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Smart meters for industrial energy conservation and efficiency optimization in Pakistan: Scope, technology and applications

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ABSTRACT

The electrical grid in most of the developing countries has inefficiencies in different areas such as transmission and distribution, power quality, grid reliability and system protection. These inadequacies in grid operations and asset protection, along with revenue leakage constitute an overall troubled energy profile. The fixes usually proposed in this regard are directed at reducing distribution network losses and improving residential and commercial demand side management. Lessons from the residential and commercial implementation of smart meters can be extended to industrial consumers to help relieve grid congestion and achieve better efficiency goals. This paper reviews smart meter technology and applications across residential, commercial and industrial sectors. We point out the areas for power quality and energy efficiency improvement within industries and propose ways for achieving them through smart meters, specifically in the context of Pakistan. We have incorporated empirical evidence from experimental setup at our university grid as proof of concept. We have also elaborated on the implementation methodology to avoid the possible pitfalls in the proposed solution.

Contents

1. Introduction

Pakistan's energy demand has sharply risen over the past few years and still continues to rise. The total electricity demand is expected to reach 49,078 MW by 2025 [1]. Over the years

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generation capacity has not increased in the same proportion as the demand which has created serious energy deficit. According to Pakistan Electric Power Company (PEPCO), the average power shortfall in Pakistan is more than 5000 MW [2] and is likely to become worse in the coming years (Fig. 1) [3]. Further the operational inefficiencies within the grid are quite huge; energy theft is prevalent on most parts of the electrical network and line losses add up to 19.7% of total generation in the country [4]. As a result, the country is facing frequent daily blackouts which have serious economic implications. The oil imports have increased to support electricity generation and resultant oil bills have sky rocketed over the past few years, adding further burden on the economy. It has been estimated that load shedding has cut about 3–4% of Pakistan's GDP, costing about $13.5 billion per year to the country's economy [5,6]. Converting 5000 MW average daily shortfall at the current rate of generation, this amount would have been enough to cover the cost of energy shortfall for approximately 11 years (Appendix).

The solutions that are often suggested with regards to energy crisis include increase in generation capacity and demand side management. In Pakistan's case, a prudent approach would be to look at energy conservation opportunities and incorporate more renewable energy sources into the energy mix. Refs. [7–12] review the conventional and renewable energy scenario in Pakistan and give suggestions for the efficient use of renewable technologies. Khan and Pervaiz have specifically identified the technological shortcomings of Solar PV in Pakistan and point out the areas for improvement [11]. Similarly Mirza et al. have evaluated wind energy development in the country and have given a policy perspective on development [12]. Distribution network losses are another area for efficiency improvement. As for the distribution network, [13,14] discuss the methods for identification and prevention of electricity theft using smart meters.

The demand side management (DSM) solutions proposed to overcome energy deficit are usually designed for the residential and commercial consumers. The most common form of DSM that is presently practiced in Pakistan is the worst kind i.e. complete load-shedding (blackout) although there exist other forms of DSM schemes which are more flexible in terms of load constraint. Architecture for DSM in buildings has been discussed in detail in [15]. Normally the industrial demand is not incorporated into the demand management plans even though industrial demand constitutes significant portion of the total load. There are only a few studies that are specifically tailored for industries. Ref. [16,17] elaborate on the energy efficiency improvement opportunities within industries. This paper builds upon the previous work and identifies constraints and opportunities for smart meter use specifically for industries in Pakistan. It then lays out a detailed plan for the implementation of proposed solutions. This study can be extended within reasonable limits to any developing country. To our knowledge, this work is a first of its kind in addressing energy efficiency improvement using smart meters for industries in Pakistan. Rest of the paper is organized as follows: Section 2 gives the technology description of smart meters; Section 3 elaborates the use of smart meters in residential, commercial and distribution network settings through various technical development pathways; Section 4 identifies the industrial efficiency solutions using smart meters; Section 5 details the implementation methodology; Section 6 gives out the future direction for such efficiency measures and Section 7 concludes the study.

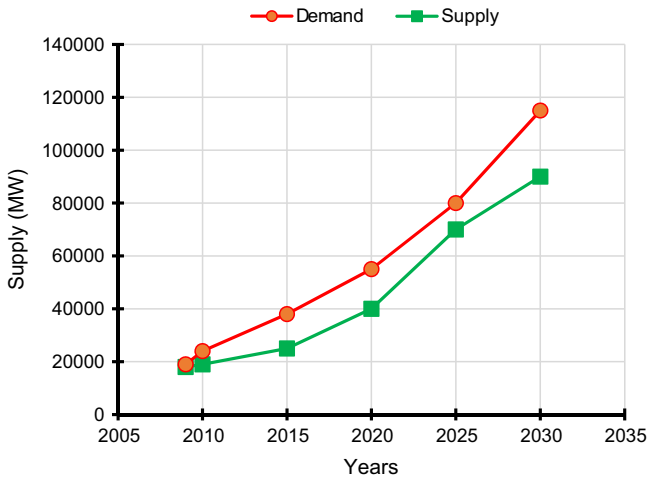

Fig. 1. Demand and supply projections.

2. Technology description

Smart meters are meters that record electrical energy consumption and periodically send the data back to a central server for monitoring, analysis and control. Fig. 2 shows the features of a typical smart meter, which are further detailed as follows:

- *Measurement of electrical parameters:* Basic smart meters measure only the energy values whereas the advanced versions are capable of measuring a range of electrical parameters such as voltage, current, power, frequency and power factor [18]. These electrical parameters are important metrics in load management, load profiling and fault analysis. Most of the smart meters already rolled out in different smart metering programs in Pakistan feature only the most basic specifications. However, recent implementations have begun to use the advanced features [19]. This choice is driven by both the benefits that these additional features offer and the availability of low cost smart meters that offer these functionalities.
- *Periodic data recording:* Smart meters record different electrical parameters at particular time intervals. The granularity can usually vary from a few minutes to a few hours. This periodic recording of data provides a more detailed insight of the event occurrence and helps develop a greater understanding of load use patterns. Presently Pakistan's entire electrical grid features legacy meters whose readings are manually recorded every month. Due to low granularity, the information that can be extracted out of these readings is quite limited. Further, in many cases the readings can't be trusted because of the prevalent bribery amongst the linemen who record the meter readings. Therefore the load forecasts are often inaccurate and the resulting demand management practices are quite basic. Smart meters ensure highly granular and credible meter readings, and can therefore help devise effective demand management strategies [20]. In addition, smart meters generate alerts and notifications for a series of alarm conditions on different monitored parameters. These alerts are useful in identifying non-technical power losses in the electrical grid. In Pakistan, power losses and energy theft form a significant chunk of the total generation and their identification is often difficult, particularly in congested inner city areas [21]. Smart meter alerts offer a feasible solution for identifying and eliminating these system inefficiencies.
- *Communication:* Smart meters usually send data that they have recorded to a central server, where it can be accessed by the utility and the user. In some cases, the data for utility is sent directly to utility communication nodes [22]. Communication infrastructure allows different possible modes of data exchange between the server and the meters. The communication modes