Scientia Africana, Vol. 10 (No. 2), December, 2011, pp 105 - 123
 ISSN 1118 - 1931

CONSERVATION OF ELECTRICAL ENERGY IN A PETROCHEMICAL INDUSTRY IN NIGERIA

Ibe, A.O. and Yorkor, B.
Department of Electrical & Electronics
Faculty of Engineering
University of Port Harcourt

Received 8 – 6 – 10
Accepted 4 – 5 – 11

ABSTRACT

The petrochemical industry is generally energy intensive and electrical power energy forms one of the major sources of energy. A survey was carried out to gather data relating to electrical energy generation and consumption in the petrochemical plant. Electrical power consumption varies widely among the many processes. The technological and economic viability of advance control and power technology systems in the petrochemical industry is evaluated. Findings revealed that ***42 percent*** *of the daily power generated amounting to* ***27.6 Mega Watt*** *is wasted.*

A conservative projection calculated from plant documentation and computer simulation of processes shows that the industry has the potential to save ***133943.11 Mega Watt*** *of electrical power per annum. This is capable of supplying un-interrupted electricity for all the communities in its area of operation in a year. A model for effective management of electrical power for the petrochemical industry is presented. The petrochemical industry can achieve system reliability, higher productivity, reduce energy cost, and reduce down time and maintenance costs through proper conservation of electrical power.*

Key words: Petrochemical industry, Control technologies, Power technologies, Electric motors, Energy efficiency, Power Factor.

INTRODUCTION

Conservation of electrical energy is an essential step we can all take towards overcoming the mounting problems of the worldwide energy crisis and environmental degradation.

The petrochemical industry is generally energy intensive and electrical power energy forms one of the major sources of energy for the industry. The Petrochemical process involves series of energy conversion. For instance electric machines convert electrical energy into mechanical energy; process heaters convert electrical energy into heat energy and so on. In the process of energy conversion, energy losses occur resulting in waste of electrical energy. The petrochemical industry utilizes the energy in Feedstock (used as catalyst along with the raw material. Energy use in the petrochemical industry is split almost evenly between in-plant heat and power, and feedstock energy for production of plastics and other petrochemical products (Rao and Parulekar, 2004). Energy consumption varies widely among the many processes used to produce finished products. The petrochemical industry therefore offers several Energy Conservation Opportunities.

According to Hickok (1979a), today's power system engineers in the petrochemical industry are perplexed by the pressure to do something about wasted energy. There is the need to know where losses exist in system components, how to measure them and what the theoretical savings are and what can be done about them. The know-how on modern energy-saving and conservation technologies should therefore be disseminated to industrial managers, as well as to engineers and operators at the plant level. It is particularly important that they acquire practical knowledge of the currently available energy conservation technologies and techniques (ECC, 1994).

MATERIALS AND METHODS

The data gathering approach used in this study evolved substantially as practical as possible. The methodology adopted is based on the EPRI (2006) research methodology of some petrochemical industries in the United States of America. A survey was carried out to gather data relating to electrical energy generation and consumption in the petrochemical plant. The electrical engineers, plant operators and production managers provided some useful data. A survey was developed that addressed the effectiveness of control and power technologies in the petrochemical industry. A qualitative calculation of specific electrical power losses was carried out to assess areas where substantial power could be saved. The electrical engineers provided data on industrial motors, while engineers in the control room provided data on control technology used in the industry. Important contributions to data gathering were from one-on-one conversations and not limited only to research fact sheets gathered from the respondents.

Motor losses were computed using published loss data on industrial motors (Hickok, 1979a). Total petrochemical costs and savings were developed using published statistics (DoE, 2003b) in conjunction with the projected improved conversion efficiency expected from the implementation of advanced control and power technologies (EPRI, 2006).

Efficiency is defined according to API (1999) as the ratio of power output to power input or energy output to energy input.

$$\text{Efficiency} = \frac{\text{Power output}}{\text{power input}} \text{ or } \frac{\text{Energy output}}{\text{Energy input}} \quad (1)$$

Power output can be related to power losses in equipment by the following:

$$\text{Power output} = \text{Power input - Power losses} \quad (2)$$

Therefore, efficiency can be defined in terms of losses and power input as follows.

$$\text{Efficiency} = \frac{\text{Power input - losses}}{\text{Power input}} \text{ or } = 1 - \frac{\text{losses}}{\text{Power input}}$$

or in terms of losses and power output

$$\text{Efficiency} = 1 - \frac{\text{losses}}{\text{Power output} + \text{losses}}$$

All the above formulae can be applied to energy by substituting kWh for power. In either case, higher efficiency is achieved by reducing operating losses.

Type of Losses of Electrical Energy

Every energy conversion is accompanied by exchange of certain heat with the surroundings. When useful energy is converted to work, some energy is lost into the environment. Hickok (1979a) identified two major causes of wasted electrical energy in the petrochemical industry namely:

(i) Energy lost in power system components;

(ii) Using energy in operation where it is not needed.

Thermal losses

Most of the energy wasted occurs in converting fuel into mechanical energy before it gets to the input shaft of the generator. Low thermal cycle efficiency inherent in gas and/or steam turbines account for about two out of every three Btu's of energy burned into the stack, into cooling water

Scientia Africana, Vol. 10 (No. 2), December, 2011, pp 105 - 123
© Faculty of Science, University of Port Harcourt. Printed in Nigeria *ISSN 1118 - 1931*

or otherwise becoming unavailable for conversion to electrical energy (Hickok, 1979a). The only exception in these losses is where heat (or steam) is needed for the process. Thermal losses according to Hickok (1979a) account for the bigger percentage of lost energy. A large modern utility power plant has a thermal efficiency of about 36%. Table 1 shows the order of magnitude of efficiency of most industrial power plant generators (Hickok, 1979a).

Table 1: Thermal efficiency in power generation

Prime Mover	Thermal Efficiency (%)	Energy Lost (%)
Gas Turbine:		
1. Simple	24 – 30	70 – 76
2. Regeneration	28 – 36	64 – 72
Steam Turbine	25 – 35	65 - 75
STAG (steam and gas turbine combined)		
1. Unfired	30 – 45	55 – 70
2. Fired	50 – 60	40 - 50

Source: Hickok (1979a)

Electrical Losses

Electrical losses according to Hickok (1979a) vary over a wide range depending on complexity of power system, the geographical area, and the kind of plant process involved. Electrical power losses occur in small amounts, sometimes in small fraction of a percent. Though they are to be found scattered across a power system, they tend to be located toward the utilization equipment end. Table 2 is a list of the major components in power system and the range of losses associated with them (Hickok, 1979a).

Percentage electrical energy loss is determined as the ratio of power consumed internally in equipment to the total energy passed through it. The energy loss generally ends up as heat to be dissipated, the only exception is rotating machine where windage is a factor.

Table 2: Range of losses in power system Equipment

Equipment/Component	% Energy Loss (full load)
Outdoor circuit breakers (15 – 230 kv)	0.002 – 0.015
Generators	0.09 – 3.50
Medium voltage switchgear (5 – 15 kv)	0.005 – 0.02
Current limiting reactors (600v – 15kv)	0.09 – 0.30
Transformers	0.40 – 1.90
Load break switches	0.003 – 0.025
Medium voltage starters	0.02 – 0.15
Busway (480v and below)	0.05 – 0.50
Low voltage switchgear	0.13 – 0.34
Motor control centers	0.01 – 0.40
Cable	1.00 – 4.00
Motors 1 – 10 hp 10 – 200 hp 200 – 1500 hp 1500 hp and above	 14.00 – 35.00 6.00 – 12.00 4.00 – 7.00 2.00 – 4.50
Rectifiers (large)	3.00 – 9.00
Static variable speed drive	6.00 – 15.00
Capacitor (watt loss/var)	0.50 – 2.00
Lighting (lumens/watt)	3.00 – 9.00

Source: Hickok (1979a)

The wide range of electrical losses for various kinds of power system components is responsible for the large variation of overall percentage plant losses (Hickok, 1979a). Loss data on major plant electrical equipment have been presented (Hickok, 1979a). These data have been calculated or gathered from various product groups. They are based on rated load flowing through the equipment. These data are representative data to give an estimate of equipment energy losses. Electrical energy loss is measured as a function of time (i.e. Watt-hours).

Operation losses

Operating losses involve electrical energy wasted in performing useless work in work places. They include indoor and outdoor lights, air conditioning and heating blowers that burn all day and are not turn off either manually or automatically. These are generally much easier to find and eliminate. Real saving could be

Scientia Africana, Vol. 10 (No. 2), December, 2011, pp 105 - 123
 ISSN 1118 - 1931

achieved by operating these equipments only when needed. In a petrochemical plant real energy savings are in the process operation and could be achieved with close coordination with process engineers.

Advance Control System and Power Technology

Control using throttling valves presents special performance issues for petrochemical plants because there are stringent monitoring and correction requirements for throttling valves in place. This calls for frequent maintenance and hence increased operational cost.

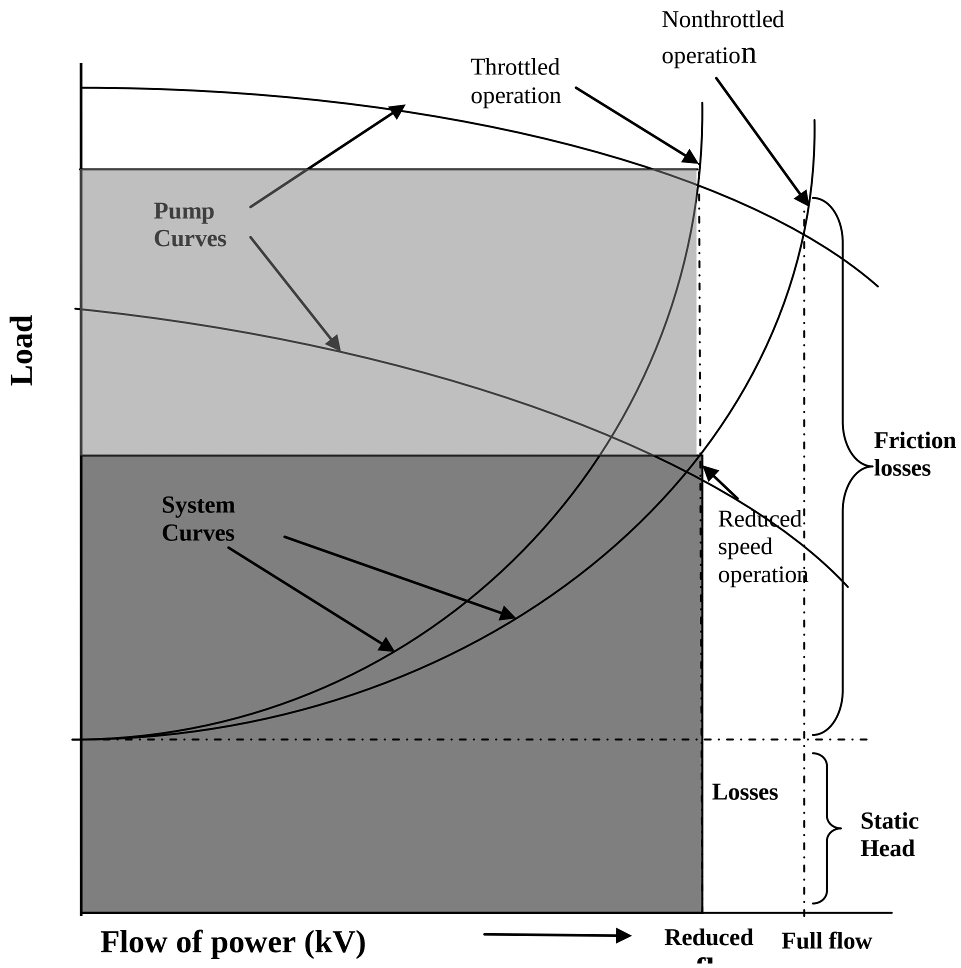
Control valve stems are a major source of fugitive gasses. To minimize this problem the valve stem packing is tightened down. The control schemes associated with this require 0.25% to 0.5% accuracy (EPRI, 2006). Sticking valve stems prevent this. Advanced power control could alleviate the problem. There is an understanding that real energy benefits can be achieved by using advanced control and there is a perception that the challenge to be faced is not technology itself but rather operator (EPRI, 2006).

Adjustable Speed Motor Control

Centrifugal pumps, fans, and compressors constitute a large percentage of the motor driven loads in the petrochemical plant. The torque requirements of these centrifugal loads vary as the square of the speed; thus, the brake horsepower required varies as the cube of the speed (API, 1999). Centrifugal loads have been designed to operate at constant speed with the process flow being controlled by some type of throttling means. The energy losses from throttling are very substantial up to 547.5 MW as computed in section 8(3).

As an alternative to throttling, the speed of the centrifugal load can be controlled using speed adjustment motor control to obtain the desired flow rate without producing excessive pressure. Because the flow rate varies directly with speed while the horsepower requirement varies as the cube of the speed (API, 1999), using speed reduction to lower flow rates will results in a significant horsepower reduction.

A typical pump head-flow curve is shown in Figure 1 (API, 1999) to demonstrate the attractiveness of using speed adjustment to control flow rate. The darker-shaded area to the lower left of each operating point indicates the power required for that operating point. The lighter-shaded area indicates the power savings that result from using adjustable reduction rather than throttling to control flow rate.



Source: API (1999)

Figure 1: System Energy Losses:
Adjustable Speed versus Throttling

RESULTS

Data obtained from plant documentation and computer simulation of processes are presented as follows: A plot of sources of electricity in the petrochemical plant is shown in Figure 2. The distribution of electrical power generated in the plant is shown in Figure 3. The daily power consumption in the petrochemical plant is shown in Figure 4. From the curve the points of minimum and maximum consumption for various output levels are identified. Monthly power consumption by each sub-system of the petrochemical plant is shown in Figure 5. Figure 6 shows electrical losses associated with use of poor factor in the industry.

Scientia Africana, Vol. 10 (No. 2), December, 2011, pp 105 - 123
© Faculty of Science, University of Port Harcourt. Printed in Nigeria *ISSN 1118 - 1931*

Figure 2: Sources of Power Supply

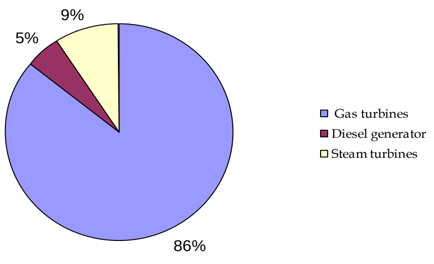
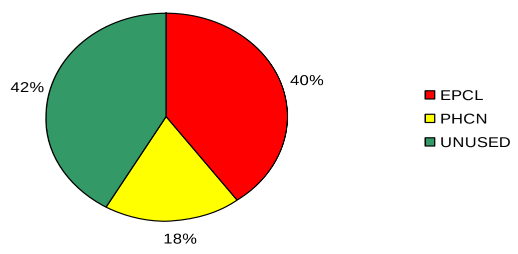


Figure 3: Percentage Distribution of Generated Power



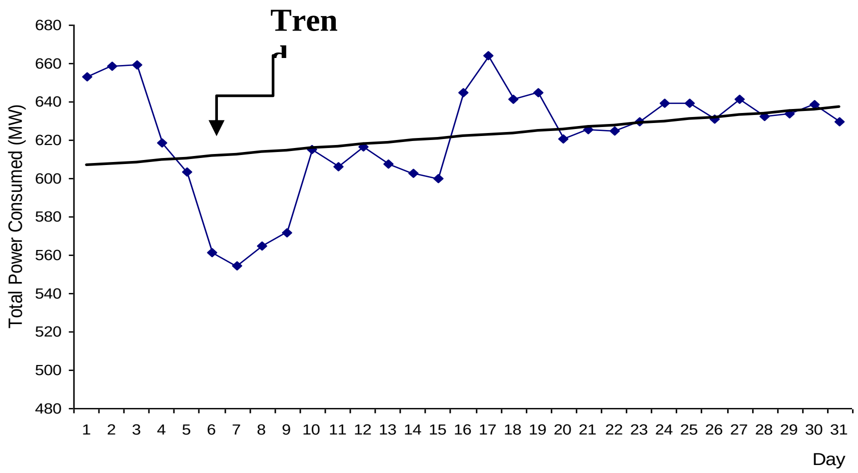


Figure 4: Typical Daily Electrical Load Demand Curve in petrochemical plant

Average	=	621.8 MW
Maximum	=	663.9 MW
Minimum	=	554.3 MW

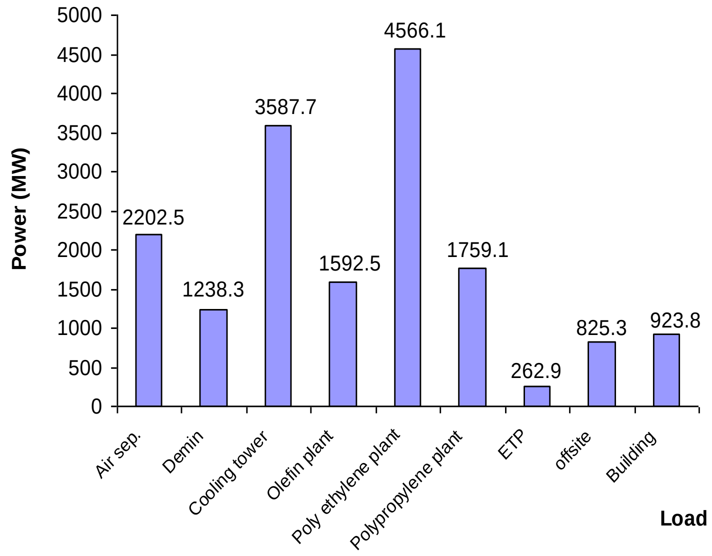


Figure 5: Consumption of Energy in an industrial process

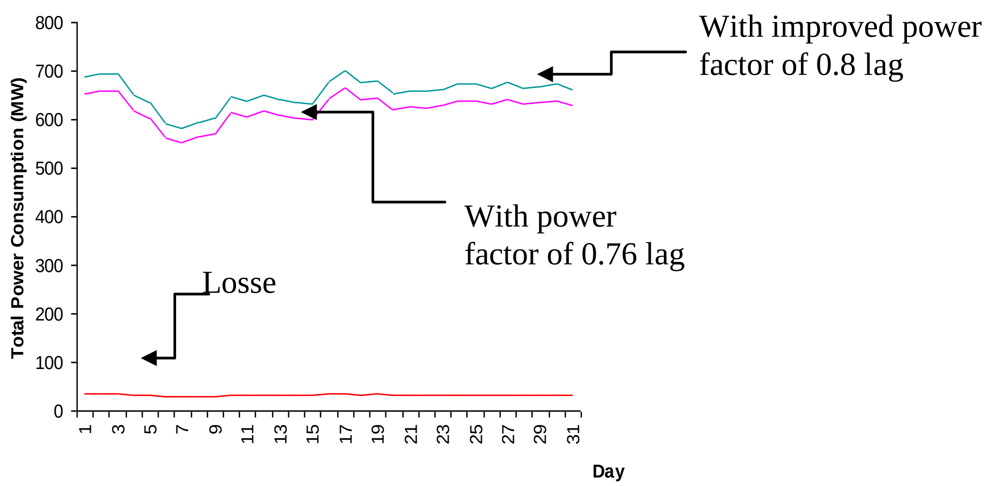


Figure 6: Daily Losses associated with poor power factor in a petrochemical plant

Scientia Africana, Vol. 10 (No. 2), December, 2011, pp 105 - 123
© Faculty of Science, University of Port Harcourt. Printed in Nigeria *ISSN 1118 - 1931*

Computation of Electrical Power Losses and Savings in the Petrochemical Plant

A qualitative computation of electrical power losses and savings in the petrochemical industry based on the EPRI (2006) research methodology of some petrochemical industries in the United States of America is presented as follows.

Loss in the electric motor driven systems

Majority of electric motors used in the industry are the range of 100 hp and above.

Motor loss from Hickok (1979a) is in the range of 4% - 7%

Motor loss (assume 6%) = (6% of 26.4 MW) = **1.58 MW per day**

Annual savings = 1.58 x 365 = **576.7 MW**

Current Power Holding Company of Nigeria (PHCN) charge per kilo Watt-hour for industry is **N8**.

Potential savings from electric motors system per year is therefore

1.58MW x 10^3 x 8 x 365 = **N 4.61 million per year**

Loss in pump equipment

Pump loss, from PSAT (DoE, 2003a) is in the range 25%-40%

Pump loss (Assume 25%) = 0.25 x (26.4 MW – 1.58 MW) = **6.21 MW**

Potential electric power savings in pumps **= 6.21 MW per day.**

Annual savings = 6.21 x 365 = **2266.65 MW**

6.21 x 10^3 x N 8 x 365 = **N18.13 million per year**

Potential for energy savings in throttle

Calculating the potential for energy savings that could be made from eliminating throttle loss with the implementation of advanced power control technology:

Throttle loss, from EPRI (2006) research is in the range 20%-50%,

Throttle loss (Assume 20%) = 0.20 x (26.4 MW – 1.56 MW – 6.21 MW) = 3.73MW.

Savings in throttle = 3.72 MW

From the study of the petrochemical complex, 80 % of the electric motors were throttled.

Assume that there is a 50 % penetration rate of drives displacing throttle losses (EPRI, 2006). Potential for savings for the petrochemical complex = (3.72 MW) (throttle loss) x (0.5) (penetration rate) x (0.8) (proportion of motors presently throttled) =**1.49MW**

Thus, the petrochemical plants would save potentially **1.5 MW per day.**

Annual savings = 1.5 x 365 = 547.5 MW

Potential savings from throttle losses at the plant = 1.5 MW x 365 x N8 = **₦4.38 m /year**

Assume that there is 100% penetration rate of drives replacing throttle losses with advanced power control.

Potential savings for petrochemical industry (assuming increase from 50% to 100%) =1095MW = N4.38 x 2 = N **8.76 million** per annum.

Lighting equipment

Data from field survey of the Petrochemical plant revealed that an average of **614 kW of electricity is wasted per day in lighting Equipment.**

Potential saving in one year for lighting equipment in the petrochemical plant would therefore be **614kW x 365 = 224.11 MW**

Current PHCN charge per kilo Watt-hour for industry is **N8**.

Potential savings from lighting system per year is therefore 224.11 x 10^3 x N8 = **N 1.79 m**

Power Factor Correction

Result of improvement on power factor from 0.76 lag to 0.8 lag is shown in Figures 7.

The Monthly power loss (for power factor at 0.76 lag) is calculated to be 1014.5 MW.

Potential annual savings = 1014.5 x 12 = 12174 MW per year. This power loss represents the electrical power that could be conserved by improving the power factor to 0.8 lag.

Potential annual savings at N8 per kWh = **N97.39 million**

Electrical Power Savings on the Use of Advanced Control Systems

In order to extrapolate from petrochemical data collected during the study, two reference documents were used: a recent energy balance for chemical plants (DoE, 2003b) and information published in the OIT/ Profiles and Partnerships.

From DoE (2003b), it is possible to calculate the energy delivered as utility supplies to operate all of chemical plants and convert this energy to equivalent power.

Data obtained indicate that the petrochemical complex consumed an estimated total of **19,274.6 MW** per month or **231,295.2 MW** per year. Thus, the petrochemical plants are potential candidates for the implementation of advanced control and power technologies.

Plant energy input

Natural gas turbine power generation =66 MW

Maximum daily demand by the complex is put at **26.4 MW**

Supply to Power Holden Company of Nigeria, PHCN, is given as **12 MW**

Total daily power demand is therefore **38.4 MW**

Unused is 66 MW – 38.4 MW = **27.6 MW. This amount of electrical power is wasted on a daily basis.**

From above, the total power supplied to the petrochemical plants **= 66 MW**

From survey information received from one respondent in the petrochemical plant, the electric power consumed in the plant per day = 26.4 MW.

From respondent information, the internal loss in a typical petrochemical complex can be assumed to be 20% of the calorific value of the fuel used.

From Figure 3, process energy used in the petrochemical industry is estimated to be 5.4 million MWh per year.

Extrapolating from the DoE (2003b) case study, the total energy can then be calculated by estimating the losses.

Losses are equivalent to 20% of energy used (EPRI, 2006), therefore,

Losses = 5.4 million MWh x 0.2 (20%) per year = 1.1 million MW h per year

Hence for the petrochemical industry, the potential for energy savings using advanced control systems = 1.1 million MWh per year x 0.1 (10%)

Potential for Energy Savings = 0.11 million MWh per year = (0.11 million MWh per year / 8,760 hours per year) W per hour **= 12.6 WM per hour**

Potential Energy Savings per year **= 12.6 x 8760hours = 110376MW**

Potential Value of the savings calculated at Eight Naira (N8) per kWh = 110376 x 10^3 x N 8.00 **= N883 million per year**

Findings revealed that 27.6MW (42%) of the 66MW generated daily are wasted. Amount of electrical power that would be save per year is 365 x 27.6 = **10,074MW**

Potential energy saving per year is 10074 x 103 x N8.00 = **N80.592million**

For the petrochemical company, the savings from advanced control are hereby predicted to be 110376MW. This is equivalent to an annual saving of **N883 million** (at PHCN power cost of N8 per kWh.)

A summary of savings/benefits of this analysis, as applied to the Petrochemical Industry is given below, assuming 100% control, 100% power penetration and improvement of power factor from 0.76 to 8.0lag:

1. Annual energy procurement would be reduced by **N883million;**
2. Annual hydraulic power consumed would be reduced 1095MW, which is equivalent to **N8.76million;**
3. Annual lighting power consumed would be reduced 224MW which is equivalent to **N1.79million;**

Scientia Africana, Vol. 10 (No. 2), December, 2011, pp 105 - 123
© Faculty of Science, University of Port Harcourt. Printed in Nigeria *ISSN 1118 - 1931*

4. Annual saving on improved power factor from 0.76 to 0.8lag is **N97.39million**;
5. Annual saving on wasted power (42% of generated power) is **N80.592million**

Hence, total annual cost of electrical power would be saved is **N1.071 Billion.**

The above calculations show the potential amount of electrical power that could be conserved in the petrochemical industry in a year. Further real benefits for the petrochemical industry will be derived from reduced waste heat and improved yields through better process control, when advanced control is introduced.

Potential savings in energy in a year are measured as an improvement of **110376 MW** for control and an improvement of **12174 MW** for power factor, **224.11 MW** for lighting, **1095 MW** for throttles and the utilization of **10074MW** wasted power. This is equivalent to eliminating, and thereby saving **133943.11MW** of generated power which can be made available for use elsewhere. This would provide a predicted total annual savings for the petrochemical industry of **N1.071 Billion**. This is the same as a continuous electricity supply for all the communities in its area of operation in a year.

DISCUSSIONS

Electrical Power Management System for the Petrochemical Industry

Energy management is an important management function of every organization. Energy management costs are recovered and turn into perpetual savings through energy conservation. For effective electrical power management in the petrochemical industry, the organization must have a written Energy Management Policy Document. The top management must be committed to implement the energy policy. The energy objective must be known to every executive and supervisor as well as plant managers. The energy must be monitored vis-à-vis the production.

The role of Energy Management is to plan and monitor energy supply and effective consumption for sustaining and achieving:

- Essential activities
- Higher productivity
- Higher standard of living

Usable energy must be managed by supply side management and user side management.

Usable energy saved is energy gained, energy saved is financial gain. Energy wasted is a financial loss. Energy wastage can be avoided by attention and corrective actions in the plants/equipment. The corrective actions are planned for reducing the gap between target energy consumption and the actual energy consumption. These action plans should include:

- Energy conservation measures.
- Improve power factor correction capacitors
- Improve process by retrofitting.
- Modernization of the plant by introducing energy efficient controls processes.
- Energy efficient process: the consumption of input energy forms are held at near target levels for each prevailing load by means of Automatic Computer Aided Process Control.

Organization for Electrical Energy Management

The organization Chart of an electrical power supply/demand indicates the way in which the Authority is distributed and designated to carry out the organization activities. Organization is not the end in itself but provide means to achieve set energy objectives.

The organization structure is built by listing essential activities, grouping the activities, deciding the responsibilities, providing interface between the groups. The organization chart shows a block diagram with hierarchical levels of authority, delegation and interfaces. The organization will depend upon the size and complexity of the plant and activities.

For a large energy intensive plants such as the petrochemical plants, the energy manager report to the plant manager and may hold an independent charge of Energy Management Group responsible for Energy Engineering, Technical Documentation, Testing, monitoring, Energy Conservation, energy Audit etc. Figure 7 is an example of organization Chart suitable for the petrochemical industry.

A knowledgeable and experienced Energy Consultant may be engaged for providing technical and management inputs.

Effective Energy Management includes:

- ❖ Enterprise Monitoring. Manage the facility's energy usage through meters and software to identify savings opportunities.
- ❖ Reduce energy consumption and save money by controlling loads.
- ❖ Energy-Efficient Devices.
- ❖ Conserve energy through installation of energy-efficient devices.

Scientia Africana, Vol. 10 (No. 2), December, 2011, pp 105 - 123
© Faculty of Science, University of Port Harcourt. Printed in Nigeria *ISSN 1118 - 1931*

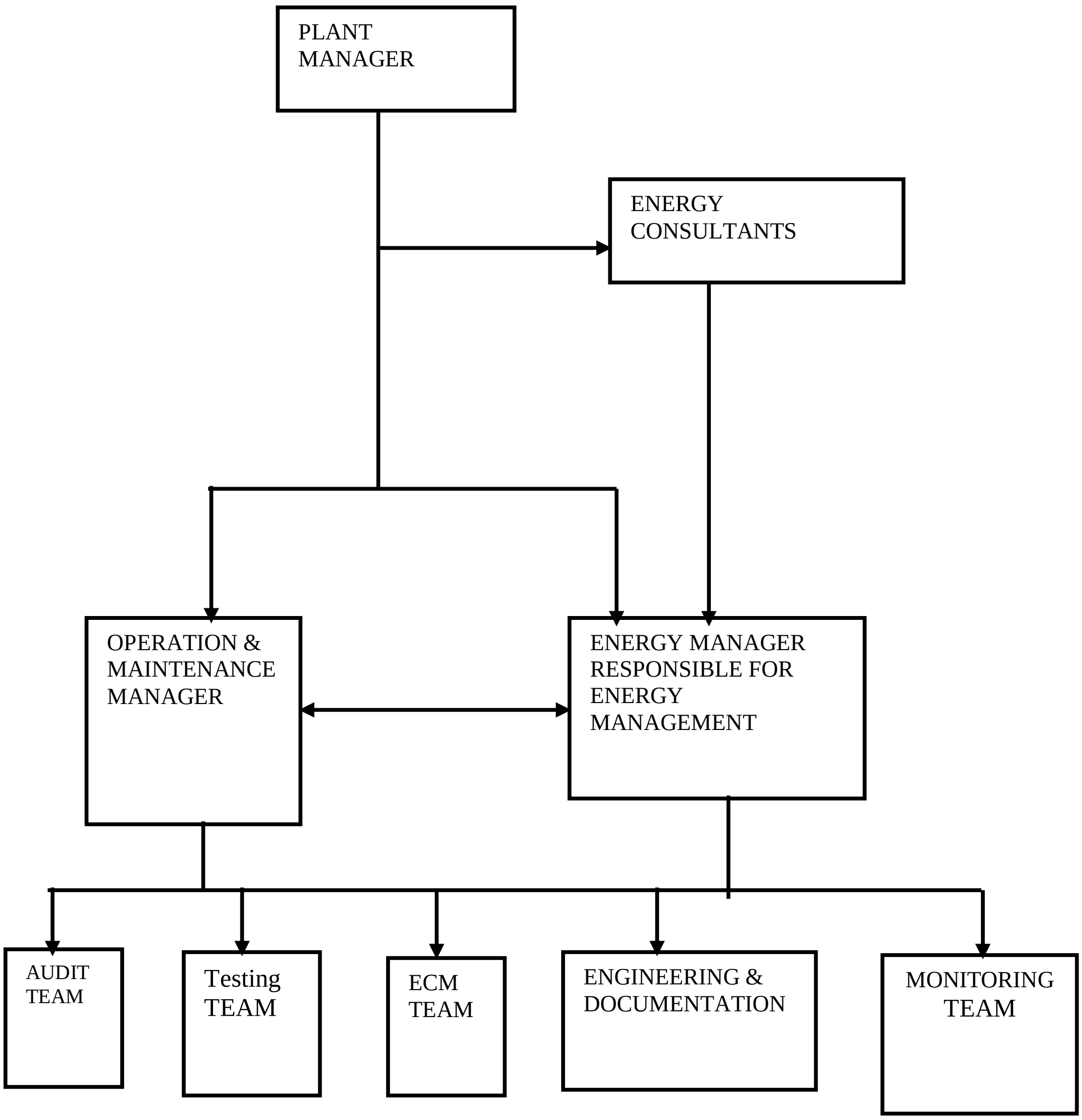


Figure 7: Organization chart for energy management of petrochemical industry

Managing Lighting Equipment

Although lighting does not represent a major percentage of the electrical energy consumption of the petrochemical plant, it nonetheless provides another area where energy savings can be achieved. The following measures can results in an energy efficient system:

- Use the high efficiency (lumens per watt) lamp that is capable of directing light to the task area.
- Switch off lights when not required (e.g. end of day work)
- Replace all incandescent lamps with fluorescent lamps
- Install automatic computer lighting control system. Automatic lighting control of lights (Lights are switched off at sunrise and switched on at sunset).
- Use solar panels for security/street lightings.
- Automatic thermostat control of water heaters
- Use solar panels for water heaters
- Timer with on/off switch. Such a control system may be adopted for lighting system, HVAC (heating Ventilation, Air Conditioning) systems for energy conservation without sacrificing quality and comfort.
- Practice Good House Keeping.

Power Factor Correction

Improving power factor by installing capacitors near load points is an electrical conservation opportunity.

The total current passing through the power system components (e.g. cables, switchgears transmission lines) produces heating losses proportional to the square of the current (I^2R) Theraja & Theraja (2005). The total current is proportional to the kVA, so by reducing kVA, losses can be reduced. To reduce kVA, it is only practical to cut exciting energy (kVar). In addition to wasting energy through transmission losses, excessive kVar loading uses up transformer, cables and transmission lines capacity, causing the supplying utility to overbuild their system. To control this, utilities pass on the excess cost through the use of power factor penalty clause in power contracts API, 1999).

The large number of induction motors in the petrochemical plant result in a low overall power factor on the system (0.76 lag). Motors that are lightly loaded accentuate the problem because motor power factor decreases rapidly with decreasing load (API, 1999). The low power factor results in higher than necessary current on the distribution system, resulting in higher losses. Improving the power factor will increase the overall efficiency of the power system of the plant. An improve power factor can also reduce or even eliminate power factor penalty charges if utility contracts contains such provisions. Figure 6 shows electrical losses associated with poor power factor in plant operation.

The following actions can therefore be adopted to increase power factor and reduce the associated losses:

1) Use of high power factor rated equipment, such as high power factor lighting ballasts.
2) Use of synchronous motors which can be operated at unity or leading (capacitive) power factor.
3) Operating high efficiency induction motors at close design horsepower.
4) Use of power factor correction capacitors (see Figure 8) to supply the reactive requirements of inductive loads.
5) Increase the excitation from in-plant generators.
6) Installing a static Var compensator.
7) Controlling voltage so as to avoid overvoltage conditions.

Figure 8 illustrates where correction capacitors can be installed in the petrochemical distribution system.

Scientia Africana, Vol. 10 (No. 2), December, 2011, pp 105 - 123
© Faculty of Science, University of Port Harcourt. Printed in Nigeria *ISSN 1118 - 1931*

Induction motors on low loads, induction furnaces, ballast of tubes lights, transmission lines on low loads etc derives lagging power factor currents and therefore the power factor of various loads is generally poor (below 0.8 lag).

Cost Consideration for Equipment Upgrade
Simple Payback

The least equipment cost per-kilowatt factor is based on simple payback, which does not account for the depreciation value of future savings. The cost per kilowatt as contained in API (1999) is given as:

$$Cost/kW = ChN(1-T) \qquad 7$$

Where

Cost/kW = profit to the user for reducing power usage by 1 kW.
C = cost of electricity in Naira per kWh.
h = hours of operation per year.
N = number of years in evaluation period.
T = income tax rate paid by the user.

This factor is the expected cost for continuously operating a load of one kW for N number of years.

The use of the factor is illustrated in the following example. Assuming an industrial electrical equipment operates continuously in Nigeria where the PHCN charge per kilo Watt-hour for industry is **N8**, and the desired payback period is 5 years. Income tax is assumed to be 20% rate. The factor would be computed as follows:

$$Cost/kW = \frac{N8}{kWh} x \frac{8760h}{yr} x 5yr \ x\left(1-0.2\right)$$

$$= \text{N280,320/kW}$$

This amount is the expected cost for continuously operating a load of one kW for 5 years in a petrochemical industry in Nigeria. This cost factor is then compared to the ratio of the price premium for the high efficiency equipment divided by the loss reduction. If the ratio is less than N280, 320 then it pays to spend money for the high efficiency equipment. For instance, if an energy efficient equipment costs N800,000 more than a standard equipment, and it reduces losses by 10kW, the incremental cost is (N800,000/10kW) or N80,000. The energy efficient equipment should be selected.

Time Value of Money

Equation (7) does not take into account the time value of money. Future savings should be adjusted for increases in power costs and the required cost of capital. The following equation API (1999) provides a cost per-kilowatt factor that allows for power cost inflation and desire rate of returns on investment.

$$Cost/kW = Ch(1-T)\frac{1+i^{N}-1}{i(1+i)^{N}} \qquad 8$$

Where

Cost/kW = Profit to the user of reducing power usage by 1 kW.
C = cost of electricity in Naira per kWh.
H = hours of operation per year
N = number of years in evaluation period
T = income tax rate paid the user.
I = effective interest rate.

But $i = \frac{1+R_2}{1+R_1} - 1 \qquad 9$

R_1 = anticipated annual inflation rate for cost of electricity.
R_2 = desired annual rate of return on investment.

Equation (8) is a useful way to include time value of money and is suitable for most economic evaluations of energy efficient improvements.

An economic evaluation using equations (7) and (8) is required by the industry to determine if the potential energy savings offset the increased costs of installing new equipment.

Scientia Africana, Vol. 10 (No. 2), December, 2011, pp 105 - 123
© Faculty of Science, University of Port Harcourt. Printed in Nigeria *ISSN 1118 - 1931*

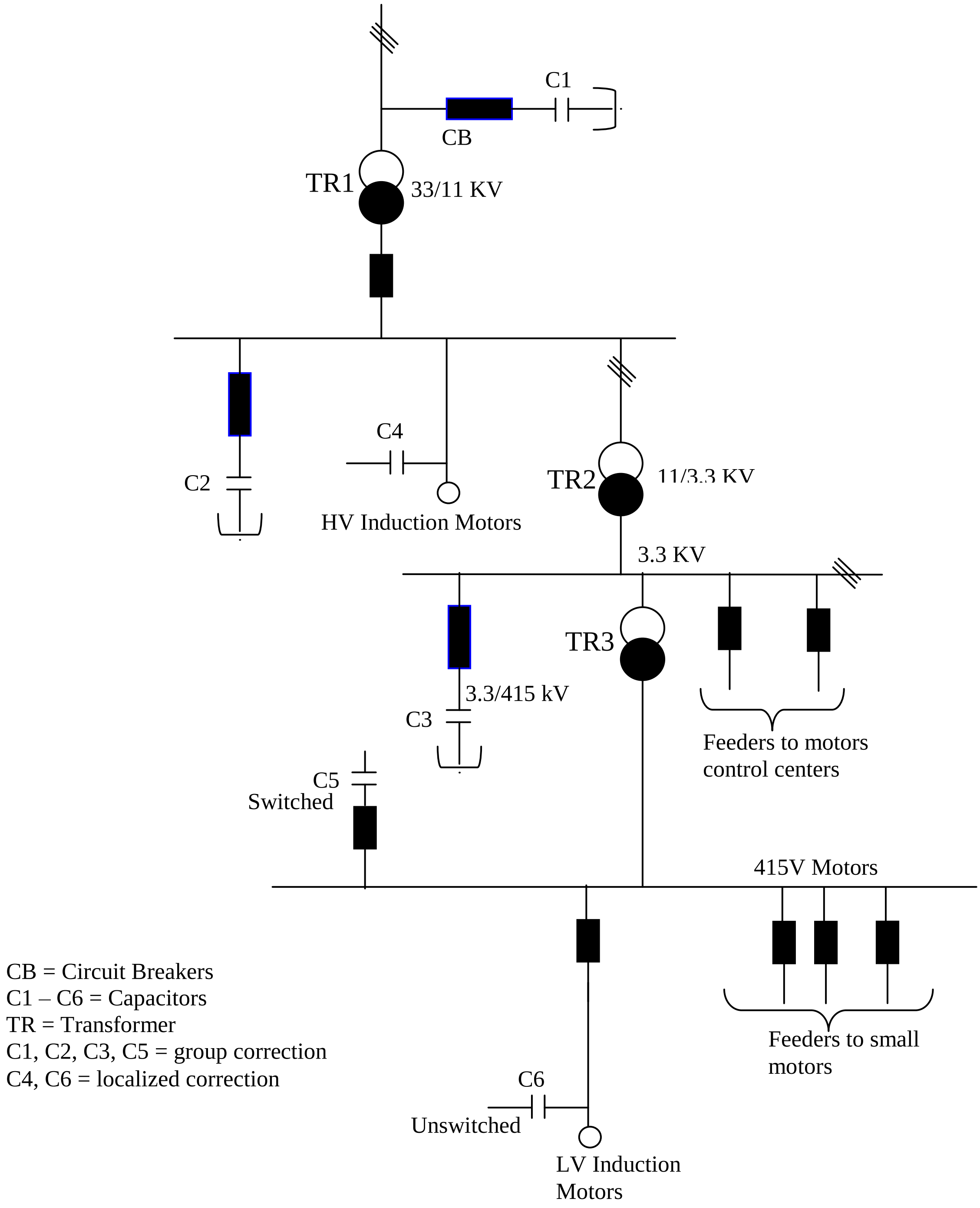


Figure 8: Location of power factor capacitors in distribution system

CONCLUSION

- The petrochemical industry has the potential to save electrical power capable of supplying electricity to all the catchment communities in its area of operation.
- Management of petrochemical industries should adopt modern control technologies and evolve measures and policies aimed at conserving electrical power so as to achieve system reliability, higher productivity, reduce down time, maintenance costs and reduce energy cost in the industry.
- Management should encourage Energy Conservation Measures and organize financial and technical support to energy conservation projects in the industry.
- Finally, Government as well as policy makers should partner with the Petrochemical Company under the present Public Private Partnership initiative on the utilization of conserved power and the 42% unused power for the benefit of the public.

  The scope of this study does not address potential future increases in petrochemical capacity. Also this study is limited only to the conservation of electrical power and does not cover energy recovery and conservation in waste recycling, steams recovery, emissions and other sources of energy waste in the petrochemical industry. It is recommended that these additional areas be the subject of further study.

ACKNOWLEDGEMENT:

The authors are pleased to acknowledge the entire management of the Eleme Petrochemical Company Limited (EPCL) for permitting us to carry out this study in their plant

REFERENCES

API, (1999): Electrical Installations in Petrochemical Processing Plants; API Recommended Practice 540, 4ed, Reaffirmed, July 2004.

DOE (2003a): Pumping System Assessment Tool (PSAT) U.S. Department of Energy Office of Industrial Technologies Best Practices Workshop.

DoE (2003b) Manufacturing Energy Footprints Chemicals NAICS 325, Energetics, Inc. for the U.S. Department of Energy.

EPRI (2006): Using Advanced Control and Power Technologies to Improve the Reliability and Energy Efficiency of Petroleum Refining and Petrochemical Manufacturing in California, EPRI Technical Report 1007415.

Hickok, H. N. (1979a): How and Where to Save Electrical Energy, part 1: A List of all Major Plant Electrical Equipment and Energy Losses. Energy Management Handbook for Petroleum Refineries, Gas Processing and Petrochemical plants. Gulf Publishing Company Book Division, Houston Texas U. S. A.

Hickok, H. N. (1979b): How and Where to Save Electrical Energy, part 11: How Electrical Losses are Measured: A systematic Approach to Saving Energy. Energy Management Handbook for Petroleum Refineries, Gas Processing and Petrochemical plants. Gulf Publishing Company Book Division, Houston Texas U. S. A.

OIT/ Profiles and Partnerships www.eere.energy.gov/industry/chemicals/pdfs/profile chap1.pdf

Rao S. and Parulekar B. B. (2004): Energy Technology: Nonconventional, Renewable and Conventional. KHANNA PUBLISHERS, Nai Sarak India.

Theraja B. L; Theraja A. K. (2005): A Text Book of Electrical Technology. S. Chand and Company Ltd, New Delhi. Multicolour Illustrative edition.

Scientia Africana, Vol. 10 (No. 2), December, 2011, pp 105 - 123
 ISSN 1118 - 1931

The Energy Conservation Center (ECC), 1994: "Cement Industry". Output of a Seminar on Energy Conservation in Cement Industry *by* United Nations Industrial Development Organization (UNIDO), and Ministry of International Trade and Industry, (MITI), Japan.