EXPLORING ENERGY-SAVING POTENTIAL FOR INDUSTRIAL SECTOR UTILIZING ENERGY EFFICIENCY MANAGEMENT APPROACH: HADITHA HYDROPOWER PLANT AS A CASE STUDY

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Abstract. Reaching energy efficiency in industrial facilities particularly in Iraq is an essential part in addressing the continuous energy crisis since the second Gulf war. In the electricity sector, the gap between nameplate capacity and actual utilizable capacity is huge and is rapidly increasing. Exploring the use of energy efficient practices can be a means to provide a cost-effective means to contribute in solving some of electricity demand problems and high energy costs for the industrial sectors in Iraq. In this paper, energy efficiency approach is used to estimates the energy savings attained from upgrading and enhancing the energy consumption aspects in Haditha hydropower plant-Iraq. The potential energy savings is computed and compared against the current consumption of the compressed air system. To achieve this point, energy audit and assessment is carried out to recommend a potential energy-efficient practice that can be implemented in the plant. The recommended energy-efficient practice has the potential to provide electrical energy saving around 172,323 kWh/yr, and $17,232 in annual cost of electricity, which correspond to a reduction of 64.58% and 35.41%, respectively. The total implementation cost for this proposed application is approximately $5,200. The findings clearly indicate that there is a possibility to have a high electrical energy savings for the tested system, which can enhance the power consumption efficiency in industrial sector and to minimize energy waste in Iraq.

Keywords: energy efficiency; hydropower plant; energy consumption; energy audit; Iraq.

Introduction:

Energy usage across the world is rising rapidly at this time. Such growth has resulted in cause for concern in terms of the affects towards energy supplies, exhaustion of resources, and the current and aftereffects on the environment. The environmental concerns include aspects such as climate-change and global warming. Also, the growing and if not, highest concerns can be witnessed across developing countries. These countries have and continue to witness increasing growth in energy demands and consumption, with little to no effective resources or capacity in place. As such, this is expected to impact the several different aspects of the average individual's life. It is without a doubt that energy consumption will continue to rise, and in light of all these aspects mentioned above, the implementation and adoption of energy efficient measures through certain practices is not only becoming recommended but now required for the betterment of the future. Such actions must be considered essential for both local and global energy policy makers.

Energy efficiency implementations has been investigated by many researchers, however energy inefficient buildings in developing countries still existed [1]. Lee & Yik [2] reviewed the approaches that were being used in both voluntary and regulatory systems for improving the buildings efficiency . The authors reported that investing into such energy efficient approaches is not justified by the possible

energy saving alone, and there is a need for regulatory government approaches. They suggested the need to adopt a mix of a well-articulated strategy that involves both voluntary and also regulatory actions to attain energy efficiency in buildings. Ahmed [3] studies the influence that building envelope have on the amount of energy needed for cooling and heating, and he found a significant association between the different aspects. Moreover, Kharrufa and Adil [4] examined the building envelope aiming to minimize the cooling loads in Iraq by investigating the effects of a roof pond. Pérez-Lombard *et al.* [5] reviewed the energy consumption practices in the developed countries. The authors concluded that a combination of private initiative with the addition of government intervention aiming to promote energy efficiency practices, supporting new efficient technologies, limiting energy consumption, and boosting social awareness on the practical usage of energy will be vital to make attainable a sustainable energy future.

The availability of energy has a decisive impact on the economy and development of any developing country. Iraq suffers from a severe shortage of power supplies [6]. The country has been subjected to many wars and calamities, which has impaired its infrastructure [7]. Presently, Iraq meets most of its electricity demand through heavily subsidized government owned power plants. However, the gap between nameplate capacity and actual utilizable capacity is huge and is rapidly increasing. When looking at electricity demand in the country, it is estimated at 28 GW, but the actual total load capacity that is generated is only about 19 GW. Therefore, any improvement in energy consumption at the current level of electrical energy production is a key step in Iraq. Currently, there are no energy efficiency standards being developed or implemented in Iraq. There is no current presence for green buildings in Iraq, nor any energy efficient systematic industrial practices. Thus, the energy sector suffers from excessive consumption of energy as a result of the lack of energy efficiency programs. Such programs can aid users understand and analyze the trends of their energy consumptions and seek potential energy saving practices. Attaining energy efficiently is very crucial for a country like Iraq due to the continuous energy crisis. Applying energy efficiency managements to industrial area was minimal in the developing countries. Most of the body of research conducted in Iraq were aiming to improve the energy efficiency of residential building [8] [9] [10]. Industrial facility functioning energy audit with optimization must be consistently implemented to scale down excessive energy consumption [11]. Engin and Ari [12] shows the importance of energy auditing as a valuable energy management approach.

Recently, Ghalandari *et al.* [13] investigated the potential of implementing energy audit on the pyro-processing unit to enhance the efficiency of the process inside a cement plant in Iran. The authors focused on evaluating the potential of electricity production using the exhaust gases using the waste heat recovery power generation. The findings of this study indicate that around 5.2 MWh power can be gained from this process and that the feasibility study revealed that approximately 6.7 years are required to return back the investment. The potential of using energy auditing to improve the energy efficiency in the pulp and paper industry inside Morocco was investigated by Boharb *et al.* [14]. Their work presents a detailed plan to enhance the energy efficiency of certain applications inside the paper plant such as compressed-air systems. The authors reported that the proposed recommendations have the potential of saving around 348 MWh in electrical energy consumptions and about 102 MWh of thermal energy, which translate to a reduction of about 11% and 2%, respectively. Krishnan *et al.* [15] identified energy savings potentials in rubberwood industries by implementing energy audit analysis. The energy auditing process was implemented in the Meenachil Rubberwood Limited, India. Multiple energy saving recommendations with its implementation cost were presented. The authors reported a total of approximately 14% reduction in the energy consumption from the existing operational condition.

The motivation of this research is to explore the use of energy efficient industrial practices, with the objective of finding cost-effective means that contribute to solving some of Iraq's electricity demand problems and high energy costs for industrial sectors. To the authors knowledge, industrial energy efficiency practices have never been employed in the governmental sector within Iraq. The current study will introduce a set of energy-efficient practices specifically developed for actual implementation at the 660-MWe Haditha Hydroelectric Power Plant in Iraq, located in Haditha, Al Anbar Province. This approach can help governmental and private entities to improve the outdated energy practices implemented in this country in order to minimize energy waste.

METHODOLOGY:

Modifying operational practices that result in little to no-cost can lead to 10-20% being saved on utility bills. Additionally, capital cost plans with payback periods of two years or less can often save an additional 20-30% [16]. In many cases, such energy saving approaches and programs will furthermore have results in minimizing the emissions in environmental pollutants. In order to reach a successful and attainable energy saving program, an energy audit analysis should be undertaken as the first task at hand. Energy audits contain a detailed examination of how a plant uses energy, what the plant pays for such amount of energy, and finally, a recommended approach for changes in operational practices or energy-consuming apparatus. This will effectively save energy and thus save dollars on energy bills and even maintenance cost of equipment. Energy audits contain a thorough examination and description towards the operation and usage of energy within a particular plant, the amount that is paid, and a recommended approach towards change in operational practices, and consumption-based energy. This is bound to save energy effectively and result in lower costs and maintenance. A complete description of energy auditing procedure can be found in the work of Turner and Doty [16] .

This work has been conducted through a collaboration between the authors and the Ministry of Electricity in Iraq represented by Haditha Dam Hydropower Plant (HPP) that conducted an energy audit for the plant. The authors have conducted a detailed energy analysis for multiple high-energy consumption equipment within the plant itself. However, in this paper the authors present only one system findings (compressed air system) as an example of this approach. Additional results and findings for the complete plant will be presented in future work. The aim of this is to provide a straight-forward yet applicable recommendation with minimum cost for the plant management to implement.

The compressed air system in Haditha plant is outdated and was installed in 1986. The system does not have any energy efficient components that can be used in its operation. Detailed observation of each potential candidate that provide the highest energy savings for this system were conducted. The current compressors motors do not have any variable frequency drive (VFD) controllers installed on them. The schematic and the actual pictures of the compressed air system is depicted in Figure 1 and the existing electrical motor is depicted in Figure 2.

The expected energy saving (*ES*) for each year, and the energy cost savings (*ECS*) resulting from this saving (by installing VFD) can be computed according to the following:

$$ES = CEU - PEU \quad (1)$$

$$ECS = ES \times \text{Avoidable cost of electricity} \quad (2)$$

here:

CEU = The current time weighted energy usage for a specified motor, kWh.

PEU = The projected time weighted energy usage for a specified motor, kWh.

Both, *CEU* and *PEU*, can be assessed as follows:

$$CEU = \frac{P \times LF \times OH}{\eta_{m,Existing}} \quad (3)$$

and,

$$PEU = \frac{P}{\eta_{m,Proposed}} \times (FR_1 \times H_1 \times OH) \quad (4)$$

where,

P is the power of motor, OH stand for the motor operating hours (annually), FR_1 is the motor power consumption (with VFD) formerly at full Load, H_1 represent the time fraction that motor will operate at full load, LF is the motor load factor, and finally; $\eta_{m,Existing}$ & $\eta_{m,proposed}$ represents the efficiency of the existing motor and the efficiency of the proposed motor, respectively.

Figure 1. The compressed air system in Haditha HPP (courtesy Haditha HPP-MOE Iraq).

Figure 2. The compressor electrical motor used in Haditha HPP(courtesy Haditha HPP-MOE Iraq).

Results and Discussions

The potential for energy savings from upgrading the electrical motors of the three 50-bar air compressors intended for the compressed air network in Haditha HPP is considered in this section. The electro-mechanical systems in Haditha HPP crucially depends on the continuous supply of a compressed air with different capacity and pressure values. Several systems, such as hydro turbines, electrical switchgears and fire-fighting systems depends on compressed air in its operational process. Haditha plant has two main compressed air systems, and the one discussed here are the 50-bar system. The system contains three LMF 50 bar piston type air compressors (VHGD 3922 W5). Each compressor uses an electrical motor with power capacity of 105 kW. The compressors are connected to two air tanks, this way the compressors will feed the two tanks with the required pressure until a signal from the pressure switches, installed on the tanks, stops the compressor. Unfortunately, due to the operational degradation and thus poor conditions of the compressors, and the increased usage of the compressed air in the plant; the compressors operate for an extended time with several Startup/Shutdown to meet the demand for the compressed air.

The expected (*ES*) for each year, and the (*ECS*) resulting from this saving, can be computed according to the following:

$$PEU = \frac{P}{\eta_{m,Proposed}} \times (FR_l \times H_l \times OH)$$

In this case for the existing compressor, the parameters are:

P = 105 kW.

OH = 2,160 hr/yr.

FR_l = 50%.

H_l = 75%.

LF = 1.00.

$\eta_{m,Existing}$ = 0.85.

$\eta_{m,proposed}$ = 0.90.

In this case, it is assumed that the electrical motor will run at 100% for the intended operating hours. Then using the above information, we get by applying equations (3 & 4):

$$CEU = \frac{105 \times 1.00 \times 2{,}160}{0.85}$$

= 266,823 kWh/yr.

$$PEU = \frac{105}{0.90} \times (0.5 \times 0.75 \times 2{,}160)$$

= 94,500 kWh/yr

Then, the energy saving from applying this modification according to equation (1) is:

ES = 266,823 kWh/yr – 94,500 kWh/yr

= 172,323 kWh/yr.

The total cost savings (TCS) for one compressor motor, based on the Iraqi government prices for governmental sector, is:

TCS = 172,323 kWh/yr × $0.1/kWh

= $17,232 /yr.

The implementation cost is essential part in evaluating the feasibility of any energy efficient recommendation. The total estimated cost to implement this specific modification on the compressor motor power line is described here. The cost of the proposed equipment to be used in this case (VFD controller) for a 105-kW compressor motor is estimated to be $4,700, based on the current market prices for high end VFDs, with an additional $500 for the installation costs. The installation cost can be eliminated if the plant used its own technical staff implements such modifications. It is clear that this modification is highly feasible since the total annual cost saving is estimated to be at $17,232. This result is very similar in principle t the findings of Boharb *et al.* [14]. The saving in this case is much higher due to the different sizing and operational schemes. Table 1 shows a summary of the proposed recommendation with the attained savings and implementations cost. Installing a VFD drive on an old electrical motor power lines inside Haditha HPP have the potential of very large saving in the consumed power. The implementation cost in this case is quite reasonable compared to what will be gained in both energy saving and electrical bill cost. The compressed air system is one of the heaviest electrical consumer systems in any industrial plant, and thus any savings will be very significant in alleviating the low energy efficiency of the system. This result can be generalized in other industrial facility inside Iraq with the aim of decreasing the power consumption of the system. This gain in the power can then be directed to other type of consumers in Iraq.

Table 1. Recommendation for Haditha HPP

Description	Annual Savings	Total Annual Cost Savings	Implementation Cost
Install Variable Frequency Drive on the 50-bar Air Compressors	172,323 kWh/yr	$17,232	$5,200

Conclusion:

Energy-efficient recommendation was specifically developed for an actual implementation at the 660-MWe Haditha hydroelectric power plant Iraq. The recommendation was based on a detailed energy auditing process which analyzed the current practice used in the operational regime of Haditha HPP compressed air system. The energy audit presented here focused on the main three 50-bar compressors electrical motors, which have the potential of large energy saving. The recommendation clearly showed a very promising results in term of energy saving potentials inside the power plant. The study outcomes can be summarized by the following points:

1- The total annual electricity savings for this proposed recommendation (VFD installation), based on one compressor, is estimated to be 172,323 kWh. This represents a reduction of 64.58% in power consumption.

2- The total electrical cost savings is expected to be $17,232 according to the price range for governmental sector inside Iraq, which corresponds to 35.41% reduction.

3- The implementation cost of this recommendation is $5,200.

The above findings show that the implementation of energy-efficient approaches in industrial plant structure will significantly decrease the energy consumption. The large saving which associated with relatively low implementation cost is very promising for the industrial sector in Iraq. Finally, this study will provide the Iraqi government and private industrial facilities owners an overview about the potential of implementing energy efficient practices in Iraq.

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