TECHNICAL OPPORTUNITIES FOR END-USE ELECTRICAL EFFICIENCY IN THE INDUSTRIAL SECTOR OF GHANA

E. A. Jackson,
Department of Electrical/Electronic Engineering,
Kwame Nkrumah University of Science and Technolog,y
Kumasi, Ghana.

ABSTRACT

In a power system faced with a rapidly growing demand, averaging 8.4% per annum between 1991 and 2001, it is essential to examine ways not only to improve the efficiency of supply but also to manage the demand in order to defer or reduce the investment in new power generation. This is important in the light of scarcity of capital on the global financial markets. The Volta River Authority (VRA), the main company responsible for the generation, transmission and some distribution of electric power, has to implement various short term strategies to meet this continued growth in demand for power. It has been importing power from La Cote d'Ivoire to augment generation from the two hydro sources. It commissioned in 1997, a 550 MW combined-cycle thermal power plant at Aboadze near Takoradi at an estimated cost of US$ 426.9 million. The high cost of meeting this demand calls for an alternate program of reducing the demand through higher end-use efficiency. A demand-side management unit set up in 1994 to reduce load demand, has organised public education campaigns through mass media advertisements, seminars and energy audits in selected industries, However, these have been short term efforts to address the load demand problem. There is an urgent need to expand these activities into major energy efficiency programs and conservation measures, well planned to service both the rural and urban domestic consumers as well as industries. The paper reviews the opportunities for improving the efficiency of electricity use in the industrial sector of the country.

Keywords: Power, demand, end-use efficiency, demand-side management, opportunities, Ghana

1. INTRODUCTION

1.1 Background on Electricity Supply and Demand

The commercial electricity supply of Ghana is hydro based with a total installed generation capacity of 1,760 MW. This is made up of two hydroelectric plants on the Volta River, with installed capacity of 1,180 MW, a 30 MW Diesel plant and a recently constructed 550 MW Combined Cycle Thermal Plant. The present demand forecast for 2000 -2011 is 2382 MW requiring additional generation capacity of 662 MW to the present level of 1760 MW (VRA, 2002)

The demand for electrical energy has been growing at an average rate of 8.4% per annum since 1991. This high growth of electricity demand in the country and major droughts, in 1983, 1994 and 1998 compelled VRA to supplement and improve the security of its power supply system with the thermal plant.

1.2 Energy Efficiency and Demand Side Management Initiatives

The Ministry of Mines and Energy (MOME), the policy-making authority for energy in the country embarked on energy efficiency projects in the mid-1980s. It started the Power Sector Reform process in 1995 to encourage private sector participation in the power sector. Two Acts of Parliament were enacted in 1997, establishing the Public Utilities Regulatory Commission (PURC) and the Energy Commission (EC). The PURC sets tariffs and regulates the power utilities. while the EC licenses energy sector operators like the utilities, petroleum and gas pipeline operators and marketing establishments:

The Ministry transferred its role in the promotion of energy efficiency to the Energy Foundation which was established in 1997. Energy Foundation has been implementing various energy efficiency and Demand Side Management programs in the industrial sector (Ofosu-Ahenkorah 1995). An Industrial Assessment Centre (IEAC) was also set up in 1997 at the School of Engineering, Kwame Nkrumah University of Science and Technology, with the assistance of the US-DOE, to train students in Energy Management and also audit industries in the country (EF 1999). IEAC has trained over 20 students and audited 17 industrial establishments, including 13 timber firms. The initial emphasis has been on no cost or low cost areas where potential energy savings have ranged from 12 to 15%.(IEAC 1997).

Ghana's industrial base is dominated by mining, food processing, wood products, textiles, metal refining and beverages. This paper looks at motors, industrial processes and industrial structure where energy could be used more efficiently.

2. MOTORS

Electric motors are the largest single use of electricity in most industrial plants and consume over 60% of all electricity in many industrial plants (BPA 1992; MOME 1995). It is possible to obtain direct electricity savings through the use of more efficient motors as well as indirect savings through the use of motor speed controls that better match motor output and load. Increasing the power factor is also another important energy and cost saving measure.

2.1 Energy-Efficient Motors

A nation wide survey in the U.S.A. shows that larger motors dominate electricity usage. Motors in the 3.7 to 93 kW size range use 52% of the sector's energy, while larger motors account for 45.6% of electricity consumption (RE 1991). Similar conditions are expected in Ghana since similar processes and technologies are used by industries world wide.

Energy-efficient motors now available are typically from 2 to 6 percent more efficient than their standard or counterparts. The efficiency gain is obtained through better quality steel, more copper and a smaller air gap between the rotor and stator. This efficiency improvement translates into substantial energy savings: For instance, the price premium for an energy-efficient motor is typically 15 to 30 percent above the cost of a standard motor (McCoy et al 1993). Over a typical 10-year rating life, a motor can easily consume electricity valued at over 45 times its initial purchase price. Hence for typical 56kWh motor costing $4,000, the cost of energy needed to operate it in ten years is $180,000 at $0.05 per kWh. If the energy-efficient motor costs 25% more than standard one and it is 3% more efficient, then the cost premium of $1,000 is negligible compared to the savings of $5,400.

Energy-efficient motors should therefore be considered in the following cases (Hydro 1992):

- ⇒ for all new installations;
- ⇒ when major modifications are made to existing facilities or processes;
- ⇒ for all new purchases of equipment packages that contain electric motors, such as air conditioners and compressors;
- ⇒ when purchasing spares or replacing failed motors instead of rewinding old, previously rewound, standard efficiency motors;
- ⇒ as part of an energy management or preventive maintenance program;
- ⇒ to replace grossly oversized and underloaded motors.

A survey of motors in Ghana shows that motors were operating on the average of 54% rated load. 22% of them could be classified as underloaded or oversized (Jackson 1997). Motor oversizing occurs in part because of poor service quality - wide voltage fluctuations and imbalances. Oversizing prevents the motor from overheating and possibly burning out when the voltage drops well below nominal level or when the voltages on different phases are unequal. Improving service quality will however, enable proper motor sizing and provide other benefits.

The benefits of energy-efficient motors go far beyond saving energy. In most applications, these high-quality motors are more reliable, longer lasting, quieter and generate less waste heat than standard motors do. Since they use less electricity, energy-efficient motors also have a positive environmental impact by helping to reduce thermal power plant emissions. (NREL 1995).

The most effective strategy for optimizing the energy efficiency of motors is to pay attention to well-known but often neglected principles and practices of design, system integration and equipment maintenance. Optimizing an entire electric motor system can achieve a savings of more than 50%, because poorly matching components and electrical loads drain energy at very high rates (NREL 1995)

2.2 Motor Speed Controls

Many motors in industries are used for compressors, pumps, blowers and driving heating and cooling systems. Although the power needed for these tasks might vary, most motors have only one speed setting: typically, the motor runs at full power, while moveable air vanes or flow-restricting valves control the output of the driven machine. The costly results are wasted energy, cumbersome and imprecise mechanical control systems and wear and tear on equipment (Mohan et al 1985; WCDSR 1994). To avoid this waste, many industries, in the industrialized world are turning to the Adjustable-Speed Drives (ASD) for motor speed control. This technology varies motor speed to modulate the amount of power being delivered to the driven machine: the lower the speed, the less power needed by the motor. ASD-controlled motors use less energy than do fixed-speed motors, work without mechanical restrictors and offer precise control. They can therefore extend equipment life, lower maintenance costs, reduce interruptions in operation and reduce noise. Even though ASD's are relatively expensive to install, these advantages make them more cost-effective than fixed-speed systems over the long term (WCDSR 1994; NREL 1995).

In a case study of ASDs in use at a Wisconsin wastewater treatment plant, the ASD system consumed 20.4 percent less energy than a conventionally controlled system. Other case studies show that ASD-controlled centrifugal pumps generally use 20 to 25 percent less energy than fixed-systems do. Centrifugal pumps such as those monitored at the wastewater treatment plant account for 50 to 60 percent of motors' energy consumption in industry, so these savings can be significant. In addition ASDs have been shown to provide energy savings of up to 50 percent for other applications such as boiler fans and water feed pumps (WCDSR 1994).

In Ghana ASDs can be used in most industries including The Ghana Water & Sewerage Corporation, breweries, mining, wood and chemical plants. It is estimated that the use of ASDs could reduce total electricity consumption in the USA by about 7% (Geller 1986). The overall savings potential could even be greater in Ghana since percentage of industrial electricity use is greater and there may be more motor operation at partial loads (Jackson, 2000). At the moment only a few industries use ASDs in some of their operations.

2.3 Power Factor Controls

1Maintaining a power factor of 0.95 or greater will reduce distribution losses, lower maximum power demand and increase motor efficiency. When motors operate near their rated load, the power factor is high, but for lightly loaded motors the power factor drops significantly. While motor full and part load power factor characteristics are important, they are not as significant as nominal efficiency. Hence when selecting a motor, it is better to purchase a high efficiency motor and correct for power factor (Bonnett 1990).

Power factor correction is a very cost-effective means of reducing power demand. For example, if only the value of reduced distribution losses is considered, correcting a 0.8 power factor to 0.95 is estimated to have a benefit/ cost ratio of 3 to 15, depending on the load and price (Geller 1986). Low power factors can be corrected by installing external capacitors at the main plant service and/or at individual pieces of equipment. Power factor can also be improved and the cost of external correction reduced by minimising operation of equipment above its rated voltage.

The Ministry of Energy has started a program of encouraging industries to raise the power factors to a minimum of 0.95. There is a surcharge penalty of industries with power factors lower than 0.95. An initial energy audit of Ghanaian industries showed that the bulk of energy waste in industry was associated with heat, power factor correction and other electrical systems (Ghana,1992).

3. INDUSTRIAL PROCESSES

After motor drives, electrolytic processing is the next largest industrial electricity end-use in industrialized nations. Electrolytic process such as aluminium production is very important in Ghana. In fact the aluminium smelter in Ghana, Volta Aluminium Company (VALCO), is the single largest consumer of electricity in Ghana and presently uses about 35% of the electricity produced. Process heating is the other major category of industrial electricity use.

3.1 Aluminium

The same production techniques are used throughout the world - the Bayer process to convert bauxite to alumina and the Hall-Heroult process to electrolytically reduce alumina to aluminium. Electrolysis (smelting) accounts for nearly all of the electricity consumed in aluminium production. Energy-efficient smelters now consume less than 13 kWh/kg of aluminium (Geller 1990).

Measures that can be used to provide incremental improvements in electrical efficiency include:
optimizing the cross-section of bus-bars;
better control of cell operating conditions;
better control of electrolyte composition;
improved insulation.

It is estimated that these improvements typically pay for themselves in 1-4 years through the electricity savings (Gamba et al. 1986). Recycling obsolete aluminium to ingot requires only 5% of the energy necessary to produce ingot from bauxite and can greatly cut down on electricity consumption. With the use of recycled metal, a die cast part needs 85% less energy than if made from primary metal (Cochran et al; 1983).

3.2 Steel

There are three steel industries in Ghana, all operating electric arc furnaces (also known as minimills). Electric minimills typically consume 0.55-0.75 kWh/kg of liquid steel. Use of scrap steel rather than iron ore lowers electricity consumption by about 25%. Other opportunities for reducing power consumption include preheating of scrap, use of oxygen lancing to assist melting, use of improved electrodes and ultra-high power furnaces.

Significant electricity savings can also be achieved by closing furnaces, recovering waste gases and using these gases (mostly CO and H_2) to preheat primary material or generate process heat and/or electricity. A large Brazilian steel company, Usirninas, installed a thermoelectric plant and computerized controls which enabled it to reduce its purchased electricity per ton of steel output by 30% between 1981 and 1989 (Geller 1990).

A promising new technology for producing steel or steel alloys is *plasmasmelt* - using electricity to generate a gas plasma which is injected into the furnace along with ore and coal powder. The recovery of waste gases is facilitated in this process. A full-scale plasma-based ferrochrome facility is operating successfully in Malmo, Sweden (Eketorp 1989). Plasma-based steelmaking appears to be very efficient if scrap metal is used as the raw material, consuming about one-third as much electricity as a conventional electric arc furnace operating with scrap (Eketorp 1989).

4. INDUSTRIAL STRUCTURE

The type of economy and rates of expansion of different sub sectors have an important effect on electricity demand. Electricity intensity varies greatly between industries. Electricity use per unit of value added for nonferrous metals is over 10 times greater than that for the food and beverages or chemical industries. The seven most electricity-intensive industries account for 52% of industrial electricity use in Brazil but only 13% of industrial value added (Geller 1986).

In the USA and other industrialized countries, the shift away from basic materials processing toward fabrication, finishing and service activities has significantly reduced energy demand. It is estimated that over 45% of the overall reduction in industrial energy intensity in the USA since 1973 is due to this structural shift (Ross et al. 1985).

Restructuring economic development away from energy intensive industries is an important challenge for policymakers in Ghana unless there is a clear competitive advantage in these fields.

5. CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The report covers the technical opportunities for end-use electricity conservation in the industrial sector. It is seen that increasing end-use efficiency can save Ghana energy through a more rational allocation of investments between electricity supply and demand. Taking advantage of the potential for greater end-use efficiency requires a concerted effort on the part of government and utilities in Ghana.

The World Bank is assisting Ghana in developing the institutions and implementing the programs necessary for effective energy management. The political and financial commitment to end-use efficiency at both the international and national levels must be commensurate with the potential benefits. For Ghana, any immediate savings in energy implies that it can either import less energy from or export more energy to its neighbours. This can be achieved only if the management and all those associated with energy efficiency are committed to the program which is spelt out below in the form of recommendations.

5.2 RECOMMENDATIONS

1. Evaluation of Electricity Demand
- Review existing information on patterns of electricity end-use in the industry and conduct additional surveys to determine how electricity is currently used in the country.

2. Standards
- Develop minimum efficiency standards for equipment. These standards should be the same as those in the developed world else all the inefficient equipment will be dumped on us. The Ghana Standards Board, the Ministry of and Energy, and the Universities should be involved here.

3. Tariffs and Incentives
- Reduce taxes and duties on energy-efficient industrial equipment so that they are more attractive to purchase than the inefficient ones .
- Tax related incentives should also be offered to businesses that invest in energy efficiency.
- Study other incentives, including loans, direct installation, rebates, and preferences for consumers who are energy-efficient. The Utilities, the Ministry of Energy, the Internal Revenue Service and the Ministry of Finance and Economic Planning are to implement these recommendations.

4. Information and Education Programs
- Develop manuals, consumer guides and other educational materials.
- Develop training programs and professional courses for industrial energy managers. The Energy Foundation and the Universities should be involved here.

5. Energy Audit
- Conduct more energy audits.

6. Planning and Institutional Development
- Investigate and support technology transfer.
- Promote the use of energy-efficient motors in industries.
- Promote the use of Adjustable Speed Drives (ASD) for motor speed control in industries.
- Develop savings goals and the means of achieving them.

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