkungan Institut Sepuluh Nopember*.

Octavia, Dona, Suharti, Sri, Murniati, Dharmawan, I. Wayan Susi, Nugroho, Hunggul Yudono Setio Hadi, Supriyanto, Bambang, Rohadi, Dede, Njurumana, Gerson Ndawa, Yeny, Irma, & Hani, Aditya. (2022). Mainstreaming smart agroforestry for social forestry implementation to support sustainable development goals in Indonesia: A review. *Sustainability*, *14*(15), 9313.

Prarestu, Eri R. (2022). *Audit Energi Listrik Pada Proses Pengolahan Air Bersih Di Instalasi Pengolahan Air Purwaharja Pdam Tirta Anom Kota Banjar*. Universitas Siliwangi.

Ramadani, Firnindita Syahri, & Devanti, Syauqie Ayunda. (2021). *Analisis Efisiensi Pompa Distribusi Dan Specific Energy Consumption Pada Proses Produksi Air Bersih Di Pdam Surabaya*. https://doi.org/10.29244/jsil.8.03.193-202

Siregar, Munawar Alfansury. (2020). Pengaruh Variasi Sudut Keluar Impeler Terhadap Performance Pompa Sentrifugal. *Jurnal Rekayasa Material, Manufaktur Dan Energi*, *3*(2), 166–174. https://doi.org/10.30596/rmme.v3i2.5278

Taebe, Awad Akbar, & Slamet, Agus. (2023). Identifikasi Biaya Energi pada Sistem Penyediaan Air Minum Kota Bangkalan Perusahaan Umum Daerah Air Minum Sumber Sejahtera. *Jurnal Teknik Sipil Dan Lingkungan*, *8*(03), 193–202.

Wu, K. (2019). Research on the energy audit from the perspective of environmental protection. *IOP Conference Series: Earth and Environmental Science*, *252*(4), 42055. IOP Publishing.