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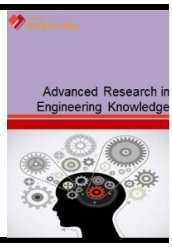

Strategies for Energy Saving in Water Pumping and Storage Systems of Water Treatment Plant

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ABSTRACT

Before water is delivered to the consumer, it has been gone through few stages and treatment process. This whole water treatment processes are happened in water treatment plant. Electrical energy plays an important role because it is used to operate the water treatment plant in water treatment process and delivery. For the past few years, the profit is unable to cover the operating cost of water treatment plant due to high electrical energy consumption. In the most recent energy audit found out that the motor that pumps the water from clean water tank to the balancing reservoir consume extremely high electricity which is due to uncontrolled motor water pumping schedule. In order to investigate and improve the current situation, a software simulation using LabVIEW is done which is aim to proposed a suitable pumping schedule based on the water demand. The result from the simulation is desirable and shows that the number of pump operates depend on water demand has the potential in reducing the unnecessary energy and cost of operation.

1. Introduction

Electrical energy plays an important role because it is used to operate the water treatment plant in water treatment process and delivery [3]. Electrical energy usage is significant expense for water treatment plant. The news by The Star newspaper has stated that electric tariff up by average 15% effective from January 1, 2014 [4]. With the new electricity tariff, the cost of operation will increase. Thus, energy audit plays an important role in reduce energy usage without affecting the productivity. Energy audit can identify which parts or processes of water treatment plant consume the most energy and solve the problem. In most of the energy audits studies has shown that the pumps consume the most electrical energy [3, 5, 15, 20]. The studies by United States of Department also had proven that more than 20% of electrical energy consumption is used by pump [5]. This shown that the electricity affects the operational cost of water treatment plant. Thus, energy saving plan is needed to reduce electricity consumption and cost of operation.

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Treated water supplied to consumer has been gone through few stages and treatment process before it is being delivered to us. The whole water treatment processes are happened in water treatment plant. A water treatment plant is to produce clean water for public consumption. The processes start from the rain that falls into dam or the river flows to the water intake house where it will be pumped to water treatment plant where the raw water or untreated water is treated by going through the process of aeration, coagulation, flocculation, sedimentation, filtration, disinfection and conditioning [1,2].

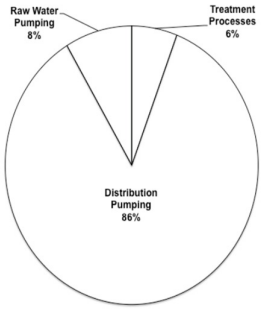

Fig. 1. Energy Consumption in a Water Treatment Plant [3]

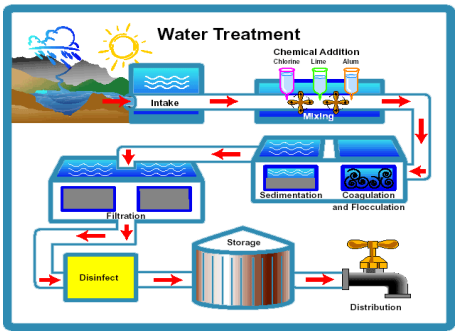

Fig. 2. Water Treatment System [8]

Simulation is a numerical technique for conducting experiment on computer [6]. In order to solve the high electricity consumption by motor pump, simulation study can be done to investigate the pump efficiency. Simulation study gives a more precise insight about the interaction of variable to performance [7]. This means that the performance of a system can be investigated by modifying the system parameter. Besides that, the parameter and system properties are easier to change in a virtual system compared to physical system. With simulation study of water pumping and storage systems, new operating procedure or information can be explored without interrupting the ongoing process of the systems [7].

In Perlis, there are four water treatment plants. They are Perlis Water Treatment Plant, Arau Water Treatment Plant, Timah Tasoh Water treatment Plant and Arau Phase 4 Water Treatment Plant. All these water treatment plant are under the Syarikat Air Perlis (SAP). The main purpose of this study is to investigate the energy efficiency of water pumping and storage system of water treatment plant in Arau Phase 4 by using LabView software. The study is aim to reduce the energy usage and the cost of operation.

This paper organized as follows: Section 2 dicusses the related works of the research. Section 3 describes the proposed methodologies used in the research. Section 4 presents the outcomes and discussions of the experiments. Finally, conclusion and future works of are described in Section 5.

2. Related Works

According to an investigation by the United States of Energy / Lawrence Barkeley National Laboratory had claimed that more than 20% electricity is used by electric pump [5]. In the study by T. Augustyn, it identifying avenue that can be pursued in order to increase the pumping system efficiency, reduce electrical running cost, and the pace at which power station [5]. In the paper, it also mentioned that a pump is selected based on flow (Q) and pressure head (H) and the Darcy-Weisbach is used to calculate the frictional and shock loss. In study by Y.F. Liu and B.J. Zhi, they focus on low efficiency with the method of valve adjustment in operation of domestic water pump, variable speed control by permanent magnet speed control technology and replace the baffle with permanent magnet speed to reduce electricity consumption and improve the pump efficiency for long period [21]. Instead of that, they also suggest install variable speed drive (VSD) to save energy by controlling the pump speed [3, 5, 12, 20]. Controlling the pump speed means it allow the pump to operate under fixed flow and variable pressure conditions or variable flow and fixed pressure. Furthermore, the papers also suggest making an operation schedule of water pump to show the on peak, mid-peak and off-peak hours. They also suggest monitoring the pump to avoid losses due to mechanical or electrical fault.

3. Methodologies

3.1 Energy Audit Conducted at the Water Treatment Plant

3.1.1 Identifying problem

From a recent energy audit report, it is found out that the pumps consume the highest electrical energy compared to other device. Two major pumping process in water treatment plant is raw water pumping process which is extract raw water from river and treated water pumping process in which deliver the treated water to balancing reservoir. The energy usage between this two type of pump is being calculated and compared using the equation below:

$$Pin = Pout \times \frac{100}{\eta} \quad (1)$$

whereby,

η is the efficiency in percent (%).
Pin is the input power consumption in watts (W).
Pout is the output power or actual work in watts (W).

Table 1 shows the tariff applied in water treatment plant and is used to calculate the cost of operation. To calculate the total input power used by the motor pumps in 1 day, the input power needs to be multiply with the number of pump and number of hour of motor's operation which is illustrated in equation below:

Number of Kilowatts of electricity used by pumps if running full capacity in 1 day
= Input Power x Number of Pump x 24 hours (2)

Table 1
Tariff Applied in Water Treatment Plant [12]

TARIFF D – LOW VOLTAGE INDUSTRIALTARIFF	
For the first 200 kWh (1-200 kWh) per month	38.00 sen/kWh
For the next kWh (201 kWh onwards) per month	44.10 sen/kWh
The minimum monthly charge is RM 7.20	

Table 2
Comparison of Power Usage and Cost of Operation between Treated Water Pump and Raw Water Pump

Raw Water Pump	Type of Pump	Treated Water Pump
15872.40kW	Power Usage	95, 238 kW
RM 6, 987.35	Cost of Operation	RM41, 987.76

Table 2 clearly shows that treated water pump consume high electrical energy compared to raw water pump.

3.1.2 Collection of water treatment plant data

Before modelling the system, data such as the pump's capacity, pump's input power, and tank's capacity needed to be collected. Collected data are tabulated in the Table 3 below:

Table 3
Parameter and its specification

Parameter	Specification
Pump's Input Power	793.65kWh
Pump's Capacity	1864m^3/h
Tank Capacity	6000m^3

3.2 Modelling the System

LabView, which is graphical language software, is used in modelling the system. By using software simulation, the situation can be simulated virtually and improved virtually without any change in physical hardware. The system is made up of two separate subsystems, which is the motor pumping system and the tank filling system. Firstly, these two subsystems were constructed seperately and in the end were combined into one complete system. The interface has one balancing reservoir and 6-treated water pumps. The system was then verified by comparing the result simulated with the calculated measurement. Table 4 shows the total power used by treated water pump over 24 hours by mean of simulation. The simulated result was same as the calculated result. The simulation results are shown in Table 2. Thus, the system is said to be successfully modelled.

Table 4
Power usage by pump over 24 hours

Time (hours)	**Power (kW)**
24	95, 238

3.3 Modelling the System

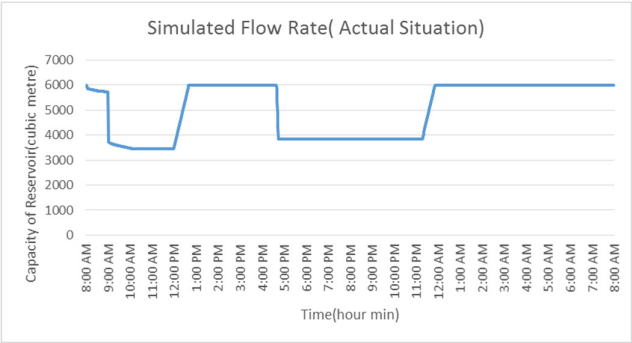

Fig. 5. Simulation of Sample Water Flowrate

The system optimised is based on the Figure 5.Three different scenarios are simulated as below:

(a) Method#1: 3 Pump Running Continuously
(b) Method#2: Pump Running When Low Water Level
(c) Method#3: Pump Operate Solely Depend on Water Level

3.4 Energy Saving Analysis

The energy saving analysis was done by comparing the total input power used by the actual situation with the proposed scenarios in sub section 3.3. The percentage of cost reduction (%) is calculated based on the equation (3) below:

$$\% \text{ Reduction (Cost)} = [(\text{Proposed Method} - \text{Ref. Cost}) / \text{Ref. Cost}] \times 100 \quad (3)$$

4. Results and Discussion

Table 4 shows the total output power used by pumps and cost of operation of different scenarios. It clearly shown that the method #3 is the best solution to cut down the power usage and the cost since it has the highest cost reduction among the three proposed methods.Table 6 shows the proposed schedule of method #3 in which the number of motor pump required to operate according to water demand. By employing this method, unnecessary wastage of energy and cost of operation can be greatly reduced.

Table 4
Power usage by pump over 24 hours

Model	Reference	Method #1	Method #2	Method #3
Output Power (kW)	41987.76	57142.8	17989.4	13461.15
Cost (RM)	41987.76	25187.77	7921.00	5924.17
Reduction (%)	-	40	81	85

Table 5
Number of Motor Pump Required to Operate According to Water Demand

Period	Water Demand	No of Motor Required to Operate
0800-0850	Moderate	0
0850-1400	High	2
1400-1415	Moderate	1
1415-1830	Low	0
1830-1900	Moderate	0
1900-2400	High	2
2400-2415	Moderate	1
2415-0600	No	0
0600-0800	Low	0

5. Conclusions

Treated Water Plant Arau Phase 4 is one of the water treated plant that located in Perlis and serves to deliver about 5 million water to the houses and factories. High electrical fee due to high power has been increasing the cost of operation until unable to cope with the losses. In a recent energy audit report shown that the pumping process consume the highest energy among the others process. In order to identify which type of pumps consume the highest electrical energy, an analysis of electrical consumption by water pumps was made. From the analysis, it is found out that the treated water pump that pump water to balancing reservoir at Bukit Tuntong consume the highest electrical energy compared to raw water pumps that extract the untreated water from the river. Therefore, the water level of the storage and number of motor operate are concerned and the simulation are repeated using different value for both variable. Total input energy used and the cost of operation of different situation is calculated and tabulated as comparison purpose. From the result collected during the simulation of 3 pump running continuously, it is found out that it can reduce about 40% cost of operation compared to current situation. In addition to that, results collected during simulation when the 2 pump operate only when low water level shows 81% cost reduction. Lastly, the simulation's result of the pump operate depend on the water demand shows 85% cost reduction. This is due to the simulation is solely depend on the water demand which mean that the number of motor operate depend on how much water are demanding during that period.

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