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Energy efficiency of wastewater treatment plant through aeration system

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ABSTRACT

High energy consumption affects the wastewater industry especially in our country since the utility bills for sewer services is subsidized by the government. It has been identified as a highest electricity energy contributed to the operational expenditure cost bare by the licensee operator company. Hence, a proper and effective solution is needed to reduce the amount of bill need to be paid by the company by decreasing the consumption of energy during operation. Through the energy audit conducted earlier, the auditor identified that there are several equipment or machine consume high energy. Energy consumption varies considerably between wastewater unit processes and facilities, but several other trends are also exist. Eventually, aeration seem to be proven as an element that consumes more energy compared to the other based on the energy audit report. In order to reduce the energy consumption in the aeration system, High Speed Turbo compressor is proposed to replace the existing roots blower. From the analysis that has been gathered from the case study which has been applied in one of the wastewater treatment plant in Malaysia, through the usage of High Speed Turbo compressor, it has been proven that the energy consumption might reduce up to 42% compared to the usage of roots blower. As per calculation, the expected return of capital expenditure will be within the period of 1.22 y which proved that the proposed system will not only affecting the cost efficiency, but also generates revenue in short period of time.

Keywords: Wastewater treatment plant; Energy efficiency; Energy management; Aeration system

1. Introduction

In this era, world always opts for more reliable sources and improvisation of the existing technology to an improved version of energy efficient system. Energy efficiency means the usage of technology that will consume less energy to perform the same function [1]. The term energy efficiency of tently used to describe any activities which involves the energy-saving measure. From several observation and experiment conducted earlier, the term energy efficiency should be distinguished from energy conservation. Examples of energy conservation includes turning down a thermostat during winter season while energy efficiency through replacement of traditional incandescent bulb with a compact fluorescent bulb that uses lesser electrical energy to produce the same amount of light.

Looking at the enormous changes in the amount of the waste materials produced by human activities, it is clearly shows that there will be another alternative on how the usage of waste products are becoming one of the next upcoming options to generate power. Although the alternative sources of the power generation should be ventured on, it is highly advisable to be critically aware of the power consumption splurge by the consumers especially the industrial tenants.

At the same time, wastewater treatment plant (WWTP) consumes larger proportion of total energy consumption in Malaysia. In other words, it devours on the existing tight supply of fossil fuels and coals while making it worse by releasing the greenhouse gases. In order to optimize the operation of WWTP, more reliable system needs to be implemented in term of aeration facilities, control and the operation load of the plant [2].

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Municipal wastewater is a domestic waste for a designated area or region. This wastewater chemical content is not fixed and may vary for different countries and environment. Different design of WWTP need to be applied accordingly in different countries based on their water chemical properties. So, an energy efficient plant should always optimize the production processes and utilised its facility in every possible way. WWTPs are one of the numerous players which influencing the development of energy sustainability.

The process of increasing energy efficiency will regularly costs up-front payment but it has been proven by various applications that this capital expenditure will be paid in the form of the reduction of energy costs within short period of time. Thus, it is highly crucial to investigate the optimization plan for the WWTP that consumes a significant amount of energy by operating 24 h a day, seven days a week. There are many successful examples that shows enormous potential through the increasing of energy efficiency. One of it is the Strass wastewater treatment plant in Austria, which has reached 108% of energy recovery through the increasing of energy efficiency throughout its operational system. Some of the lessons learned from Strass WWTP are it has implemented an advanced process analysis tools and occupied with the ability to quantify gains. Because of these operators and tools, the system was sufficiently flexible and adequately equipped for constant optimization to ensure its efficiencies were maximized at every time point regardless any changes in the system. This was the key contributor to the well-known achievement of the optimization effort. If any breakdown of the electrical loads that is beyond expectations were to happen, temporary metering will be used [3].

Another example of a successful energy efficient WWTP is the Ithaca Area Wastewater Treatment Facility. It implements the Submetering at various unit processes and equipment to obtain electric power usage. From the data/information acquire from the Submetering, the energy conservation measures could be taken into considerations to determine either the system is cost-effective or another way around. Also, a power optimization research has been done at the plant and through this process, the plant implemented a few methods proposing for energy saving through capital improvements, operation modifications and also on-site generation [4].

Sheboygan Wastewater Treatment Plant, also puts on its best effort on achieving an energy efficient system. Some of the actions which already have been implemented to reduce the overall plant energy usage is by upgrading the older motors to those premium-efficiency motors and variable frequency drives (VFDs). Also, the plant has been installed with air control valves on headers to aeration basins. The valves need to be sized correctly so that the downstream of the air flow meters can minimize the airflow disturbances in the targeted area. Besides that, SCADA systems has been upgraded and the blower controls are replaced. This changes are made to ensure that the top notch plant's equipment is guided by an efficient programmer to avoid any loss of usage. In another view, Sheboygan also demonstrate the potential of public-private partnership, which also known as performance contracting which permit the facilities to avoid initial costs of installation while still beneficial from the technology.

Wastewater reclamation and reuse systems should consist of both design and operational requirements which are necessary to ensure reliability of the treatment process. In this matter, reliability provides features such as alarm systems, standby power supplies, treatment process duplication (backup) and automatic controllers (real-time monitoring). Looking from the public health standpoint, provisions for adequate and steadfast actions are imperative for an advanced wastewater treatment process.

In this paper, an energy audit has been conducted to analyse energy consumption in a wastewater treatment plant which adopted hybrid activated sludge with moving bed biological reactor (MBBR) or known as HYBAS in the system. This wastewater treatment plant which currently located in Malaysia will be featured in the case study. Based on the energy audit and design calculation, a potential energy efficiency approach is proposed through the installation of high speed turbo compressor to replace the existing roots blower in the aeration system. Then, the plant's system will be assessed through load balancing so that it is easier to understand on how loads are calculated and the corrective action steps and procedures that need to be considered A proper calculation on the electricity cost and return of investment will be done to prove either the proposed approach is the best to optimize the energy consumption in the aeration system of the wastewater treatment plant case study. Lastly, a final conclusion and recommendations for future study will be discussed in the last section in this paper.

2. Energy audit

According to the Electricity Supply Act 1990 and Efficient Management of Electrical Energy Regulations 2008 section 1(1A), any installation which receives electrical energy from a licensee or supply authority with total electricity consumption equal to or exceeding 3GWh as measured at one metering point or more over any period of six consecutive months are required to conduct an energy audit by an authorize competent person known as Register Electrical Energy Manager or REEM (Energy Commission). High energy consumption in the wastewater treatment plant (WWTP) is due to the systems and processes implemented.

For the WWTP in this case study, this plant has the capacity to serve the population of 300,000 PE included pump house (daily average flow of 67,500 m^3/d) and based on a hybrid system which consist of both suspended and fixed biomass growth. As shown in Fig. 1, this plant features Hybrid Activated Sludge with Moving Bed Biological Reactor (MBBR) or known as HYBAS to adhere to National Water Services Commission's latest requirement for removal of nitrogenous.

Sewage treatment processes plays an important role in the plant energy consumption and it consists of five main processes. The first one is inlet pump house (IPH) where pumping system under each module comprise six (6) numbers of raw sewage pumps with four (4) and two (2) standby. Raw sewage pump will pump a total volume of incoming raw sewage from wet well to the treatment pro-

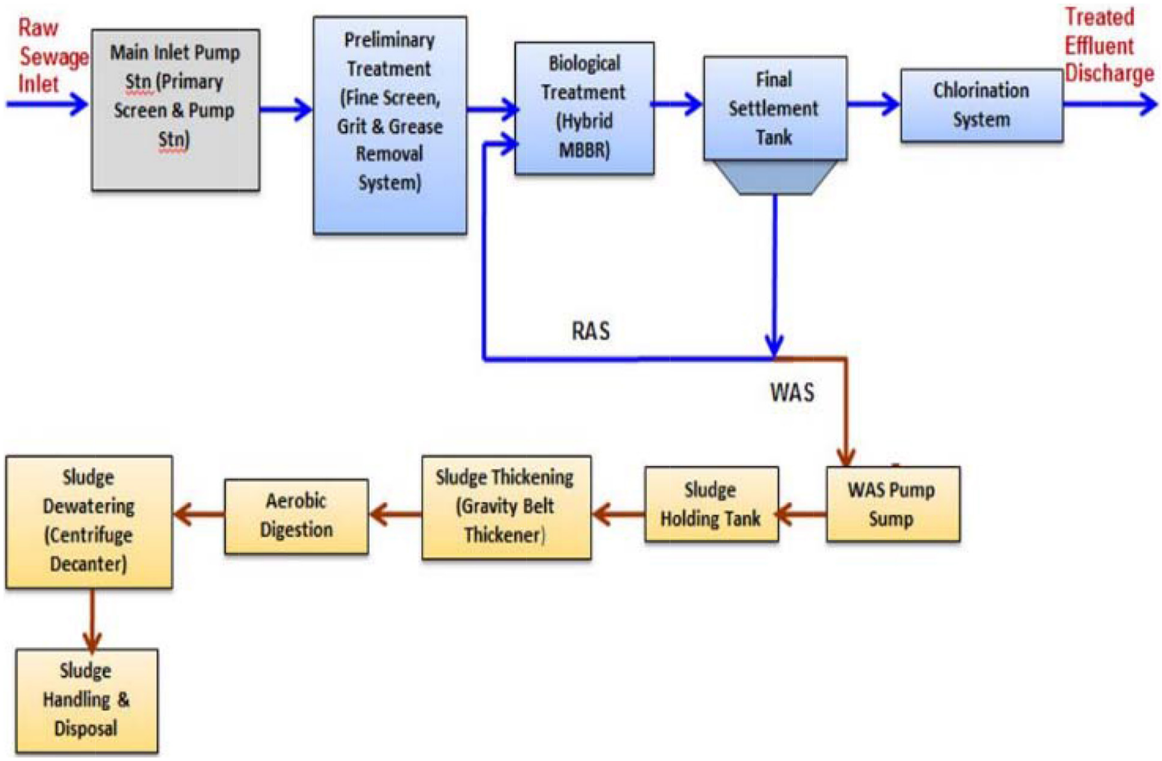

Fig. 1. Process flow of MBBR (HYBAS).

cess chamber. The incoming raw sewage is lifted to a level which allow a continuous flow through the whole plant by gravity. Second, the preliminary treatment which consists of fine screening, grit and grease removal. Next, the fine screening is where the sewage passes through to remove floating materials, rubbish, fibers and garbage. After that, the sewage proceeds to the grit and grease removal to eliminate grit and oil. Then followed by third one which is the aeration tank (AT) where in here, the MBBR hybrid system is adopted for the biological treatment process. There are four MBBR aeration tanks which each tank is divided into four reactor zones; (1) anoxic zone, (2) activated sludge zone (AS), (3) hybrid zone, and (4) de-oxygen zone [5].

Fourth, the final settlement tank (FST) is located inside the tank, most of the solids are allowed to settle down and form sludge blanket at the bottom of it which will vary in thickness. Clarified effluent at the top layer of the liquor will overflow via weirs at the end of the FST and gravity slowly move into the chlorination contact tank. The fifth process is at the final effluent tank. The clarified effluent from the final settlement tanks will flow into final effluent tank before it will be discharged to the river. A portion of the effluent is recycled and used as utility water at the plant for general cleaning works, cooling blower house and others [5].

Sludge treatment consists of four main chambers. One of it is waste activated sludge (WAS) Tank, where the excess activated sludge from the FST has to be maintained at an optimum standard level in the aeration tanks. WAS Tanks are temporary storage area for sludge prior thickening and dewatering process. Mixing process which imply the process of air mixing is provided in the WAS tank. Next, the gravity belt thickener (GBT) is used to thicken the sludge for further process with the collaboration of polymer. Three units of GBT are provided to thicken WAS sludge with solids content of 0.8% solids to approximately 4.5% to 5%. Thus, a fivefold decrease in sludge volume can be achieved [5].

After that, two units of aerobic digester tank which are located underneath the GBT to digest the sludge generated from GBT. Aerobic digestion is a treatment process that utilizes aerobic microbes to stabilize the solids in the digesters. The main function of aerobic sludge digestion is to stabilize raw sludge and produce biosolids for further treatment and disposal. Final chamber for the sludge treatment is the centrifugal decanter (DC) where it dewatered the digested sludge from aerobic digesters. In this process, polymer is used to improve the dryness of sludge cake. The dewatered sludge cake will be conveyed out into an outlet discharge chute into loading truck or disposal bins placed in the centralized sludge storage area. The dewatered sludge is expected to contain approximately 20% dry solids [6].

These are the processes that involved in wastewater treatment plant. All equipment in this facility contributes towards the increasing of energy consumption of this plant and energy audit will be done to determine which equipment consumes the highest energy. From the energy audit results shown in Table 1, it illustrates that the highest demand came from aeration blower and WAS digester which consumes the highest electricity in the plants.

In this research, the focus area is on the aeration blower since this equipment is inefficient as it does not utilize its full capacity. There are three units of blower in this plant, originally designed as two units' on-duty and one unit for standby. However, detailed analysis shows that the energy

Table 1
MBBR maximum demand for each load

Load	Maximum demand (%)
WAS/digester	26
Aeration blower	24
Inlet pump	16
MBBR	14
FST	6
Sludge thickening	5
Sludge dewatering	4
FS/GRT/GRS	3
Dry well ventilation fan control panel	1
DB-IPH	1
Drainage pump	0
LCP-NAOCL	0

consumed by both blowers can be catered by only one blower if it is operated to its maximum capacity. Even this could be done, the obvious consequences that might occur are quicken the mean time between failure of the equipment and reducing its life span as the system will require that one unit blower to run using its full capacity at all time, 24 h/d. Due to these reasons, this study proposed to replace the existing roots blower with the high speed turbo compressor which will be discussed further in the next section.

3. Energy efficiency in wastewater treatment plant

Energy efficiency is a process which leads towards the reduction of the amount of energy consumption in any area or facility without effecting the convenience of end user. Previously, there are several types of studies conducted on energy efficiency for wastewater treatment plant (WWTP) which involve energy efficiency via capital improvements, energy efficiency via operation modifications, energy efficiency via on-site generation and others. In this study, energy efficiency is done via capital improvements. Capital improvement is the additional element of a permanent structural changes of the plant that will enhance the plant's efficiency. There was a case study done at the Ithaca Area Wastewater Treatment Facility where the energy efficiency was done via capital improvement and automatization of the aeration system blowers has been installed to replace the manual control system of the centrifugal blowers so that the dissolved oxygen concentration in the aeration basins could be adjusted. Thus, Similar approach will be adopted in this study with several divergent changes.

For this study, existing roots blower will be replaced with a high speed turbo compressor. Most compressors are designed for variety of applications in which they are incapable of adapting variety of flow and pressure demand faced by the WWTP. As additional to that, they are generally designed to cater for a maximum flow at maximum pressure [7]. In short, these 'general' purpose blowers are the main contributor towards the energy wastage. However, the ABS High Speed Turbo compressor (HST) is specifically designed for aeration systems as it can be operated with fine or coarse bubble diffusers, delivering high flow at alternate pressure usually found in aeration tanks.

Table 2
Performance analysis of roots blower and HST blower

Description	Roots blower	HST blower
Rated kW of blower, kW	450	400
Average actual power consumption, kW	405	168
Rated current, A	736.52	572.85
Average current consumption, A	662.87	240
Annual energy consumption based on 24 h operation for 365 d, kWh	3,499,200	1,270,080

There are various advantages of this ABS HST in terms of design and maintenance cost reduction which are as listed below:

3.1. Maintenance cost reduction

The existing blower needs to be continuously lubricated and calibrated to achieve the optimal operating efficiency. By replacing it with ABS HST, the blower will require minimal maintenance or might be maintenance-free throughout the operational period. This is basically due to the factor of it operates using the magnetic bearing. In simpler terms, the wastewater treatment plant is saving tremendously in term of the maintenance costs as they are in energy cost reductions [8].

3.2. Smaller unit

The compact unit of this ABS HST makes it easier to be installed in the existing plant as it only the 2/3 size of the existing roots blower.

3.3. Design concept

The selection and design of the existing blower usually consider the maximum design flow and pressure of the specified WWTP which ultimately means that any required replacement part of the equipment needs a period of time to be manufactured [8]. Unlike the ABS HST, it will be adjusted to meet the varying demands of the aeration system while keeping it to its peak efficiency. Table 2 compares the performance analysis of roots blower and HST blower in terms of power and current consumption.

3.4. Noise and vibration reduction

There is nonessential for hearing protection as the magnetic bearings eliminates the stationary contact that produces the deafening sound and vibrations.

Table 3 summaries the advantages and disadvantages of both blowers.

Table 3
Difference between roots blower and HST blower

	Roots blower	HST blower
Advantages	• Attain the full number of revolutions almost instantly. • Have lower power demand in the partial-load range.	• In the partial-load range, the velocity of the conveying air remains constant; lower wear out chances. • The conveying air flow is continuous. • Resistant to foreign matter. • Sensitivity to higher air temperature is low.
Disadvantages	• It is costly to alter the conveying speed. • Requires an expensive noise dampening equipment due to the low-frequency noises. • Need to install a control device to validate its operating pressures. • Sensitive to foreign matter. • Over time, the piston clearance becomes larger and leads to capacity losses.	• Starts more slowly compared to roots blower. • The energy demand in the partial-load range is higher than that of the roots blower.

4. Case study for wastewater treatment plant in Malaysia

The case study for wastewater treatment plant (WWTP) in this research is located in Klang Valley, Malaysia. Energy performance index (EnPI) for this wastewater treatment plant (WWTP A) is compared with the traditional wastewater treatment plant (WWTP B) which used conventional activated sludge (CAS) process. EnPI is a measure of energy intensity used to gauge effectiveness of the energy management efforts. The outcome of the EnPI could enhance better understanding of improvements that are to be implemented. Additionally, identification of the abnormal situations can be assessed from the projected EnPI. The main goal is to increase efficiency or decrease intensity.

Table 4 shows the population equivalent (PE) characteristic of conventional activated sludge (CAS) system (352,000 PE) and the moving bed biofilm reactor (MBBR) system (300,000 PE). Although both systems are designed to cater for similar population equivalent, the CAS power consumption does not include its pump house power as the pump house isolated from the wastewater plant. On the contrary, the MBBR's power consumption already include the pump house power. If the power for the pump house is excluded or removed from both systems, the MBBR would clearly projected lower energy consumption compared to CAS. This proved that MBBR system is more energy efficient than CAS, given their similar population index and load.

From the outlined EnPI in Fig. 2, it can be seen that MBBR provided more stable energy consumption compared to CAS. Generally, as the influent flow increasing, the power consumption also increasing. But in this case, the CAS system cannot adapt to the changes of high influent flow therefore which results on the working of the process and consequently produce low effluent quality. In December 2014, the volume of influent flow in MBBR is the highest but there are no changes to the power consumption values. This has proved that MBBR system is flexible and able to adapt with changes of influent where it is increasing during wet season and decreasing during dry season. In order to have a stable and conform to the standard effluent quality, MBBR should be opted for its adaptability trait.

Table 4
Population equivalent for both WWTP

	Population equivalent	System
WWTP A	300,000 PE (include pump house)	MBBR HYBAS process
WWTP B	352,000 PE (isolated pump house)	Conventional activated sludge process

For the optimization of energy efficiency in WWTP A, root blower is replaced with the high-speed turbo compressor (HST). As can be seen in Fig. 3, it is proven that HST consumes 42% less energy which is equivalent to 199,400 kWh compared to roots blower. The needs for this magnetic bearing blower elevates as its loading capacity is independent of rotational speed of rotor. Furthermore, it does not experience frictional wear resulting to zero power losses.

Significant energy saving opportunities can be achieved through the implementation of load balancing and power logging session which affected by several factors, including voltage, current, and power consumption. For this case study, the power logging is not done manually by the researcher as it was acquired from the wastewater treatment plant which already own the equipment to measure and record the electricity usage. By assessing the plant's system through load balancing, it is easier to understand how loads are calculated and the corrective action decisions that need to be considered. Table 5 shows the simplified load balancing for the WWTP.

Basically, the system consists of two transformers where each of its loads is interconnected which make the system a ring main unit (RMU). Transformer 1 is to cater for panel P1 (a) and panel P1 (b) while Transformer 2 for panel P1(c) and panel P1 (d).

The aim of this study is to increase the energy efficiency in this wastewater treatment plant. Therefore, the value of aeration blower in Table 6 is replaced with the HST blower rating which is 168 kW. As recorded in the total power on Transformer 2, the power needed and loading factor is reduced significantly.

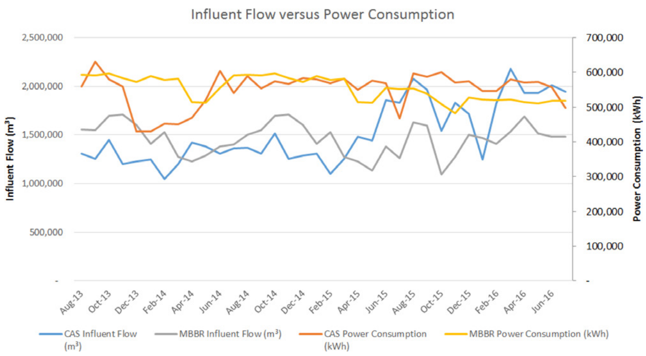

Fig. 2. Energy performance index on CAS and MBBR HYBAS.

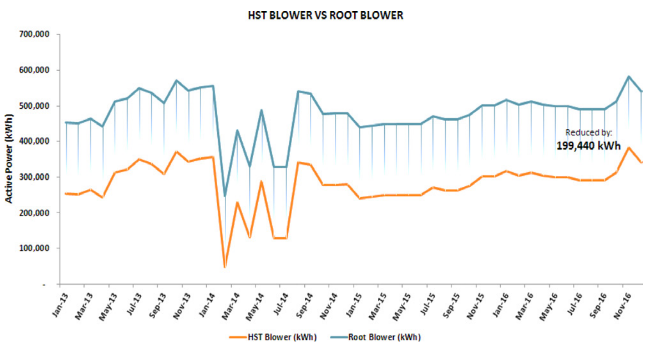

Fig. 3. High speed turbo compressor blower energy saving.

The load balancing is done by referring to the actual Tenaga National Berhad's tariff which is RM 30.3 per kW and then multiplied by the maximum demand that have been calculated. For the cost saving analysis, it needs to be done in order to advise on how the proposed plan will reduce the CAPEX and OPEX. The calculation is based on the tariff stated by TNB. The outcome of this study is to acquire an effective energy efficiency and cost saving. Below is the formula used to calculate the electricity cost ;

$$\text{Electricity Cost} = \frac{\left[\dfrac{P2 \times 50 \times 8760 \times \text{Energy Cost}}{\text{Rated Efficiency}} + \dfrac{12 \times MD}{PF}\right]}{1000} \lim_{x \to \infty} \tag{1}$$

By using above formula, electricity cost for both blowers can be obtained with simple calculation as below;

For root blower:

$$\text{Electricity Cost} = \frac{\left[\dfrac{405 \times 50 \times 8760 \times 0.365}{0.73} + \dfrac{12 \times 945}{0.96}\right]}{1000} = (\text{RM})88{,}706.81 \tag{2}$$

For HST blower:

$$\text{Electricity Cost} = \frac{\left[\dfrac{168 \times 50 \times 8760 \times 0.365}{0.86} + \dfrac{12 \times 945}{0.96}\right]}{1000} = (\text{RM})31{,}242.23 \tag{3}$$

Table 5
Load Balancing (root blower)

TRANSFORMER 1	
Transformer rating	2 MVA
Power	746.26 kW
S	877.95 kVA
Q	462.49 kVAr
θ	31.79 °
Fault Current	46.19 kA
Tx Loading Factor	43.90 %

TRANSFORMER 2	
Transformer rating	2 MVA
Power	822.18 kW
S	967.27 kVA
Q	509.54 kVAr
θ	31.79 °
Fault Current	46.19 kA
Tx Loading Factor	48.36 %

PANEL P1(a)

ITEM	DESCRIPTION	TCL (kW)	DF	MD (kW)
1	WAS/Digester	741.01	0.59	437.20
2	MBBR No. 1 & 2	167.67	0.34	57.01
3	FS/GRT/GRS	176.22	0.30	52.87
4	Aeration Blower No. 1	405.00	0.00	0.00
5	Aeration Blower No. 3 (Standby)	405.00	0.00	0.00
	TOTAL LOAD (kW)	1894.90		547.07
	TOTAL LOAD (kVA)	2229.29		643.61
	TOTAL CURRENT (AMP)	3096.24		893.90

PANEL P1(c)

ITEM	DESCRIPTION	TCL (kW)	DF	MD (kW)
1	Aeration Blower No. 2	405.00	1.00	405.00
2	Sludge Thickening	332.30	0.26	86.40
3	MBBR No. 3 & 4	167.67	0.34	57.01
4	FST	183.86	0.56	102.96
5	Sludge Dewatering	275.65	0.25	68.91
	TOTAL LOAD (kW)	1364.48		720.28
	TOTAL LOAD (kVA)	1605.27		847.39
	TOTAL CURRENT (AMP)	2229.54		1176.93

PANEL P1(b)

ITEM	DESCRIPTION	TCL (kW)	DF	MD (kW)
1	Inlet Pump No. 1	99.00	0.90	89.10
2	Inlet Pump No. 2	99.00	0.90	89.10
3	Inlet Pump No. 3 (Standby)	99.00	0.00	0.00
4	Dry Well Ventilation Fan	18.84	0.80	15.07
5	Drainage Pump No. 1	3.70	0.80	2.96
6	Drainage Pump No. 2	3.70	0.80	2.96
	TOTAL LOAD (kW)	323.24		199.19
	TOTAL LOAD (kVA)	380.28		234.34
	TOTAL CURRENT (AMP)	528.17		325.48

PANEL P1(d)

ITEM	DESCRIPTION	TCL (kW)	DF	MD (kW)
1	DB-IPH	16.00	0.80	12.80
2	Inlet Pump No. 4	99.00	0.90	89.10
3	Inlet Pump No. 5	99.00	0.00	0.00
4	Inlet Pump No. 6 (Standby)	99.00	0.00	0.00
	TOTAL LOAD (kW)	313.00		101.90
	TOTAL LOAD (kVA)	368.24		119.88
	TOTAL CURRENT (AMP)	511.44		166.50

Table 6
Load balancing (HST blower)

TRANSFORMER 1	
Transformer rating	2 MVA
Power	746.26 kW
S	877.95 kVA
Q	462.49 kVAr
θ	31.79 °
Fault Current	46.19 kA
Tx Loading Factor	43.90 %

TRANSFORMER 2	
Transformer rating	2 MVA
Power	585.18 kW
S	688.45 kVA
Q	362.66 kVAr
θ	31.79 °
Fault Current	46.19 kA
Tx Loading Factor	34.42 %

PANEL P1(a)

ITEM	DESCRIPTION	TCL (kW)	DF	MD (kW)
1	WAS/Digester	741.01	0.59	437.20
2	MBBR No. 1 & 2	167.67	0.34	57.01
3	FS/GRT/GRS	176.22	0.30	52.87
4	Aeration Blower No. 1	168.00	0.00	0.00
5	Aeration Blower No. 3 (Standby)	168.00	0.00	0.00
	TOTAL LOAD (kW)	1420.90		547.07
	TOTAL LOAD (kVA)	1671.65		643.61
	TOTAL CURRENT (AMP)	2321.73		893.90

PANEL P1(c)

ITEM	DESCRIPTION	TCL (kW)	DF	MD (kW)
1	Aeration Blower No. 2	168.00	1.00	168.00
2	Sludge Thickening	332.30	0.26	86.40
3	MBBR No. 3 & 4	167.67	0.34	57.01
4	FST	183.86	0.56	102.96
5	Sludge Dewatering	275.65	0.25	68.91
	TOTAL LOAD (kW)	1127.48		483.28
	TOTAL LOAD (kVA)	1326.45		568.56
	TOTAL CURRENT (AMP)	1842.29		789.67

PANEL P1(b)

ITEM	DESCRIPTION	TCL (kW)	DF	MD (kW)
1	Inlet Pump No. 1	99.00	0.90	89.10
2	Inlet Pump No. 2	99.00	0.90	89.10
3	Inlet Pump No. 3 (Standby)	99.00	0.00	0.00
4	Dry Well Ventilation Fan	18.84	0.80	15.07
5	Drainage Pump No. 1	3.70	0.80	2.96
6	Drainage Pump No. 2	3.70	0.80	2.96
	TOTAL LOAD (kW)	323.24		199.19
	TOTAL LOAD (kVA)	380.28		234.34
	TOTAL CURRENT (AMP)	528.17		325.48

PANEL P1(d)

ITEM	DESCRIPTION	TCL (kW)	DF	MD (kW)
1	DB-IPH	16.00	0.80	12.80
2	Inlet Pump No. 4	99.00	0.90	89.10
3	Inlet Pump No. 5	99.00	0.00	0.00
4	Inlet Pump No. 6 (Standby)	99.00	0.00	0.00
	TOTAL LOAD (kW)	313.00		101.90
	TOTAL LOAD (kVA)	368.24		119.88
	TOTAL CURRENT (AMP)	511.44		166.50

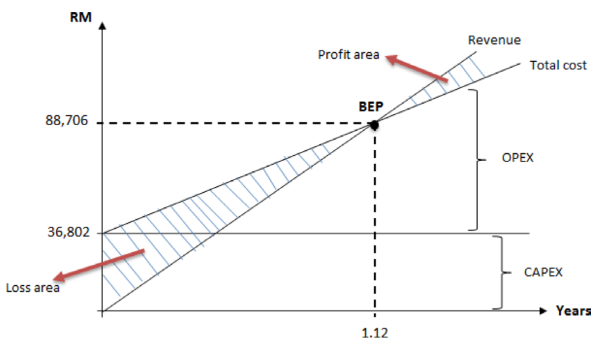

Fig. 4. Break even point graph for energy saving.

As per calculation, the expected return of capital expenditure will be in 1.22 y which has proven that the proposed system not only benefit in terms of cost efficiency, but also generates revenue in short period of time.

Return of investment (ROI):

$$\text{ROI} = \frac{\text{Capital Expenditure (CAPEX)}}{\text{Saving per year}} = \frac{700000}{(88706.81 - 31242.23) \times 12} = 1.22 \text{ years} \tag{4}$$

The graph above indicates that the expenditure for the implementation of HST blower will have the return of investment in 1.12 y.

5. Conclusion

As a conclusion, this paper has analyzed the possibilities through the increasing of energy efficiency in wastewater treatment plant (WWTP) by focusing on energy consumption in biological tank, specifically the aeration tank. This research has identified the drivers/factors that affects the energy consumption of the plant. From there, energy audit was done to optimize the moving bed biological reactor and it's already been verified that the blower and pump are the culprit for large energy consumption for this wastewater treatment plant. Therefore, it is suggested that the plant should change its current blower (root blower) that has been running inefficiently as it does not optimize its full capacity with a better energy efficient blower which is the ABS high-speed turbo compressor (HST). By doing so, the plant will optimize the energy efficient system which will further reduce the electricity cost for the wastewater plant.

For future works, the plant efficiency should be considered during the design phase. Some of the recommendations in this study are related to the improvement that could be done towards the energy efficiency of WWTP equipment and systems. These are most effective corrective measures that need to be taken into action as it will improve the plant efficiency but ideally, these corrective measures should be considered at the plant design stage. During plant design and development stage, initial capital cost should not be the sole push factor. Cost savings over the life-cycle of the WWTP can be achieved by incorporating other concepts during the design phase. Optimal plant layout, energy efficient piping networks and well designed, executed and future-proofed electrical wiring are just a few areas that could minimize long term energy consumption.

Secondly, this research goal of improving energy efficiency could be explored more, by doing in depth energy audit while focusing on equipment that is considered as one of the largest consumer of electricity which is waste activated sludge (WAS) digester. Thus, the plant would encounter a reduction of cost on electricity and indirectly increase its efficiency.

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