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# Auditing and analysis of energy consumption of an industrial site in Morocco

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ABSTRACT

Presently, the industrial sector is responsible for 21% of energy consumption in Morocco. Fully aware about the challenge of reducing energy consumption and related $CO_2$ emissions by industries, Moroccan authorities have legislated under the new law (n° 47-09 related to energy efficiency) the obligation of energy audit in Moroccan industries. In such a context, this paper is a Level II energy audit (conforming to ASHRAE classification) performed for an industrial site based in Fez (Morocco) specialized in producing and commercializing cattle feed. A detailed analysis of the characteristics of the energy use has identified a mismanagement of the electrical energy. Through the improvement of the DPF (displacement power factor) to a value of 0.98, it was shown that the factory can save about 52758.74 US$ annually. An improvement of energy efficiency of the interior lighting was also performed. The proposed action concerned the voltage regulation and has the potential of reducing 13.6% of the lighting energy consumption with the mitigation of approximately 27 533 of $CO_2$/year. Furthermore, harmonic treatment by installing passive filters for VSD (variable speed drives) was carried out. The energy savings related to the harmonic treatment were evaluated to be 26 760 kWh/year.



## 1. Introduction

Global warming is one of the biggest problems that threaten life on our planet in the coming years. The rising temperatures, melting glaciers and increasingly frequent droughts and flooding are all signs that climate change is really happening. The risks are enormous for the planet and for the future generations and therefore immediate and efficient actions are required to fully address the threat of global warming [1]. According to the report published in 2013 by the IEA (International Energy Agency) about global warming, if urgent measures are not taken for a reduction of greenhouse gases, earth's temperature will rise by 3.5 °C by the end of the century. Continued gas emissions at or higher than current rates would engender more warming and lead to several changes within the global climate system throughout the twenty first century [2]. To this effect, the IEA proposed improvement and investment in energy efficiency in buildings and industry as a solution that can help in reducing greenhouse gas emissions caused by human activities on a global scale [3,4]. The situation gets more complicated because the great part of energy supply worldwide is based on fossil fuels characterized by their harmful effect on the environment and their space and time limitation [5].

The industrial sector accounts for 30–70% of the total global energy consumption and is certainly responsible for a great part of the global greenhouse emissions [6,7]. Several recent researches have studied the potential of reducing greenhouse gas emissions by improving energy efficiency in the industrial sector [8–11]. Energy audit in industries is the most effective method used to evaluate the energy saving potential and propose a plan of corrective actions to achieve a clean and sustainable industrial process. Dongellini et al. [12] carried out an energy audit in an industrial site devoted to the production of luxury cars and have proposed and assessed a series of energy saving measures, such as thermal insulation of walls and rooftops, the replacement of old boilers and the use of heat recovery units in the HVAC systems. Authors have found that 15% of gas consumption can be reduced trough the improvement of

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**Nomenclature**

| | |
|---|---|
| AEP | average electricity price (excluding taxes) [MAD/kWh] |
| AP | apparent power [kVA] |
| $AP_L$ | apparent power for one lamp [VA] |
| $AP_{max}$ | monthly maximum apparent power [kVA] |
| CF | consumption fee [MAD] |
| DPF | displacement Power Factor [-] |
| $EC_i$ | electrical consumption associated to the time slice i [kWh] |
| $EP_i$ | electricity prices for the time slice i [MAD/kWh] |
| FEPC | fee of the excess of subscribed power [MAD] |
| $I_{DPF}$ | penalty for a displacement power factor below 0.8 [MAD] |
| $N_L$ | number of lamps [-] |
| P | active power [kW] |
| PC | power cost [MAD] |
| $P_L$ | active power for one lamp [W] |
| $P_{max}$ | maximum active power [kW] |
| PSP | subscribed power price [MAD/kVA] |
| Q | reactive power [kVAr] |
| SP | subscribed power [kVA] |
| TEC | total energy consumption [kWh] |
| THDI | total harmonic current distortion [-] |
| THDV | total harmonic voltage distortion [-] |
| V1 RMS | RMS value of the voltage of phase 1 [V] |
| V2 RMS | RMS value of the voltage of phase 2 [V] |
| V3 RMS | RMS value of the voltage of phase 3 [V] |
| $V_{avg}$ | average value of the Root Mean Square voltage in a time interval [V] |

*Acronyms*

| | |
|---|---|
| AUHF | Advanced Universal Harmonic Filter |
| MAD | Moroccan Dirham |
| VSD | Variable Speed Drive |

building envelopes. Su et al. [13] have given the results of a realized energy audit for seven Taiwanese cement in 2011 and revealed an energy saving potential of 2571.6 MWh of electricity and 1002.8 kLOE of thermal energy. According to the estimations, these energy savings can reduce $CO_2$ emissions by 4560 t. Thirugnanasambandam et al. [14] performed an energy audit for an Indian cement industry and studied the application of VSD (variable speed drives) to match the load requirements. The authors have found that about 1 865 925 MWh of energy can be saved annually for 60% speed reduction when VFDs are used (which is equivalent to a reduction of 1925 million kg $CO_2$ emission). Sait [15] conducted a detailed auditing to an educational building situated in Rabigh city, Saudi Arabia. The recommended actions had the potential to reduce the electric energy consumptions by 35.3%, while the air-conditioning units' efficiency can be increased by 31%. The audit analysis of a dry type rotary kiln system working in a cement plant in Turkey was performed by Engin and Ari [16]. The authors found that about 40% of the total input energy was lost through hot flue gas and concluded that approximately 15.6% of the total input energy could be recovered.

Morocco has little conventional energy resources and imports 96% of its energy demand. The Kingdom must meet a growing demand (around 7% per year) because of its economic development and population growth [17,18]. To meet these challenges, the Ministry of Energy, Mines, Water and Environment has developed a new national energy strategy to secure energy supplies while adopting a sustainable development approach. The improvement of energy efficiency in the industrial sector is one of the main pillars of this strategy. Accordingly, the Moroccan government is planning the obligation of energy audits in the industrial sector as an efficient way to achieve the targeted ratio of energy savings (of 12–15%) by 2020. The obligation of energy audits in industries is clearly pronounced in the 12th Article of the 47-09 law relative to energy efficiency [19].

In this paper, the main findings related to an energy audit performed for an industrial site based in the Moroccan city Fez are reported. The targeted factory is specialized in producing and commercializing cattle feed. The different stages of the production process are shown in Fig. 1. The study identifies energy losses in the factory caused by mismanagement of the electrical energy through a detailed analysis of the characteristics of energy use. A new methodology for the improvement of energy efficiency of the interior lighting is also introduced. Furthermore, harmonic treatment for VSD (variable speed drives) is carried out using SOLV$^{TM}$ software. Finally, the economic and environmental impact of the proposed action plan is evaluated according to the Moroccan context.

## 2. Methodology

The procedures followed in the present energy audit are described as follows:

- Step 1 consists of a visit of the factory where all necessary documents were collected (list of transformer stations, list of motors, compressed-air installations, monthly energy consumption bills and so on).
- Step 2 is related to the achievement of a comprehensive audit of the different installations of the factory. A three-phase power analyzer recorder and an infrared camera are used in order to detect abnormalities resulting from an inadequate use of electric energy. The specifications of the used material are given in Table 1.
- Step 3: After analyzing the collected data and the performed measurements, a detailed report is drafted (energy audit report) containing the entire detected problems by each energy consuming appliances considered (lighting, motors …). Then, proposed action plans and recommendations are addressed for improving energy efficiency in each system and the evaluation of the economic and environmental impact associated with the applicability of the actions plans and recommendations.

### 2.1. Electrical energy parameters

The analysis of monthly bills resulting from electrical energy use of the targeted factory is based on the data of the year 2014.

Most industries in Morocco have a medium-voltage billing and are connected via the delivery point substations of the National Electricity Office (ONE for "Office Nationale d'Electricité"). The main characteristics of medium-voltage billing in Morocco are described below: