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Energy, economic and environmental benefits of using high-efficiency motors to replace standard motors for the Malaysian industries

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ABSTRACT

Electric motors use major share (i.e. about 30–80% of total industrial energy consumption) of total industrial energy use around the world. Experiences from other countries show that government intervention in the form of regulations such as mandatory and voluntary approaches can save sizeable amount of energy along with the reduction in emissions associated with energy savings. This paper presents potential energy savings by introducing high-efficiency motors as a case study in Malaysian industrial sector. Emission reductions associated with the energy savings has been estimated and presented as well. It was also estimated that a cumulative amount of 1940 and 892 GWh of energy can be saved for 20 and 120 kW motors, respectively, in Malaysia relative to BAU over the next 10 years. Similarly, a cumulative amount of USD 100 million and USD 60 million can be saved as utility bills for the same motor categories. It has been found that the payback period of different capacities of motors are less than a year. Based on results, it was found that 1789 million kg of CO_2 emission can be avoided by replacing standard motors with high-efficiency motors.

1. Introduction

Electric motors have broad applications in areas such as industry, business, public service and household electrical appliances, powering a variety of equipments including air blowers, water pumps, compressors and machine tools, as can be seen in Fig. 1. In industrially developed nations and large developing nations, electric motors account for a considerable proportion of total national power consumption (APEC, 2008).

Energy use performance and energy efficiencies of the industrial sector have also been studied in different surveys in many countries (Ozturk, 2005; Christoffersen et al., 2006; Subrahmanya, 2006). In Slovenia, the industrial sector uses about 52% of total electrical energy (Al-Mansour et al., 2003). In Turkey about 35% of total energy is used in industrial sector (Onut and Soner, 2007). Approximately half of UK's generated electricity is used to drive electric motors. This means that efficiency improvements to electrical machines can have a very large impact on energy use (Mecrow and Jack, 2008). Motor driven systems account for approximately 65% of the electricity used by EU industry (Anon, 2004). In Jordan, industrial sector uses about 31% of total energy (Al-Ghandoor et al., 2008). In Malaysia, about 48% of total industrial energy is used by industrial motors and is as shown in Table 1 (Saidur et al., 2009a). In many industrialized countries, more than 70% of the total produced energy is used by electric motors. Share of electric motor energy use for some selected countries is shown in Table 1. Therefore, the cost of energy to operate motors has become a real concern for industries. On the other hand, the concern for the environment particularly through the emission of greenhouse gases and other pollutants has prompted the regulators of utilities to enforce alternative measures to meet load growth, instead of building additional power stations (Akbaba, 1999). Comprehensive references on electric motors energy savings, policy and technology is presented by Nadel et al., 2002. A comprehensive review on electric motor energy use was provided by Saidur (2010).

The electricity share by electric motors in plants is about 65% of the total electricity consumption in Turkey. Therefore, it is important to choose high-efficiency motors in industries to reduce energy use and emission produced by burning fossil fuels (Kaya et al., 2008). Many countries around the world have already implemented energy efficiency standards; many are in the process of developing them as can be seen in Table 2. It may be mentioned that energy can be saved using technology such as use of variable speed drive, use of capacitor banks to improve power factor, by regular maintenance of electric motors and by implementing energy efficiency regulations such as voluntary, mandatory approaches, incentives and energy guide labels. Electricity can be saved also by avoiding over sizing as

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Nomenclature

AEI_s^m	annual efficiency improvement of motor (%)
ANS_i^m	annualized net savings in year i for motor (USD)
AS_i^m	applicable stock in year i of motor
BEC_s^m	baseline energy consumption of motor (kWh/year)
c,k	constant value
TEI_s^m	total efficiency improvement due to the standards for motors
CRF	capital recovery factor (%)
EE	energy efficient
Em_p^n	emission p for fuel type n for a unit electricity generation (kg/kWh)
d	discount rate per year (%)
ER_i^a	emission reduction in year i of appliance a (kg)
ES_i^m	energy saving in year i of motor (kWh)
L^m	life span of motor (year)
m	motor
$MEPS$	minimum energy performance standard
NA_i^m	number of motor in year i
NA_{i-1}^m	number of motor in year $i-1$
NA_{i-L}^m	number of motor in year $i-L$
PE_i^n	percentage of electricity generation in year i of fuel type n (%)
PF_i^n	energy price in year i for fuel type n (USD)
$PV(ANS_i^m)$	present value of annualized net savings in year i for electric motors (USD)
s	year of standard enacted
SEC_s^m	standards energy consumption of electric motor (kWh/year)
SF_i^m	scaling factor in year i of motor (%)
Sh_i^m	shipments in year i of motor
SPP	simple payback period (year)
SSF_i^m	shipment survival factor in year i of motor
T	target year
TEI_s^m	total efficiency improvement of motor (%)
UES_i^m	initial unit energy savings in year i of motor (kWh/year)
x	year predicted − year start
y	predicted value
Ydr	year of discount rate base
Ysh_i^m	year i of shipment of motor
Yse_s^m	year of standards enacted of motors

mentioned by Nadel et al. (2002). However, the focus of this paper is to quantify energy savings, bill savings and emission reductions for electric motors by energy efficiency regulations.

Mahlia et al. (2004) carried out some works about the energy savings potential by implementing energy efficiency standards for room air conditioners and household refrigerator-freezers in Malaysia. Almeida et al. (2003), Garcia et al. (2007) and many others carried out some works on motor energy efficiency standards. Lu (2007) developed energy efficiency standards for central air conditioners for China and reported potential energy savings and environmental benefits of energy efficiency standards. Lu (2006) developed energy efficiency standards for refrigerator-freezers in China and reported potential energy savings and environmental benefits of energy efficiency standards. Wiel and McMahon (2005) wrote a comprehensive guidebook about global standards and labels for appliances. However, there is no such work for industrial motors in Malaysia. This study will fill that gap and it is expected that this study will

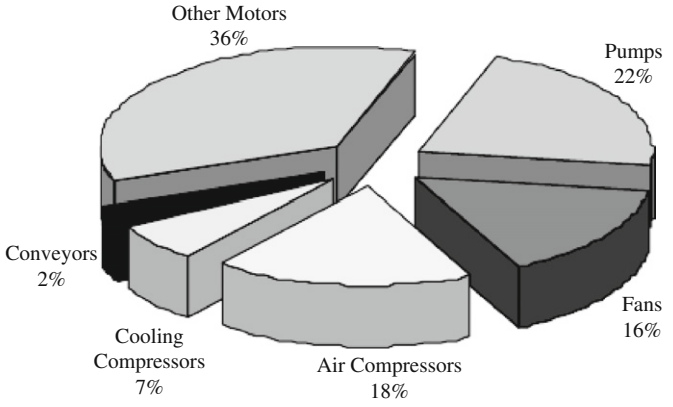

Fig. 1. Share of motor energy use by type of end-use in the industrial sector in EU (Almeida et al., 2003).

Table 1
Share of electric motor energy use for few selected countries.

Country	Motor energy use (%)	Reference
US	75	Lawrence (2008), Bin Lu (2006), Bouzidi (2007)
UK	50	Mecrow and Jack (2008)
EU	65	Almeida et al. (2003), Anon (2004), Tolvanen (2008a), Tolvanen (2008b)
Jordan	31	Al-Ghandoor et al. (2008)
Malaysia	48	Saidur et al. (2009a), Saidur et al. (2009b)
Turkey	65	Kaya et al. (2008)
Slovenia	52	Al-Mansour et al. (2003)
Canada	80	Sterling (1996)
India	70	Prakash et al. (2008)
China	60	Yuejin (2007)
Brazil	42	Garcia et al. (2007)

Table 2
Test procedures and the legal status of energy efficiency standards and labels for electric motors for selected countries (CLASP, 2009).

Country	Test procedure	Energy labels		Efficiency standards	
		Mandatory	Voluntary	Mandatory	Voluntary
Australia	Yes	No	No	Yes	No
Brazil	Yes	Yes	No	Yes	No
Canada	Yes	No	No	Yes	No
Chile	Yes	U	U	U	U
China	Yes	No	No	No	Yes
Chinese Taipei	Yes	No	No	Yes	No
Costa Rica	No	Yes	No	Yes	No
Columbia	Yes	No	Yes	No	Yes
EU Countries	Yes	No	Yes	No	Yes
India	Yes	No	Yes	No	No
Israel	Yes	No	No	Yes	No
Malaysia	No	U	U	No	Yes
Mexico	Yes	No	Yes	Yes	No
New Zealand	Yes	No	No	Yes	No
Philippines	No	U	U	U	U
South Korea	Yes	No	Yes	No	No
Poland	No	No	Yes	No	No
Thailand	Yes	No	Yes	U	U
USA	Yes	No	No	Yes	No
Vietnam	Yes	No	No	U	U

Note: U = under consideration