RESEARCH ARTICLE OPEN ACCESS

Improving Electrical Energy Efficiency in Nigerian Industries

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ABSTRACT
The issue of efficiency of energy utilization in the industry globally can never be overemphasized. it involves reduction in the electrical energy required to increase quality production and worthwhile services. It is of note nowadays that in the industries before an equipment is procured, the energy to be consumed by it would be analysed viz a viz costs. The study investigates various ways and patterns through which electrical energy is being consumed in Nigerian Industries. It highlights sources of energy wastage and proffered strategies to curb the anomaly. Lighting systems and ubiquitous induction motors are the major sources through which electrical energy is being wasted; as result of this, energy efficient motors and lighting systems coupled with efficient maintenance system are being proffered. Losses associated with low power factor are highlighted while an improved power factor is being brought to the fore. It is believed that with copious adherence to the implementation of the recommendations made, the cost of energy per each manufactured product would be handsomely reduced with concomitant profits. This will undoubtedly translate into more employment opportunities in our industries

Keywords:- Efficiency, Energy, Lighting, Maintenance, Motors, Power factor.

I. INTRODUCTION

Energy for obvious reasons is regarded as the prime mover of any economy, and the engine of growth around which all sectors of the economy revolve. Thus it becomes imperative that its development, management, and improvement must have predetermined plans and strategies that are capable of driving the economy towards a sure path of sustainable development. [1]. The aim of any industry anywhere is to make profits, increase productivity and reduce waste, conserve resources and enhance image. With ample devotion to tenets of cost reduction and deployment of energy efficient technologies and practices, all of these can be achieved. It is generally accepted that by managing the demand in the network is a good way of saving expenditure on infrastructure, as the cost of this type scheme is considerably less than reinforcing or upgrading existing infrastructure. Energy efficiency henceforth in such an industry will be a criterion for all equipment acquisition. That is, before any equipment consuming energy is procured, consideration will be given to its efficiency viz-a-viz power to be consumed by it. Manufacturers of equipment have keyed-in to this also by designing energy efficient systems; it is common place now to see printers, laptops carrying energy star [3] labels. Government in Scotland establishes energy advice centres to give advice on energy usage in households and business organization in which gains accruable is enormous.[4]. Car manufactures like Volvo, Ford, General Motors, BMW and Rovers implement energy monitoring and registration systems in their plants in order to tap into energy efficiency benefits. [3]. Plant systems are designed and fitted with appropriate controls and other components that optimize their end-use energy efficiency. By imbibing energy–efficient practices, all energy consuming systems are from time to time monitored, cleaned, adjusted, maintained and operated to ensure that they make the most efficient use of energy [9]. Awareness are created within employees through systematic training and validation on how best to carry out daily operations and maintenance works using powerful methodology of Total Productive Maintenance (TPM). As a result of technologies usually deploy in automobile industry, Induction motors, often referred to as “factory workhorse” is usually used. These motors, being inductive loads require a current flow to create magnetic fields to produce the desired work. This brings low power factor. A low power factor is expensive and inefficient. Utility companies do charge additional fees when the power factor is less than 0.95, it reduces electrical system’s distribution capacity by increasing the current flow and causing voltage drops. Power factor correction brings the power factor of an Alternating Current (AC) system closer to unity. It is believed that improving power factor will increase energy efficiency and reduce cost. Also by acquiring energy efficient motors, 2 to 8% efficiency can be gotten compared with standard motors. They owe their higher performance to key design improvements and more accurate manufacturing tolerances [6]. Another system of note in an automobile industry is lighting system. About 19% of the world's electrical energy demand is used for lighting; the carbon monoxide emissions generated by this sector equal roughly 70% of those produced by the global automobile fleet [3]. In 2005, lighting in the industrial sector consumed 18% of the total global consumption. By replacing inefficient fluorescent fittings with Light Emitting Diode (LED) and compact fluorescent lighting, a lot of energy can be saved with concomitant cost reduction [5].

II. METHODOLOGY

The study involves identification of loads commonly used in industries in Nigeria. It uses data obtained from a Nigerian automobile industry as case study where loads are majorly induction motors and lighting. Truly, induction motors provide drives that impart motion on various equipment that are used in any industrial concern. On the other hand, good illumination has been said to be sine qua non to quality products. In view of these, energy efficient technologies are assembled and juxtaposed with the installed devices with the aim that when the inefficient ones are replaced with efficient types, the energy efficiency of the system would be grossly improved. When losses are mitigated, efficiency soars [6]. Losses due to poor power factor is corrected, energy efficient lightings and motors are proffered. An efficient maintenance programme: Total Productive Maintenance is pinpointed to stabilize the energy efficient technologies deployment. The usage of Ms Excel to handle industrial data presentation is used to drive the point home. Recommendations given will be an asset for the reader.

III. THE POWER FACTOR

In electrical system, different types of loads are used, that is, resistive, capacitive and inductive elements.

In a resistive load, voltage and current waveforms are in phase, that is, they change their polarities at the same instant in each cycle. As a result of this, all the power entering the load such as capacitive and inductive elements are present, energy stored in them results to time difference between current and voltage waveforms.

Incidentally, consumers in industrial and public electrical networks are primarily of an ohmic-inductive nature. Inductive loads result to lagging reactive power where current waveform lagging the voltage. And circuits containing inductive and capacitive elements do have a power factor less than unity.

Consequently, the total apparent power used includes non-productive power consumed in them. Power factor is the ratio of true power to apparent power [8].

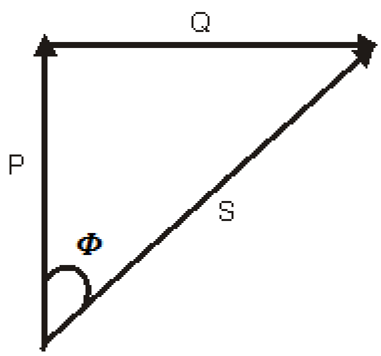


Figure 1: Power Factor Triangle

$$Power\ \ factor = \frac{True\,Power}{Apparent\ Power}$$

PF = Cos φ = P/S Where

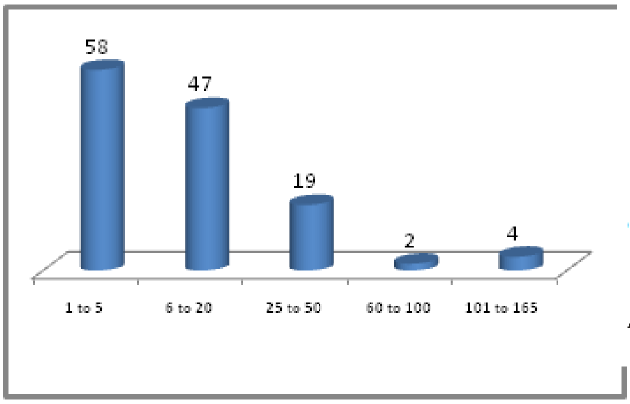
P = Active (True or real) Power (watts)
S = Apparent Power (VA, volts amps)

When the Power factor is low, it means Apparent power is much than necessary, that is, large KVA for given amount of power [8] hence wattles current will flow and that the current being drawn from PHCN is non productive which also indicates that the supplier need to provide more generating capacity than actually required. Also, there will be poor voltage regulation for transformers [8].

IV. IMPROVING POWER FACTOR

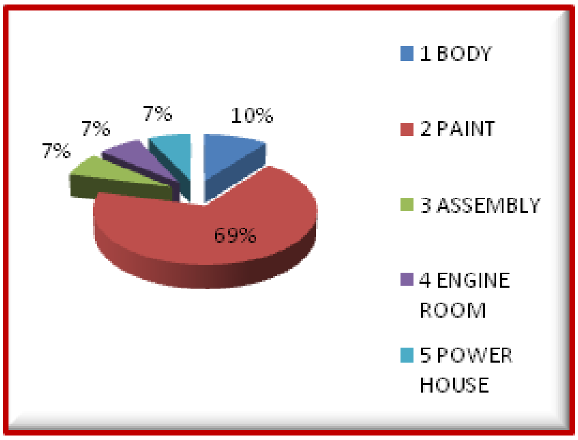
A typical automobile manufacturing industry consists of various sizes of electric motors ranging from 1hp to

160hp [2]. Going by this, loads are mainly inductive. These motors are being used for processes involving treatment of car body, air intakes for humidification system of spraying cabins, blowing fans for oven, extraction system for spraying cabins, ground and aerial conveyor [2]. Figures 2 shows distribution of induction motors according to horse-power and concentration of same respectively according to shop



(a) Electric Motor Distribution by Sizes in Horse-Power

Source: Akinwole (2012)



(b) Percentage Distribution of Electric Motors in an Automobile Industry

Figure 2

As a result of the aforementioned, low power factor as low as 0.7 do ensue. Due to low power factor, the system will be grossly inefficient. Hence, there is need to improve the power factor by using Capacitors' banks connected across the supply at the point closer to the equipment [8].

V. DETERMINING THE KVAR OF CAPACITOR BANKS

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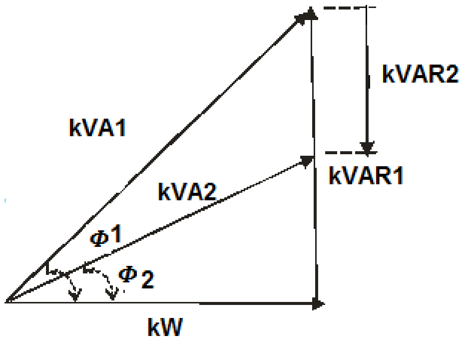


Figure 3: Power Factor Improvement Triangle [8].

KW = Power Consumed by the system

KVA1 = Apparent Power Before Correction.

KVA2 = Apparent power after Correction.

KVAR1 = inductive KVAR

KVAR2 = Capacitive KVAR

$\text{Cos } \varphi_1$ = PF before correction.

$\text{Cos } \varphi_2$ = PF after correction.

$$\text{Cos } \varphi = KW/KVA \quad (1)$$

$$\text{Tan } \varphi = KVAR/KW \quad (2)$$

$$KVAr = KW \times \text{Tan } \varphi \quad (3)$$

From equation 3,

$KVAR2 = KW \times (\tan \varphi_1 - \tan \varphi_2)$ (4)

$\varphi_1 = \cos^{-1} PF_1$ (5)

$\varphi_2 = \cos^{-1} PF_2$ (6)

To calculate $KVAR_2$, true power, φ_1, φ_2 must be known.

Current drawn by the capacitor bank:

$$I_C = \frac{kVAR_2}{kV} \quad (7)$$

also $I_C = \frac{V}{X_c} = \frac{V}{\frac{1}{\omega C}}$

So, Capacitor $C = \frac{I_c}{V\omega}$ in µF

VI. ENERGY EFFICIENT MOTORS

Energy efficient motors are higher quality motors with increase reliability and longer manufacturer's warrantees, providing savings in reduced downtime, replacement and maintenance cost. Saving this energy and money requires the proper selection and use of energy – efficient motors. Energy efficient motors should be considered in the following instances. [6].

- For all new installations
- When major modification are made to existing facilities or processes
- For all new purchases of equipment packages that contain electric motors, such as air-conditioners, compressors etc.
- When purchasing spares or replacing failed motors.

VII. ELECTRIC MOTORS EFFICIENCY

It is defined by the motor manufacturer as how efficiently a motor turns electrical energy into mechanical energy. To the end user, motor efficiency percentage is important because it is directly related to the cost of operating the motor. The higher the motor efficiency percentage, the less power is required; using less power conserves energy and saves money. The efficiency of a motor is the ratio of the mechanical power output to the electrical power input.[6].

That is,

$$Efficiency = \frac{Output}{Input} \quad (7)$$

$$= \frac{Input - losses}{Input} = \frac{Output}{Output + losses} \quad (8)$$

Design changes, better materials and manufacturing improvements reduce motor losses, making premium or energy efficient motors more efficient than standard motors [6]. Reduced losses mean that an energy efficient motor produces a given amount of work with less energy input than a standard motor.

KVA Demand = KW / (η × Cos φ) (9)

Where

η =Efficiency, Cos φ= PF

VIII. DETERMINING ENERGY SAVING BY USING ENERGY EFFICIENT MOTORS.

The equation 11 [6] can be used to determine the power to be saved when energy efficient motors are deployed. The total annual energy saving can be determined. Also, if the cost of procurement is known, one can deduce the payback in years.

$$KW_{Saved} = KW \times \frac{L}{E_{st}} - KW \times \frac{L}{E_{pr}} \quad (10)$$

$$KW_{Saved} = KW \times L \times \left(\frac{100}{E_{st}} - \frac{100}{E_{pr}}\right) \quad (11)$$

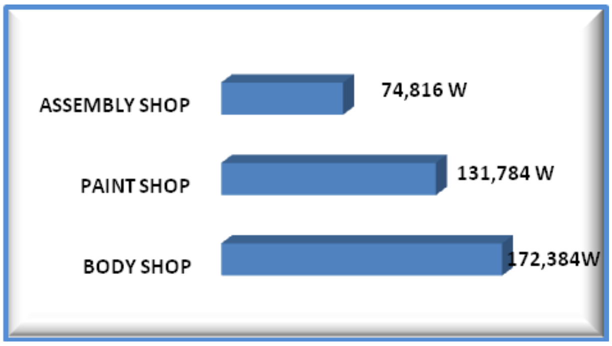
Where motor E_{St} = Efficiency of standard

E_{Pr} = Efficiency of Energy efficient motors

For example, for 9KW motor, E_{St} = 86%, E_{St} = 90%, taking load factor L = 75%

IX. LIGHTING

Due to emphasis on quality of cars produced in automobile industries, lighting is taken seriously since it allows greater visibility to every minute space and also enhances quality audits [3]. Figure 4 shows power consumed for lighting per production shops in a typical car manufacturing outfit. The chart shows that in the assembly shop, where engines, car wirings, trimmings are being done; 74.8kWh is being consumed per hour. Paint shop equipment which are majorly induction motors based, consumes 131.78kWh per hour and body shop housing spot welding machines do consume 172.38kWh per hour.



Source: Akinwole (2012)

Figure 4: Power (W) per Shop Being Consumed for Lighting.

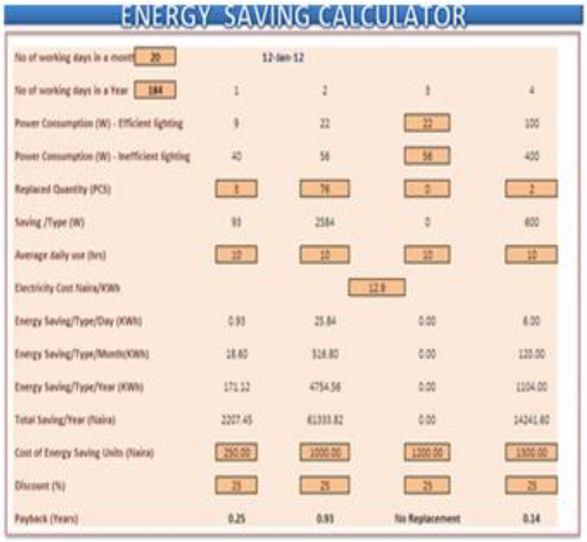
X. ENERGY EFFICIENT LIGHTING.

With emergence of ubiquitous LED technologies and compact fluorescent tubes, a lot of energy is being saved globally. Figure.8 shows some energy saving lighting fittings. To enhance efficiency, it is generally recommended that ballast fluorescent fittings be replaced with energy saving types. By replacing inefficient incandescent bulbs with highly efficient compact fluorescent lamps (CFLs) can reduce the electricity used for lighting by three-fourth or more. The statistics shows that electricity consumed by incandescent lighting and Compact fluorescent lighting over 10000hours in kWh is 600kWh and 130kWh respectively [3].

Figure 5: Energy Saving Fittings.

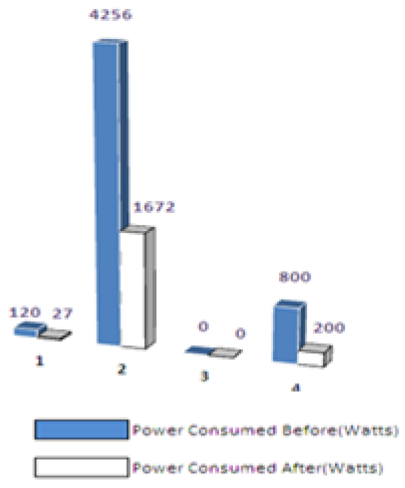
XI. ENERGY SAVING CALCULATOR

The energy saving calculator automatically calculates the energy and cost (Naira) saving capabilities of replacements done viz- a- viz a day, month and year. If the cost of fittings and discounts given are entered, the payback on investment will be calculated and displayed. Non programmers have no choice than to employ excel to provide solutions to their problems [10].



ENERGY SAVING CALCULATOR

No of working days in a month	20	12-Jan-12			
No of working days in a Year	184	1	2	3	4
Power Consumption (W) - Efficient lighting		9	22	22	100
Power Consumption (W) - Inefficient lighting		40	56	56	400
Replaced Quantity (PCS)		3	76	0	2
Saving /Type (W)		93	2584	0	600
Average daily use (hrs)		10	10	10	10
Electricity Cost Naira/KWh			12.9		
Energy Saving/Type/Day (KWh)		0.93	25.84	0.00	6.00
Energy Saving/Type/Month(KWh)		18.60	516.80	0.00	120.00
Energy Saving/Type/Year (KWh)		171.12	4754.56	0.00	1104.00
Total Saving/Year (Naira)		2207.45	61333.82	0.00	14241.60
Cost of Energy Saving Units (Naira)		250.00	1000.00	1200.00	1500.00
Discount (%)		25	25	25	25
Payback (Years)		0.25	0.93	No Replacement	0.14



Source: Akinwole (2012)

Figure 6: Energy Saving Calculator- the Chart Automatically Plots Power Consumed Before and After Replacement of Inefficient lighting with an Energy Efficient Types.

The energy saving calculator automatically calculates the energy saving capabilities of energy efficient bulbs [2]. This is achieved by changing the variables indicated by the rectangles. The developed calculating aid also automatically plots a bar chart for visual appreciation of the acts of changing energy inefficient lighting systems [2], Figure 6. The tool was developed by the author using Excel application software.

XII. DETERMINING ANNUAL ENERGY SAVING USING ENERGY SAVING LIGHTING

To replace 76 units of 56W fluorescent fittings with 22W energy saving types.

$\text{Power}_{76\text{ units}} = 56 \times 76 = 4256\text{W}$

$\text{Power}_{76\text{ ES units}} = 22 \times 76 = 1672\text{W}$

$\text{Energy}_{\text{saved}} = 4256–1672= 2584\text{W}$

$\text{Energy}_{\text{saved/day}}= 2584 \times 10 =25840\text{Wh}$

$=25.84$ KWh (10hours/day)

$\text{Energy}_{\text{saved/Annum}} = 25.84\times1840$

$= 4754.56$ KWh (1840days)

Amount saved annually (₦12.9/ KWh)
=4754.56×₦12.9= ₦ 61,333.82

XIII. EFFICIENT MAINTENANCE SYSTEM USING TOTAL PRODUCTIVE MAINTENANCE

Total Productive Maintenance (TPM) can be defined as proactive programme for the improvement of equipment performance through daily involvement of every stakeholder. TPM is a Japanese idea that can be traced back to 1951 when preventive maintenance was introduced into Japan from USA [11]. Nippondenso of Toyota introduced plant wide preventive maintenance in 1960. In preventive maintenance operators produced goods using machines and the maintenance group was dedicated to the work of maintaining the machines. When high level of automation was introduced, maintenance became problem as so many more maintenance personnel are required. So the management decided that the routine maintenance of equipment would now be carried out by the operators themselves-an autonomous maintenance, one of the features of TPM [11]. The maintenance group then focused on maintenance works of upgrade and equipment modification that would improve its reliability. TPM is active at symptoms level [2]; most of the actions are done at the bottom of the pyramid. By so doing, there is no continuous supply of problems; resulting to disappearance of critical problem at the tip of the pyramid [2]. But without TPM, reverse is the case, there is always continuous supply of the problem, little or no activity at symptom level resulting to critical problem(Break down) which lowers the efficiency of the production zone. Maintenance group put many actions at the tip (Breakdown). The methodology uses Edmund Deming PDCA (Plan–Do–Check–Act) wheel [6] to achieve its laudable objectives. An action is planned, done, checked for control purpose, if there is a deviation from the reference input (initial plan), further action is put again. The repeated and continuous nature of continuous improvement follows this usual definition of control and is represented by PDCA [7] cycle

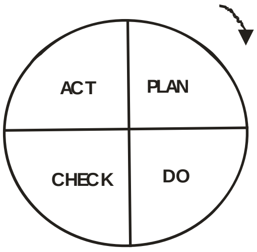


Figure 7: Edmund Deming PDCA Wheel

XIV. CONCLUSIONS

Going by submissions in the study, it is pertinent to always consider the following recommendations in order improve electrical energy efficiency in our industries:

1. To make energy efficiency a watchword whenever new equipment is to be acquired.
2. No equipment should be procured without considering its KVA demand.
3. Cablings and electrical equipment should be selected in relation to allowable voltage drops from them.
4. Any unused production line should have their lightings disengaged.
5. Every action should be employed to reduce the number of generators engaged.
6. Maintenance supporting functions should always embrace the tenets of TPM
7. Production of items must always be juxtaposed with energy efficiency.
8. A periodic energy auditing of the industry should be encouraged. This will reveal the current energy consumption and its costs.
9. Energy efficient bulbs should be used to replace incandescent bulbs and fluorescent fittings having ballasts.
10. Energy efficient motors should be procured to replaced burnt induction motors instead of rewinding them, while schemes should be put in place to replace other inefficient motors.

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