Energy Audit Guidebook for Water Utilities in the Philippines

Prepared by the:

Energy Management Association of the Philippines

University of the Philippines

For the:

Alliance to Save Energy

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The Alliance to Save Energy is a non-profit coalition of prominent business, government, environmental, and consumer leaders who promote the efficient and clean use of energy worldwide to benefit consumers, the environment and economic growth. The Alliance has been working internationally for more than a decade in over 30 developing and transition countries.

Realizing the large energy costs attributed to water pumping in developing country cities, in 1998 the Alliance developed a program called Watergy to maximize efficiency in urban water and wastewater systems. The program has made impressive gains improving water supply services for developing country citizens, improving overall system efficiency in municipal water systems, reducing costs and negative environmental impacts, and expanding water and wastewater services to underserved populations. The Alliance has implemented Watergy in over 40 cities around the world and is currently active in India, Mexico, Brazil, Philippines, Sri Lanka and South Africa.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of Figures

1.0 INTRODUCTION [1]

The World Bank estimates that roughly 35 percent of Filipinos are without access to clean drinking water and 65 percent lack water for sanitation. The issues overwhelming the water sector include disparities in water supply coverage across regions, depletion of groundwater, and undercapitalized municipalities. Filipino municipalities lack sufficient management capacity and resources to make the dramatic improvements necessary to expand service coverage. By focusing on the elimination of these inefficiencies, the quality and quantity of water services to the country's poor can be dramatically increased.

In the process of improving overall water system efficiency, municipal water authorities should view energy and water consumption as linked inputs, rather than viewing them as separate and unrelated.

Energy is necessary for moving water through municipal water systems, making water potable, and removing waste from water. Each liter of water moving through a system represents a significant energy cost. Water losses in the form of leakage, theft, consumer waste, and inefficient delivery all directly affect the amount of energy required to deliver water to the consumer. Wastage of water regularly leads to a waste of energy.

Activities undertaken to save water and those to save energy can have a greater impact when they are planned together. For example, a leak reduction program alone will likely save water and reduce pressure losses leading to energy savings from reduced pumping demand. Replacing a pump with a more efficient one by itself will likely save energy. If the two are coordinated together through a Watergy™ efficiency program, the reduction in pressure losses from leaks will allow smaller pumps to be purchased for the upgrade than otherwise possible, saving additional energy and money.

The Alliance to Save Energy, with funding from the United States Asia Environmental Partnership (US-AEP), a program of the U.S. Agency for International Development, has partnered with two water utilities in Iloilo and Cebu to carry out a municipal water and energy efficiency program in the Philippines. The water utilities in Cebu and Iloilo face severe water resource scarcity and disproportionately high electricity costs caused by water pumping in both cities. By improving the efficiency of the existing pumping systems within these municipalities, resources can be put to more productive use while municipal budgets can be better allocated through reduced pumping costs.

The goals of the program include:

1. Improve overall system efficiency in municipal water systems, reducing costs and negative environmental impacts, while expanding water and wastewater services to the country's underserved populations.

2. Build capacity of municipalities, water utilities, companies and NGOs focused upon urban infrastructure development to develop a comprehensive strategy to work on identifying the potential for energy savings from this often overlooked sector.

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[1] Alliance to Save Energy Philippines Fact Sheet, April 2005.

Fig. 1.1 Energy Audit Team at a Water Utility.

3. Create efficiency models based upon capacity building partnerships with local water and wastewater municipal entities to ensure sustainability within the country

In 2004, the program focused on building the capacity of local groups to conduct energy audits in Filipino water utilities. With assistance from The Energy Research Institute in India, the Alliance trained a group of engineers from the Energy Management Association of the Philippines (ENMAP) and the University of the Philippines (UP) to conduct a comprehensive energy efficiency audit of the Metro Iloilo Water District (MIWD).

This was the first known, comprehensive energy audit to be conducted in a Filipino water utility. UP engineers, as a result of this training, designed and instated a water utility energy auditing course within its College of Engineering. Based on the knowledge and experience gained by these engineers, the Alliance hired a team of auditors from ENMAP and UP to conduct a similar energy audit in the Metro Cebu Water District (MCWD). The auditors also provided MCWD with comprehensive classroom training on energy audits. Data supporting the energy savings associated with implementation of recommendations provided will be used to interest other local municipalities to incorporate energy efficiency into their operations and maintenance programs and replicate the municipal efficiency model in other areas of the country. The Alliance also continues to engage in outreach efforts to create a network of appropriate private sector manufacturers of high-efficiency water and energy technology and services.

In order to effectively replicate the municipal energy efficiency model in other water utilities in the country, an *Energy Audit Guidebook for Water Utilities in the Philippines* has been prepared. This guidebook contains step by step procedures on how to conduct an energy audit on energy intensive facilities in a water utility including the study of pumps, electric motors, transformers and water treatment.

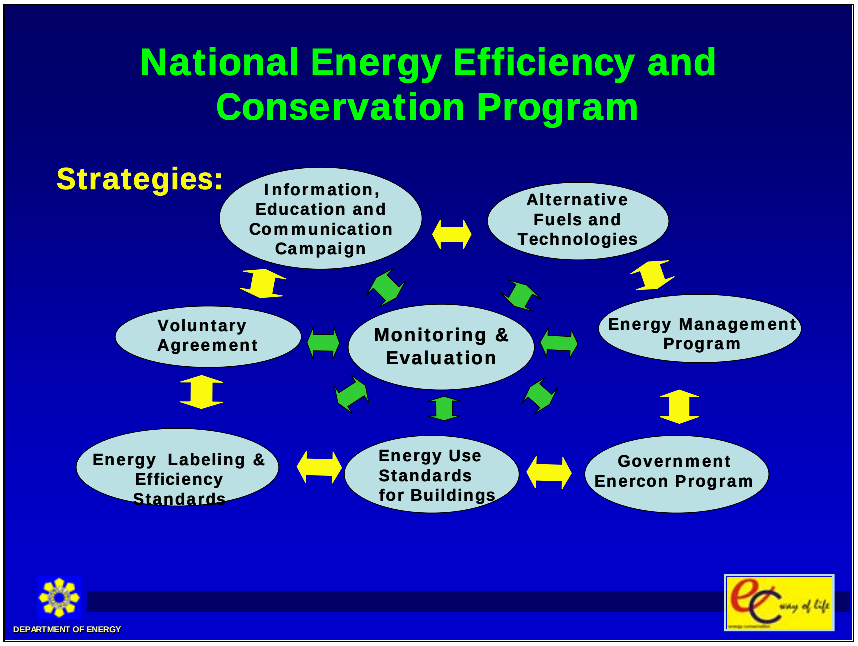
2.0 PHILIPPINE ENERGY EFFICIENCY POLICIES AND PROGRAMS

It is a declared policy of the Philippine Government to promote the judicious conservation and efficient utilization of energy resources through adoption of cost-effective options for the efficient use of energy to minimize environmental impact. The Philippine government's centerpiece program on energy efficiency and conservation is embodied in the revitalized National Energy Efficiency and Conservation Program which was launched by President Gloria Macapagal-Arroyo in August 2004. The program also referred to as the "EC Way of Life", provides strategic measures for cushioning the impact of high oil prices.

The primary goal of the government towards energy efficiency and conservation is to make it a way of life, along with increased awareness and the attainment of 240.8 MMBFOE worth of energy savings from the implementation of energy efficiency and alternative fuels programs for the period 2005-2014. It is projected that about 62 million tons of $C0_2$ and equivalent Greenhouse Gas (GHG) emissions will be avoided during the same period. Specifically, the objectives of the energy efficiency and conservation program are to a) increase participation of companies that manage energy consumption efficiently from the commercial, industrial and transport sectors, as well as from the government sector without applying constraints on the productivity and services provided; b) strengthen consumer understanding of energy use; c) encourage Energy Service Companies (ESCOs) to accelerate implementation of energy efficiency programs in the commercial and industrial sectors; and d) reduce GHG emissions as a result of improved energy consumption performance.

The strategies to achieve these goals include: the aggressive promotion of energy conservation and energy efficient technology to effect higher energy savings both for the consumer and producer through information, education and communication campaigns; intensification of collaborative efforts with the private sector in implementing energy efficiency programs through voluntary agreements; continuation on a regular basis, the implementation and expansion of the appliance and equipment energy standards and labeling of building energy use standards; integration of energy efficiency concepts in the procurement practices of the government; provision of technical assistance in identifying, implementing and evaluating effective measures to improve energy use efficiency; use of alternative fuels to reduce dependence on imported oil; and periodic program monitoring and evaluation to assess the effectiveness of the national energy efficiency and conservation plan.

The Philippine Government also manages an "Energy Management Program" for the industry sector. This is geared to assist industrial and commercial establishments in determining the most cost-effective approaches for the judicious and efficient utilization of energy.



The program provides assistance with a) energy audits; b) heat rate improvement of power plants; c) system loss reduction for distribution utilities; and d) Demand Side Management (DSM) Programs. Table 2.1 below shows the potential cumulative energy savings of the Energy Management Program.

Table 2.1 Potential Cumulative Energy Savings from the Energy Management Program ('000 BFOE).

PROGRAM	2005	2010	2014
Energy Audit/Recognition Programs	5,490	23,120	41,020
Heat Rate Improvement	400	2,260	4,320
Systems Loss Reduction Program	1,080	3,090	3,790
Demand-Side Management	330	1,170	1,270

3.0 ENERGY AUDIT: AN OVERVIEW

3.1 WHAT IS AN ENERGY AUDIT?

Water utilities are intensive energy users and continually seek ways to improve their productivity through the effective and judicious use of energy. An effective manner of reducing energy consumption is to conduct an energy audit. An energy audit involves a critical examination of an energy consuming facility. It determines the performance of a facility in terms of energy use and relates its energy consumption to production and compares it with the performance of similar organizations. An energy audit is an imperative first step for any organization interested in implementing an energy management program within their facilities. It assists with identifying areas where potential savings can be made.

The results of an energy audit can improve the energy efficiency of a facility. Increasing the energy efficiency will enhance the facility's operations and products in numerous ways:

- It can reduce energy costs. Depending on the process, energy costs amount to 15 to 40% of the production cost. (This percentage is determined based on pilot studies of selected water utilities) Reducing the energy expenses can help the company redirect the resulting savings to improve the facility or the business. The savings can also be passed on to the customers which could boost the sales of the company. For municipal water utilities especially, the energy cost reduction can help achieve a lower water tariff, increased service connections, and additional operational funds for expansion or improvement of service.

- It can help the company improve the quality of its product. For example, improving pump performance in a water utility district can ensure the right volume and pressure of water that needs to be supplied. Both energy efficiency and product quality are closely related to effective maintenance and attention to operational details.

- It can lead to corollary benefits such as reduced maintenance costs and improved worker safety. Many energy efficient technologies are more reliable than their inefficient counterparts. For example, fluorescent lighting will require less maintenance and fewer replacements than incandescent lighting. Repairing steam leaks and insulating steam lines can make the steam system safer for the operators who work around it. This in turn can improve employee morale and productivity.

- It can help reduce pollution. With reduced pollution, payment of any existing environmental fees and fines can be minimized. This will help the company improve relations with its neighbors and the general public.

3.2 LEVELS OF ENERGY AUDIT

The type of energy audit to be undertaken depends on the objectives of the exercise, available resources, extent of work and expected results. Generally, an energy audit can be categorized into two types - preliminary audits and detailed audits.

3.2.1 Preliminary Audit (Walk Through)

A preliminary audit consists of recording and analyzing energy use (purchased energy) in a facility over a fixed period of time. This can be executed by a quick walk-through of the facilities and the analysis of utility and fuel bills. A preliminary audit may take 1 to 3 days to complete depending on the complexity of the facility. An energy cost center is the smallest segment (department, system or building) of the facility for which actual energy consumption can be measured and held accountable for its energy use.

3.2.2 Detailed Audit

A detailed audit consists of recording both purchased and generated energy use data for every cost center in the water district over a fixed period of time and also calculating the energy balances and efficiencies. This audit may require back-up portable measuring instruments referred to as "energy audit equipment". It may take 1 to 2 weeks to complete a detailed audit depending on the size and type of the facility.

3.3 ENERGY AUDIT PROCESS

The energy auditing process consists of four (4) stages as follows: a) planning, b) collecting energy consumption data, c) data analysis, and d) making recommendations.

3.3.1 PROJECT PLANNING

There are various steps involved in implementing an energy management program in water utilities. Before the implementation of the actual energy audit there are crucial phases that first need to be completed. These are as follows –

Step 1. Get the Commitment of Top Management

Complete support and commitment from the top management is key to successfully implementing an energy management program. This has to be sought first before starting an energy audit. Without this commitment, the program will likely fail to achieve its objectives and goals.

Fig. 3.1 A Detailed Audit.

The best way to convince management is to present facts and statistics on energy and cost savings. One can present the historical energy consumption profile of the facility highlighting the increasing trend of energy use and related costs. The consumption profile is determined through a thorough examination of the utility bills. The experiences of other companies in implementing an energy management program can also be related by highlighting their energy conservation activities with the corresponding amount of reduced energy consumption. Clear and substantial benefits that can be derived from an effective energy management program can also be emphasized to get the support of top management.

Step 2. Assign an Energy Audit Team

After getting the support of top management, an energy audit team must be established. The energy audit team is responsible for visiting the facility. They are tasked with a) collecting energy-use data, b) measuring actual performance of equipment, c) calculating energy balances and efficiencies, d) developing energy standards, e) evaluating energy conservation opportunities and f) preparing the final audit report.

Step 3. Clearly Define Objectives and Goals

An explicit statement of the objectives and goals of the energy audit should be made. This is to establish energy standards, to identify and analyze energy conservation opportunities and to establish an accounting and reporting system in order to provide a base for planning future energy programs. Goals and targets need to be decided upon. They should be achievable, measurable, specific, and include a time line for implementation. Methods of monitoring and reporting must also be established.

Step 4. Prepare Energy Audit Equipment

Portable measuring devices are required to take actual measurements and monitor parameters (e.g. pressure, flow, voltage, current) of the equipment. These measurements are very important in determining energy efficiencies. Tools commonly required for energy audits in municipal water utilities include the following:

- ***Voltmeter***. A voltmeter is useful for determining operating voltages on electrical equipment and especially useful when the nameplate has worn off of a piece of equipment or is otherwise unreadable or missing. The most versatile instrument is a combined volt-ohm-ammeter with a clamp on feature for measuring currents in conductors that are easily accessible. This type of multi-meter is convenient and relatively inexpensive.

- ***Wattmeter/Power Factor Meter***. A portable hand held wattmeter and power factor meter are very handy for determining the power consumption and power factor of the individual motors and other inductive devices, and the load factors of motors. This motor typically has a clamp-on feature which allows easy and safe connection to the current-carrying conductor, and has probes for voltage connections.

- ***Flowmeter***. A portable flow meter which measures the flow rates in liters per second or cubic meters per hour and water velocities is one of the most important energy audit equipment in water utilities.

- ***Lightmeter***. This instrument is used to measure illumination levels in facilities. A lightmeter that reads in footcandles allows direct analysis of lighting systems and comparison with recommended light levels. It is useful to have a portable lightmeter that can fit into a pocket.

- ***Thermometers***. Several thermometers are required to measure ambient temperatures in offices and other worker areas, and to measure the temperature of operating equipment.

- ***Tape measures***. The most basic measuring device is the tape measure. A 25-foot and 100-foot tape measures are used to verify the dimensions of the walls, ceilings, doors and distances between pieces of equipment, for example, to determine the length of a pipe.

3.3.2 COLLECTING ENERGY CONSUMPTION DATA

After the planning stage, the energy audit team should prepare a checklist of data that will be utilized for the computation of energy efficiencies together with the required worksheets or data sheets. This is followed with an introductory meeting with the facility manager and supervisor to explain the purpose of the audit and to request the background data required during the facility inspection. The meeting will ensure an efficient data collection stage. Interviewing the technicians and operators of the equipment will also help the auditors in the collection of reliable data.

The first set of data required for the analysis of the energy intensive systems includes utility and fuel bills for the last 2 or 3 years, facility layout, process flow charts, production output, historical performance data of equipment, if any, operating hours and an inventory of equipment. The next step is to collect data that covers the various parameters actually measured from the equipment in the facility. In municipal water utilities, the major equipment to be measured consists of pumps and electric motors. Table 3.1 shows a summary of the types data required during the auditing of water districts. These types of data will be discussed in detail in chapters 4 and 5.

Table 3.1 Energy Audit Data Required in Water Utilities.

GENERAL	PUMPS	ELECTRIC MOTORS
■ Utility bills ■ Fuel bills ■ Facility layout ■ Production output ■ Operating hours ■ Inventory of equipment	■ Rated head ■ Discharge and shaft speed (nameplate) ■ Actual discharge ■ Pump suction pressure ■ Discharge pressure ■ Pump shaft speed ■ Pipe sizes ■ Water level (source) ■ Flow velocity	■ Motor application ■ Nameplate data ■ Rated power ■ Rated voltage ■ Current ■ Full load amps ■ Power factor ■ Load profile

The data collected will provide the basis for setting bench marks, forecasting energy use for future years, identifying energy-intensive cost centers, establishing energy standards and setting energy conservation goals.

3.3.3 ANALYZING ENERGY AUDIT DATA

After collecting the data, the next step is to calculate energy balance and efficiencies. It must be noted that equations involved in the computation of energy efficiencies vary from one energy intensive system to another.

3.3.3.1 CALCULATION OF ENERGY BALANCES

Calculating the energy balance is imperative to define the energy input, energy utilized and energy dissipated or wasted within the systems. It requires knowledge and use of certain engineering principles, in particular, the first and second laws of thermodynamics. Applied to incompressible fluids, in the case of water systems, Bernoulli's equation, which is an application of these two concepts, is the tool used in calculating the energy balance. All parameters obtained from physical measurements are added to the energy balance equations for a thorough analysis. Details of these computations are shown in preceding sections in the guidebook.

3.3.3.2 CALCULATION OF ENERGY EFFICIENCIES

The efficiency of the equipment, process or systems being studied can be determined, once the energy balance is calculated. In general, energy efficiency is defined as,

$$\text{Energy Efficiency, \%} = \frac{\text{Energy input} - \text{Energy Losses}}{\text{Energy input}} \times 100$$

The calculated energy efficiency of the various systems found in the facility can be compared to industry norms and standards. The sources for the standards can be equipment suppliers, technology developers and consulting firms. Any energy intensive equipment whose efficiency is significantly below industry norms is obviously a candidate for improvement. A rough estimate of possible energy savings could be obtained by using the following steps:

Step 1. Determine the difference between the calculated efficiency and the normal efficiency.

Step 2. Multiply the difference computed in step 1 with the total energy input. This will give the potential energy (kJ) and peso savings.

This estimate can be used in establishing energy conservation goals and in preparing energy budgets.

3.3.4 EVALUATING OPPORTUNITIES AND MAKING RECOMMENDATIONS

In order to generate several energy reduction options that can be implemented, several opportunities for energy saving should also be identified. The relative merit of each energy saving opportunity must be evaluated. The following questions can assist in the process:

- How much money will be required to capitalize on each recommendation?
- How much energy and money will be saved in each recommendation?

- How much time will it take to implement each recommendation?

The skill and experience of the audit team is crucial in identifying cost effective and feasible energy saving measures. If installation of equipment or replacement is necessary, a list of alternative options should be obtained e.g., installing new compressors both with and without load management controls.

The costs of the proposed measures should also be determined. This usually involves calling manufacturers or suppliers to ask for quotes or browsing vendor catalogues. The benefits of each identified measure should be calculated. To do this, a baseline estimate of energy use for the existing system will be prepared and compared to energy use with the proposed modification. The baseline must be accurate, otherwise the rest of the analysis will be incorrect. Ideally, the baseline will be derived from metered data and if this is not available then detailed information on annual hours of use and energy demand (based on audit measurements or meters placed on the equipment for a period of time) may be utilized. One may also employ existing energy consumption software to assist energy auditors in the preparation of the baseline estimate for an existing equipment or process.

3.3.5 ENERGY AUDIT REPORT WRITING

An energy audit report must be prepared and presented to top management. The report should be concise and highlight the audit process, and the resulting audit findings and recommendations.

The report should consist of an executive summary highlighting the total savings and description of each recommended measure. A description of the facility audited should also be provided. This helps management understand how the recommendations will affect overall production processes. The report should include information on the facility's energy use and costs (usually illustrated with tables and graphs). The recommended measures come next and make up the bulk of the report. Measures analyzed but not recommended may also be included, particularly if these were discussed earlier with the facility staff.

Data assumptions should be clearly described or listed. This will make it easier to review the calculations and identify possible errors. It will also assist with updating the calculations if the assumptions change. For example, the cost of energy may change over time. These assumptions may be listed once in the report or the relevant assumption may be highlighted under each individual measure.

4.0 ENERGY AUDITS IN WATER UTILITIES

In municipal water utilities, the biggest consumers of energy are the pumps, electric motors, and transformers. This section shall discuss the theoretical principles involved in each energy intensive equipment and system, the step-by-step procedures of doing an energy audit, the calculation of energy efficiencies and the identification of energy saving opportunities.

4.1 ENERGY ASSESSMENT OF PUMPS

Pumps are motor-driven machinery used to "push" water to flow through pipelines between sites. There are different types of pumps intended for specific applications. For large distribution systems, pumps with rotating impellers are generally used. These include single-stage and multi-stage centrifugal, axial and mixed-flow pumps. Selection of the correct type of pump depends upon the required head and discharge as well as the site where the pump is to be installed. Centrifugal pumps are surface mounted whereas submersible pumps for ground water supply are of the mixed-flow type. Axial flow pumps are meant more for low head, high discharge applications.

4.1.1 BASIC PRINCIPLES INVOLVED

This section covers discussion on the basic principles involved in the efficient operation of pumps which include the energy relations for incompressible fluid flows, piping system characteristics, pump performance parameters, matching the pump and procedures in the selection and operation of pumps.

4.1.1.1 ENERGY RELATIONS FOR INCOMPRESSIBLE FLUID FLOWS

Given an incompressible fluid (such as water) steadily flowing through a specific section of a conduit or passage, the total energy or head *H* at any point along that conduit section is:

$$H = \frac{p}{\gamma} + z + \frac{V^2}{2g}$$

where:

H	=	Total head
$\frac{p}{\gamma}$	=	Pressure head
z	=	Elevation head
$\frac{V^2}{2g}$	=	Velocity head

All of these terms are expressed in length units (meters). The sum of the pressure and elevation heads is called the *static head*. In steady flow, the *velocity head* is normally neglected since its value is much lower than the static head.

For a given section through which flow takes place, the Bernoulli equation for energy of incompressible flow is:

$$H_1 + h_p = H_2 + \Sigma h_L$$

where:

H_1	=	Total head at the beginning of the section

h_p = Head gain of water flowing through pump
H_2 = Total head at the end of the section
Σh_L = Total head loss of water during flow

The following are factors that contribute to head loss of water flowing though a given section:

- Friction due to pipe roughness
- Flow entrance and discharge (including leaks)
- Contractions or expansions of conduit cross section
- Pipe fittings (valves, couplings, flanges, etc)
- Pipe bends and elbows

Each of these factors impedes the flow of water. These losses are expressed as functions of velocity of flow through a particular point of the flow section. To facilitate calculation of these head losses, there are charts and tables available that can be used.

4.1.1.2 PIPING SYSTEM CHARACTERISTICS

Since head losses are functions of velocity and velocity is obtained by dividing the flow rate Q by the cross-sectional area of the conduit, then it follows that head losses are functions of Q. For a given system, as Q increases, the head losses also increase. Another way of looking at this would be: in order to overcome high head losses, Q must be sufficiently high.

With reference to the construction of a flow passage or system (including pipe sizes, lengths, fittings used and other sources of head loss) and using Bernoulli's equation, a head-flow rate curve of this passage from one end to the other can be plotted. The difference in static head is constant throughout the entire passage regardless of the amount of flow. On the other hand, head losses increase during flow to the end of the system. An example of a flow system between two reservoirs and the corresponding system curve is shown on Figure 4.1.

The sum of the static head and the dynamic head is called the total dynamic head of the system. Plotting a fairly accurate system curve is essential for system evaluation and selection of the correct machinery for the system.

4.1.1.3 PUMP PERFORMANCE PARAMETERS

Parameters that describe a pump's performance include pump discharge or capacity, pump head, water power, pump shaft power, pump efficiency, net positive suction head, and specific speed

Since a pump continuously transfers its shaft energy to the water through the impellers, the discharge is defined as the amount of water pumped per unit time and is symbolized by Q. Units are in liters per second (l/s), cubic meters per second (m^3/s) or gallons per minutes (gpm).

The pump head is the net work done on a unit weight of water by the pump impeller. It is the amount of energy added to the water between the suction and discharge sides of the pump. Pump head is measured as the pressure difference between the discharge and suction sides of the pump during a pump test. In a piping system where a pump is included, the pump head can also be defined using the Bernoulli equation:

$$h_p = H_2 - H_1 + h_L$$

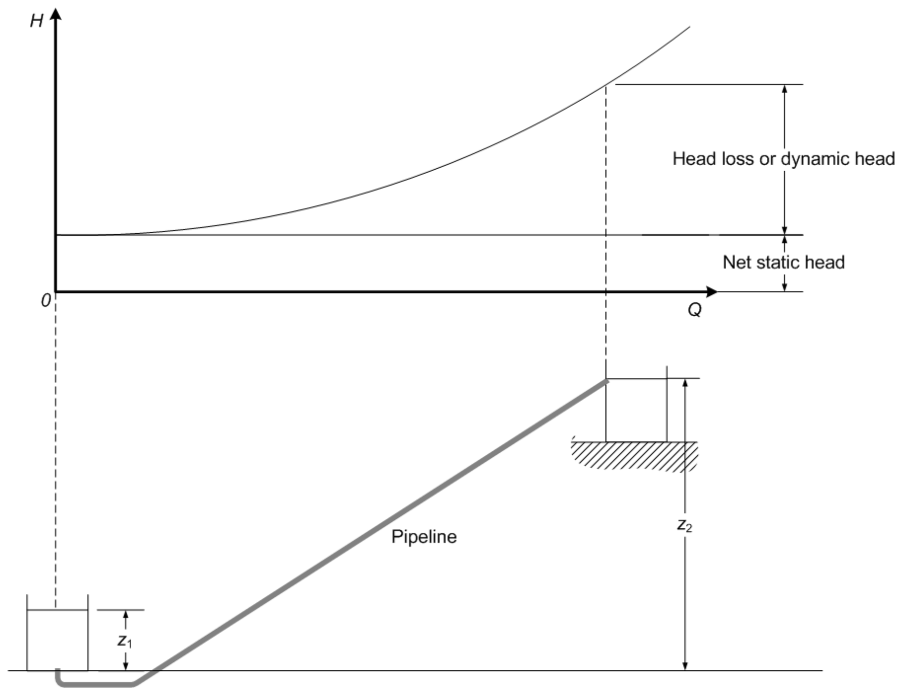


Fig. 4.1 An Example of a Flow System Between Two Reservoirs and the Corresponding System Curve.

From the above equation, the pump must be enough for the water to match the total head of the system. The unit for the pump head is the meter (*m*) or foot (*ft*).

The power transferred to the water by the pump is called the water power. This power could be measured by assuming that it is the rate of lifting a certain quantity of water to a certain elevation. So, the water power is obtained from the following relation, results being in SI units:

$$P_{water} = \frac{\gamma \, Q \, h_p}{1000}$$

where:

P_{water} = Water power in kilowatts, kW
γ = Specific weight of water, 9,810 N/m^3

This shows that in order to calculate for the water power, the pump discharge (in m^3/s) and the pump head (in *m*) must be known or measured.

A certain amount of shaft power must be supplied by the driving motor to the pump. Part of this shaft power (also called the brake power because the pump serves as a braking resistance to the driving motor) is converted into the water power, whereas other portions are used to run the pump against internal friction, imbalance and other imperfections of the pump. The greater the imperfection of the pump, the more shaft power is required. High shaft power is also necessary if the total dynamic head of a piping system is high.

The motor that drives the pump likewise draws input energy such as electricity or fuel. Part of this input energy becomes the shaft power supplied to the pump while a portion is used to turn the motor against its own internal friction, imbalance and other imperfections. Just like the pump, higher input of energy is required if the motor imperfections are greater and if the motor load is high.

Since only a portion of the input power is converted to water power, then the pump has to be rated in terms of its efficiency - the ratio of the water power to the input power. The overall efficiency of the pump-motor unit can be calculated as:

$$\eta_{total} = \frac{P_{water}}{P_{input}}$$

Since the pump converts only a portion of the shaft power supplied by the motor, then the pump efficiency could be calculated from:

$$\eta_{pump} = \frac{P_{water}}{P_{shaft}}$$

The motor likewise has its own efficiency rating:

$$\eta_{motor} = \frac{P_{shaft}}{P_{input}}$$

From the above equations of efficiency:

$$\eta_{total} = \frac{P_{water}}{P_{input}} = \frac{P_{water}}{P_{shaft}} \times \frac{P_{shaft}}{P_{input}} = \eta_{water} \times \eta_{motor}$$

The overall efficiency of the pumping system is the product of the pump efficiency and the motor efficiency. If both are high values, then the overall efficiency is likewise high. However, all values of efficiency are below 100% because of losses in energy due to imperfections. It then follows that if these imperfections are corrected, the efficiencies can increase.

When a pump draws in vapor along with the water at the suction side (this happens when the suction pipe is not completely filled with water), gas pockets or bubbles form inside the pump, specifically on the impeller surfaces. The formation and subsequent collapse of these vapor-filled cavities is called cavitation and is destructive to the impeller because liquid would continually hit the impeller surface until the impeller material wears and pitting or cavities are formed. A cavitation situation occurs when the water level at a source is lower than the suction pipe of the pump by a certain level.

The net positive suction head (NPSH) is the amount of energy required to prevent the formation of vapor-filled cavities of fluid within the eye of impeller. This particular case is called the required net positive suction head ($NPSH_r$), which is a function of pump design and is usually determined experimentally for each pump. The head within the eye of the impeller is referred to as the net positive suction head available ($NPSH_a$) and this should exceed the $NPSH_r$ to avoid cavitation.

Specific speed is an index number correlating pump flow, head and shaft speed at the point of highest efficiency. It classifies pump impellers with respect to their geometric similarity. Two impellers are geometrically similar when the ratios of corresponding dimensions are the same for both impellers.

The specific speed is important when selecting impellers for different conditions of head, capacity and speed. Usually, high head impellers have low specific speeds and low head impellers have high specific speeds. Centrifugal pumps, mixed flow pumps and axial flow pumps could be classified according to specific speed, as seen in Figure 4.2.

Note that the efficiencies vary with specific speed and that there are specific speeds where efficiency of pumps is highest. In terms of cost, there is an advantage in using pumps with high specific speeds. For a given set of conditions, operating speed is higher. As a result the selected pump can generally be smaller and less expensive. However, pumps operating at higher speeds will wear out faster.

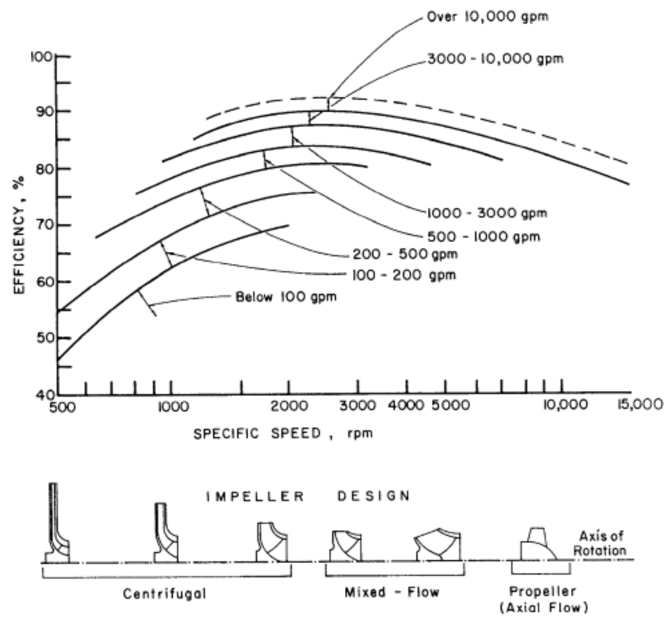


Fig. 4.2 Specific Speed for Different Pump Configuration.

The major factors that influence pump performance and are:

- Impeller size (diameter)
- Rotational speed of the pump

Pump head, discharge, torque and power are expressed as functions of speed and impeller diameter:

$$h = K_1 D^2 n^2$$

$$Q = K_2 D^3 n$$

$$T = K_3 D^5 n^2$$

$$P = K_4 D^5 n^3$$

where:

D	=	Impeller diameter
n	=	Pump speed
h	=	Pump head
Q	=	Discharge
T	=	Shaft torque at pump
P	=	Pump power
K_i	=	Constants

This means that there are ranges of values for all these parameters for given impeller diameters and speeds. Characteristics of a pump for different impeller diameters at fixed pump speeds would appear similar to Figure 4.3. Curves for varying pump speeds with a fixed

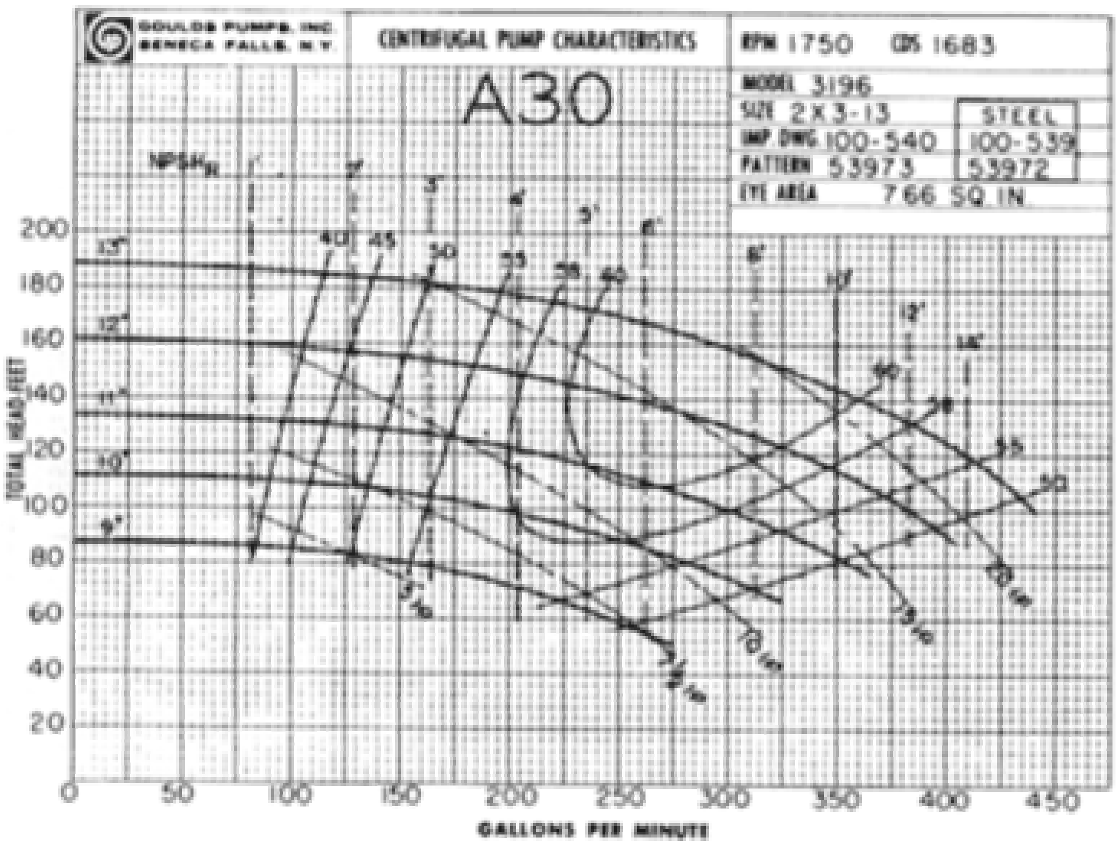


Fig. 4.3 Centrifugal Pump Characteristics.

impeller diameter would also have the same results.

The points on these curves are enveloped within regions of pump efficiencies. In the case of Figure 4.3, the innermost region indicates the area of maximum pump efficiency. It is always desirable to operate a pump within that region.

Pumps are normally operated at fixed speeds. Pump curves for single speeds and fixed impeller diameters would appear similar to Figure 4.4.

The curve labeled with "η" is the pump efficiency curve. It can be seen that efficiency varies with the head "H" and discharge "*Q*". There is a head and a discharge that corresponds to the point of highest pump efficiency. This point on the head-discharge curve (labeled in the figure as "H") is known as the best efficiency point. It is desired that a pump must operate at this point.

Pump curves vary depending on the sizes and types of pump and are usually drawn from test results of these pumps. Pumps of the same model and manufacturer would have similar curves. Pump manufacturers must always supply the appropriate pump curves that correspond to their products to customers.

4.1.1.4 MATCHING THE PUMP TO THE SYSTEM

For the pump to work at the best efficiency point, it must be matched to the system. This is where the importance of accurately plotting the system curve lies. As was shown earlier, the piping system

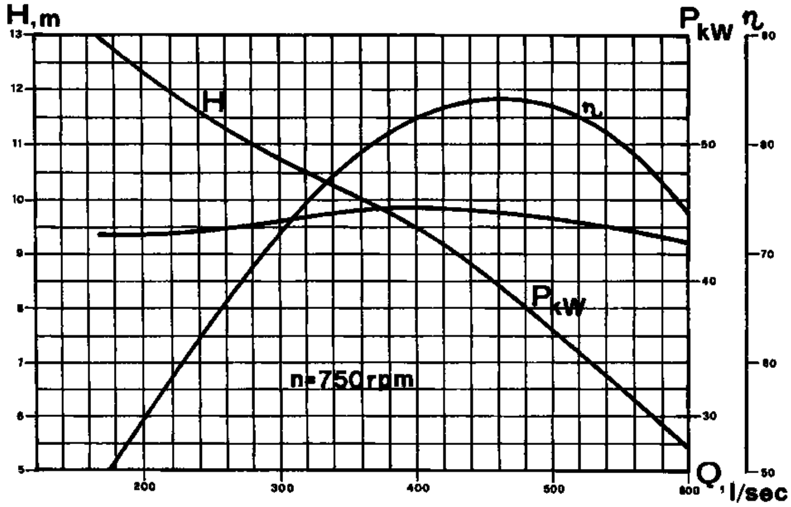


Fig. 4.4 Sample Pump Curve for Single Speed and Fixed Impeller Diameter.

from end to end is a point on the system curve. It is preferable that the selected pump must service the system at that specific point while it, at the same time, operates at its best efficiency point.

One selection procedure is to determine the system head and required discharge, then select a pump with a rated head and discharge that matches that point. Pumps are catalogued to facilitate ease in selecting an appropriate model.

The system curve could be superimposed on different pump curves. If the system point coincides or is close to the best efficiency point of the pump, then that particular pump model would be suitable to service the system. An illustration of this curve matching approach is shown below.

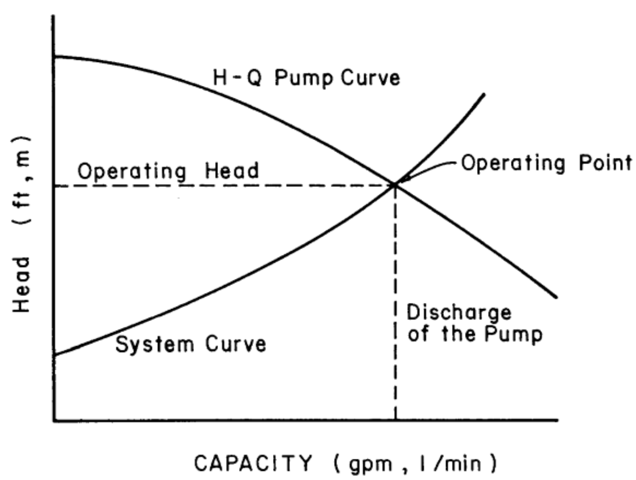


Fig. 4.5 System Curve.

There would be variations in a system through time and use and this could lead to a deviation from the plotted system curve. Such cases must be predicted through careful analysis, planning and forecasting. This will help define options that can be adopted to improve the system through its lifetime. Options include modifying the pump impellers or operating speeds (using, say, variable speed drives), replacing it completely, or putting in additional pumps either in series (to increase head) or in parallel (to increase discharge). Operating procedures such as fixing operating schedules of pumps to maintain system operating points can also be modified.

4.1.1.5 SELECT PROCEDURES TO AVOID DURING SELECTION AND OPERATION OF PUMPS

Selecting and operating a pump requires correct actions to ensure continued system reliability and energy efficiency. Incorrect matching could lead to a pipe being undersized (rated head and capacity are below the system head) or oversized (rated head and capacity are above and away from the system head). An undersized pump would be forced to work harder to match the required flow of the system, thus requiring more input energy leading to low pump efficiency. On the other hand, an oversized pump would have a discharge higher than required and to bring this discharge down, the operator should partially close the discharge side valve (throttling). But throttling a pump increases the system head, so the resulting operating point of the pump could deviate significantly from its best efficiency point. This could result in a high power input (since the partially-closed valve acts as a blockage in the pipeline) and, therefore, low efficiency. The difference in the cost of running a mismatched pump against the appropriate pump may be so high that it might be more feasible to purchase the correct pump or pumps for the system.

Here are some reasons for incorrect selection of pumps:

- Safety margins were added to the original calculations. Several people are involved in the pump buying decision and each of them is afraid of recommending a pump that proves to be too small for the job.
- It was anticipated that a larger pump would be needed in the future, so it was purchased earlier to save buying the larger pump later on.
- It was the only pump the dealer had in stock and a pump was needed badly.
- It could also be the only pump available in the end-user's inventory.
- The system operating point was determined through rough, inaccurate estimation only.

4.1.2 DATA GATHERING AND ANALYSIS

Data gathering and analysis are the main activities in any energy assessment. This section will discuss the different parameters that will be actually measured and how these parameters are used in order to calculate energy efficiencies.

4.1.2.1 PREPARATION

Evaluating pump performance requires the collection of pertinent data for use in analysis. This discussion is limited to analyzing only the pump; discussions on analysis of the electrical side are found in section 4.2.

The following measurable data to be acquired from the pumps which can be tabulated in a worksheet as shown in Table 4.1 are:

- Rated head, discharge and shaft speed as written on the pump plate
- Actual discharge
- Pump suction side and discharge side pressures
- Pump shaft speed
- Suction and discharge pipe sizes
- Water level at the source
- Flow velocity in the pipeline

In addition to the above measurable data, the following documents need to be obtained in order to better understand how the pumps are performing:

- Pump curves (manufacturer supplied or as tested by end-user)
- Records of pump maintenance, repair and modifications
- Records of pump daily, weekly and monthly operations including accumulated outputs
- Test data of the motors that drive the pump; essential here would be the motor efficiency
- Updated records of static water levels at the source
- Pump settings for deep-well pumps
- Elevation of suction side of centrifugal pump

The following are the recommended energy audit equipment and tools to be used during testing and data gathering:

- Flow meters, preferably of the non-invasive type, such as ultrasonic flow meters as these could also measure flow velocities
- Totalizers, calibrated and installed on the pump
- Pressure gages and vacuum gages
- Stopwatch
- Tape measure, to measure pipe circumference
- Tachometer, preferably the stroboscopic type, to measure pump motor speed
- Camera, for recording any visual observations

Additional important data including the input power data for the analysis of pumps can be obtained from electrical readings.

4.1.2.2 INSTALLATION OF MEASURING INSTRUMENTS

After gathering the preliminary data, measuring instruments can now be installed. Below are some tips in installing the instruments:

- For centrifugal pumps:

  - Pressure gauges are to be installed at pressure taps on the suction and discharge sides of the pump.

  - A piece of reflective tape or a spot of reflective paint is to be placed on the centrifugal pump input shaft or flywheel for stroboscope readings

- The ultrasonic flow meter is to be installed on a long, straight and smooth section of the discharge line (about 8 to 10 pipe diameters downstream from flange or fitting of the pump) and following the manufacturer's procedures for correct installation and setting. In the event that pipeline conditions result in zero or erroneous readings by the ultrasonic flow meter, an alternative method would be to record water volume delivered over a prescribed time interval. This requires the use of a calibrated totalizer to be installed on the discharge line and a stopwatch.

Table 4.1 Energy Audit Worksheet for Pumps.

Pump Station #		PUMP 1	PUMP 2	PUMP 3	PUMP 4	PUMP 5
Rated Parameters	**Units**					
Make						
Model						
Type						
Flow	m^3/hr					
Head	m					
Pump Setting	m					
Motor KW	KW					
Pump Efficiency	%					
Motor Efficiency	%					
Speed	rpm					
Operating hrs /day	hrs					
Measured Parameters	**Units**					
Actual Flow	m^3/hr					
	lps					
Head	m					
Power	KW					
Hydraulic KW	KW					
Overall Efficiency	%					
Pump Efficiency	%					
Specific Energy Consumption	KWh/ML					

- For deep-well pumps, a pressure gauge is to be installed only on the discharge pipeline. Also, it would not be possible to get stroboscope readings for this type of pump.

4.1.2.3 TESTING PROCEDURES

Below are several testing procedures that may be carried out in the pump system.

a) Pre-Test

- Record the date, day and time of testing. Note that this is essential since testing may take place during peak or lean hours such that demand may change during those times.
- Note conditions of pump, pipes, pump house, control boxes and all other outlying fixtures and facilities surrounding the pump.
- Note valve settings, particularly whether the discharge valves are partially closed (which means the flow is being throttled to lower the discharge rate)
- Measure suction and discharge pipe's outside circumferences using the tape measure. Compute for the pipe diameter.

b) Pump Discharge

- With the ultrasonic flow meter installed, key in the correct parameters (pipe size and thickness, pipe material, etc.) in the meter control panel. Set the meter to record mode. Once discharge and pipeline velocity readings are generated, record these and do a second trial.
- In the absence of an ultrasonic flow meter, use the quantity-time method of measurement. Set a stopwatch to "0". Note the divisions on the totalizer. Since the totalizer is continuously registering readings, set a reading prior to starting the stopwatch. Once that reading is reached, start the stopwatch. The moment the stopwatch reaches the specified time interval (10 to 15 minutes), note and record the final reading on the totalizer. Flow rate could then be calculated from

$$Q\ (m^3/h) = \frac{\text{Final reading} - \text{Initial reading}}{\text{Time interval}}$$

c) Suction and Discharge Pressures

- With gauges installed, open the valves at the pressure taps. Record pressure readings.
- Perform several recordings within a specified time interval.

d) Pump Speed

- Aim the light gun of the stroboscope at the tape or paint spot on the shaft of flywheel of the pump.
- Record stroboscope readings.
- Repeat readings within a specified time interval.

4.1.2.4 DATA ANALYSIS

Data analysis comprise of calculating several energy efficiency indicators.

a) Calculating the Pump Head

- If suction and discharge pressures were recorded (such as for centrifugal pumps), the pump head can be calculated from:

$$h_P = \frac{(P_{discharge} - P_{suction})}{\gamma}$$

- For deep-well pumps, the static water level, pump setting and discharge pressures must be known or recorded. The pump head could then be obtained from:

$$h_P = \frac{P_{discharge}}{\gamma} + z_2 - z_1 + h_L$$

This is on the assumption that the pressure at the well is atmospheric (that is, gauge pressure is zero). The elevation z_1 is the well water level as measured from the ground, z_2 is the level where the discharge pressure gage is located, h_L is the head loss from the suction side of the submersible pump to the point where the pressure gauge is located.

b) Plotting the Pump Operating Point

Using the measured flow rate and the calculated pump head, the pump operating point is plotted on that pump's curve. The point should be close to the best efficiency point of the curve. If the operating point is far away from the BEP of the pump, then there is a performance issue concerning the pump.

c) Calculating the Water Power

Using the measured flow rate and the calculated pump head, the water power in kW is calculated using:

$$P_{water} = \frac{Qh_p}{367.2}$$

Note that Q is in m^3/h and h_P is in meters.

d) Calculating the Pump Efficiency

For this portion, the readings from electrical measurements at the control panel must be obtained and the input power computed. Also, data on the pump motor, particularly the motor efficiency, must also be available. The overall efficiency of the pump is:

$$\eta_{total} = \frac{P_{water}}{P_{input}}$$

The pump efficiency is then obtained from:

$$\eta_{pump} = \frac{\eta_{total}}{\eta_{motor}}$$

e) Calculating the Specific Energy Consumption (SEC) and Energy Cost / ML

The specific energy consumption is defined as the number of kW-hrs of input energy used per 1,000,000 liters (1,000 m^3) water delivered. For this, the required parameters are: the measured pump discharge Q (m^3/h) and the input power in kW. The SEC is then calculated from:

$$SEC = \frac{1{,}000\ P_{input}}{Q}$$

From the SEC, the cost for generating a million liters of water could be obtained by multiplying the SEC by the cost per kW-hr (obtained from the installations power bill). It is desired that a low SEC be achieved.

f) Water Balance and Pressure Profile of a Pump Network

If the pumps tested belong to a network, then the water balance and pump pressure profiles must be determined to identify additional issues that could play a role in understanding the pump's performance. The sum of the *Q*s of all the pumps in the network must equal the flow out of the pumping network (say, into a reservoir or at a junction). The pressure profile of each pump must also be determined based on logged pressure readings collected during the day. Fluctuating pressure profiles indicate fluctuations in demand during a day's operation.

There are a variety of conclusions that could be generated given the results obtained upon analysis. The most obvious ones are the deviation of the pump's actual operating point from its best efficiency point, the computed pump efficiency, the SEC and the input power consumption. The discussion below is focused on *pump and pipeline issues*.

With reference to the pump's rated speed, head and discharge, the pump's actual performance should fall close to these values. If not, the system could be facing numerous issues including:

- There is a mismatch between the system and the pump owing to inaccurate estimation of system head or using whatever pump is available regardless of required system head. The pump, as a result, consumes more input energy. For undersized pumps, the pump has to work harder to meet the required head and discharge. In the case of oversized pumps, discharge is controlled through throttling, which increases the system head and induces the motor drive to work harder for lower discharge.

- In the case of parallel pumping systems, the pumps may not be identical. As a result, one pump may cause the other to "starve" because of differences in suction pressures. This could lead to irregular operation of the pump with the lower suction pressure since it is deprived of water from time to time.

- Some of the pump curves used for the analysis may be out of date due to modifications and repairs made on existing pumps. Therefore, this could lead to erroneous matching of the operating point and the pump's supposed best efficiency point. Any modifications are made on pumps lead to changes in the pumps' characteristics. Therefore their performance curves should be updated from data obtained from recent tests prior to installation.

- The pumps may be in a worn-out condition. Impellers may have been damaged. Shaft bearings may need replacement. Motor couplings may require servicing or replacement or there is leakage in the pump casing. Sediments may have been trapped within the pump. There are other problems that are associated with worn-out pumps. These could be identified by thorough a detailed inspection.

- The suction and discharge lines may be sized incorrectly. Pump manufacturers usually specify correct pipe sizes for pumps. Use of incorrect sizes may be due to supply availability issues when required.

- There could be blockage in the pipelines. Blockage increases the head at discharge and decreases the NPSH at suction, causing the pump to work harder or starve.

- The pump placement may lead to low NPSH. Long suction lines contribute to head loss which leads to low NPSH. This problem is also caused by fluctuating water levels at the source.

- There can be numerous obstructions along the suction or discharge line. Repairs may have been made on some pipe sections and perhaps for economic reasons, flanged short sections were used to replace worn-out portions of the pipeline. These obstructions contribute to head loss and the pump has to work hard to bring the water to the required flow. Stream velocities in these sections are high because the pipe is not completely filled with water. Therefore, the pump has to push more water to fill the pipes.

- Typically, motor drives that operate pumps run at fixed speeds. If demand changes during the day, pumps continue to turn at those speeds even if the demand is lower. This could turn into an operational procedure issue if pressures are unmonitored during the day.

- The motor drives may be worn out and require servicing. Worn motors require more energy to turn, so these must also be checked to identify servicing needs.

- If the pump and piping system are sound, then inefficiencies may be attributed to the electrical side, particularly at the control panels.

All of the above issues have effects on energy consumption and efficiency of the pumping system.

4.1.3 ENERGY EFFICIENCY OPPORTUNITIES FOR PUMPS

Corrective and preventive measures can be implemented once the pump efficiency and energy issues have been identified within the system. These measures will vary with regard to the costs involved and amount of work carried out during implementation. Actions may be executed as part of regular maintenance activities at no significant additional cost or may require supplementary investments. The feasibility of corrective measures could be rated by the energy savings and payback period as a result of adapting these measures.

It is important to prioritize the recommendations based on a list of classifications to ensure maximum returns. One way would be to classify measures according to *cost of implementation*. Using this as the basis, these energy saving approaches could fall under the *no-cost, low-cost, medium-cost or major-cost* category. Each category is defined below.

No-cost measures refer to actions wherein no additional costs are incurred. This could include additional work done as part of the regular maintenance activities and with select modifications in regular operational procedures. For example, cleaning and servicing of pumps and pipelines to remove blockages is part of standard maintenance procedure.

Low-cost measures entail additional investments at minimal cost. These could include replacement of certain items such as meters, valves, damaged pipe sections and minor repairs of pumps and motors.

This could also involve hiring contractors to service pumps or motors.

Medium-cost measures could include major modifications made on pumps or motors (such as reducing the number of impellers for oversized pumps and replacing or machining pump impellers) as well as replacing long sections of pipeline.

Major-cost measures cover purchase of new equipment (pumps, variable speed drives and other equipment in support of energy savings). This category can serve as a reference among the energy saving approaches. The no-cost, low-cost and medium-cost measures categories may be determined as percentages of major-cost measures.

The use of fundamental theories of pumps and fluid mechanics could serve as useful aids in devising energy-saving strategies. For instance, the pump affinity laws relate changes in pump speed or impeller diameter to corresponding changes in flow, head and water power. The affinity relations are shown below:

For constant impeller diameters	For constant pump speed
$\frac{N_1}{N_2} = \frac{Q_1}{Q_2}$	$\frac{D_1}{D_2} = \frac{Q_1}{Q_2}$
$\frac{N_1^2}{N_2^2} = \frac{H_1}{H_2}$	$\frac{D_1^2}{D_2^2} = \frac{H_1}{H_2}$
$\frac{N_1^3}{N_2^3} = \frac{P_1}{P_2}$	$\frac{D_1^3}{D_2^3} = \frac{P_1}{P_2}$
N is the pump speed	*D* is the impeller diameter

From the above, it can be observed that by trimming an impeller or reducing pump speed, the flow, head and power decrease.

Upper management, production and engineering teams must work in close coordination in selecting and implementing measures. Feasibility of adopting recommendation should be judged based on the estimated savings earned and the payback period instead of only the costs involved. It is important to note that cheap investments could lead to increasing expenses during operation. It is also imperative that management considers all potential approaches for improvement during the decision process to ensure that all facets of the system are covered.

A list of all possible approaches would be helpful since this allows the end-users to have options. Short listing measures could be based on criteria based on projected energy cost savings and payback period.

4.1.3.1 COMPUTING FOR PROJECTED ENERGY SAVINGS

The following baseline data must be on hand in order to determine the projected savings upon implementation of the above measures.

- Electrical consumption of the pump for the year
- Electrical cost for operating the pump for the year
- Computations of actual pump efficiency

The pump efficiency should increase after the implementation of these measures. This would mean a lower power input for the water power delivered by the pump at the measured operating conditions. This projected input would then be evaluated for a specified time of operation (for e.g., a year) to yield the projected energy consumption. The difference between the current energy consumption and the projected energy consumption is the annual energy savings (this must be a positive value). Multiplying the energy savings by the cost per kWh results in the projected annual cost savings.

4.1.3.2 IMPLEMENTING ENERGY SAVING MEASURES

Implementation of the recommendations must be carried out once the measures have been short-listed and accepted. Implementation usually commences with the adoption of the no-cost recommendations and observing for any changes in pump performance over a certain period of time. If no substantial changes are recorded, then the other measures must be implemented. It is important to note that all energy-saving measures must be thoroughly studied and planned prior to implementation. This process would help in establishing a simulation of the system to anticipate future changes.

As implementation takes place, it is important that any changes within the system (additional pipelines to new consumers, changes in reservoir levels, etc) be noted. It must be recalled that audits and devising measures were done with the current system. Any changes with the system may require a repeat of the audit procedures and review of the measures to be implemented.

4.2 ENERGY ASSESSMENT OF ELECTRIC MOTORS

The electric motor is the water district's workhorse. In the energy management context, electric motors are considered as 'too efficient' that there is a tendency to commit the following errors:

- Install any old motor that can do the job or work
- Use it until it fails or forget it until it breaks down.
- Basing the performance of motors through their efficiency level rather than through their loading levels

These harmful practices must be avoided, minimized or totally prevented.

Electric motors account for approximately 75% of the industrial sector's total electricity consumption. Similarly, electric motors and drive systems are two of the largest components of electrical demand in commercial facilities *(IIEC, 1998)*. Moreover, based on actual energy audits conducted in water utilities, it is observed that pump motors use about 81 to 92% of the total electrical energy consumption in water utilities.

There are generally two major types of electric motors used by the water utilities for their pump applications. These are the general-purpose capacitor start and the typical poly-phase design. Table 4.2 describes the characteristics and typical applications of these motor types.

Most motors are rated for continuous duty. This means that they can operate at full loading and torque continuously without overheating. Some motors employed in certain types of applications will frequently be rated in short term duty (or intermittent duty) such as 5 minutes, 15 minutes, 30 minutes or 1 hour. Just like humans, motors can be asked to handle very strenuous work as long as it is not required on a continuous basis.

4.2.1 BASIC PRINCIPLES INVOLVED

The following is a review of the common principles studied in any electrical system.

4.2.1.1 SPEED OF AN ALTERNATING CURRENT MOTOR

The speed of an alternating current (AC) motor depends on two things: the number of poles of the stator winding and the main frequency. At 60Hz, a motor will run at a speed related to a constant of 7200 divided by the number of poles which is a constant for electric motors.

To calculate the speed of a motor, the following formula can be used

$$n = \frac{2 \times f \times 60}{P}$$

Table 4.2 Characteristics and Applications of Motors Used by Water Utilities.

MOTOR TYPE	CHARACTERISTICS	APPLICATIONS
General Purpose Capacitor-Start	▪ Because of its improved starting ability, the capacitor start motor is recommended for loads which are hard to start. ▪ The motor has a capacitor in series with a starting winding and provides more than double the starting torque with one third less starting current than the split phase motor.	▪ This has good efficiency and requires starting currents of approximately five times full load current. ▪ The capacitor and starting windings are disconnected from the circuit by an automatic switch when the motor reaches about 75% of its rated full load speed. ▪ Special applications include: compressors, pumps, machine tools, air conditioners, conveyors, blowers, fans and other hard to start applications.
Typical Polyphase Design	▪ The three-phase motor has excellent starting torque characteristics yet the normal starting circuit requirements are low compared to single-phase motors. ▪ Its high starting torque and running characteristics enable the motor to drive practically any equipment where load must be brought up from standstill to operating speed smoothly and quickly	▪ Popular applications include: grinders, lathes, drill presses, pumps, compressors, conveyors, also printing equipment, farm equipment, electronic cooling and other mechanical duty applications.

where:

N = Speed
F = Net frequency
P = No. of poles

This speed is the synchronous speed. During unloaded conditions, the speed will be very close to the synchronous speed and will then drop when the motor is loaded.

4.2.1.2 CONCEPT OF SLIP

Slip is used in two forms. One is the slip RPM which is the difference between the synchronous speed and the full load speed. When this slip RPM is expressed as a percentage of the synchronous speed, then it is called percent slip or just 'slip'. Most standard motors run with a full load slip of 2 to 5% (with normal values of only 1 to 3%). The formula for slip is given below

$$\text{Slip (\%)} = \frac{\text{Synchronous speed} - \text{Running speed}}{\text{Synchronous speed}}$$

4.2.1.3 TORQUE

Torque is defined as the twisting force exerted by the shaft or a motor. The starting torque for a motor differs significantly depending on the size of the motor, among other things. A small motor (less than 30kW) normally has a value of 2.5 to 3 times the rated torque, and for a medium size motor, say up to 250kW, a typical value is between 2 to 2.5 times the rated torques.

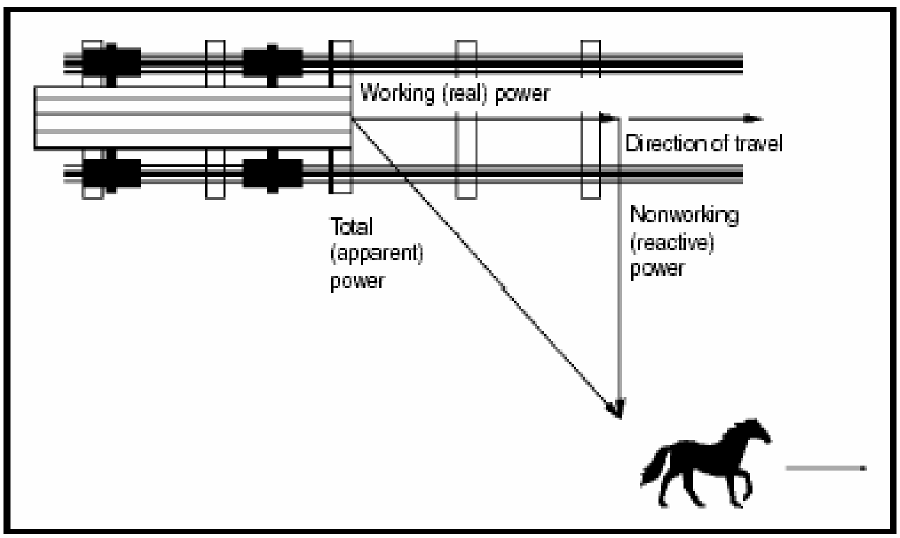


Fig. 4.6 Graphic Representation of the Power Triangle.

4.2.1.4 THE POWER TRIANGLE AND POWER FACTOR

It is important to get acquainted with the various relationships that form the basis of motor performance determination and analysis. The concept of power triangle is an essential component of determining motor performance. Consider the example provided below to acquire a basic understanding of the concept.

From the figure above, imagine a horse pulling a railroad cart along a railroad track. Because the railroad tracks are uneven and the horse will trip on the tracks, the horse must pull the cart from the side of the truck at an angle to the direction of the cart's travel. The power to move the cart down the track is the working (real) power. The effort of the horse is the total (apparent) or 'visible' power. Because of the angle of the horse' pull, not all of horse's effort is used to move the cart down the track. The cart will not move sideways; therefore, the sideways pull of the horse is wasted effort or nonworking (reactive) power.

The angle of the horse's pull is related to power factor, which is defined as the ratio of real (working) power to the apparent (total) power. If the horse is led closer to the center of the track, the angle of side pull decreases and the real power approaches the value of the apparent power. Therefore, the ratio of the real power to the apparent power approaches unity or its value approaches 1. As the power factor approaches 1 or unity, the reactive (nonworking) power approaches 0. Apparent Power is the combination of the Real Power and Reactive Power.

$$\text{Power Factor} = \frac{\text{Real Power}}{\text{Apparent Power}}$$

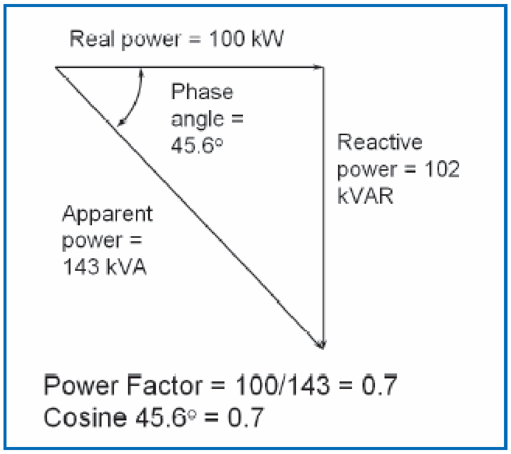


Fig. 4.7 Power Triangle Example.

For example, using the power triangle given above, if the real power is 100 kW and the Apparent Power is 143 kVA, then using the PF formula, then

$$\text{Power Factor} = \frac{100 \text{ kW}}{143 \text{ kVa}} = 0.70 \text{ or } 70\%$$

This means that only 70% of the power provided by the electrical utility is being utilized to produce useful work. Figure 4.8 describes the consequences if the horse tries to pull the cart nearer the railroad track. The real power is still 100 kW, but take note that the effort or Real Power is only 105 kVA now and the Power Factor is now 0.95 or 95%. This ratio is an effective measure of system electrical efficiency.

4.2.1.5 POWER FACTOR

Percent power factor is a measure of the requirements for magnetizing the amperage of the motor. Low and unsatisfactory power factor is caused by the use of inductive (magnetic) devices and can indicate possible low system operating efficiency. For the water utilities, these devices include non-power factor corrected fluorescent and high intensity discharge lighting fixtures and ballasts and most significantly, induction motors.

Induction motors are the primary cause of low power factor because water utilities on a regular basis utilize numerous units of this model without it being fully loaded. The correction of a low power factor within the system is of vital economic importance in the generation, distribution and utilization of AC power. Below are some of the effects of low power factor.

- ***System Capacity***. Your kVA is the total power available. Your useful power or kW = (kVA) x (pf). The higher the system's power factor, the higher the available system capacity. With increased system capacity, the voltage will remain more stable as loads are cycled on and off. Also additional loads if required can be added to the system
- ***System Losses***. With a higher power factor, less current flows through your system. There is less power loss (I^2R losses) during the heating of cables, bus bars, transformers, panels, etc. These devices will run cooler and will last longer too.
- ***Utility Charges***. Electric utilities must maintain a higher power factor on their distribution system for efficiency. They will typically bill customers for a low power factor. Most utility companies that bill a Power Factor penalty requires a user to maintain at least a 85% power factor.

The major benefits of power factor improvement are: increased plant capacity, reduced power factor 'penalty' charges from the electric utility, voltage supply improvement and less power losses in feeders, transformers and distribution equipment.

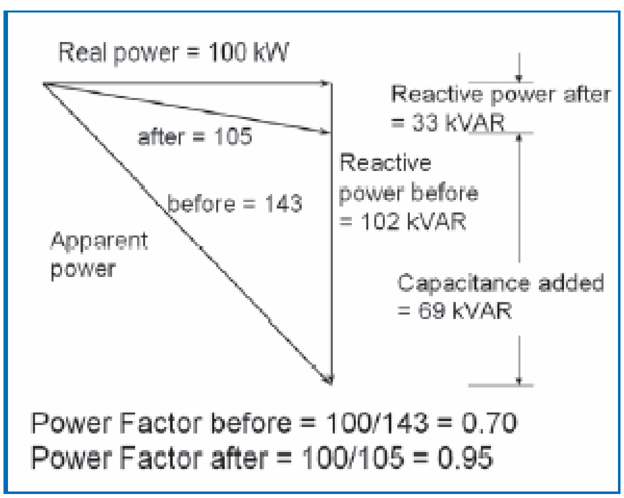


Fig. 4.8 Effect of Power Factor Correction.

4.2.1.6 POWER FACTOR CORRECTION

Capacitor correction is relatively inexpensive for both material and installation costs. Capacitors can be installed at any point in the electrical system, and will improve the power factor at the point of application and the power source. However, the power factor between the utilization equipment and the capacitor will not be affected. Capacitors are usually added at each unit of equipment (with low power factor), ahead of a group of small motors (ahead of motor control centers of distribution panels) or at the main service. The National Electrical Code serves as a reference highlighting installation requirements for capacitors.

The advantages and disadvantages of each scheme of capacitor installation are shown in Table 4.3 below.

If the loads contributing to the power factor are relatively constant, and system load capabilities are not a factor, correcting at the main distribution panel could provide a cost advantage. When the low power factor is caused due to the existing operating conditions of select units of equipment, individual equipment correction would be more cost effective.

Table 4.3. Advantages and Disadvantages of Capacitor Installation Schemes.

INSTALLATION SCHEME	ADVANTAGES	DISADVANTAGES
Capacitor on each unit of equipment	▪ Increased load capacity of the distribution system and can be switched on and off with equipment; no additional switching required ▪ Improved voltage regulation because capacitor use follows load ▪ Capacitor sizing is simplified ▪ Capacitors are coupled with equipment and move with equipment if relocation is done	Small capacitors cost more per KVAR than larger units (economic break point for individual correction is generally 10 hp)
Capacitor with group of equipment	▪ Increased load capability of the electric service ▪ Reduced material costs relative to individual correction ▪ Reduced installation costs relative to individual correction	Switching means may be required to control amount of capacitance used.
Capacitor at main service	▪ Low material and installation costs	Switching is required to control amount of capacitance used; Does not improve the load capabilities of the distribution system

System power factor can be improved by:

- Minimizing the operation of idling or lightly loaded motors.
- Replacing standard motors with energy-efficient motors as they burn-out.
- Operating motors near its rated capacity to realize the benefits of high power factor.
- Installing capacitor in the AC circuit to decrease the magnitude of reactive power.

4.2.1.7 INRUSH CURRENT

Inrush current can be several times greater than the operating, or steady-state current. For example, in a 3-phase motor, the inrush current generally lasts between 75 and 150 msec with a current spike between 500% and 1200% of normal levels. Although short lived, this surge can create problems.

A common problem found in motors is the tripping of the circuit protector. If the protector is not sized to handle the existing inrush current levels, it can trip upon the energizing of the circuit or during circuit operation.

Excessive inrush current can also shorten the life of switches and circuit protectors. Switches are especially susceptible since the current spike occurs as the contacts are closed, causing the contacts to become pitted. In severe cases, excess current can weld switch contacts together.

Electrical load management and maximum demand control can be achieved by cutting off the peaks and/or reducing the base load. These can be further implemented by:

- Load rescheduling
- Staggering of motor loads
- Off-peak hour operation
- Shedding of non-essential loads

4.2.1.8 POWER QUALITY

Power supply is one of the most important factors affecting the selection, installation, operation and maintenance of an electrical motor–driven system. The information provided below reflects the standards defined by the National Electrical Manufacturers Association (NEMA) of the United States and the Philippine Distribution Code.

The Philippine Distribution Code, which was promulgated by the Energy Regulatory Commission (ERC), has set certain performance standards for distribution and supply. These include the power quality standard for voltage unbalance as contained in Section 3.2.5, which states that:

> *3.2.5.1 " . . . Voltage Unbalance shall be defined as the maximum voltage deviation from the average of the three phase voltages, divided by the average of the three phase voltages, expressed in percent.*
>
> *3.2.5.2 The Maximum Voltage Unbalance at the Connection Point of any User, excluding the Voltage Unbalance passed on from the Grid, shall not exceed **2.5%** during normal operating conditions.*

Since power supply is one of the major factors affecting the selection, installation, operation and maintenance of electrical motor-driven systems, motors must be carefully selected based on known service conditions. The common service condition, as defined by the National Electrical Manufacturer's Association (NEMA) Standards Publication MG1-1993-14.30, Rev.1 for Motors and Generators includes their operation within a tolerance of +/- 10 percent of rated voltage.

Operation under unusual service conditions may result in efficiency losses and additional energy consumption. Both standard and energy efficient motors can have their efficiency and lifetime reduced by a poorly maintained electrical system. Monitoring the voltage is important for maintaining high efficiency operation and correcting potential problems before failures occur. Preventive maintenance personnel should periodically measure and log the voltage at the motor's terminals while the machine is fully loaded.

The calculated values for percent voltage unbalance measurements and deviations from the rated voltage for each motor should be less than +/-2.5 and +/- 10%, respectively. Although motors are designed to operate within 10% of the rated voltage, it is better to keep the voltage as close to the nameplate value as possible, with a maximum (ideal) deviation of 5%.

The values of percent phase current unbalance should be less than the recommended value of 10%. The effects of line current unbalance are: torque pulsation/vibration, increased mechanical stress in the motors, overheating of one or two of the phase windings and decreased motor efficiency.

Perfectly balanced line currents may not be expected because of some imperfections in the construction of the electrical system and considering that differences between voltages at the terminals exist. Nevertheless, any deviation beyond 10% should be considered abnormal and in general, this situation must cause an alarm if the motor is to be protected for a longer lifetime.

It may generally be shown through audit data that certain under-loaded motors have been oversized for the intended application. They may also be driving variable mechanical loads on the shaft. Further measurement of the electrical parameters and load profile of these motors is the only way to determine the cause of partial or low loading and if they exist for majority of the time of operation and not only instantaneously. Note that load profiling takes longer periods of observation. General motor loading standards are 20 to 120% for acceptable short periods (intermittent), 50 to 100 % for acceptable operating and 60 to 80% (usually near 75%) for optimum conditions.

The practice of using an oversized motor on certain applications that require extra overload capacity to drive the load is highly useful in terms of capital investment and operational cost. However, a margin of 20% that is provided for safety consideration should be enough to handle the extra power needed in some situations. By this practice, the motor can be allowed to run at 80% loading for most of the time. This is the recommended level of efficient operation by most manufacturers.

4.2.2 DATA GATHERING AND ANALYSIS

This section will discuss the different parameters of electric motors that will be actually measured and how these parameters are used in order to calculate energy efficiencies.

4.2.2.1 MOTOR SURVEY / INVENTORY

For the initial motor survey, motor nameplate parameters (printed or indicated figures of nameplate ratings) should be obtained if available and legible. These parameters include motor application, kW or hp rating, rated voltage (V), full load amps (FLA) and rated efficiency.

Note that all electric motors should have a nameplate listing vital data about its installation and operation. Below are nameplate definitions and terminologies for electric motors while Table 4.4 shows a sample worksheet which can be used for data gathering:

- **Motor Application** identifies the level of motor utilization or the equipment the motor is driving.

- **Rated Power**, measured either in kW or in hp, is the rate of performing work or transferring energy.

- **Rated Voltage** in Volts is the voltage rating for which the motor is designed and maybe operated. Generally, this will be 115 V, 230 V, 115/230 V or 220/440 V and is known as the nameplate volts.

- The **Full Load Amps (FLA)** is the amount of current the motor can be expected to draw under full load (torque) conditions. It is also known as the nameplate amps.

  Note that the FLA is different from the Locked Rotor Amps and the Service Factor Amps. The **Locked Rotor Amps (LRA)** is the amount of current the motor can be expected to draw under starting conditions when full voltage is applied and is also known as the starting inrush. The **Service Factor Amps (SFA)** is the amount of current the motor will draw when it is subjected to a certain overload percentage equal to the service factor on the nameplate of the motor or under service factor load condition. For example, a motor with a service factor of 1.15 means it can handle a 15% overload, but only intermittently and not continuously. This is since the Service Factor (SF) is a multiplier that indicates the amount of overload a motor can be expected to handle. For example, a motor with a 1.0 SF cannot be expected to handle more than its nameplate horsepower on a continuous basis. A motor with a 1.15 SF (which is typical SF for most motors), can be expected to safely handle intermittent loads amounting to 15% being its nameplate horsepower.

- The **Rated Efficiency** is the percentage of input power that is actually converted to work output from the motor shaft. Unfortunately, it is only recently that the rated efficiency is being stamped on the nameplate of most imported electric motors. If the rated efficiency values (at full load or 100%) are not available on the motor nameplate, they can be taken from Table 4.5 below assuming the motors are of standard US Motors brand, either ODP (Open-Drip-Proof) or TEFC (Totally-Enclosed-fan-Cooled) type at 1800 rpm.

4.2.2.2 INSTALLATION OF MEASURING INSTRUMENTS

Measurements are done on the phase voltages and line current amperes during the electric motors' actual load operation. Phase voltages are measured using the scheme 'La-Lb' (Vab), 'Lb-Lc' (Vcb) and 'Lc-La' (Vca) utilizing test probes. Line currents are measured by clamping the meter to each line terminal - La, Lb and Lc (the motor terminals) or the lines for the motor's circuit breaker/switch panel board.

Table 4.4 Energy Audit Datasheet for Electric Motors.

Tag No.	Application	Rdg	kW	Volt	Amp	Eff.	Vab	Ia	kW	kVA	Vcb	Ic	kW	kVA	Vca	Ib

Table 4.5 Efficiency Levels at Full and Partial Loads for 1800 RPM, ODP and TEFC Motors.

Efficiencies for 1800 rpm, Standard Efficiency Motors								
Motor Size	Load Level in Percent							
	ODP				TEFC			
	100%	75%	50%	25%	100%	75%	50%	25%
10	86.3	86.8	85.9	80.0	87.0	88.4	87.7	80.0
15	88.0	89.0	88.5	82.6	88.2	89.3	88.4	80.7
20	88.6	89.2	88.9	83.3	89.6	90.8	90.0	83.4
25	89.5	90.6	90.0	86.6	90.0	90.9	90.3	83.4
30	89.7	91.0	90.9	87.3	90.6	91.6	91.0	85.6
40	90.1	90.0	89.0	86.3	90.7	90.5	89.2	84.2
50	90.4	90.3	90.3	88.1	91.6	91.8	91.1	86.3
75	91.7	92.4	92.0	87.7	92.2	92.5	91.3	87.1
100	92.2	92.8	92.3	89.2	92.3	92.1	91.4	85.5
125	92.8	93.2	92.7	90.7	92.6	92.3	91.3	84.0
150	93.3	93.3	93.0	89.2	93.3	93.1	92.2	86.7
200	93.4	93.8	93.3	90.7	94.2	94.0	93.1	87.8
250	93.9	94.4	94.0	92.6	93.8	94.2	93.5	89.4
300	94.0	94.5	94.2	93.4	94.5	94.4	93.3	89.9

Source: U.S. Department of Energy.

The True Power (input kW) values are measured using the Two-Wattmeter method with 'line b' as the common for the voltage test probes. True power (kW1) and apparent power (kVA1) are measured with the test probes at 'La-Lb' and the clamp at 'line a' while kW2 and kVA2 were measured with the test probes at 'Lb-Lc' and the clamp at 'line c'. Two to three sets of instantaneous measurements are gathered to be able to check and assure the validity of the measurements and to check if motor loading is variable. All these parameters can be measured using a power meter like the *Fluke Digital Power Meter.*

The following is a step-by-step measurement of electric motors.

Step 1. Clamp the Current Transformer (CT) in Line A, clip the red test probe on line A and the black test probe on Line B (which serves as the common line) for this purpose. Record all the parameters.

Step 2. Clamp the CT on line C, clip the red test probe on Line C and the black test probe on Line B. Record all the parameters.

Step 3. Clamp the CT on Line B and the red test probe on Line C and the black test probe on Line A. This step is for the determination of the magnitude of the current on Line B and the voltage on Phase A-B.

Note that for Steps 1 and 2, the direction of the arrow indication on the CT should be pointing towards the load side (in usual cases, pointing downwards).

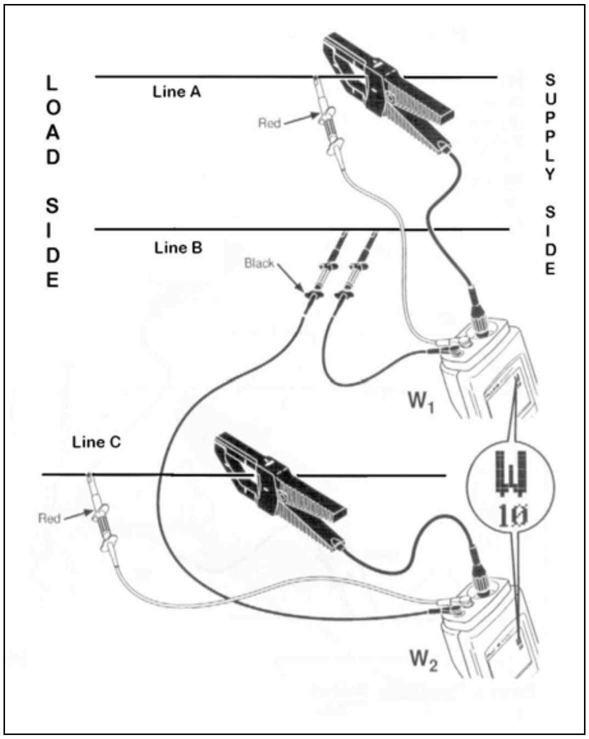


Fig. 4.9 Power Meter Test Probes and Clamp Installations (Using the Two-Wattmeter Method of Electrical Measurement).

When the power meter does not have a power factor reading, the load power factor level can be estimated by the relationship of the first and second kW reading obtained from the two-wattmeter method of input kW measurements. These relationships are given below:

- If Load PF = 1, kW_1 & kW_2 = 1/2 kW_{total}
- If Load PF = 50%, kW_{1st} = 0, kW_{2nd} = kW_{total}
- If Load PF is between 50 to 100%, one wattmeter will read more than the other & kW_{total} kW_1 & kW_2

If Load PF < 50% and the one wattmeter will have a negative value, reverse the connection of the voltage or current probes to get a positive reading.

Subtract the reversed reading from the other wattmeter reading.

4.2.2.3 DATA ANALYSIS

Electric motors are evaluated by their individual performance in terms of phase voltage unbalance, line current unbalance, power factor and percent loading. Below are some of the computations used to evaluate the performance of electric motors:

$$\text{\% Phase Voltage Unbalance} = \frac{\text{Maximum Voltage Deviation from Average Voltage}}{\text{Average Voltage}} \times 100$$

$$\text{\% Voltage Deviation Rated} = \frac{\text{Maximum Voltage Deviation from Rated Voltage}}{\text{Rated Voltage}} \times 100$$

$$\text{\% Current Unbalance} = \frac{\text{Maximum Current Deviation from Average Voltage}}{\text{Average Voltage}} \times 100$$

Phase voltage unbalance is defined by the *National Electrical Manufacturers Association (NEMA)* as 100 times the absolute value of the maximum deviation of the line voltage from the average voltage on a three-phase system, divided by the average voltage. The line current unbalance is calculated using a similar formula as that of the phase voltage unbalance.

On the other hand, power factor (PF) can also be calculated using the two-wattmeter method as follows:

$$PF = \frac{kW_{total}}{[(kW_{total})^2 + (kVAR_{sum})^2]^{0.5}} \times 100$$

where:

kW_{total} = $kW_1 + kW_2$
$kVAR_{sum}$ = $kVAR_1 + kVAR_2$
$kVAR_1$ = $[(kVA_1)^2 - (kW_1)^2]^{0.5}$
$kVAR_2$ = $[(kVA_2)^2 - (kW_2)^2]^{0.5}$

There are several ways to determine or estimate percent loading or electric motor operating loads. The simplest way is by direct electrical measurement using a power meter to get the input kW and dividing it by the motor's rated power in kW obtained from the nameplate. Determining if an electric motor is properly loaded enables a manager to make informed decisions about when to replace them and which replacement to choose.

The percent loading can be calculated using the formula:

$$\text{Motor Loading (\%)} = \frac{\text{Input kW x Rated Efficiency}}{\text{Rated hp x 0.746 kW/hp}} \times 100$$

There are other estimation methods that can be used to determine motor loading. A common way is to divide the actual average amperes (for the 3 lines) and divide this by the rated amps or FLA. This is called the **Percent Full Load Amperage Technique**. This practice is used in connection with the rule of thumb that says "If the measured current under full load is less than approximately 75% of the figure in the nameplate, then a smaller motor can be used instead as replacement". This technique, however, only considers the amperage parameter. Remember that power considers the voltage, amperage and power factor.

Another more practical method is to use two out of three parameters for power measurement. This is called the **Voltage Compensated Amperage Ratio Technique** since the voltage level also compensates the amperage level depending on the motor load. Motor loading is determined by the formula given below:

$$\text{Motor Loading \%} = \frac{\text{Average Amps Measured x Average Volts Measured}}{\text{Nameplate Amps x Nameplate Volts}} \times 100$$

This technique and the Percent Full Load Amperage Technique can be considered using only a common multimeter which is quite cheap as compared to the power meter. However, if the measured current under full load is below 60% of the rated, this method or technique is not applied because at low loading (loading less than 50%), the relationship of the current with the loading is almost non-linear.

4.2.2.4 INTERPRETATION OF RESULTS

Most electric motors are designed to operate between 50 to 100 % of their rated load. One reason is that the motor's optimum efficiency is generally at 75% of the rated load, and the other reason is that motors are sized generally for the starting requirements.

Several surveys of electric motors show that a majority of the motors in use are improperly loaded. Underloaded motors, those loaded below 50% of the rated load, operate inefficiently and exhibit low power factor. Low power factor increases losses in electrical distribution and utilization equipment, such as wiring, motors and transformers, and reduces the load handling capability and voltage regulation of the facility's electrical system. Moreover, if the motor continuously has low loading, it can be replaced by an appropriately sized model or a lower capacity motor which will have a loading closer to 75%. Figure 4.10 below shows the typical range of efficiencies for motors of different capacities and different loading levels. The figure also shows that especially for large motors, the peak efficiency levels occur at 40 to 50% loading. This is why it is better to base the motor performance on its loading rather than its efficiency level which is not easy to ascertain accurately.

Motor efficiency is important in selecting a motor, but consideration of the application and proper sizing for that application can save more energy. Benefits of properly-sized motors are increased power factor, increased efficiency and reduced initial cost for replacement consideration.

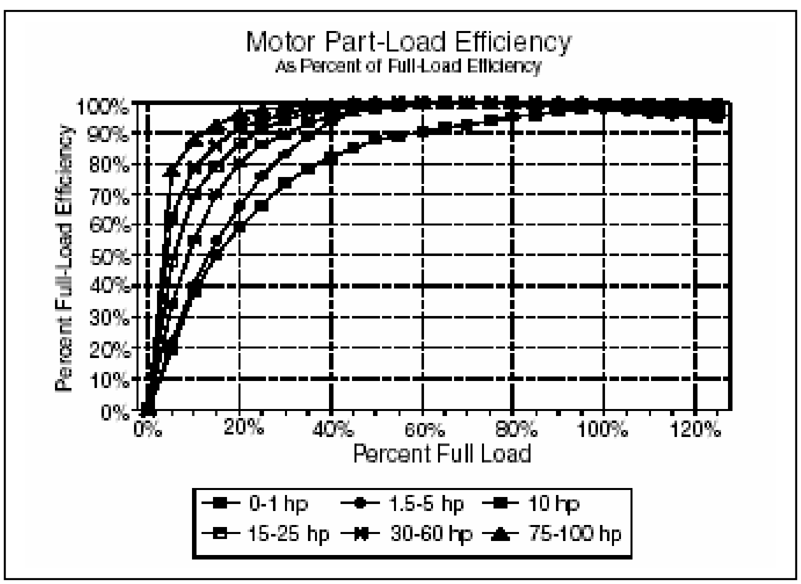


Fig. 4.10 Part Load Motor Efficiency Ranges.

Voltages at the motor should be kept as close as possible to the nameplate value, with a maximum deviation of 5%. Although motors are designed to operate within 10% of the (rated) nameplate voltage, large deviations significantly reduce efficiency, power factor and service life (see Figure 4.11). When operating at less than 95% of design voltage, motors typically lose 2 to 4 points of efficiency, and service temperatures increase, greatly reducing insulation life. Running a motor above its design voltage also reduces power factor and efficiency. Because voltage decreases with distance from the stepdown transformer, all voltage measurements should be taken, only if possible and accessible, at the motor terminal box or its circuit breaker.

The taps on the transformer may be changed to bring the voltage values as close to that of the rated for the electric motor. However, as this is an electrical systems approach, the other loads on the transformer and electric panel must be reviewed and checked in order to determine the effects on these loads.

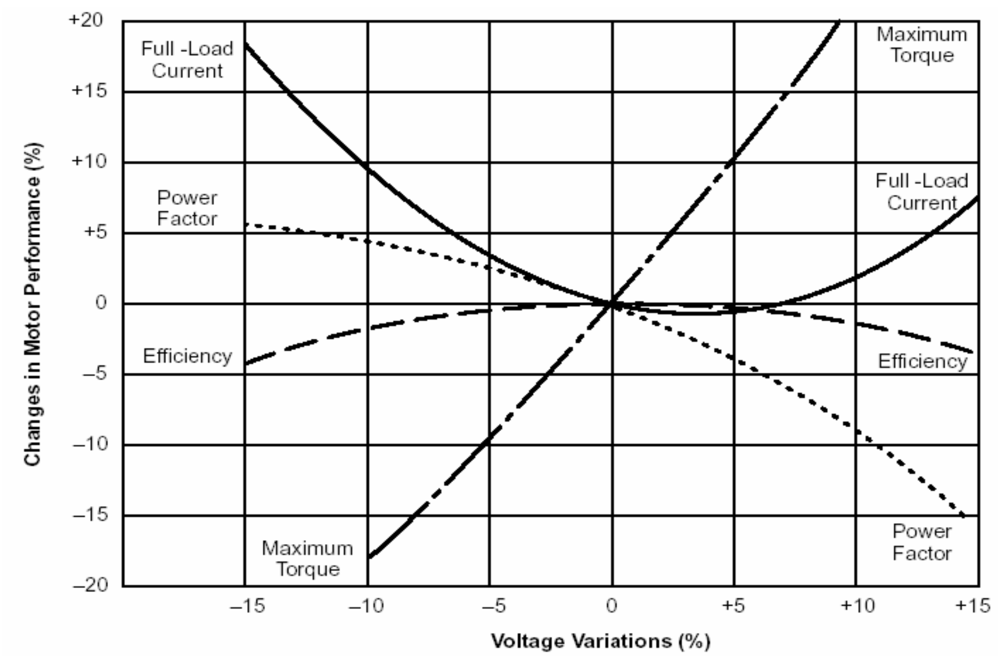


Fig. 4.11 Voltage Variation Effect on Motor Performance.

4.2.3 ENERGY EFFICIENCY OPPORTUNITIES FOR ELECTRIC MOTORS

There are several energy efficiency opportunities for electric motors. Table 4.6 lists down the various problems, their common causes and effects and with corresponding solutions.

4.2.3.1 BEST ENERGY MANAGEMENT PRACTICES

- Maintain cleanliness of motors by blowing off dusts, greasing, surface cleaning (grit), foreign deposits, and painting (only if needed, excluding the motor nameplate)

Table 4.6 General Analysis of Power Systems.

PROBLEM	COMMON CAUSES	POSSIBLE EFFECTS	SOLUTIONS
Unbalance Voltages	Improper transformer tap settings, one single phase transformer on a polyphase system, single-phase loads not balanced among phases, poor connections, bad conductors, transformer grounds or faults.	Motor vibration, premature motor failure, and energy waste. A 5% imbalance causes a 40% increase in motor losses.	Balance loads among phases.
Voltage deviation	Improper transformer settings, incorrect selection of motors.	Over voltages in motors reduce efficiency, power factor, and equipment life, and increase temperature.	Check and correct transformer settings, motor ratings and motor input voltages.
Poor connections may be in distribution or at connected loads.	Loose bus bar connections, loose cable connections, poor crimps, loose or worn contactors, corrosion or dirt in disconnects.	Wastes energy, produces heat, causes failure at connection site leads to voltages drop and imbalances.	Use infrared (IR) camera to locate hot spots and apply appropriate actions.
Undersized conductors	Facilities expanding beyond original designs, poor power factors.	Voltage drop and energy waste.	Reduce the load by conservation load scheduling.
Insulation leakage	Degradation over time due to extreme temperatures, abrasion, moisture, chemicals, conductor insulation that is inappropriate for conditions.	May not cause breaker to trip, and may leak to ground or to another phase. Variable energy waste.	Replace conductors, insulators.
Low power factor	Inductive loads such as motors, transformers and lighting ballasts; non-linear loads such as electronic loads.	Reduces current carrying capacity of wiring, voltage regulation effectiveness, and equipment life. May increase utility costs.	Add capacitor to counteract reactive loads
Harmonics	Office electronics, PBXs, UPSs, variable frequency drives, high intensity discharge lighting, and electronic and correct coil ballasts.	Over heating of neutral conductors, motors, transformers, switch gear. Voltages drop, lower power factors, and reduce capacity.	Take care with equipment selection and isolate sensitive electronics from noisy circuits.

Source: GERIAP Guidance Manual 2003.

- Electrical panels should not be cluttered, surroundings, including cables and conduits should be cleaned, panel knock-out holes should be plugged (if not used), loose wiring tightened and temporary wires avoided.

- Maintain the accuracy of portable measuring equipment (like power meters) and monitoring gadgets (like voltmeters and ammeters) through regular calibration and panel instruments should be kept clean and marked red at values not to be exceeded.

- Provide proper ventilation *(Rule of Thumb: For every 100°C increase in motor temperature over the recommended peak the motor life is estimated to be halved).*

- Demand efficiency restoration after motor rewinding, because if rewinding is not done properly, the efficiency can be reduced by up to 5 to 8%.

The decision to replace the electric motor compared to having the motor rewinded will depend on the following factors:

- Rewind cost versus new motor cost
- Rewind efficiency loss versus number of rewinds
- Motor size and original efficiency
- Annual operating hours (continuous is best)
- Cost of electricity (which is getting higher and higher)
- Each rewind can cause up to a 2% decrease in efficiency
- It is usually best t replace non-specialty motors
- If rewind cost exceeds 50 – 65% of new energy-efficient motor price, buy a new motor.

4.2.3.2 PREVENTIVE MAINTENANCE SCHEDULE

Regular analysis of motor performance prevents major breakdown. Performance evaluation of a motor should be done as routinely as possible. Applied motor maintenance will keep it running smoothly with minimal stress on the system and reduced downtime due to failures. As the saying goes "Motors are like people, they will perform their best if cared for and maintained well". Table 4.7 gives some suggested maintenance schedule for motors.

Table 4.7 Recommended Preventive Maintenance Schedule for Electric Motors.

Frequency Schedule	Preventive Maintenance Activity
Monthly	Check shaft alignment; lubricate bearings; check belt tension and alignment; check oil level
Semi-Annual	Check for overheating; remove dust
Annual	Check motor rotation

4.2.3.3 RULE OF THUMB

Rule of thumb is defined as a useful principle having wide spread application but not intended to be strictly accurate or reliable in any situation. It can be used a rough or useful principle or method, based on experience, rather than precisely accurate measures. Select rules of thumb for electric motors are provided below.

- At 3600 rpm, a motor develops 1.5 lb-ft per hp.
- At 1800 rpm, a motor develops 3.0 lb-ft per hp.

- At 1200 rpm, a motor develops 4.5 lb-ft per hp.
- At 440 and 460 Volts, a 3-phase motor draws 1.25 amps per hp.
- At 220 and 230 Volts, a 3-phase motor draws 2.50 amps per hp.
- At 220 and 230 Volts, a single-phase motor draws 5.0 amps per hp.

4.2.4 ADVANCE RETROFITS IN VIEW OF ENERGY EFFICIENCY

Several energy saving opportunities have been discussed in Section 4.2.3 emphasizing the no-investment or low to medium-cost investment counter measures on how to improve energy efficiency of electric motors. Municipal water utilities can go beyond these and may consider investing on advance retrofits or new energy efficiency technologies. Some of these advance retrofits on energy efficiency are described below.

4.2.4.1 HIGH EFFICIENCY MOTORS

Design changes, enhanced materials, and manufacturing improvements reduce motor losses, making premium or energy-efficient motors more efficient than standard efficiency motors with the same capacity. Reduced losses mean that an energy-efficient motor produces a given amount of work using lesser energy than a standard motor. Table 4.8 depicts typical rated efficiencies of standard and energy-efficient motors with different capacities.

The U.S. Department of Energy recommends that all motors operating over 1,000 hours per year should be surveyed and tested. Using the detailed audit analysis results from the motor loading survey, a motor replacement scheme or program can be divided into the following categories:

- **Motors that are significantly oversized and under-loaded** (lower than 50% loading) - replace with more efficient, appropriately sized models at the next opportunity, such as scheduled plant downtime.
- **Motors that are moderately oversized and under-loaded** (50% to 75% loading) - replace with more efficient, appropriately sized models when they fail.
- **Motors that are properly sized but of standard efficiency** (greater than 75% loading) - replace most of these with energy-efficient models when they fail

Table 4.8 Typical Full Load Efficiencies of Standard and High Efficiency Motors.

MOTOR SIZE (HP)	STANDARD EFFICIENCY *	HIGH EFFICIENCY *
1	76.9%	83.7%
2	81.2%	85.1%
5	84.0%	88.3%
$7\ ^{1}/_{2}$	86.2%	90.1%
10	87.2%	90.3%
15	88.4%	91.5%
20	88.2%	91.7%
30	90.4%	92.9%
40	91.3%	93.5%
50	91.9%	93.5%
75	92.8%	94.4%
100	92.9%	94.9%
150	93.5%	95.4%
250	94.1%	95.6%

* 100% Load

In addition, according to the *Guidelines for Energy Conserving Building Design* published by the Philippine Department of Energy, motors operating more than 750 hours per year should be of the high efficiency type.

One should consider buying an energy efficient motor in the following circumstances:

- For all new installations
- When purchasing equipment packages, such as compressors, HVAC systems and pumps
- When major modifications are made to facilities/processes
- Instead of rewinding older, standard efficiency units
- To replace oversize and under-loaded motors
- As part of a preventive maintenance or energy conservation program

There are benefits that can be derived from using high efficient electric motors and they are as follows:

- Higher quality construction
- More reliable
- Longer warranties
- Produces less waste heat
- Saves significant amount of energy

The estimated annual savings that can be realized using a high efficiency motor is determined using the formula:

$$S = kW \times (1/E_{std} - 1/E_{he}) \times \text{No. of operating hours}$$

where:

S = Annual energy savings for the use of high efficiency motor, kWh

kW = Useful input power of the motor, kW

E_{std} = Efficiency of the old or standard motor at loading level (in decimal)

E_{he} = Efficiency of high efficiency motor at loading level (in decimal)

Hours = Motor operating hours per year

The calculation of the motor replacement capacity (in relation to the input kW measured) can also be used to determine whether the capacity of an existing or available motor is ideal to replace a burned-out motor. The use of high-efficiency motors as replacements is usually a long-term investment. Advantages for the use of these motors over the standard type can be considered during the whole life span of such energy-efficient equipment. It is also important to note that the use of these motors becomes more viable if the capacity is downsized for underloaded and oversized motors.

4.2.4.2 AUTOMATIC POWER FACTOR CONTROLLER

There are numerous options available to reduce the voltage applied to the motor in response to the applied load, the purpose of this being to reduce the magnetizing losses during the periods when the full torque capability of the motors is not required. Typical of these devices is the automatic power factor controller. The power factor controller is a device that adjusts the voltage applied to the motor to approximate a preset power factor.

Automatic power factor control systems are designed to turn power factor capacitors on or off to maintain a desired target power factor under varying conditions of the load on the low voltage distribution systems of industrial and commercial facilities.

Automatic systems, rather than fixed capacitors, should be applied if any of the following conditions occur:

- Electric utility bill structure include the demand kW or a power factor penalty clause.
- The facility experiences capacity problems (in kVA) causing overheating of system components resulting in increased operating costs and energy (kW) use.
- The facility is not able to maintain a desired power factor especially when extreme load fluctuations are present.
- Sustained leading power factor problems are experienced when the electric distribution system is lightly loaded.

This control monitors the system power factor to maintain the desired target power factor. The only information required to appropriately size the equipment to the electrical distribution system is the monthly maximum kVAR, calculated based on data for the previous twelve months.

Automatic equipment eliminates the need to install smaller capacitors and any associated switching devices on the electrical distribution system, thus eliminating additional installation costs.

Design features should ensure long service life and many years of trouble-free operation and should have a majority, if not all of these additional components:

- Virtual elimination or significant reduction of capacitor inrush current that causes early contact failures and misoperation of sensitive electronic equipment because properly designed air core inductors will substantially reduce contact wear and transients on capacitor switching. Moreover, capacitor stages are switched on and off on an alternate basis. Each stage operates for equal periods to ensure even wear.

- The controller utilizes “switching time delay” and “loss of voltage drop-out” features or protects the capacitors from over voltage by allowing the discharge network to drain the capacitor voltage before the capacitor is re-energized. The loss of voltage dropout disconnects all capacitors if power failure occurs. After power is restored, the automatic controller energizes the capacitors, step by step until the desired power factor is attained.

- A microprocessor-based controller measures the reactive current on every passage of the voltage through zero ensuring accuracy down to zero power factor. Programmable stage ratios can allow for larger capacitor banks to be utilized but should include numerous alarms.

Suitably rated current limiting fuses are utilized providing additional protection form faults that would have to be cleared by upstream protective devices if each capacitor module has no current limiting fusing.

State of the art, low loss, self-clearing capacitors are utilized and every capacitor cell is protected with an internal pressure sensitive interrupt for additional system protection.

These controllers may, for example, be beneficial for use with small motors operating for extended periods of light loads where the magnetization losses are a relatively high percentage of total loss. Care must be exercised in the application of these controllers. Savings are achieved only when the controlled motor is operated for extended periods at no load or light load.

Particular care must be considered with their use with other than small motors. A typical 10 hp motor will have idle losses in the order of 4 to 5% of the rated output. In this size range, the magnetization losses that can be saved may not be equal to the losses added by the controller plus the additional motor losses caused by the distorted voltage wave form induced by the controller.

In general, these devices just like the simple capacitor bank will be more viable if the facility power factor level is less than 85% (with penalty) as compared to a PF level of 85 or 90% (with discount) because of the lower rate of discount compared to penalty and the higher cost of capacitor needed for a higher PF than that with a lower PF because of the KVAR requirement. Average real savings of 15 – 25% on maximum demand charges are projected.

4.2.4.3 SOFT STARTERS

Soft starters have different characteristics as compared to other starting methods. It has thyristors in the main circuit, and the motor voltage is regulated with a printed circuit board. The softstarter utilizes the fact that when the motor voltage is low during start, the starting current and torque is also low.

During the first part of the start, the voltage to the motor is so low that it is only able to adjust the play between motor and the driven mechanism (as in this case the pump). In other words, eliminating unnecessary jerks during start.

Gradually, the voltage and torque start to accelerate the motor. One of the benefits of this starting method is the possibility to adjust the torque to the exact need, whether the application is loaded or not. In principle, the full starting torque is available but with a big difference that the starting procedure is much more forgiving to the driven machinery with a lower maintenance costs as a result.

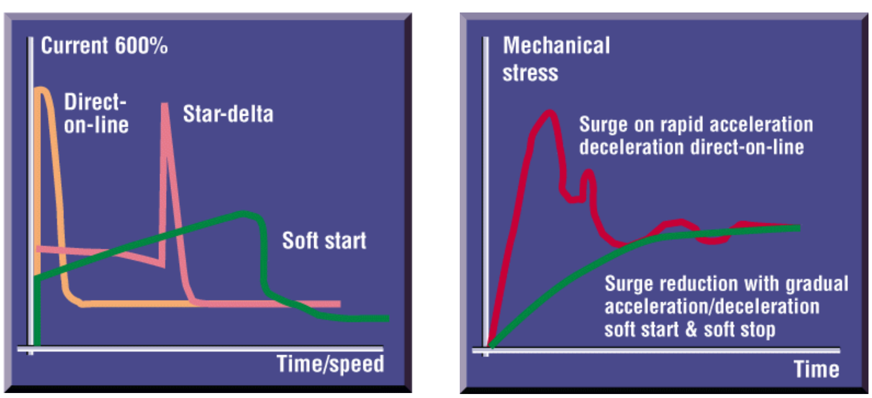


Fig. 4.12 Current and mechanical stress projections with softstarters.

Another feature of the softstarter is the softstop function, which is very useful when stopping pumps where the problem is water hammering in the pipe system at direct stop as for star-delta and direct-on-line starts.

Benefits of softstarters include the following:

- Less mechanical stress and maintenance
- Lower maximum demand, peak current and power used
- Improved power factor
- Lower motor temperature and increased motor life

The electric utility must provide substation capacity to handle the worst case starting loads for a plant or industry. When motors are started across the line, there is typically an inrush current of about 600 to 800% current. The utility uses a demand meter that determines the maximum power requirement over a fixed period of time, usually 15 minutes.

The demand charge for the month is determined by this reading and the service equipment has to be sized accordingly. If several large loads are started within the metering time interval, the accumulative result may be very high, even though the average load is relatively low.

The use of 'soft-starter' controls to accelerate the loads over a period of time will reduce the inrush currents, but may not reduce the demand charges significantly because of the way metering is done. One way to control the demand is to stagger the starting of large loads, so that they do not allow a large motor to run through a period of downtime than to make repetitive starts.

Savings projections of softstarters are pronounced with motor loadings from 10 – 50% while if the load is greater than 50%, it tends to have the motor efficiency reduced.

4.2.4.4 VARIABLE FREQUENCY DRIVES / VARIABLE SPEED DRIVES

In order to maintain proper power factor and reduce excessive heating of the motor, the nameplate volts to hertz ratio must be maintained. This is the main function of the variable frequency/speed drive. The four main components that make up the alternating current (ac) VSD are the converter, inverter, the DC circuit that links the two, and a control unit. The function of each component is given below.

- The converter contains a rectifier and other circuitry that converts the fixed frequency ac to dc (direct current).

- The inverter converts the dc to an adjustable frequency, adjustable voltage ac (both must be adjustable to maintain a constant volts and hertz ratio).

- The dc circuit filters the dc and conducts the dc to the inverter.

- The control unit controls the output voltage and frequency based on feedback from the process (for water utilities, the pressure sensor)

VSDs are applicable to pump-motor systems with high annual operating hours, variable load characteristics and those units of moderate to high hp ratings.

Variable frequency drive systems offer many benefits that result in energy savings through the efficient and effective use of electric power. The energy savings are achieved by eliminating throttling, performance and other friction losses associated with other mechanical or electromechanical adjustable speed technologies. Efficiency, quality and reliability can also be drastically improved with the use of VFD technology. The application of a VFD system is very load dependent and a thorough understanding of the load characteristics is necessary for a successful application. The type of load (i.e., constant torque, variable torque, constant horsepower) should be known as well as the amount of time that the system operates (or could operate) at less than full speed. Looking at Figure _ below will show that the ideal application of a VFD is a pump motor system with a range of flow output between 40 to 65% majority of the time of its operation.

Some additional benefits of VSDs are:

- Capability to match motor and load to output
- Improved power factor
- Improved process precision and equipment life
- Increased production flexibility
- Extended motor operating range
- Load savings over other throttling methods

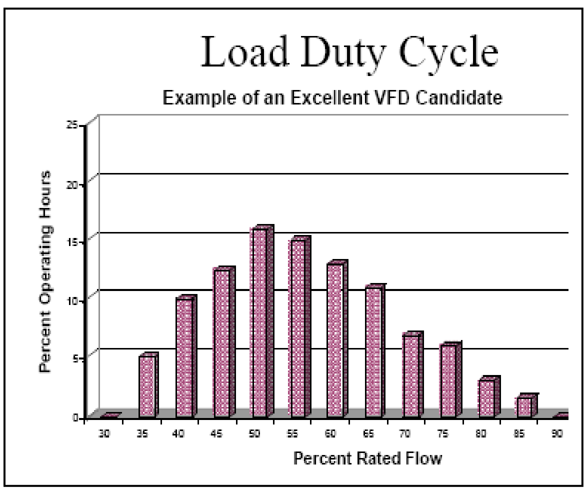


Fig. 4.13 Example of excellent VFD application considering the motor load duty cycle.

Many pump applications involve the control of flow or pressure by means of throttling or bypass devices. Throttling and bypass valves are in effect series and parallel power regulators that perform their function by dissipating the difference between source energy supplied and the desired sink energy.

These losses can be dramatically reduced by controlling the flow rate or pressure and by controlling the pump motor's speed with a variable speed drive.

Figure 4.14 shows the energy savings potential for a variable speed pump. The VFD pump is compared with a valve control system that would be adjusted to maintain constant pressure in the system. These systems do not account, however, for system characteristics (i.e., head or static pressure), which would need to be included in an actual design. These figures show that the amount of savings achievable from the VFD is based upon the percent volume flow for both cases. The consumption savings would be determined by the percent of time at a particular load multiplied by the amount of time at that particular load. Note that proper estimation of savings for VSDs require pump curve plots.

The growing use of VSDs, which are non-linear loads, has increased the complexity of system power factor and its corrections. The application of pf correction capacitors without a thorough analysis of the system can aggravate rather than correct the problem, particularly if harmonics are present.

The electronics used in VSDs maybe susceptible to power quality related problems if care is not taken during their application, specification and installation. The most common problems include transient overvoltages, voltage sags and harmonic distortion. These power quality problems are usually manifested in the form of nuisance tripping.

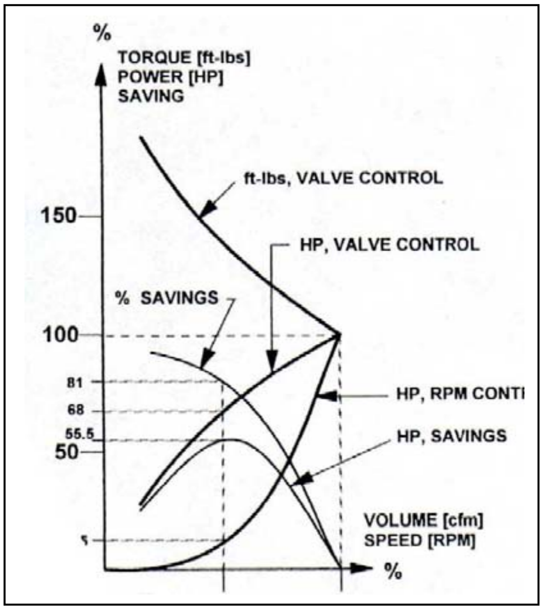


Fig. 4.14 Energy saving potential VSD application against valve control.

a) Transient Overvoltages

Capacitors are devices used in the utility power system to provide power factor correction and voltage stability during periods of heavy loading. Customers may also use capacitors for power factor correction within their facility. When capacitors are energized, a large transient overvoltage may develop causing the VSD to trip.

b) Voltage Sags

VSDs are very sensitive to temporary reductions in nominal voltage. Voltage sags are typically caused by faults on either the customer's or the utility's electrical system.

c) Harmonic Distortion

VSDs introduce harmonics into the power system due to non-linear characteristics of power electronics operation. Harmonics are components of current and voltage that are multiples of the normal 60Hz AC sine wave. VSDs produce harmonics, which if severe, can cause motor, transformer and conductor overheating, capacitor failures, faulty operation of relays and controls and reduce efficiency and may shorten the lifetime of these devices if exposed for a long period of time.

There are other issues to consider with the use of variable speed drives. Some of these are listed below.

- Harmonics-mitigating equipment are now being packaged with VSDs, maintaining power factor improvements but adding to their high cost.
- Heat build-up with sustained operations at low speeds because there are already VSDs which can control motor rpm down to less than 50% of rated speed.
- Consider a decreased starting torque. Higher hp VSDs can be specified enabling a higher starting torque or consider programmable VSD starting features.
- There is potential motor damage when the VSD is located far from the motor. For pulsed-width, modulated drives, keep cable lengths to 50 – 100 feet.
- VSDs can only be retrofitted with inverter-duty motors. Some VSD suppliers are saying that any old standard efficiency motor can be retrofitted with VSDs, others are saying otherwise. To be safe, require guarantees from the VSD supplier.

4.3 ENERGY ASSESSMENT OF TRANSFORMERS

A transformer is an electrical device that transfers energy from one electrical circuit to another by magnetic coupling without moving parts. It is often used to convert between high and low voltages and accordingly between low and high currents.

The transformer was an important element in the development of high-voltage power transmission and central generating stations.[1]

Transformers are electrical equipment used in converting a given alternating current (AC) voltage to a desired AC voltage. They are essential in electrical distribution systems and are normally used to step up voltages for high voltage transmission over long distances and then to reduce the voltage to a suitable and safe level for facility equipment.

Commercial and industrial facilities normally have dry type distribution transformers. More than 40 million utility-owned, liquid-filled units are currently in service. These transformers are usually low-cost, lightweight units, located outside the building.

Power losses from transformers in different systems may be a big factor in overall system efficiency. Some energy programs estimate that converting these transformers to higher efficiency units would result in billions of dollars of savings each year.

When considering transformers, the total cost must be evaluated appropriately since these will be used for decades. For proper evaluation of alternatives, data regarding load and no-load losses should be supplied by the manufacturers. Simple power calculations can show possible losses at different loading levels. Normally, an increase in acquisition cost will secure a unit with less operating costs. In most applications, very short paybacks are attainable.

A lot of utilities have accepted losses from their less efficient transformers since purchasing energy-efficient units has proved to be difficult. Reasons for this include cost considerations in initial purchase of units and passing on to end users the burden of extra charges.

4.3.1 MINIMIZING TRANSFORMER LOSSES AND CABLE LOSSES

Minimizing transformer losses can increase efficiency. Transformer losses may be categorized in two. *Core loss*, also referred to as the no-load loss, is the result of the magnetizing and de-magnetizing of the core during normal operation. This occurs whenever the transformer is energized and does not vary with load. The second type of loss is the *coil or load loss*.

[1] Wikipedia, The Free Encyclopedia

This loss occurs in the primary and secondary coils of the transformer. Coil loss changes with the load and is a function of the resistance of the winding materials.

Transformer performance may be evaluated using the following equations:

$$\text{Load Factor} = \frac{\text{Average Load}}{\text{Peak Load}}$$

Load factor is referred to as the ratio of the average load supplied during a designated period to the peak load occurring in that period, in kilowatts. Simply, it is the actual amount of kilowatt-hours delivered on a system in a designated period of time as opposed to the total possible kilowatt-hours that could be delivered on a system in a designated period of time. Utilities are generally interested in increasing load factors on their systems. A high load factor indicates high usage of the system's equipment and is a measure of efficiency. High load factor customers are normally very desirable from a utility's point of view. Using a year as the designated period, the load factor is calculated by dividing the kilowatt-hours delivered during the year by the peak load for the year times the total number or hours during the year.[2]

$$\text{\% Optimum Loading} = \left(\frac{\text{No Load Loss}}{\text{Full Load Loss}}\right)^{1/2}$$

The percentage of optimum loading of a transformer may be calculated by getting the square root of the no load loss divided by the full load loss. No load loss data and full load loss data are obtained from manufacturer's datasheet. A transformer is designed to have maximum efficiency when operating at its optimum loading condition.

$$\text{\% Loading} = \frac{\text{Average kVA}}{\text{Rated kVA}}$$

The percentage loading of a transformer is the ratio of the actual KVA load and the rated KVA of the transformer. This value should be near the percent optimum loading for the transformer to operate at its peak efficiency rating. The energy losses in the cable may be computed based on the given equation above.

$$\text{Losses in Cable (kWh)} = \frac{3 \times Ia^2 \times R \times l \times h \times LF}{n \times 1000}$$

where:

Ia	=	Line current
R	=	Resistance of the line per meter
L	=	Length of the wires
H	=	Number of hours of operation
LF	=	Load factor
N	=	Number of wires

4.3.2 TRANSFORMER MANAGEMENT

In loading transformers, it is imperative that the right type and size of transformer is used for the right application. Since, transformers represent a large capital cost to most utilities, using an oversized transformer for small loads will be a waste of capital. The percentage of the no-load losses will increase and the overall efficiency will decrease.

On the other hand, under sizing a transformer will result in unnecessary high

[2] http://www.hepn.com/ed/load_factor.htm

winding losses. Investment will also be wasted since the life will be greatly reduced and transformer failure might occur. Parameters such as maximum loading and utilization factor are always considered.

In determining the economic viability of replacing existing transformers with either smaller or larger transformers, several factors are considered. The loading on the transformer at different loading conditions throughout the year and capital costs, replacement costs and the economic factors associated with energy costs are analyzed. A full range of economic parameters can be considered including interest rates, life cycle length and energy demand and time-of use costs. Replacement transformers may be determined by looking at different reference tables.

Accurate transformer management analyses will be beneficial to prevent failure of transformers and can help you manage your inventory of transformers over time to reduce capital expenditures.

4.3.2.1 DEMAND SIDE MANAGEMENT[3]

> *Water is precious and scarce. If we all work together in the spirit of "izandla ziyagezana" ("one hand washes the other") to pay for water and use it wisely, we can all contribute to the task of managing water for the future... The undertaking of a Water Demand Management Program to save water through the efficient use of water is not a luxury but an absolute necessity."*
>
> Water Wiser Program,
> Johannesburg, South Africa

Reducing the amount of water consumed, while maintaining the level of benefit to the customer can greatly reduce both the consumer's and utility's cost. Water utilities can save money, because reducing demand effectively creates more system capacity. By decreasing demand, a water utility can help avoid investments in new facilities and equipment. In addition, reducing the amount of water flowing through a system will likely reduce frictional energy losses, thereby reducing the cost of pumping. The consumer benefits from demand reduction through the reduced cost of delivery, the diminished chance of water shortfalls, and the decreased likelihood of major investment expenditures. Although some utilities are wary of demand-side programs that may affect revenue, in most cases, both the short and long-term savings from demand-side programs far outweigh costs.

This section describes several cost-effective methods and technologies that can be helpful in reducing municipal demand on both water and energy resources. The cost-effectiveness of many of these methods and technologies in practice, however, requires accurate pricing of water to consumers to convey the true cost of the water supplied by water treatment and delivery systems.

In addition to proper pricing, other factors that determine the applicability of certain demand-side measures to water utilities include the market penetration of water-using appliances, the types of industries linked to the system, and the technologies available for the domestic market.

In Australia, for example, Sydney Water's Mt. Victoria treatment plant was operating at close to capacity, so the utility conducted a least-cost capacity upgrading study. The study found that the most cost-effective option to increasing capacity combined several demand management programs that would significantly reduce water consumption, wastewater discharges, and nutrient loading. By turning to demand-

[3] http://www.watergy.org/demandside/dsm.html

side actions, the utility could defer and reduce the costs of expanding the treatment plant.

4.3.2.2 A "WIN-WIN" FOR UTILITIES AND CUSTOMERS

The goal of demand-side management is to provide the customer the same or greater benefit using less water. In most cases, a water customer derives no additional value from using water inefficiently. For example, a consumer flushing a toilet does not get any added benefit from a toilet that wastes water.

Water use can be reduced through relatively simple customer actions, such as turning off the faucet while brushing teeth or using nontoxic wastewater to water plants. In addition, such water saving devices as horizontal axis washing machines, low flow showerheads, faucet aerators, and ultra low flush toilets can reduce consumption. Ensuring each water customer uses water efficiently will help optimize the performance of the entire utility's system. It may also defer or eliminate the need for spending large amounts of capital for added capacity.

The City of Toronto, for example, has been actively pursuing demand side management activities. The city has invested in programs such as ultra low flush toilet incentives, industrial water capacity buyback, and horizontal axis washing machine promotion, with the goal of reducing peak water demand by 15 percent. Toronto estimates that its demand side reduction efforts will cost about one-third as much as creating an equal amount of new capacity. In addition, thousands of dollars in savings have accrued to end users using less water.

Mexico City offers another example of how reducing demand can increase capacity. Because of the difficulty of finding new water sources for a burgeoning and increasingly middle class population, city officials launched a water conservation program that involved replacing 350,000 old toilets. These replacements have already saved enough water to supply 250,000 additional residents.

4.3.2.3 CO-BENEFITS

The impacts of demand-side measures can actually be much greater when organized in conjunction with supply-side actions. For example, by coordinating a major demand-side program with the purchase of new energy-efficient pumps, the water utility will not only save energy from the reduction of water moving through the system, but can also buy smaller, less expensive pumps to meet the reduced pumping demand. In many cases, demand reduction should precede system upgrades to help determine what the real baseline water demand is on the system.

One of the most appealing aspects of demand-side management activities compared with investing major capital improvements is the ability of the water utility to develop, expand, or reduce a given demand-side program quickly to meet current conditions. Demand-side programs can have a major impact within a year, whereas major capital development projects must be made years in advance and are hard to alter to meet changing circumstances.

The City of Toronto cited flexibility as one of the critical benefits to its demand-side project. With many uncertainties surrounding future demand, Toronto was much more comfortable making smaller and incremental investments in demand-side management instead of making a 5 or 6 year investment for new capacity.

Another co-benefit of decreasing water use is the reduced demands on rivers, lakes, and groundwater resources. This is especially important considering the number of major lakes and waterways that are disappearing and aquifers that are declining due to overuse of water resources.

For example, the largest natural lake in northern China, Lake Baiyangdian in the Hebei province is likely to dry out completely due to a combination of over drafting and diminished rainfall. This will likely have a major negative effect on the populace and stability of the region.

An example of the overuse of groundwater can be found in Ahmedabad, India, where over extraction has caused the city's water table to drop an average of 7 ft per year in the past 20 years. Not only does this put the future of the regional aquifer in jeopardy, but it also forces consumers who rely on groundwater to pay more to get it. The local power company estimates that it requires an additional 0.04723 watts per gallon to pump water to the surface with every 7 ft drop in the water table. This translates into an additional 1 million kWh per year to bring the same amount of water to the surface at an added annual cost of more than US$60,000.

4.3.3 ENERGY EFFICIENCY OPPORTUNITIES FOR TRANSFORMERS

Below are some opportunities for the reduction of energy use through transformers.

4.3.3.1 WINDING CONSIDERATIONS

Winding material used in transformer construction - copper or aluminum - affects efficiency. No other metal is better than copper except for silver. The resistance of copper material is far less than that of aluminum or other same-sized diameter steel wires. Smaller resistance means less heating or I^2R losses. Copper windings also minimize transformer full-load losses and may decrease the size of cores, minimizing no-load losses. Another option to reduce transformer losses is to use larger diameter wires to reduce effective resistance of wires.

Matching transformer capacities to load also affects efficiency. Overly sized transformers will not be as efficient as transformers that are appropriately matched to their loads. Since core losses are independent of loading, size selection is a compromise between core loss and coil loss.

4.3.3.2 TEMPERATURE EFFECTS

a) What is Temperature Rise of a Transformer?

Like any other device that uses electricity, transformers also give off waste heat as a byproduct of their operation. Heat dissipated in transformer operation causes an internal temperature rise in the transformer. Generally, temperature rise is dependent on the efficiency of the transformer. Higher efficiency transformers have a lower temperature rise, while inefficient units will have a higher temperature rise.

The temperature increase is defined as the average temperature rise of the windings above the ambient temperature, when the transformer is operating at nameplate ratings.

b) Transformer Efficiency and Temperature Rise

The actual load and no-load losses in watts from the transformer manufacturer is desired, but sometimes this data is not provided. In this situation, the temperature rise may be a rough indicator of the transformer efficiency.

In comparing copper-wound transformers designed to achieve an 80°C rise and high efficiency to standard-efficiency aluminum-wound units that are designed for a 150°C rise, we will see that the higher-efficiency 80°C rise transformers have a shorter payback than the less-efficient 150°C rise transformers. Moreover, a lower-temperature-rise transformer will not just have fewer losses but it will also have a longer life expectancy.

c) How Does Temperature Affect the Life of a Transformer?

One of the biggest factors that affect transformer life is the temperature. In fact, increased levels of temperature reduces the life of a transformer. Further, a lot of failures are caused by the breakdown of the insulation system, so anything that adversely affects the insulating properties inside the transformer reduces transformer life. Factors such as transformer overload, moisture, poor quality oil or insulating paper, and extreme temperatures affect the transformer's insulation properties.

Life expectancy of transformers greatly decreases when the transformers are loaded above nameplate ratings over an extended period of time.

d) Lower Temperature Rise Means Increased Overload Capability

When operating with a lower-temperature-rise, the transformer will have a higher overload capability. When an 80°C rise dry-type unit is using 220°C insulation, this has 70°C reserve capacity compared to a 150°C unit. This leads the 80°C unit to operate with an overload capability of 15-30% without any effect on the transformer life expectancy.

e) Designing a Transformer with Lower Temperature Rise

A low temperature rise transformer uses windings with lower resistance. The low resistance of copper allows transformer construction to be small and still possess a low temperature rise. For example, an aluminum-wound transformer coil requires conductors with approximately 66 per cent more cross-sectional area than a copper-wound transformer coil to obtain the same current-carrying capacity.

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f) High Efficiency and Conditioned Spaces

High efficiency means low heat generation, thus lower ventilation and air-conditioning requirements. Choosing this type of transformer, properly sized for load requirements, gives the greatest efficiency, longer life and increased overload capability.

There are certain factors which prevent the use of higher efficiency transformers. Most end users are not familiar with energy-efficient transformers and the economics of their use. Most electrical contractors buy the inefficient units without any regard for the energy consumption since they do not pay the electric bills. The high-efficiency units are usually not stocked at electrical distributors and there is usually a high mark-up for the high-efficiency units. Energy users should consider energy-efficient transformers for their facilities. The return on investment can be observed through a cost-benefit analysis.

5.0 ENERGY ASSESSMENT OF WATER TREATMENT PLANTS

Water taken from a surface or ground water source is referred to as "raw" water to distinguish it from treated or "finished" water. Raw water is treated not just to remove disease-causing organisms but also to remove silt, grit and humus material (suspended solids), which can have a detrimental effect upon pipes, meters and other components of the water distribution system. Treating raw water also improves the taste and eliminates objectionable odors or color.

The water treatment process can range from a simple filter or chlorination, to a compact treatment plant. A small rural community drinking water system, with a high quality ground water source, may need very little, if any, treatment. For much larger public water systems, particularly when the water source is subjected to repeated human contact such as heavy recreational use, the treatment process is much more complicated and will likely include a combination of the following processes.

- **Initial Filtration** - Often the initial step is to filter the water through some course screens to remove any fish, bugs, leaves, twigs and debris.

- **Coagulation and Sedimentation** - Alum and lime are added to the water. These chemicals then bond with suspended sediments, bacteria and fine particles present in the water to form a sticky floc, which looks like white foam or suds on the water. Over time and as the water is stirred slightly all the fine particulate matter is bonded to the floc, which eventually becomes heavy and sinks to the bottom of the tank.

- **Disinfection** - This is the controlled addition of some germ-killing chemical, usually chlorine, to the water. This treatment step can take place early, late or even repeated in the water treatment process. Often it is a final step.

- **Aeration** - Taste and odor problems are often a result of the presence of dissolved gases such as natural occurring hydrogen sulfide or living organic material such as algae, or decaying organic material, industrial waste or even residual chlorine. Forcing tiny bubbles of air through the water facilitates the release of these gases from solution reducing unpleasant odors and taste.

5.1 ENERGY REQUIREMENTS OF A WATER TREATMENT PLANT

Pump and compressor motors account for 80 – 90 % of the electricity used in water supply and treatment. Therefore a significant opportunity exists for water treatment plant managers to use less energy and save money by adopting more energy efficient technologies and management practices. In California, U.S.A., nearly 40 % of the drinking water systems with surface water sources have a need to build, rebuild or make significant improvements in their treatment facilities.

Approximately 35 % of capital expenditure in the water supply industry is meant to repair or replace equipment. Legislation regulating water quality and safety also has a significant impact on capital expenditures.

5.2 ENERGY EFFICIENCY OPPORTUNITIES

Potential energy savings in the water supply industry range from 20 – 50%. These efficiency measures fall into three broad categories – Operations, Components and Systems:

5.2.1 OPERATIONS

The following efficiency measures may be undertaken at little or no cost. Facilities personnel can perform monitoring and maintenance on equipment to increase system efficiency and prolong equipment life.

- Monitor and maintain equipment
- Check optimum ambient temperature and ventilation
- Measure system pressures, flow rates and elevation
- Review piping system design including elevations for sizing
- Switch production to off-peak times

5.2.2 COMPONENTS

These measures involve replacing standard motors with high efficiency counterparts. The motors most widely used in the industry are 1800 rpm, vertical hollow shaft motors that are 250 hp or less in size. The National Electrical Manufacturers Association (NEMA) and Consortium for Energy Efficiency (CEE) jointly developed the NEMA Premium specifications, an industry wide definition of premium efficiency. NEMA Premium efficiency motors have;

- Cooler running temperatures
- Longer insulation life
- Longer bearing life
- Less vibration
- More tolerance of phase imbalances and overload conditions

5.2.3 SYSTEMS

All these efficiency measures can be best approached by employing a "systems approach" to motor efficiency. Rather than considering motor efficiency in isolation, the entire motor operating system should be considered when implementing efficiency measures. Specific recommendations include;

- Designing and selecting appropriate motor systems
- Matching motor system to loads
- Using Variable Frequency drives (VFD) instead of throttle valves
- Reviewing system requirements

5.2.4 OTHER INITIATIVES

- Process Efficiency Improvements. Calculations of Kwh/ML ratios for each treatment plant has allowed plants to be ranked on the basis of their energy efficiency.

- Introduction of a control and data acquisition system, so that all treatment plants can be monitored from a single remote control.

- Introduction of a new treatment system, which allows the water used to clean the filtration system to be recycled.

6.0 TECHNO-ECONOMIC ANALYSIS OF INVESTMENT FOR ENERGY CONSERVATION

The economic analysis for a project can be conducted through several methods. Patterns of capital investment, revenue or savings, cash flow, and cost cash flows differ from project to project making it difficult to use one standard method to calculate the economic status. The numerous methods are divided based on two common criteria -- (1) undiscounted (non-time value); and (2) discounted (time value). The former measures the worth of a project regardless of the time element while the latter includes the time value of money for making economy studies. The undiscounted measures of a project in turn employ two common methods to evaluate projects. These are the payback period method and the return on investment method.

Nowadays, life cycle costing is becoming more and more relevant and its significance is being appreciated.

6.1 LIFE CYCLE COST

Energy equipment is typically purchased as individual components but they work best only when operating as a part of a system. The energy and materials used by the system depend on the design of the pump, the installation and the system's operational procedures. These factors are interdependent and must be carefully matched with each other throughout their working lives to ensure the lowest energy and maintenance costs, maximum equipment lifetime and other benefits. The initial purchase price is a small part of the life cycle cost.

The life cycle cost (LCC) of any equipment is the total cost to purchase, install, operate, maintain and dispose of that equipment during its 'lifetime'. To determine the LCC of a pumping system, for example, involves following a methodology to identify and quantify all the components of the LCC equation.

If LCC is used as a comparison tool to study potential design and overhaul alternatives, the LCC process will show the most cost-effective solution within the limits of the available data.

The components of a life cycle cost analysis typically include initial costs, energy costs, operation costs, maintenance and repair costs, downtime costs, environmental costs, and decommissioning and disposal costs.

Elements of the LCC Equation

$$LCC = C_{ic} + C_{in} + C_b + C_o + C_m + C_s + C_{env} + C_d$$

where:

LCC	=	Life cycle cost
C_{ic}	=	Initial costs, purchase price (pump, motor, system, pipe auxiliary services)
C_{in}	=	Installation and commissioning costs (including training)
C_b	=	Energy costs (predicted cost for system operation, including pump driver, control and any auxiliary services)
C_o	=	Operation costs (labor cost of normal operating conditions)
C_m	=	Maintenance and repair costs (routine and predicted repairs)

C_s = Downtime costs (loss of production)
C_{env} = Environmental costs (contamination from pumped liquid and auxiliary equipment)
C_d = Decommissioning/disposal costs (including restoration of the local environment and disposal of auxiliary services)

It should be noted that this calculation does not include the raw materials consumed by the plant (i.e., water).

6.2 NET PRESENT VALUE (NPV) CRITERION

In determining a criterion for comparing investment alternatives, one likely candidate is to express the total cash flows for each alternative as a single equivalent value, which reflects the time value of money. Such a single value summarizes the values of all cash flows.

The present worth of discounted cash flows is an amount which is equivalent to a project's cash flow for a particular interest rate **i**. Thus, the present worth of investment proposal **j** at interest rate **i** with a life of **n** years can be expressed as:

$$NPV_j\,(i) = \Sigma\ F_{jn}\,(1 + i)^n$$

where:

F_{jn} = Net cash flow from project j during the year n

A project's net present value (NPV) is calculated by subtracting the present value of the initial investment from the present value of all future cash receipts and disbursements. The interest rate chosen for discounting future cash flows is usually taken to be either the prevailing interest rate in the money market (cost of capital) or the return the company is currently earning on its own invested capital. If the NPV is positive, the implication is that investment is desirable, since the return is greater than the discount rate. Calculation can be facilitated by the discount table or by a personal computer.

The NPV criterion has advantages and disadvantages and they are listed as follows:

Advantages

- It considers the time value of money according to the value of discount rate selected for calculations
- It concentrates the equivalent of any cash flow in a single index at a particular point in time
- It is an amount by which equivalent receipts of a cash flow exceed or fail the equivalent disbursements of that cash flow

Disadvantages

- It assumes inflows and outflows can be forecasted for the entire lifetime of the project and requires equal time for comparison of several investment alternatives.
- The choice of discount rate can affect rankings of alternatives

Sample Problem

A new pump has been proposed by engineers in order to increase the productivity of their operation. The initial investment is PhP 25,000.00 and the pump has an expected life of 5 years. Increased productivity attributable to the furnace will amount to PhP 8,000.00 per year after extra operating costs have been subtracted from the value of the additional production. Is this proposal a sound one? Use the Net Present Value (NPV) method in confirming this proposal.

The following steps can be taken in solving this problem:

- Choose an appropriate discount rate
- Compute the present value of cash proceeds expected from the investment
- Compute the present value of cash required of the investment

NPV = PV of Cash Proceeds - PV of Cash Outlays

A table can be utilized to determine the cumulative Present Value of the furnace up to its expected life of 5 years. Use 10% and 20% discount rates for comparison.

YEAR	VALUE (PhP)	PV at 0% (PhP)	PV at 10% (PhP)	PV at 20% (PhP)
0	- 25,000.00	- 25,000.00	- 25,000.00	- 25,000.00
1	8,000.00	8,000.00	7,272.72	6,666.67
2	8,000.00	8,000.00	6,611.57	5,555.56
3	8,000.00	8,000.00	6,010.52	4,629.63
4	8,000.00	8,000.00	5,464.11	3,858.02
5	8,000.00	8,000.00	4,967.37	3,215.02
TOTAL (Net PV)		**15,000.00**	**5,326.29**	**- 1,075.10**

Discounted at 10%

$$NPV = \frac{-25{,}000}{(1+0.1)^0} + \frac{8{,}000}{(1+0.1)^1} + \frac{8{,}000}{(1+0.1)^2} + \frac{8{,}000}{(1+0.1)^3} + \frac{8{,}000}{(1+0.1)^4} + \frac{8{,}000}{(1+0.1)^5}$$

NPV = - 25,000 + 7,272.72 + 6,611.57 + 6,010.52 + 5, 464.11 + 4, 967.37

NPV = 5,326.29

Discounted at 20%

$$NPV = \frac{-25{,}000}{(1+0.2)^0} + \frac{8{,}000}{(1+0.2)^1} + \frac{8{,}000}{(1+0.2)^2} + \frac{8{,}000}{(1+0.2)^3} + \frac{8{,}000}{(1+0.2)^4} + \frac{8{,}000}{(1+0.2)^5}$$

NPV = - 25,000.00 + P6,666.67 + 5,555.56 + 4,629.63 + 3,858.02 + 3, 215.02

NPV = - 1, 075.10

Therefore, NPV using the discount rate at 10% is better since the NPV at this rate is greater than 0. As PV will depend on the discount rate, there is not one NPV measure, but a schedule of NPV.

6.3 INTERNAL RATE OF RETURN (IRR) CRITERION

It is the interest rate that reduces the present value of a series of receipts and disbursements to zero. The IRR for the investment proposal **j** is the interest rate that satisfies the equation

$$NPV_j\,(i) = 0 = \Sigma\ F_{jn}\,(1 + i^*)^n$$

Solving for **i*** directly is difficult and tedious unless done on a personal computer. The usual approach is to search the appropriate value by trial and error at different values of discount rate.

Below are the advantages and disadvantages of the IRR criterion:

Advantages

- Many business people are familiar with this method since this is a widely accepted index of profitability
- Does not require prior determination of a discount interest rate, and it can be directly related to profit goals
- This method can be employed when comparing two or more projects

Disadvantages

- This method is quite tedious since it is a trial and error method.
- Dependency on its investment base. A return of 20% on an investment of P50, 000.00 is not necessarily preferable to a return of 12% on an investment of P1,000,000.00.

Sample Problem

An investment of P 1,000,000 can be made in a pumping station that will produce uniform annual savings of P 250,000 for 10 years. The company is willing to accept any project that will earn 10% or more, before income taxes, on all invested capital. Determine whether it is justified using the IRR method.

Below are the steps needed to follow in solving this problem

- Find the discount rate that will make the PV of cash proceeds equal to the PV of cash outlays
- NPV = 0
- By trial and error
  - Manual: a bit tedious
  - Computer: easy

PV of Cash Outlay = PV of Cash Proceeds

P1,000,000 = P250,000 (P/A, i%, 10)

Now, in solving for the (P/A, i%, 10), choose a relatively low i%, such as 5% and relatively high i%, such as 15% using the interest tables.

At i = 5%:

0 = - P 1,000,000 + P 250,000 (P/A, 5%, 10)
0 = - P 1,000,000 + P 250,000 (7.7217)
0 = - P 1,000,000 + P 1,930,425
0 ≠ P 930,425

At i = 25%:

0 = - P 1,000,000 + P 250,000 (P/A, 15%, 10)

0 = - P 1,000,000 + P 250,000 (3.5705)
0 = - P 1,000,000 + P 892,625
0 ≠ - P 107,375

The trial and error will have to be continued until you get a value which will give NPV = 0. Linear interpolation can be used to find an approximation of the unknown i%. The answer, i%, can be obtained graphically to be approximately 21%, which is the i% at which the NPV = 0.

Linear interpolation for the answer, i%, can be accomplished by using similar triangles

$$\frac{25\% - 5\%}{-107,375 - 930,425} = \frac{i\% - 5\%}{0 - 930,425}$$

$$i\% = 22.93\%$$

The approximate solution above was merely to illustrate the trial and error process, together with linear interpolation. The error in this answer is due to non-linearity of the NPV function and would be less if the range between interest rates used in the interpolation were smaller.

Since the project will earn 22.93%, which is greater than 10%, it is justified using the IRR method.

6.4 PAYBACK PERIOD CRITERION

The payback period is the number of years required for the earnings from the investment to equal the investment without considering the interest or cost of money. It is an estimate of the length of time over which the funds will be at risk and mainly indicates a project's liquidity rather than its profitability.

The advantages and disadvantages of the payback period criterion are as follows:

Advantages

- Simple to use and calculate
- Intuitively appealing since it can be used as an approach to measure the project's risk considerations
- Often used by the government and industry

Disadvantages

- Fails to consider earning after the payback period
- Does not adequately take into consideration the timing of proceeds
- Dangerous if used as the only criterion for investment decisions and should be regarded as a supplemental information in conjunction with other methods, especially the ones which considers the time element

Sample Problem

An investment of P 100,000.00 on a new pump will produce uniform annual revenue of P 25,000.00. Annual disbursements will be P 10,000 each year for operation and maintenance costs. Calculate the simple payback period of this project.

To calculate for the payback period of this project, the initial investment will be divided by the difference of the annual revenues and expenses. Thus, for this project the payback period is 6.67 years.

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Annual Revenues} - \text{Annual Expenses}}$$

$$\text{Payback Period} = \frac{P\ 100{,}000.00}{(P\ 25{,}000.00 - P\ 10{,}000.00)}$$

$$= 6.67 \text{ years}$$

The payback period does not indicate anything about the project desirability but the speed with which the investment will be recovered.

7.0 IMPORTANCE OF METERING AND MONITORING

Considering that the pumping stations work throughout the day, metering and monitoring systems in such a facility reduces wastage of energy and facilitates evaluation of energy parameters on a continuous basis. Pumping cost per unit of water (Pesos/ML) indicates the present level of efficiency of the system as a whole. In the absence of such monitoring and measuring tools, the O & M personnel are always handicapped to implement further energy efficiency improvement options.

7.1 PARAMETERS TO BE MONITORED

The identifiable parameters for monitoring and recording on a daily basis are the following:

- Head in meters for individual pump discharge pipe lines (immediately after pump), common headers and receivable points on the demand side
- Valve opening positions
- Motor operating parameters, such as KW, voltage, current, frequency, power factor and running hours
- Daily energy accounting system to evaluate energy parameters unit wise, station wise and system wise
- Daily power shut down hours due to grid and internal problems
- Water flow during summer months and non-summer months
- Diesel-generator set operating parameters such as fuel consumption, voltage, frequency and operating hours

Considering the type of operations, suitable formats for monitoring energy and water parameters on a continuous basis generated are shown below:

Table 7. 1 Monitoring Parameters for Pumping Stations.

Date:

TIME	VOLTAGE	AMPS	PF	kW	Hz	KWh

Daily Energy Consumption (kWh): ______________________________

Running Hours of the Station (hr): ______________________________

7.2 Daily Report on the Operation of Pumps

PUMPS		PUMP #1	PUMP #2	PUMP #3
Pumps running				
No. of hours run				
kWh	Start			
	End			
	Start			
	End			
Head at pump in meters				
Common header (m)				
Valve position (% open)				
Cumulative daily				
	Energy, kWh			
	Hours, h			
Flow Measurement (from installed flow meters)				
(i) For individual				
(ii) For common header				
(iii) Frequency at the time of flow, Hz				

7.3 System Wise Monitoring Parameters

		From WTP	From Supplementary Pumping Stations	Total
Daily basis				
Water flow allowed in hours	Start			
	End			
Head at City end				
Energy, kWh	Start			
	End			
Weekly basis				
Water flow allowed in hours	Start			
	End			
Head at City end				
Energy, kWh	Start			
	End			
Monthly basis				
Water flow allowed in hours	Start			
	End			
Head at City end				
Energy, kWh	Start			
	End			

7.2 ADVANCED SYSTEMS USED FOR MONITORING

In order to aid in metering and monitoring, a Supervisory Control and Data Acquisition (SCADA) system and a Maximum Demand Indicator Controller can be adopted.

7.2.1 SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) SYSTEM

A SCADA system is normally utilized in monitoring and automating large industrial systems. The basic system consists of a central computer that communicates with the different control points. For water utilities, these control points include pumps, reservoirs and pumping stations. Different sensors are installed at these stations and data is sent to the main computer for monitoring. Typical water distribution systems may have hundreds of control points, and all processing of information is handled by the central computer.

a) Reduction of Water-related Energy Consumption

A big portion of the energy consumption of local governments comes from water distribution systems. Half the cost of operating and maintaining a municipal water system comes from the energy consumption of the plant. A big portion of this comes from pumping the water alone. By using a SCADA system, energy costs are expected to go down.

b) Optimizing Water Supply Efficiency

One of the sources of energy savings comes from selecting the most cost-effective water wells. The main computer monitors the performance of each well by tracking pumping energy required for each gallon the well produces. With changing demands for water over time, the central computer makes sure that the most efficient pumps are turned off first and turned off last.

c) Optimizing Time of Use

Another source of energy savings is by optimizing the time of use. There are some electrical rates that vary depending on the time of day. Intelligent terminals have microcontrollers that are programmed with their time of day rates. These devices communicate with the SCADA system and they will know how to respond.

d) Optimizing System Pressure

System pressure optimization is another source of energy cost savings. Systems without supervisory control normally generate line pressure which is much higher than is needed. The SCADA system is used to monitor and manage the pump to have efficient operation. Costly mechanical breakdowns are also avoided with early warning devices from the SCADA system.

e) Reducing System Leaks

The remainder of the savings comes from the cost of water. By monitoring and controlling the pressure levels, leakage and unnecessary water loss are minimized. SCADA systems also help discover and locate system leaks.

f) Operational Benefits

The optimized parameters from the SCADA system allow personnel to respond faster and more intelligently. Without SCADA, pumps may be running longer than necessary just to avoid problems. The turning on or off of the pumping equipment will not be optimized because of their dependence on manual control.

In using the power of the computer for optimization, SCADA systems are becoming ideal solutions to the complex problem of water system energy management. The sophistication and power of SCADA technology is rapidly increasing level of expertise in design, installation. The application of SCADA systems is rapidly increasing and the costs of the SCADA system hardware is dropping. This system is fast becoming one of the municipal government's effective in managing energy consumption.

7.2.2 MAXIMUM DEMAND INDICATOR CONTROLLER – A PLC BASED CONTROLLED SYSTEM

High-tension (HT) consumers have to pay a maximum demand charge in addition to the energy charge (kWh) for the number of units consumed. This charge is usually based on the highest amount of power used during some period (say 15 minutes) during the metering month. The maximum demand charge often represents a large proportion of the total bill and may be based on only one isolated 30 minute episode of high power use.

Considerable savings can be realized by monitoring power use and **turning off or reducing non-essential loads** during such periods of high power use.

Maximum Demand Controller is a device designed to meet the need of industries conscious of the value of load management. Alarm is sounded when demand approaches a preset value. If corrective action is not taken, the controller switches off non-essential loads in a logical sequence. This sequence is predetermined by the user and is programmed jointly by the user and the supplier of the device.

8.0 EFFECTS OF OPERATING AND MAINTENANCE ON ENERGY CONSUMPTION

Five to twenty percent of annual commercial building utility bills can be saved through low-cost O&M improvements—but only if they are implemented. Performing the O&M assessment and determining which improvements are most cost-effective is often the most time consuming and costly part of the O&M tune-up process. Once the improvements are selected and prioritized many of them may be implemented very quickly and inexpensively. For example, control strategy or schedule improvements, where the greatest savings often occur, may only take a few hours to implement. The O&M tune-up activities may be the first step in developing a sustainable finance mechanism for the organization. Once an organization funds the initial O&M assessment and tune-up improvements, future energy efficiency work can be funded from the savings generated by the low cost O&M improvements. This kind of sustainable finance mechanism requires monitoring and tracking savings so that they can be dedicated to future improvements.

Purpose

- Implement the most cost-effective solutions that maximize building performance and minimize energy waste.
- Document the improvements and their effects in order to benchmark the performance of energy-using equipment and systems.
- Develop a sustainable finance mechanism for energy efficiency measures for the organization.

Action Tips

- Implement the improvements over a selected period of time such as six months to three years depending on budgets and paybacks. The savings from the initial O&M improvements may help offset the cost of other lower priority but important improvements as well as more expensive capital improvements leading to optimal building performance.
- Measure and document the effects of the improvements to create a baseline to track O&M activities against and ensure that improvements deliver the expected results.

An O&M assessment differs from a traditional energy audit, even though they share the goal of reducing operating costs and energy waste and improving the building environment. Traditional energy audits identify technology- intensive, energy-efficient capital improvements. O&M assessments identify low-cost changes in O&M practices that can improve building operation. The O&M assessment may be performed prior to an energy audit because it offers ways to optimize the existing building systems, reducing the need for potentially expensive retrofit solutions. It may also be performed as part of an energy audit, because implementing the low-cost savings identified in the assessment can improve the payback schedule for capital improvements resulting from the energy audit. Table 8.1 summarizes the basic differences between the O&M assessment and the traditional energy audit.

Table 8.1 The Differences Between a Traditional Energy Audit and an O & M Assessment

TRADITIONAL ENERGY AUDIT	O & M ASSESSMENT
Emphasizes investigating existing building systems for *equipment replacement (retrofit) opportunities* leading to energy cost savings	Emphasizes investigating existing building systems *to identify low cost O & M improvements* leading to energy cost savings
A typical energy audit on-site process is relatively fast (16 hours)	O & M assessment on-site process is relatively time consuming (2 days to 2 weeks)
Seldom includes functional testing of present building systems	Generally includes some degree of functional testing of present building systems
Generally performed by an outside consultant	Generally performed by an outside consultant
May include building simulation models	Rarely includes building simulation models
Results in a list of energy conservation retrofit measures	Results in a master list of O & M improvements
Typical recommendations are time consuming and expensive to implement	Typical recommendations are fast and inexpensive to implement
Typical paybacks are estimated at three or more years	Typical paybacks are estimated at less than two years (often less than one year)
Generally requires an outside contractor to implement equipment replacements	In-house staff can often implement many O & M improvements.

Although the O&M assessment can be as expensive and sometimes more expensive to perform than the traditional energy audit, the findings from the assessment are usually much less expensive to implement because they don't involve installing large capital improvements. In fact, managers can consider most O&M assessments outside of typical corporate hurdle rates, because the risk of not realizing savings is so low. The O&M assessment does not ignore capital improvements and may include recommendations to further investigate certain retrofit opportunities, but its true goal is to identify the low-cost improvements. Because energy audits are specifically part of an equipment replacement process, they are often performed as a financing requirement. For an owner to obtain funding either in-house by way of their capital projects department or from third party financing (such as an energy service performance contract), a solid energy audit provides the necessary assurances that the investment is financially sound. It is a good idea to combine the energy audit and the O&M audit, which investigates low-cost O&M enhancements. With financial investment, the O&M assessment can help owners to understand and evaluate the energy-efficiency opportunities in buildings by optimizing performance and minimizing energy waste of existing equipment. This is not to say that an O&M assessment should be done in place of an energy audit. Both have an appropriate place in the overall energy management process and should be considered complementary.

Depending on the complexity of the building systems and the expertise and availability of the in-house building staff, a building owner may choose an outside consultant to perform the assessment. Commissioning consulting firms and engineering firms that provide commissioning and diagnostic or retro-commissioning services as part of their core business activities usually are well suited to perform O&M assessments. They have the necessary experience and business commitment to the process to help scope and deliver the specified project in a cost effective and timely manner. Some good reasons to bring in an outside consultant to perform or assist in performing an O&M assessment include:

The owner's staff may not have the skill or time to perform an in-depth assessment.

- Consultants specializing in commissioning and O&M services have vast experience with similar buildings enabling them to offer a new or different perspective. In other words, they aren't invested in doing things the "old way."
- Consultants are also "tooled" for performing the work. Most have generic assessment procedures that they can customize to fit the building they are hired to assess.
- Consultants have analytical skills and tools for diagnosing hidden problems and determining the cost effectiveness of selected improvements.

Four O&M assessment approaches may be considered and these include:

1. Hire an outside expert to perform the assessment from start to finish. This approach often works well for owners who have one or more buildings with no O&M staff, or minimal staff with little time or training.

2. Owners or managers with multiple buildings and a well trained, interested, available O&M staff, may want to hire an outside consultant to work with the building staff for the first one or two buildings. After the building staff is trained in the process they can go on to assess the rest of the buildings themselves.

3. Use the second approach but retain the outside consultant throughout the entire project to oversee critical parts of the assessment process either as assigned or as needed. Owners who use this approach often ask the consultant to analyze data and estimate savings.

4. Divide the assessment work between the outside consultant and the O&M staff. Depending on the scope of the project and staff availability, the O&M staff can obtain all of the nameplate data and perform the equipment condition assessment. This allows the consultant to concentrate on operating issues and the impact that various building users have on the operation and maintenance of the building.

9.0 CASE STUDIES ON ENERGY AUDITS

9.1 METRO ILOILO WATER DISTRICT (MIWD)

Metro Iloilo Water District (MIWD) covers the city of Iloilo and the towns of Oton, Pavia, Santa Barbara, Cabatuan, Maasin and Barangay San Jose in San Miguel. MIWD supplies water round the clock and has two sources of water supply, the river source and supplementary source from production wells.

MIWD extracts its surface water from Tigum river through an intake dam in Barangay Daja, Maasin with a capacity of about 30,240 m^3 of water per day. From the dam, water is conveyed by gravity through a one and a half-kilometer pipeline, 18 inches in diameter to a sedimentation basin in Barangay Buntalan, Maasin and 24 inches CLCC pipe that goes directly to raw water basin at reservoir in Santa Barbara, Iloilo. It is then conveyed to the Water Treatment Plant (WTP), which has a capacity of 37,000 m^3/day. From the WTP, water is then conveyed by gravity to Iloilo City passing through a 7,500 m^3 covered reservoir.

Supply for Iloilo City, including its nearby utilities is supplemented by the eight (8) production wells from San Miguel and Oton with a combined capacity of 13,800 m^3/day. Another production well in Santa Monica, Oton with a capacity of 2,160 m^3/day supplies the water requirement of its municipality.

9.1.1 BACKGROUND

The major source of the water to the Iloilo City is the river water collected in the reservoir. Additional water requirement is met by the bore wells installed at various locations. These bore wells operate about 23 hrs/day. The specific power consumption was evaluated for dam source and bore well sources and it was found out that the dam source has the lowest specific energy consumption (SEC). The water is then treated at the WTP, where there are two (2) submersible pumps that pump the water from the basin to the flash mixers.

An ultrasonic flow meter was used to measure the flow from the pumps, and it was found out that the operating efficiency of the pump is considerably lower than the rated pump efficiency due to high head operation. The best performance of the pump can be obtained at a total head of 8 meters. Due to high actual head, the output of the pump is reduced when compared to rated output of the pump. Based on the output of these pumps, the inlet to the WTP is throttled to balance the input and output and avoid overflow. This has resulted in reduced processing capacity of the WTP. As seen in Table 8.1, the present operating capacity is 89% which is low due to the reduction in the output of the pumps.

Table 9.1 Processing Capacity of WTP.

Particulars	m^3/day
Installed capacity	37,000
Present operating capacity:	
Pump SP # 1	16,589
Pump SP # 2	16,330
Total	32,919

9.1.2 METHODOLOGY AND APPROACH

A team of engineers from TERI, India and UP/ENMAP were involved in the energy audit study. During the study, all the pumping stations were visited and studied in detail. The audit involved carrying out various measurements and analysis covering all major energy consuming sections, to realistically assess losses and potential for energy savings. The study focused on improving energy use efficiency and identifying energy saving opportunities at all pumping stations. The analysis included simple payback calculations where investments are required to be made to implement recommendations, to establish their economic viability.

The audit study used a wide array of latest and sophisticated portable diagnostic and measuring instruments to support the energy audit investigations. The specialized instruments that were used during the energy audit included:

- Portable load manager to monitor and log the transformer parameters
- Clamp-on electrical power analyzers to measure and log the individual motor parameters
- Ultrasonic water flow meter to measure the velocity and flow rate of water pumps and pipelines
- Digital pressure sensor to measure the delivery head of the pumps

The methodology approached during the audit study for all the pumping stations is discussed in the following sections.

9.1.3 DATA COLLECTION AND ANALYSIS

This included collection of details like:

- Power supply inputs and electrical data
- Pump, motors, starters and cable connections
- Capacitor bank details
- Water supply input and output details
- Operating parameters of the stations
- Throttling of valves
- Problems related to power supply and equipment
- Storage tank details

The electrical data included maximum demand, units consumed, power factor, tariff details, etc.

Test Runs. Test runs were conducted at each pumping installation to assess the efficiency values applicable for motor-pump sets.

Hydraulic KW required and Combined Efficiency. The hydraulic KW required to raise the water to assigned head and combined efficiency of the pump-motor was evaluated.

Data Analysis. Analysis have been made based on data collected, measurements taken and test carried out. The various factors considered for the analysis are generally as follows:

- Operating load
- Energy consumption pattern
- System efficiency
- Specific energy consumption

The analysis helped in identifying:

- Sizing adequacy of motor with regard to pump capacity/head
- Efficiency parameter analysis
- Power factor improvement and demand reduction
- Transformer loading
- Estimation of leakage in the system, etc.

9.1.4 ENERGY CONSERVATION OPTION

The energy audit team has recommended short term, medium term and long term measures. The MIWD staff has also identified additional options based on their monitoring activities conducted after the audit. The energy conservation opportunities were as follows:

Short-Term Measures

- Direct injection of aluminum sulphate at pumping structure
- Increase the output of the raw water pumps by reducing measured actual head

Medium-Term Measures

- Replacement of pump at PS#10
- Replacement of pump and motor at PS#3A
- Rehabilitation of well and replacement of pump and motor at PS#7
- Replacement of pump and motor at PS#1
- Replacement of pump and motor at PS#11

Long-Term Measures

- Construction of a by-pass line from 600mϕ raw water pipeline to the pumping structure

Out of all the options identified by the audit team, the short term measure on increasing the submersible pump output of the WTP pumps was the most successful.

9.1.5 ENERGY SAVINGS

In November 2004, one (1) submersible pump of the WTP was shut down when adequate water reserve volume was achieved. The water level was increased thus increasing pump efficiency during high water reserve, however, since the low water level in the dam started in February 9, 2005, this activity was temporarily stopped.

Table 9.2 shows a summary of the annual savings, cost and payback period for the 3 categories of energy conservation measures.

Table 9.2 Summary of the Annual Savings, Cost and Payback for the Energy Conservation Opportunities.

	Annual Savings		Cost	Pay Back
	kWh	PHP	PHP	yrs
Short Term	98,373	442,681	Marginal	Immediate
Medium Term	390,005	1,755,021	3,989,970	2.27
Long Term	125,580	753,480	1,540,603	2.04
TOTAL	**613,958**	**2,951,182**	**5,530,573**	**1.87**

9.2 METROPOLITAN CEBU WATER DISTRICT (MCWD)

The Alliance to Save Energy partnered with the Energy Management Association of the Philippines (ENMAP) and the University of the Philippines (UP) to conduct a detailed energy audit within the Metro Cebu Water District (MCWD) in June 2004. The study covered eight (8) pumping stations at the Talamban area and four (4) turbine pumps at the Mandaue Booster Pumping Station, both under the Metro Cebu Water District (MCWD) with the main objective of identifying energy saving opportunities.

9.2.1 BACKGROUND

MCWD's water sources consist of one (1) surface water source, the Buhisan Dam, which accounts for about 3% of the total supply (feeding the Tisa Filter Plant with raw water), and ground water sources, particularly from 101 wells all over Metro Cebu which account for the remaining 97% of the supply. Only 8 stations in the Talamban area were audited in detail.

The Talamban raw water system consists mainly of seven (7) wellfields, namely, W4.12, W4.11, W4.10, W4.7, W4.2, W4.8 and K2.2, a chlorination facility and a 5000-m^3 reservoir tank. Pump stations W 4.14 and W 4.9 are also located in the Talamban area. However, the raw water goes directly to the supply line.

9.2.2 METHODOLOGY AND APPROACH

A team of four engineers from ENMAP and UP were involved in the energy audit study. During the study, eight pumping stations at the Talamban area and four turbine pumps at the Mandaue Booster Pumping Station were visited and studied in detail. The audit involved taking various measurements and analysis of all major energy-consuming sections to evaluate losses and identify energy conservation opportunities. The study focused on how energy efficiency in the pumping stations can be improved. The analyses included simple payback calculations where investments are required and to determine its economic viability. The major areas of study include the pumps and pumping system, electrical supply and electric motors.

The audit study used various measuring instruments in order to determine different parameters needed to compute for efficiency. The specialized instruments that were used included:

- Clamp on electrical power analyzers to measure and log the individual motor parameters such as voltage, current, power factor, kW and kVA.

- Ultrasonic water flow meter and dial-type on-line flow meters of MCWD to measure the velocity and flow rate of water pumps and pipelines.

The methodology approach during the energy audit for all the pumping stations was as follows:

9.2.3 DATA COLLECTION AND ANALYSIS

This included collection of data such as:

- Power supply inputs and electrical data
- Pump, motors, starters and cable connections
- Water supply input and output details
- Operating parameters of the stations
- Throttling of valves
- Problems related to power supply and equipment
- Storage tank details

Data Analysis. Analyses and computations of efficiency were made based on data collected and measurements taken. The various factors considered for the analyses are as follows:

- Operating load
- Energy consumption pattern
- System efficiency
- Specific energy consumption (SEC)

9.2.4 ENERGY CONSERVATION OPTION

The recommended energy efficiency options for MCWD are summarized in the table below.

Table 9.3 Energy Conservation Measures for MCWD.

No.	Proposal	Annual Savings		Cost of Implementation	Payback Period
		kWh	PhP	PhP	Years
No cost					
1	Check pump line for blockages (W4.11)	56,826	227,307	None	-
2	Check pump screens, casing and lines	16,860	84,291	None	-
Low cost					
3	Check pipe sizes and change (W4.11)	56,826	227,307	Minimal	0.66
4	Inspect impellers for any damage	16,860	84,291	Minimal	1.13
Medium cost					
5	Replace Pump K2.2	24,757	108,931	92,300	0.85
6	Pump modification	56,826	227,307	452,340	1.99
7	Replace impeller if damage	16,860	84,291	285,740	3.39
Major cost					
7	Replace Pump 4.2	45,514	182,049	400,924	2.00
8	Replace Pump 4.11	83,876	335,500	602,000	1.79
10	Install 140 kVAR Capacitor Bank	22,235	122,295	350,000	2.86
11	Use of large capacity HE	89,821	449,106	974,460	2.17
Total		**487,261**	**1,821,077**	**3,157,764**	**1.73**

The prices of the pumps were quoted (verbally) by Grundfos Philippines in US dollars (FOB Manila) and an exchange rate of 56.50 Php to 1 US$ was used.

9.2.5 ENERGY SAVINGS

MCWD has several pumping stations. The Talamban and the Mandaue areas are just 2 out of 14 locations where MCWD pumping stations are located. Because of the Watergy program, MCWD became aware of the importance of reducing energy consumption. Although only two locations were included in the detailed energy audit, MCWD applied what they have learned from the program and disseminated the energy conservation measures that were recommended. In so doing, a projected total annual savings of PhP 54,465,954.08 can be realized as seen in Table 9.4.

Table 9.4 Total Annual Savings at MCWD.

Well Area	Talamban	Mandaue Booster	Compostela	Central	Cabantan	Casili	Canduman	Guadalupe
kWh Consumption *								
Before	417,182.41	87,795.85	12,869.23	148,349.08	88,548.35	267,419.25	158,891.34	112,600.00
After	398,918.80	31,499.82	11,827.00	129,661.05	67,371.27	247,889.44	126,795.20	88,846.26
Reduction (kWh)	18,263.61	56,296.03	1,042.23	18,688.03	21,177.08	19,529.81	32,096.14	23,753.74
Reduction (%)	4.38%	64.12%	8.10%	12.60%	23.92%	7.30%	20.20%	21.10%
Water Production (cu.m.) *								
Before	696,537.41	186,611.40	21,567.93	255,176.42	125,634.53	374,942.52	221,870.54	158,369.41
After	770,393.29	363,747.00	33,592.28	250,503.87	111,032.23	421,859.70	260,062.86	156,773.28
Increase (cu. M.)	73,855.88	177,135.60	12,024.35	(4,672.55)	(14,602.30)	46,917.18	38,192.33	(1,596.13)
Increase (%)	10.60%	94.92%	55.75%	-1.83%	-11.62%	12.51%	17.21%	-1.01%
Monthly Power Bill, Php								
Before	2,520,147.05	519,677.92	76,684.08	878,189.21	524,119.77	1,581,391.75	939,337.47	667,531.00
After	2,434,724.48	574,354.20	70,176.09	767,878.23	399,116.58	1,466,111.97	749,881.68	527,318.46
Savings	85,422.58	(54,676.28)	6,507.99	110,310.98	125,003.19	115,279.78	189,455.79	140,212.54
Systems Recovery Rate, %	68.00%	68.00%	68.00%	68.00%	68.00%	68.00%	68.00%	68.00%
Production Cost, Php/cu.m.	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34
Monthly Sales, Php								
Before	2,055,621.20	550,727.56	63,651.28	753,076.65	370,772.62	1,106,530.37	654,784.32	467,379.80
After	2,273,584.68	1,073,490.15	99,137.55	739,287.03	327,678.31	1,244,992.35	767,497.52	462,669.30
Increase	217,963.48	522,762.58	35,486.27	(13,789.62)	(43,094.31)	138,461.98	112,713.20	(4,710.50)
Total Annual Savings	3,640,632.74	5,617,035.66	503,931.16	1,158,256.28	982,906.52	3,044,901.14	3,626,027.86	1,626,024.42

Source: MCWD, 2005

Table 9.4 cont'd.

Well Area	Mananga	Mactan	Tisa	Banilad	San Vicente	Jaclupan	Total	
kWh Consumption *								
Before	95,760.75	33,505.43	188,708.21	112,914.26	522,360.43	754,096.50		
After	75,810.97	30,794.43	203,495.45	89,618.72	472,385.26	661,796.87		
Reduction (kWh)	19,949.78	2,711.00	(14,787.24)	23,295.54	49,975.17	92,299.63	**KWHR**	364,290.55
Reduction (%)	20.83%	8.09%	-7.84%	20.63%	9.57%	12.24%		
Water Production (cu.m.) *								
Before	230,315.02	64,052.46	319,573.50	233,650.93	497,340.55	993,670.52		
After	235,193.07	86,476.98	397,187.29	278,406.99	733,897.40	1,227,840.63		
Increase (cu. M.)	4,878.05	22,424.51	77,613.79	44,756.06	236,556.85	234,170.11	**m3**	947,653.74
Increase (%)	2.12%	35.01%	24.29%	19.16%	47.56%	23.57%		
Monthly Power Bill, Php								
Before	567,669.75	199,574.73	1,116,419.40	667,585.80	3,089,128.44	4,456,473.51		
After	448,934.07	183,572.33	1,203,704.92	530,077.84	2,794,137.09	3,911,828.16		
Savings	118,735.68	16,002.40	(87,285.52)	137,507.96	294,991.35	544,645.35	**Php**	1,742,113.79
Systems Recovery Rate, %	68.00%	68.00%	68.00%	68.00%	68.00%	68.00%		
Production Cost, Php/m3	4.34	4.34	4.34	4.34	4.34	4.34		
Monthly Sales, PhP								
Before	679,705.68	189,031.63	943,125.32	689,550.62	1,467,751.42	2,932,520.45		
After	694,101.79	255,210.85	1,172,179.14	821,634.70	2,165,878.00	3,623,603.28		
Increase	14,396.11	66,179.23	229,053.81	132,084.08	698,126.58	691,082.83	**Php**	2,796,715.72
Total Annual Savings	1,597,581.52	986,179.51	1,701,219.53	3,235,104.46	11,917,415.18	14,828,738.11	**Php**	54,465,954.08

Source: MCWD, 2005

10.0 FINANCING OPPORTUNITIES FOR WATER UTILITIES

based on the article by Mary Jade Roxas-Divinagracia, Pricewaterhouse Coopers

Water is a basic need. While 80% of the country's population has access to potable water, less than 50% gets it through piped water supply systems. The situation seems to be worse in remote areas around the Philippines. Although water projects, whether new development, expansion or system improvement (such as Watergy™) have been identified to remedy the current situation, there is one major impediment - - availability of financing.

10.1 THE LOCAL WATER UTILITIES ADMINISTRATION

The water and wastewater sector in the Philippines is divided into three (3) areas of responsibility: (a) Metro Manila; (b) provincial urban areas; and (c) rural areas. The Metropolitan Waterworks and Sewerage System (MWSS) oversees the water supply and distribution in Manila through its two concessionaires – Manila Water Company Inc. and Maynilad Water Services, Inc. The provincial urban and rural areas are served by municipal-owned water utilities with a limited number of small-scale privately-owned utilities. The Local Water Utilities Administration (LWUA) supervises these other water service providers (WSPs).

LWUA has served as a "specialized lending institution" for the promotion, development and financing of local water utilities. Yet, in the recent past, there has been a need to identify alternative sources of financing primarily because LWUA alone can no longer fund all the projects of WSPs. Compared to other Asian countries, the Philippines has one of the lowest investments in infrastructure -- around 3.3% of GDP.

Over the next five years, LWUA has identified the need to provide over 88,000 new service connections, estimated to cost Php2.5 billion annually. However, due to fiscal constraints and tight budget, LWUA can no longer expect funding support from the government.

Recognizing the need to find alternative sources of financing, the government issued Executive Order 279 in 2004. EO 279 aims to institute reforms in the financing policies for water supply and utilities and to rationalize LWUA's organizational structure. It divides WSPs into four (4) categories depending on their creditworthiness and ability to source funds.

- It defines creditworthy WSPs as financially self-sustaining WSPs capable of accessing financing from government and private financial institutions (GFIs and PFIs).
- Semi-creditworthy WSPs are those that will be classified as creditworthy in the short-term. These entities can approach LWUA for financing but are encouraged to obtain funding from GFIs and PFIs.
- Pre-creditworthy WSPs refer to those that will graduate to being creditworthy in the longer term.
- Non-creditworthy are those that will become pre-creditworthy in the medium term.

The last two categories will have difficulty accessing funds elsewhere other than LWUA and government grants.

10.2 CORPORATE FINANCE VS PROJECT FINANCE

There are two major types of financing: corporate finance vs. project finance.

- Corporate finance is granted to creditworthy entities, those belonging to the first and second categories of WSPs. Being creditworthy, they have access to bank financing and usually involve low financing and transaction costs.

- Project finance on the other hand, relies on the creditworthiness of the project and not on the entities themselves. Financing is provided by lenders because they believe that the project will generate enough cash flows for debt service. Project finance is more expensive because it needs to be carefully structured to provide comfort to its financiers that the project is economically, technically, and environmentally feasible. The project should be capable of servicing debt and generating financial returns commensurate with its risk profile. Under project finance, even if the WSPs belong to the last two categories, financing is possible for new projects that have been identified as self-sustaining. Yet, the size of the project should warrant the additional costs that will be incurred if such is packaged as project finance. One difficulty of project finance is that not a lot of local banks are used to providing funds based on the project's merits alone; most would still want the comfort of traditional financing, that is, getting hard collaterals as security. Watergy™ projects, which largely entail the acquisition and installation of energy-saving and water-saving technologies for WSPs, are in most cases evaluated on the basis of payback periods and economic impact of potential savings.

LWUA has been the primary source of funds for most water utilities. Lately, however, LWUA's funding has been limited. EO 270 encourages increased involvement of GFIs in the funding requirements of water service providers. While programs that can be tapped for water projects have been created by the GFIs, the list of requirements is usually lengthy and only creditworthy WSPs can access these funds. Interest rates can also be prohibitive thereby impacting on the water tariffs.

The local government units (LGUs) are also encouraged to enhance its participation in providing basic services to the community it serves such as water supply and distribution.

10.3 ALTERNATIVE SOURCES OF FINANCING

The following are some of the alternative sources of financing that the WSPs can explore to fund their projects.

- Issuance of bonds. Projects that can generate stable cash flows can be funded through bond flotation. This mode of raising finance gives the investors an alternative investment choice and provides the direct stakeholders (like the constituents/consumers) the opportunity to be more involved in community projects. The government has encouraged the issuance of LGU bonds by providing tax incentives to investors.

- Internal Revenue Allotment (IRA) of LGUs. EO 279 encourages LGUs to help finance water sector projects. The purpose of these IRAs is to provide basic social services to the community as well as support infrastructure projects. Water supply is a basic social service and an infrastructure project and hence, eligible for financing.

- LOGOFIND or Local Government Finance and Development Project. This is a project of the Department of Finance and funded by the World Bank and can be a source of financing for LGU-owned water systems. The objective is to assist LGUs in the provision of basic municipal and urban infrastructure and social services. Other than funding, LOGOFIND provides technical assistance, such as institutional strengthening or capacity building to the LGUs.

- LOGOFIND welcomes applications from the 3rd to 6th income class LGUs. However, 1st and 2nd class LGUs may access the fund as long as it is for sanitation and environmental projects which can include water initiatives.

- Carbon funds. For projects that are environmentally-friendly, a CDM financing can be explored. Certificates of Emissions Reduction (CERs) can be obtained if projects qualify. These certificates have value and can be traded. There are some financing institutions who accept CERs as part of the collateral. However, the carbon financing is not substantial and usually contributes about 5-15% of the project costs, depending on the additionality of the project.

The transaction is usually structured wherein the CDM investor agrees to provide funding to the project company, in this case the WSPs. In return, the project companies are obligated to deliver the CERs to the investor at an agreed price. The CDM investors do this in anticipation of higher CER prices in the future. The loan is repaid by the project company either through the delivery of the CERs or if there are still cash considerations as may be agreed.

Another option is to invite private sector participation (PSP). While there are numerous modes of private sector participation, the optimal route will largely depend on the specific objectives of the entity being privatized.

One project finance solution involving PSP is through the build-operate-transfer (BOT) scheme and its variants. Under this scheme, a third party is invited to fund and build the project, operate it for a certain period of time and turn it over to the government or water district. The operation of the facility will give the investor the venue to recoup its investments and earn a reasonable return. The project proponent may also be repaid in the form of revenue sharing or if operation is undertaken by the utility, through a fixed lease payment on a periodic basis. Most of the project risks are borne by the proponent and require higher returns or some form of guarantee.

The advantages of doing a BOT include knowledge and technology transfer, automatic franchise if needed and incentives for projects that qualify. However, it usually takes a significant amount of time to process a BOT-funded project as it requires numerous documentations and approvals from different government agencies.

Another emerging PSP solution for Watergy™ type of energy-efficiency improvement projects in the Philippines is made available through energy saving performance contracting by energy service companies (ESCO). In either the North American or French business models, ESCOs advance the cost of equipment retrofits (such as new pumps, motors, controls, automation, transformers, capacitors, etc.)

which they hope to recoup through energy savings over a predetermined period of performance. An investment-grade energy audit and carefully negotiated measurement-and-verification protocol provide the most significant bases for the ESCOs and WSPs to negotiate energy service agreements (ESA). Depending on the business model preferred, financing for the equipment retrofits can be sourced directly from current idle credit of the WSPs or a project loan of the ESCO, or a combination of both.

While there are plenty of options that can be explored, there is no fits-all solution to the problem facing the WSPs. Each of these options needs to be evaluated, taking into account the specific objectives of the WSPs. These objectives may include raising finance, making use of private sector management skills and expertise, and improving service to the public. Trade-offs between these objectives are almost always necessary. The optimal route is usually the strategy that minimizes these trade-offs.

11.0 CONCEPT OF AN ENERGY MANAGEMENT CELL

Several energy management programs have been initiated in the industrial and commercial sectors in the Philippines. However, they have not been sustained due to lack of expertise and resources. The concept of the energy management cell can be introduced and supported in order to sustain energy management programs and activities, thereby sustaining the efficient use of energy.

The creation of energy management cells (EMCs) has been supported by The Alliance to Save Energy and the United States – Asia Environmental Protection (US-AEP) as part of their overall capacity building efforts in water utilities. This EMC serves as an important catalyst in implementing energy efficiency concepts in both water supply and treatment infrastructure and streetlighting infrastructure. Below is the process involved in establishing an EMC as well as an overview of the activities that may be undertaken.

11.1 SETTING UP AN ENERGY MANAGEMENT CELL: THE PROCESS

An EMC should initially comprise of at least two engineers - one a mechanical engineer and the other an electrical engineer. These skill-sets are required as the energy audit process requires electro-mechanical technical capability. Experience with pumping, electric motors and treatment operations in the water sector is ideal. It is essential that the EMC personnel possess strong leadership, good communication and managerial skills.

11.2 ACTIVITIES OF EMC'S

The EMC will serve as the resource center for water utilities and the EMC personnel will be responsible for initiating and carrying on the broad range of activities described below:

11.2.1 EMC AND ITS INTERACTION WITH WATER UTILITIES

The EMC personnel will educate municipal water utilities on the benefit of taking advantage of untapped energy efficiency opportunities in municipal water systems.

- The EMC should organize regular seminars to disseminate the concept of energy efficiency to all water utilities.
- The EMC should guide the interested/short-listed water utilities to contract with the appropriate technical consultants/ESCO's to undertake energy audits (walk-through and field study) within their premises. The EMC can also assist in preparing tender/bid documents for the procurement of energy efficiency goods and services, evaluate the technical expertise and capabilities of interested consultants and ESCOs. EMC's should eventually be prepared to work with the water utilities guiding them through the process of signing performance contracts.
- The EMC will direct the water utilities to the suitable financial institution/agency/ state department for implementing energy efficiency measures.
- The EMC should supervise the energy audits at municipalities and also provide

training to local staff in energy efficient O&M practices.

- The EMC should facilitate discussions between the water utilities and technical consultants in understanding the recommendations made in the energy audit reports.

- The EMC should also oversee monitoring and verification of the implemented projects.

11.2.2 NETWORKING ACTIVITIES

An important activity of the EMC is to engage the interest of the following groups in promoting energy efficiency in the water utilities:

- The EMC personnel should also involve the participation of the people at the municipal level (Mayor, Commissioner, City Engineers) and State-level (Water and Electricity Boards, Urban Development Department, Local Government Units, Department of Finance) and other related agencies.

- The EMC with support from the above mentioned departments will be able to lobby for policy changes that promote the clean and efficient use of energy.

- The EMC will also liaise with appropriate national and international level institution and agencies as required, to identify technical assistance and funding that can serve client water utilities

11.2.3 KNOWLEDGE SHARING ACTIVITIES

The EMC should be aware and be updated on the energy efficiency programs and implementation measures being undertaken by the government. The EMC should actively liaise with EMCs stationed in other areas to exchange information.

11.2.4 OTHER POSSIBLE ACTIVITIES

- The EMC can explore the possibility of setting up a "Revolving Fund" to initiate and fund energy efficiency activities.

- The EMC can set up an online system to track and monitor energy use and water supply system efficiencies by municipalities. This will help in keeping a regular check and in suggesting measures that can be commonly applied to all municipal water utilities.

Fig. 11.1 Knowledge Sharing and Networking Activities.

12.0 CONCLUSION

Energy is indeed necessary for moving water through water utilities, making water potable and safe for drinking purposes, and removing waste from water. Each liter of water moving through a system represents a significant energy cost. Water losses in the form of leakage, theft, consumer waste, and inefficient delivery all directly affect the amount of energy required to deliver water to the consumer. Wastage of water regularly leads to a waste of energy.

Through its Watergy program, the Alliance to Save Energy, with funding from the United States Asia Environmental Partnership (US-AEP), a program of the U.S. Agency for International Development (USAID), has shown and demonstrated to its water utility partners in Iloilo and Cebu the importance of introducing energy efficiency in their operating system. During the start of the project, the water utilities in Cebu and Iloilo were facing severe water resource scarcity and disproportionately high electricity costs caused by water pumping in both cities. By improving the efficiency of the existing pumping systems within their municipalities, resources were put to more productive use while municipal budgets can be better allocated through reduced pumping costs.

The goals of the program were clearly attained. Improvements in the overall system efficiency in water utilities such as MCWD and MIWD, reducing costs and negative environmental impacts, while expanding water and wastewater services to the country's underserved populations were achieved. The capacity of municipalities, water utilities, companies and NGOs focused upon urban infrastructure development to develop a comprehensive strategy to work on identifying the potential for energy savings from this often overlooked sector was strengthened.

The Alliance in coordination with ENMAP and UP have created a guidebook on energy audits for water districts in the Philippines, to continue to spread the heightened level of awareness and interest in energy and water savings to all Filipino water districts.

This guidebook highlights the various steps involved in conducting an energy audit in water utilities. It specifically discusses the assessment of the three primary energy consuming facilities, namely a) pumps, b) electric motors, and c) transformers. The mathematical equations required for the computation of energy efficiencies is provided. It also includes a brief discussion on advanced retrofits and advanced technologies.

In the two case studies presented, the energy and cost savings potential in each water district is clearly outlined to serve as "real time" examples.

In addition to this, the guidebook also includes a discussion on financing opportunities to assist water districts in the identification of financing options to implement their energy conservation projects. A chapter on how water utilities can start their own energy management program and how they can sustain this through the creation of energy management cells is also included.

It is hoped that this guidebook can assist the water utilities in reducing their energy consumption, increase their productivity and help mitigate environmental impacts.

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