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Short communication

Impact of wide-spread use of uninterruptible power supplies on Pakistan's power system

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HIGHLIGHTS

- The author's analyses commonly used multiple types of UPSs in laboratory.
- It explores the charging/discharging processes of UPSs with respect to THD and efficiency.
- Domestic UPSs have significant negative effect on power system in Pakistan.
- We estimated the UPS losses cost to consumers in Pakistan.
- Building policy for UPSs efficiency improvements are suggested in conclusion.

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ABSTRACT

The shortage of electrical energy has led Pakistan to a severe energy crisis. A huge mismatch of demand and supply forces the utilities to resort to load-shedding. To overcome this chronic problem the people need to either conserve energy or use some means to fulfil their energy requirements during the load-shedding hours. An easier approach in this regard is the utilization of an uninterruptible power supply (UPS) at user ends. However, due to the absence of any Governmental regulations the Pakistani markets are flooded with low-quality, locally-made UPSs. In this context it was decided to conduct this research, i.e. to explore the impact of these UPSs on the Pakistan's power system.

Different types of UPS have been studied in our laboratory. Their charging and discharging processes have been investigated with respect to the harmonics in current and their efficiencies. The UPSs have been estimated to contribute a loss of 410 MW in Pakistan's power system. The cost of the energy lost in these UPSs, from year 2007 to 2013, has been estimated around 1934 million US dollars. The paper finally concludes that there is a need of energy policy in Pakistan to regulate the use of UPSs and related power quality issues.

1. Introduction

Electrical energy is the basic need of agricultural, domestic, industrial and almost every field of life. Due to lack of planning by stake holders, the demand and supply gap has been increasing, for a decade causing further electrical energy shortages. This has resulted in lowering the gross domestic product (GDP) and the volume of manufactured exports in Pakistan (Diboma and Tatietse, 2013). Different energy policies and smart solutions are given by researchers to meet energy requirements (Lu et al., 2013; Anaya and Pollitt, 2014, 2015). A UPS is a backbone for critical loads during load-shedding but the UPSs being used, particularly in Pakistan, have low efficiencies. The efficiency of a UPS is calculated by monitoring its losses. The UPSs have energy efficiency and power quality issues e.g. voltage dip, total harmonic distortion and voltage regulation because they behave as a non-linear load (Pai and Huang, 2006; Tsai and Liu, 2003; Bekiarov and Emadi, 2002; Guerrero et al., 2008; Giuntini, 2011; Moreno-Munoz et al., 2011). Common types of UPS losses are: a fixed-term (no-load) loss, linear-term loss (growing linearly with load current) and a square-term loss (growing with the square of the load current) (Giuntini, 2011). The fixed-term losses have more significant impact on the UPS system efficiency when evaluated at low load. On the basis of power utility, UPSs are classified into three configurations (Kwon

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et al., 2001; Aamir et al., 2016): off-line or stand-by, line-interactive and on-line UPSs. Most of the domestic users in Pakistan use low-power, locally-made, transformer-based, off-line UPSs (500–1000 VA). This may help the policy makers to evaluate utility energy efficiency improvements programs for residential consumers' benefits (Armel et al., 2013).

The transformer's fixed losses, in a UPS, depend on its core material and play important role in the efficiency of a domestic UPS. The characteristics of the core material are dependent on the higher Core temperature, higher flux density and lower loss. The choice of the core material is based on the characteristics, design parameters and acceptable compromised parameters of a transformer (Yang et al., 2012). Due to the absence of any regulations on such UPSs, the local manufacturers in Pakistan do not select appropriate core materials which results in overheating and low efficiency.

Batteries are important for energy back-up in a UPS. The capacity and life of a battery depends on several factors such as charging mode, temperature, maintenance and age (Chuang et al., 2010). Fast charging of a battery causes overheating which reduces battery life by 50% for every 10 °C increase in temperature above the optimum 25 °C operating temperature (Masters, 2004). There is no charging-discharging current limitation in the UPSs being considered here for the battery life. The batteries used in domestic UPSs in Pakistan are mostly lead acid, which have short life. The life of a lead-acid battery decreases rapidly if it is discharged below 30% (Joseph and Shahidehpour, 2006). The battery charging current can create problems such as voltage sags, flickers and harmonics which cause user annoyance, abnormal operation or physical damage to the electrical equipment (Amoli et al., 2010; Johansen, 2013). From a power distribution system operator's point of view, the power losses during charging are an economic concern and result in the overloading of transformers and feeders. Not only power losses, but also power quality (e.g. voltage profile, unbalance, harmonics, etc.) can have a detrimental effect on a power distribution network (Nyns et al., 2010). A UPS battery charging can be compared with the battery charging in hybrid vehicles whose impact on electric utility networks has been reviewed by several researchers (Yilmaz and Krein, 2013; Purwadi et al., 2014; Sourkounis et al., 2010; Benzai and Zhiqiang, 2011).

The UPS is a non-linear load and can generate harmonic voltages and currents in the network, in addition to the power losses. The UPS sales market of domestic sector in Pakistan is growing day by day. Majority of the domestic consumers in Pakistan use low power rating square-wave type UPSs. Fig. 1 shows the consumption of electrical energy in different sectors of Pakistan (NTDC survey report 2012-13). In Pakistan, the domestic sector accounts for highest percentage (51.18%) of the total electrical energy consumption.

A survey was conducted to estimate rating, type, energy consumption and number of UPSs installed in different echelons of domestic consumers in rural and urban areas of Pakistan. An experimental setup was installed in order to measure the power losses, charging current harmonics of different UPSs available in domestic sector of Pakistan. This research presents an overview of locally-made UPSs' efficiency, power quality issues and cost of losses of the UPSs which were tested in the laboratory. Locally-made low-power rating UPSs, which are not type tested (for certification), are considered in this research because of their large numbers in our power distribution networks. The analysis of the test results shows that the performance of UPSs has a significant impact on the electrical power demand in Pakistan.

2. Methodology

2.1. Utilization of UPSs in Pakistan

A field survey was conducted to estimate the total number of UPSs connected to the power system in the region of Lahore Electric Supply Company (LESCO). It deliveries electrical power to the rural and urban areas of four districts of Punjab (Lahore, Kasur, Sheikhupura and Okara). A questionnaire was prepared to collect the data from utility supply consumers (sample is given in

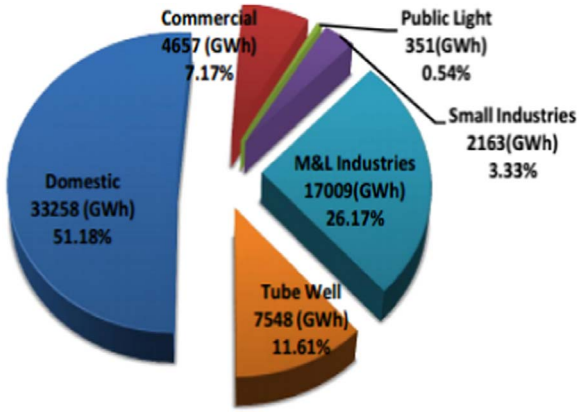

Fig. 1. Consumption of the electrical energy in different sectors of Pakistan.

Table 1
Energy consumption wise number of consumers and UPSs in LESCO.

No. of consumers	Energy units (kWh)	Consumers using UPS	No. of UPSs
1,159,130	0–50	1%	11,591
738,674	51–100	5%	36,934
744,990	101–200	30%	223,497
183,455	201–300	60%	110,073
50,347	301–400	70%	35,243
19,895	401–500	70%	13,927
9174	501–600	70%	6422
5059	601–700	70%	3541
2809	701–800	70%	1966
1867	801–900	70%	1307
1317	901–1000	80%	1054
945	1000–1100	80%	756
4256	above 1100	90%	3830

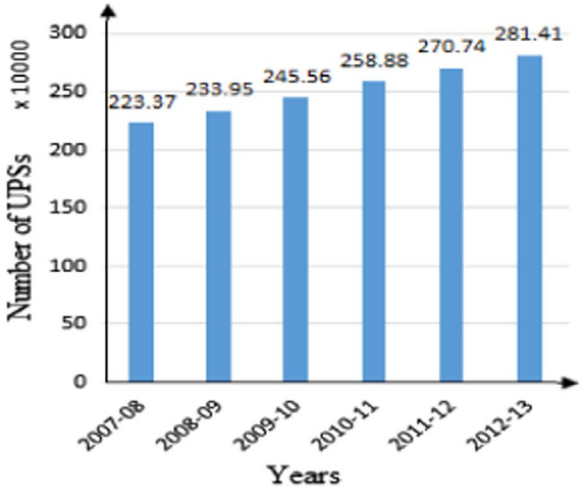

Fig. 2. Domestic UPSs in Pakistan.