Energy Efficiency Through the Use of Technology in South African Industry

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***Abstract*-- South Africa's increasing cost of industrial energy has recently caused the country to be ranked among the top five countries in the world with the most expensive industrial electricity tariffs. For various reasons, energy is often not optimally used in industry. According to Zavanella and Zanoni (2009), there has been a growing interest in more rational and responsible consumption of energy, especially in industrial processes and services. This research study demonstrates the use of technology for energy efficiency in the industry, in order to reduce energy consumed per unit produced on industrial process plants.**

***Index Terms*-- Energy demand, energy management, energy efficiency, industry.**

I. Introduction

At least 77% of South Africa's primary energy needs are provided by coal (DoE, 2014). This has put the country among the top countries that rely solely on fossil fuel as its primary source of energy. The reliance on fossil fuel as primary energy source is likely to put the country under pressure once its abundant coal reserves are depleted or become uneconomical to mine. Petes and Kavalov (2007) indicated that about 60% of coal production in South Africa comes from underground mines and most currently operating coal mines in the country are approaching the end of their economic life; there is a common consensus that the development of new reserves will be much more costly, comparatively speaking, than the development of the old deposits.

II. SOUTH AFRICAN INDUSTRY

South Africa is considered to be the most industrialised country on the African continent (Inglesi, 2010). Upon gaining its democracy in 1994, most of South Africa's businesses, including industry, were exposed to competition with their global counterparts (IDC, 2013). According to Künne (2013), competitiveness in the South African manufacturing sector, particularly on the global market, is one of the biggest challenges facing the industry.

South Africa's industrial electricity is among the most expensive in the world. During the last three years the country's industry has experienced dramatic price increases of electrical energy from the national power utility Eskom. These increases surpassed the country's average inflation rate (Thopil and Pouris, 2013) and this catapulted the country ranks of the countries with expensive electricity, particularly industrial electricity. Schussler (2014) confirms that South Africa is ranked in the top five countries with expensive industrial electricity tariff.

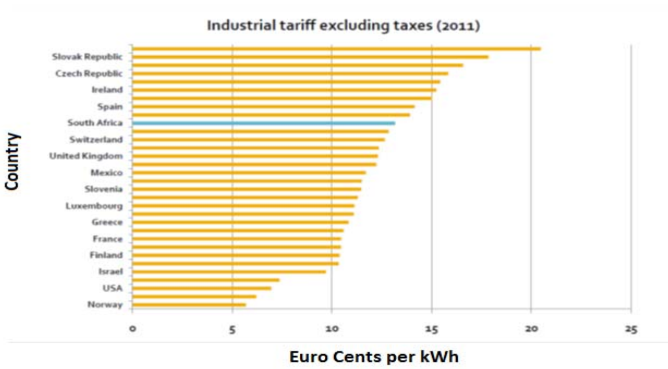

Figure 1: Ranking based on industrial electricity tariff, (Schussler, 2014).

A. *South Africa's Energy Demand Profile*

South Africa's economy is energy intensive. According to STATSSA (2009), the energy intensity of the country as a measure of GDP, is above average with only 10 other countries in the world having higher commercial primary energy intensities. This is mainly attributed to the nature of the country's economy, which comprises heavy industries such as mines and metal processing, which are by nature energy intensive. South Africa's Department of Mineral and Energy (DME) (2008) has described the industry and mining sectors as

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the heaviest users of energy, accounting for more than two-thirds of the country's energy usage.

B. *Technology in Energy Efficiency*

The vast number of energy efficient technologies, especially in the electrical energy sector, could have multiple benefits for the consumer as these could be used in a variety of ways, such as control of process speed, equipment preservation and quality management, while simultaneously reducing energy consumption (Siemens, 2011). According to Siemens (2011), recent, computer integrated technologies with fast and more decision-making capabilities, such as Programmable Logic Controllers (PLCs), have resulted in a great deal of process innovation and energy efficient technology.

Van Rhyn and Pretorius (2011), and Numbi et al. (2014) have indicated the manner in which technology can be utilised in industry for energy efficiency. In a research study by Numbi et al. (2014), the researcher demonstrated how the development of two technologies-based control models for energy management of a mining crushing process based on jaw crushers, resulted in improving energy efficiency of the system. According to Numbi et al. (2014), due to the inefficiency of the jaw-crushing machine, whose no-load power consumption is between 40 and 50% of its rated power, the optimal switching control technique has been proven to be a better candidate for reducing both energy cost and consumption of the jaw-crushing station.

III. ENERGY EFFICIENCY TECHNIQUES

There are many ways of reducing energy consumption/usage or make changes in the patterns of how energy is consumed. This can be achieved either through the use of technologies such as maximum demand controllers or by merely shifting the time of energy consumption, i.e. load shifting; or even optimising the point of consumption to ensure that only optimum energy will be consumed in a system. Depending on many factors such as available skills and capital requirements, or even the type of processes used in a particular industry etc., industrial energy users should obtain information on the type or method of energy efficiency which would be best suited to their process plants or businesses in order to derive maximum benefit from energy saving initiatives. Various energy efficiency techniques are available and mostly used for industrial energy efficiency management:

A. *Maximum Demand Control Technique*

This technique is mostly employed to curb or reduce demand peaks in a facility. The controller technique monitors, by means of a main facility meter, the peak demand usage also referred to as kVA (apparent power) (Carrel & Carrel LTD, 2015). By monitoring the electrical distribution network's peak demand, this method can be employed to automatically switch off some of the electrical loads/equipment (as prioritised by the user) in the plant/business in order to reduce the increased electrical power (BEE, 2005). According to BEE (2005), this technique can be used to shed or switch off non-critical loads in the operation, i.e. loads that do not affect the main process or are not vital to the continuous operation of the critical process equipment of the business.

Although this technique will ensure that the maximum demand in the facility is controlled in accordance to the user's present values, it does not take the continuous active energy (kWh) consumed into consideration.

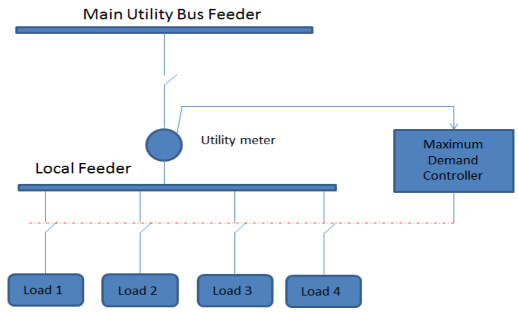

Figure 2: Maximum demand control configuration, (BEE, 2005).

B. *Load Shifting Technique*

The load shifting method also referred to as time of use (TOU), is very similar to the maximum demand controller technique. This method of energy demand control involves using energy during off peak or standard periods when energy costs less. This technique could help to reduce the high cost of electricity used during peak demand times. According to Mohamed and Khan (2009), a load shifting technique is considered the best method of reducing customer demand during peak periods. Electricity utility companies usually offer economic incentives in their electricity rate structure.

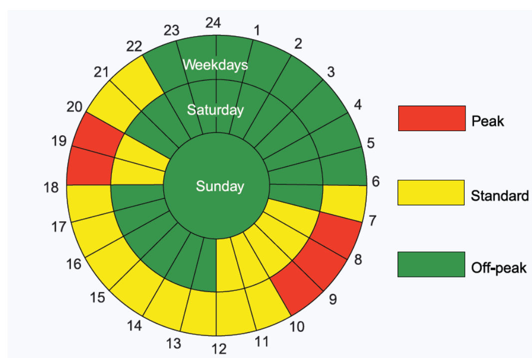

Figure 3: Tariff wheel showing peak, standard and off-peak times in a day, (Eskom, 2014)

Figure 3 shows that, different electricity rates are charged to consumers by the utility company depending on when consumers use electricity. The rate structure is subdivided into three categories and each has different rates, i.e.

- peak rate, which is the highest rate consumers are charged for electricity consumption during peak times,
- standard rate, which cost less than peak rate and is charged to consumers according to their electricity consumption during standard times, and
- off peak rate. This is the lowest rate of all the rates and it is charged to consumers during off peak periods.

Load shifting could assist in reducing the utility bill (Numbi et al., 2014), but this method does not address energy demand reduction as the same amount of energy could still be consumed at different time. While costs could be a driving factor in deciding to implement load shifting in a manufacturing plant, this technique requires greater discipline and planning as off peak periods mostly fall outside normal office hours, during which there is less supervision.

C. *Energy Efficient Equipment Technique*

This method of energy saving involves an initial outlay to procure energy efficient appliances/equipment. Although this mostly involves high initial capital expenditure, it could be best suited in cases where new equipment has to be acquired in any case and/or old equipment has to be replaced.

Energy efficiency equipment provides a high ratio of mechanical power output to input power (Smith, 1979). For example, in case of electric motor, a better or improved air-gap design of the motor, together with winding insulation, could help to reduce electrical current losses, thus improving efficiency of motor while providing the desired mechanical output or torque with minimum electricity input. Energy efficiency equipment could assist in the reduction of both energy demand and maintenance cost, without any additional work required after installation (Rao, 2012). Although this technique comes with high initial cost, once installed or implemented, it has the capability of reducing energy consumption without any process adjustments.

Electric motors are often considered for this method. Since industrial motor-driven equipment constitutes approximately two-thirds of electric consumption (Mertens, 2009), using energy efficient motors in processes could significantly reduce the input electrical energy required to perform the same task that inefficient motors normally perform. Although at first sight this may seem improbable, Mertens (2009) maintains that the choice of motors with higher efficiency can translate to substantial savings.

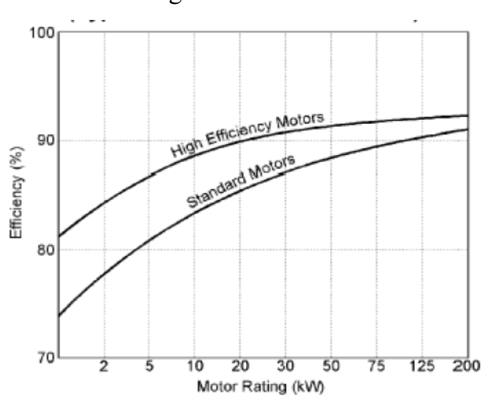

Figure 4: Standard 3-phase induction motor vs. high efficiency motor, (BEE, 2005).

In a research study conducted by van Rhyn and Pretorius (2015) on utilising high and premium efficiency three phase motors with VFDs (Variable Frequency Drives) in a public water system, the researchers found that by replacing the original motors with high and premium efficiency three phase motors supplied via VFDs, an energy saving of about 46% was achieved, with a reduction of 53% in electricity demand during the supply utility's critical evening peak.

D. *Power Factor Control Technique*

Ware (2006) defines power factor as the ratio between the useful (true) power (kW) to the total apparent power (kVA) consumed by an item of A.C. electrical equipment or complete installation. Power factor is a measure of how efficiently electrical power is converted into useful work output, and a power factor close to unity, i.e. one (1) means that the amount of input power to the system is closely converted to the useful work output. Ideally, a power factor equal to unity is needed as anything less means that extra power is required to achieve the actual task at hand (Ware, 2006). A low power factor means the user is not fully utilising the electrical for which s/he is paying (Eaton, 2014).

Inductive loads, mainly from induction motors, cause a low power factor in industry (Mohamed and Khan, 2009) and the authors claim that inductive loads require reactive power for the creation of magnetising current that facilitates magnetic field in the required circuit. The reactive power drawn by inductive loads increases the amount of apparent power in the distribution system (Mohamed and Khan, 2009).

Power factor control is the method used to control the power factor of a system to be as close to unity as possible. According to Su, Lin and Liao (2013), the power factor correction method is often overlooked as an energy saving technique. The authors state that, reducing the reactive power produced by power generators through power factor correction (PFC), not only enhance system operating efficiency and economic targets, but greenhouse gas emissions is also reduced.

E. *Process Optimisation Technique*

Optimum control of process can be fruitful in the utilisation of exact or minimum energy required to process material. For example, visualisation of real-time processes on SCADA systems could help the process operator to adjust critical plant variables, resulting in utilising only required energy. Even though this technique requires much technical know-how, particularly skills required to setup or design control systems, it has the potential of reducing energy demand if applied correctly. According to Siemens (2011), Advanced Process Control (APC) methods are tools of vital importance for improving plant efficiency, while simultaneously safeguarding product quality and operability.

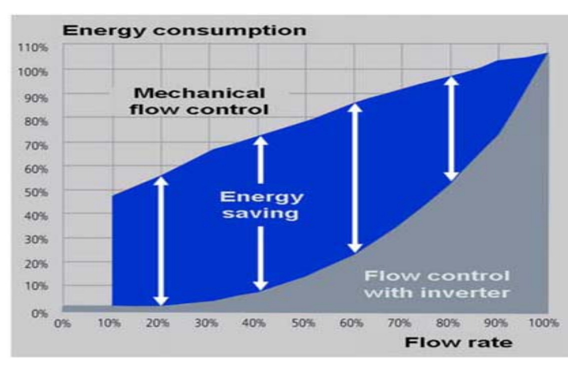

Figure 5: Energy consumption curve of an optimized speed-controlled pump versus valve throttling, (Siemens, 2011).

Energy savings of about 15% can be achieved in industrial plants by means of intelligent process automation (Siemens, 2011). Process automation, as part of optimisation, has the potential to control variables that will ensure the optimum use of energy resources. This can be done by automatically switching off of energy consuming loads that are not in use, or controlling optimally the power consumption in such a way that only optimum energy is utilised in an energy consuming process.

In a project conducted by Grontmij (2011), a company demonstrated how the use of PlantConnect system supported the process optimisation and energy saving of a waste water treatment plant (WWTP) in a Turkish waste water sector. According to Grontmij (2011), with a network of instrumentation, programmable controllers and SCADA workstations for process control management of energy, the company managed to realise a considerable energy saving that also led to the overall improvement in WWTP's efficient energy consumption. Energy saving of at least 50% was achieved by optimising the effluent pump station, waste disposal and BOD in the primary treatment process, aeration, sludge retention time (SRT), sludge load (F/M ratio), return sludge pumping station, sludge treatment and sludge stabilization (Grontmij, 2011).

IV. CASE STUDY

A case study on energy efficiency in the manufacturing industry is discussed. The purpose of the case study is to demonstrate to audience how energy efficiency was achieved by means of the application of technology on an industrial process plant. Mathematical calculations were used to determine the difference in baseline energy consumption on a process plant before and post technology implementation, and the resultant shows whether money was saved or energy efficiency was achieved. According to Akinsooto, de Canha and Pretorius (2014), energy savings are not measured, but they are computed between two known energy values, i.e. the difference between the baseline energy use and actual energy use, or in real applications, the difference between the adjusted baseline energy use and actual energy use.

A. *Data Collection Method*

Two types of data were collected for the case study. The first was data on process production output, collected weekly. This data was collected for 13 weeks before and 12 weeks post technology implementation. The data was collected in order to determine the process production output before and post energy efficiency technology implementation.

B. *Project objective*

The objective of the project was to improve the control (optimise) of three arc furnace electrodes in order to produce a stable arc that will reduce current. According to Perez (2004), the movement of furnace electrodes over the scrap in the arc furnace during melting produces an alteration of the arc length. This means that when electrodes are low, i.e. closer to the melting material, the arc will be shorter and the current drawn will increase. The opposite will occur when if the furnace electrodes are lifted (Perez, 2004).

C. *Data collected*

Data for this project was collect by measuring and recording weekly electricity consumption (kWh) and weekly furnace production in tonnages.

Table 1: Weekly furnace electrical energy consumption and amount of steel melted (tons) BEFORE.

Week No.	**Week Ending date**	**Year**	**Production (Ton)**	**Consumption (kWh)**
1	04-Oct	2009	760	476 300
2	11-Oct	2009	970	632 100
3	18-Oct	2009	960	613 124
4	25-Oct	2009	840	547 740
5	01-Nov	2009	860	544 218
6	08-Nov	2009	820	507 873
7	15-Nov	2009	760	472 066
8	22-Nov	2009	990	542 781
9	29-Nov	2009	980	613 938
10	06-Dec	2009	900	537 902
11	13-Dec	2009	820	537 902
12	20-Dec	2009	730	418 276
13	27-Dec	2009	360	218 699
		MEAN	**827**	**512 532**

The data in Table 1 was used to calculate the baseline power consumption of the furnace and this is defined as the ratio of power consumed in a week to the total production of that particular week. In the case of this experiment, the mean values were used to calculate the baseline energy consumption values, before and after technology implementation. Therefore, Baseline Power Consumption (Before)

$$\frac{Mean\ Power\ Consumption\ \ per\ week}{Mean\ Tons\ produced\ \ per\ week} = \frac{512\ 532.23}{827}$$

$$= 619.75\ kWh\ /\ ton\ /week$$

Table 2 shows data captured after controls were optimized.

Table 2: Weekly furnace electrical energy consumption and amount of steel melted (tons) AFTER.

Week No.	**Week Ending date**	**Year**	**Production (Ton)**	**Consumption (kWh)**
1	10-Jan	2010	930	541 815
2	17-Jan	2010	910	522 040
3	24-Jan	2010	620	388 991
4	31-Jan	2010	900	542 930
5	07-Feb	2010	720	447 541
6	14-Feb	2010	960	557 732
7	21-Feb	2010	830	473 371
8	28-Feb	2010	810	465 496
9	07-Mar	2010	990	553 619
10	14-Mar	2010	790	474 977
11	21-Mar	2010	890	523 652
12	28-Mar	2010	880	531 786
		MEAN	**852.5**	**501 996**

From Table 2 data above, i.e. data after new controls were installed; the new baseline power consumption (BPC) post technology implementation is calculated to be:

Baseline Power Consumption (After)

$$= 619.75\ kWh/ton/week$$

Case Study data demonstrates a saving of up to 30.9 kWh/ton/week. This is the difference between the two sets of calculated Baseline Power Consumption, i.e. before and after project implementation and represents a saving in baseline energy consumption of approximately 5%.

V. CONCLUSION

The case study discussed indicates a positive saving or reduction in the of baseline energy post technology implementation. This saving or reduction in energy consumption, if converted into monetary value, can be useful in paying back the initial capital invested to acquire the energy efficiency technology.

Energy efficiency improvements by means of technology can play a vital role in promoting economic growth particularly in South African industry, and also assist in the improvement of energy security while at the same time assisting in the mitigation of climate change. Using result from the case study, the conclusion is drawn that, technology can assist in the reduction of energy consumed per unit produced on a process plant.

VI. REFERENCES

Periodicals:

[1] Enerdata. (2015). Global Energy Statistical Yearbook 2014. Available on: http://yearbook.enerdata.net. (Accessed: 26/06/2015).

[2] Indian Bureau of Energy Efficiency (BEE). (2005). A statutory body under ministry of power, government of India. Available on: http://www.beeindia.in. (Accessed on 15 March 2015).

[3] Mohamed A. & Khan, M.T. (2009). A review of electrical energy management techniques: supply and consumer side (industries). A journal of Energy in Southern Africa. Vol 20 No 3.

[4] Su, C., Lin, M., & Liao C. (2013). A Method of Evaluating Energy Efficiency to Justify Power factor Correction in Ship Power Systems. IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, Vol. 49, No.6.

[5] Rao, G.R.N. (2012). Energy Efficiency in Industrial Sector. Ieema journal.

[6] Thopil, G. & Pouris A. (2013). International positioning of South African electricity prices and commodity differentiated pricing. South African Journal of Science. Article No. 0075, 4 pages. http://dx.doi.org/10.1590/sajs.2013/20120075.

[7] Zavanella, L. & Zanoni, S. (2009). Energy and Inventories. In: Jaber, M. "Inventory Management: Non-Classical Views", Taylor & Francis - CRC Press, BOCA RATON, pp.73-95, (2009), ISBN: 978-1-4200-7997-5

[8] Ware, J. (2006). Power Factor Correction (pfc). Journal of IEE Wiring Matters. Available on: www.iee.org. (Accessed 11 February 2015).

Books:

[9] Eskom. (2014). Eskom's Megaflex Tariff 2014. Available on: (http://www.eskom.co.za). (Accessed on 21 April 2015).

[10] Smith, T.E. (1979). Industrial Energy Management For Cost Reduction. ISBN 0-250-40340-4. Ann Arbor Science Publishers, Inc.

[11] South African Department of Trade and Industry (dti). (2007). National Industrial Policy Framework. ISBN 1-920106-10-3.

Technical Reports:

[12] Carrel & Carrel LTD. (2015). Manufactures, Importers and Distributors of Electrical Engineering Products. Available on: www.carrel.co.nz. (Accessed 12 August 2015).

[13] Eaton, (2014). Power factor correction: a guide for plant engineer. Technical Data SA02607001E.

[14] Department of Minerals and Energy (DME). (2008). The National Energy Efficiency Strategy of South Africa. Available on: www.energy.gov.za. (Accessed 13/04/2011).

[15] Grontmij. (2011). Process optimization and saving energy with PlantConnect. Available on: www.Grontmij.com, (Accessed: 20/04/2015).

[16] Kumo, W.L., Rielander, J. & Omilola, B. (2014). South African Economic Outlook. Available on: www.africaeconomicoutlook.org. (Accessed 11 May 2015).

[17] National Development Plan (NDP) (2011). National Development Plan 2030. South African National Planning Commission.

[18] Statistics South Africa (STATSSA). (2009). Energy Accounts for South Africa: 2002-2006, Discussion document: D0405.1.

[19] Industrial Development Corporation (IDC). (2013). South African economy: An overview of key trends since 1994.

[20] National Energy Regulator of South Africa (Nersa). (2014). MYPD3 Application 2014 – 2018. Available on: http://www.nersa.org.za/. (Accessed on 09 February 2015).

[21] Petes, S.D. & Kavalov, B. (2007). The Future of Coal. Institute for Energy. European Commission, Joint Research Centre.

[22] Van Rhyn, P. & Pretorius, J.H.C. (2011). Measurement and Verification. Unpublished manuscript.

[23] Siemens. (2011). Energy Management and Energy Optimization in the Process Industry. White Paper.

[24] Schussler, M. (2014). Eskom Tariff Application. Economists.co.za. Available on: http://www.nersa.org.za/Admin/Document/Editor/file/Consultations/Electricity/Presentations/SASBO.pdf, (Accessed: 25/04/2015)

Papers from Conference Proceedings (Published):

[25] Akinsooto, O., de Canha, D. & Pretorius, J.H.C. (2014). Energy savings reporting and uncertainty in Measurement & Verification. Paper submitted for Australasian Universities Power Engineering Conference, AUPEC 2014, Curtin University Perth, Australia.

[26] Gimson, C. (2009). Measuring instrumentation in a plant: Selection and installation. Energy Efficiency Made Simple Vol. II.

[27] Inglesi, R. (2010). Aggregate electricity demand in South Africa: Conditional Forecast to 2030. Department of Economics, University of Pretoria, South Africa. Applied Energy 87 (2010) 197-204.

[28] Mertens, E. (2009). Motors and variable speed drives. Energy Efficiency Made Simple Vol. II.

[29] Numbi, B.P., Zhang, J. & Xia, X. (2014). Optimal energy management for jaw crushing process in deep mines. Journal. Energy 68 (2014) 337-348.

[30] Van Rhyn, P. & Pretorius, J.H.C. (2015). Utilising high and premium efficient three phase motors with VFDs in a public water supply system. 2015 IEEE 5th International Conference on Power Engineering, Energy and Electrical Drives (POWERENG).

Dissertations:

[31] Perez, J.C.F. (2004). Monitoring of the energy consumption working points in the electric arc furnace. Pontificia Universidad Javeriana. Engineering Faculty, Electronic Department.