engineering proceedings

MDPI

Proceeding Paper

Diagnosis of Energy Crisis of Pakistan and Assessment of DSM as Viable Solution †

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† Presented at the 8th International Electrical Engineering Conference, Karachi, Pakistan, 25–26 August 2023.

Abstract: Pakistan is facing the deepest energy and economic crisis of its history. In fact, the ongoing economic crisis is more or less due to the energy crisis. In spite of this critical situation, Pakistan began from a meager 70 MW installed capacity at the time of the creation of the country and now has raised that capacity to 40,923 MW with a huge transmission network infrastructure based on 58,679 km transmission lines and a consumer base of 36.5 million. Despite this massive progress, there is a continued power deficit, mounting circular debt, and large losses, which all indicate a depleted picture of the power sector. This paper primarily undertakes the diagnosis of these crises and provides a basic assessment of demand-side management as a potential avenue to overcome energy crises. In this context, a detailed overview of the energy and power sectors of Pakistan, including the outdated T&D system, is undertaken. These diagnoses suggest that poor administration, governance, and inappropriate policies have contributed to these crises. In the meantime, efforts to overcome these crises with expensive capacity additions have also failed to address the energy crisis. However, a careful review of the literature and on-the-ground matters indicates that DSM is the most reliable solution. Sectoral DSM potential is estimated. Implementing the proposed measures will help greatly to overcome these crises.

Keywords: DSM; energy crisis; efficiency and conservation; energy policies

Citation: Chughtai, A.; Uqaili, M.A.; Mirjat, N.H.; Shaikh, F.U. Diagnosis of Energy Crisis of Pakistan and Assessment of DSM as Viable Solution. *Eng. Proc.* **2023**, *46*, 35. https://doi.org/10.3390/engproc2023046035

Academic Editors: Abdul Ghani Abro and Saad Ahmed Qazi

Published: 27 September 2023

1. Introduction

The need for energy has dramatically expanded during the last few decades. However, the generation has not been increased at the same rate to satisfy this increasing demand. In some countries, the mismatch between demand and generation has led to power shortages that have a negative impact on their national development objectives by causing network instability, load shedding, and power outages. Pakistan has never had such a serious economic and energy crisis as it has today. The growing demand–supply imbalance has caused frequent load shedding. Insufficient generation capacity is one of the key causes of this large imbalance. The reductions in hydro generation during winter, limitations of indigenous gas reserves, and mounting circular debt causing non-availability of furnace oil also contribute to the crisis. The situation is further worsened due to the absence of a consistent strategy for energy conservation and improvement of efficiencies, which have resulted in losses and wastage of energy to a great extent. As a comparison, it should be mentioned that Pakistan's consumption per unit of GDP is twice that of the world average, and it is five time more than that of the UK and Japan. A typical example that is brought up is that, due to old equipment design, steel-making as compared to the developed countries, is at least 20% in excess of the needed power consumption for the purpose of making steel [1].

Demand-side management (DSM), a growing alternative approach that makes use of consumer engagement to maintain the balance between demand and generation. Energy efficiency, price- and incentive-based DSM, and distributed energy resources (DER), particularly renewables, are all included in DSM [2]. The current circumstances in Pakistan provide the ideal motivation and timing for demand-side management, technological application, and governmental intervention, as detailed in this study.

The country faces a significant demand–supply energy mismatch in the power sector. The current shortfall is approximately 5000 MW. The sharp increase in electricity demand is due to heavy residential loads such as air conditioning, lighting load, and electrical appliances, etc. It is true that power generation capacity could not keep pace with the growth in demand due to the lack of investment. The demand of electricity in Pakistan has increased dramatically in the last 10 years. Pakistan has seen the large-scale installation of cooling and other conditioning systems, particularly in urban areas. Every region in Pakistan has shown struggles with the large gap between electricity supply and demand of 5 GW due to the lack of the policy.

In Pakistan, DSM is non-existent in practice. There is a saving potential of 2250 MW, but, unfortunately, the energy wastage is increasing with increased energy production. It is estimated that 18% of the total energy consumption in the country can be saved. Correspondingly, the net oil imports would be reduced by 51%. It is worth mentioning that for every dollar of GDP, Pakistan's consumption of energy is 25% more than that of the Philippines and 15% more than that of India. Across all sectors, there is an accumulative margin of 20% energy savings in the country [3].

DSM is very crucial for Pakistan to overcome the energy crisis in this country. The inadequate generation capacity is the contributing factor to load shedding. Plus, the simultaneous growth in the population and the economy of Pakistan is causing the energy demand to skyrocket. Population growth alone is expected to contribute 1000 MW per year to the country's energy demand [4]. Unfortunately, even the existing energy generation capacity is not fully utilized due to the fuel shortage, which prohibits the plants from operating at full capacity, resulting in severe load shedding and blackouts. The preceding factors lead to the conclusion that the impact of the supply and demand side conditions on the design, planning, and operation of a power system can change over time. The only constant aspect that should be regarded is the involvement and implementation of energy efficiency and conservation policies and initiatives at the national and utility levels, which should be the only future strategy for the long-term development of Pakistan's power sector and the reduction in demand.

2. Overview of Energy Sector and the Crisis

Pakistan is a South Asian developing country that suffers from significant energy challenges. The major causes of these energy-related issues include high energy generating costs, subsidy burdens, funding shortages, large circular debt, inadequate planning, heavy reliance on imported fossil fuels, and mismanagement of power infrastructure [5,6]. The lack of use of DSM measures and other energy sources causes difficulties in Pakistan's power sector. According to the NTDC 2022 study, Pakistan has a total installed capacity of 40,923 (MW) and a demand of 34,941 (MW), as per a NEECA study, and there is saving potential of 30%, 25%, and 20% in the domestic, industrial, and agriculture sectors, respectively [5]. The statistics show that Pakistan has sufficient installed capacity for energy production and savings across sectors to easily meet the country's current demand. As a result, no load shedding should occur throughout the country. However, due to the mismanagement in energy sector, the country's present demand cannot be met, and urban regions in Pakistan have 8–12 h load shedding, while rural areas face 14–17 h of power outages [6,7].

There are four major power producers in the country: WAPDA (Water and Power Development Authority), KE (Karachi Electric), IPPS (Independent Power Producers), and PAEC (Pakistan Atomic Energy Commission). Figure 1 depicts the installed capacity for generating electricity and shows total energy generation, which mainly comes from thermal sources. Thermal sources account for over 58% of installed capacity, while Pakistan generates 61% of the current power utilizing thermal resources. The cost of producing power from thermal sources is higher than that of the other possible sources. Furthermore, as compared to the cost of power generation, the rate charged to the ultimate customer is cheap. The government is paying for the difference between the cost of power generation and the ultimate rate paid to customers as a subsidy. However, the government should cut the electricity sector subsidies since the government cannot afford large amounts of subsidies owing to limited resources.

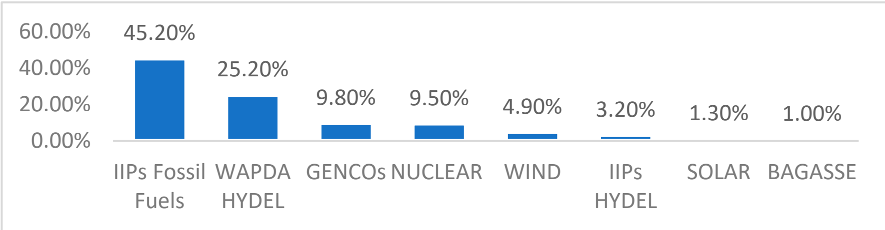

Figure 1. Installed Generation Capacity. NTDC Power System Statistics 47th Edition [7].

The high cost of energy generation, the costs of subsidies, a lack of funds, a huge circular debt, and poor power infrastructure are all major components of Pakistan's energy challenges. Furthermore, inadequate planning and implementation are exacerbating the issue in Pakistan's energy sector. This condition puts Pakistan's economic progress at risk and compromises people's social well-being. It might be claimed that the government must aggressively handle energy issues because the country is already paying a large price as a result of these crises. And, to address the energy challenges, the optimization of energy production systems and the formulation of appropriate energy production mixes, for present and future energy policy development, are highly important along with other measures.

Nevertheless, it is interesting to note that there has been a significant increase in generation capacity compared to the meager 70 MW at the time of Pakistan's establishment 73 years ago. The current installed capacity of 40,923 MW as of June 2022 is 585 times greater than the installed capacity as of 1947 [7].

3. Present Transmission and Distribution System

3.1. Transmission Network

Currently, the total length of 500 kV transmission lines is 8097 km while the total length of 220 kV transmission lines is 11,519 km, the number of 500 kV grid stations is 17 while the number of 220 kV grid stations is 49, and the total transformation capacity of 500 kV is 25,100 MVA while the total transformation capacity of 220 kV is 35,360 MVA. The total transmission loss is 2.8% [7,8].

3.2. Electricity Consumption in Pakistan

Electricity consumption is increasing at an alarming rate whereas the supply is inadequate and is restricted by various factors, predominantly the shortage of fuel and technical constraints (Table 1).

Table 1. Number of Consumers [7].

Domestic and Commercial	Industrial and Others	Agriculture
97%	2%	1%

As domestic consumption is dominant, it is relatively easy to regulate using DSM strategies in a short period of time. One of the most appropriate strategies to address demand and supply challenges is DSM. When the output is not sufficient to meet the needed demand, it controls the peak load and minimizes the energy usage. The primary goal of DSM is to shift demand from peak to off-peak hours, which may help to smooth the power dispatch curve (demand curve).

3.3. Transmission and Distribution Losses: Its Ranking and Status

Pakistan has an extremely high rate of electricity distribution and transmission losses, ranking 14th out of 131 countries as of 2019. In Pakistan, DISCO-wise, T&D losses are 17.13% and KE 15.35 for the period 2021–2022 [9].

4. Methodology

The approach for this study is based on a review of current policies, policy framework, and practices for DSM measures in Pakistan's electricity sector. It then focuses on the existing literature of related and previous studies conducted in Pakistan or in similar areas. Several significant issues impact the sector, and the policies are investigated. The Figure 2 below depicts the impact areas of demand-side management.

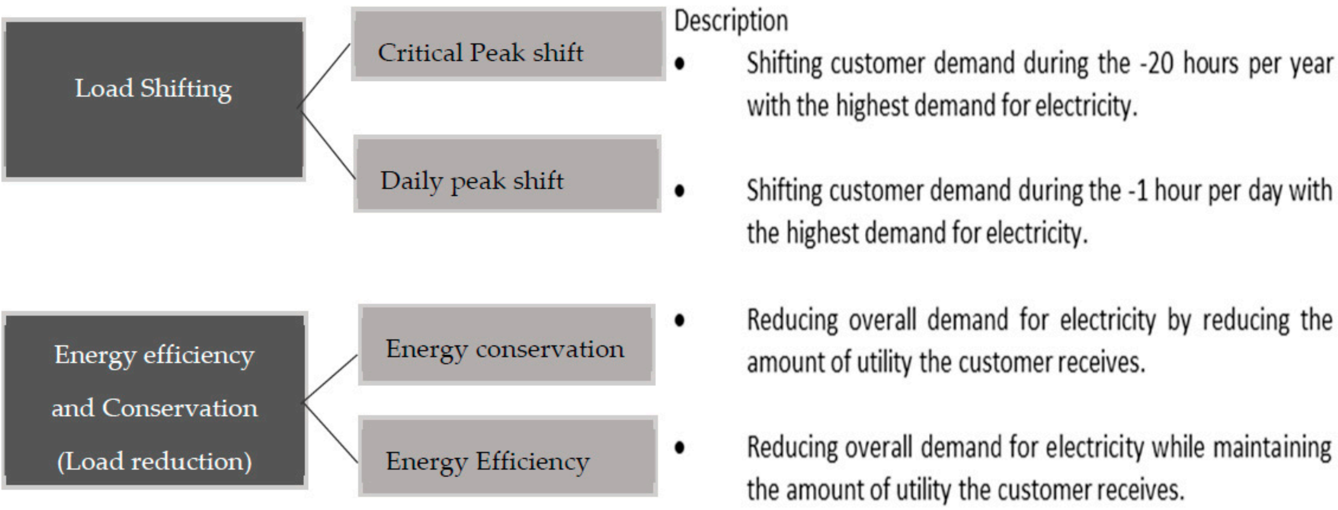

Figure 2. Major impact areas of demand-side management [10].

The institutional framework and DSM deployment so far in Pakistan is discussed in the following sections.

4.1. Building Code of Pakistan (BCP)

The Pakistan Building Code is a document that offers standards for the design, construction, and safety of buildings. It was initially issued in 1986 by the Government of Pakistan Ministry of Housing and Works. BCP (EP-2011) were incorporated into the Building Code of Pakistan in 2013 in order to make this document more relevant for building, energy, and conservation practitioners and to help the government execute energy efficiency and conservation strategies [11,12].

4.2. WAPDA Pioneer of Early DSM Measures

WAPDA's Energy Conservation and Load Management section was founded in 1985 and was tasked with installing time-of-day metering (ToD) on industrial units; however, DISCOs currently install the meters.

4.3. Proposed National Energy Efficiency and Conservation Policy 2022

The National Energy Efficiency and Conservation Policy of 2022 was drafted with a vision to inculcate a culture of conservation and efficient use of energy based on guiding principles [13].

4.4. Demand Management through Smart Metering and Advance Metering Infrastructure

Currently, load shedding is accomplished by shutting down around 15 feeders from a grid station (each feeder supplying approximately 3 MW of power). Smart meters might be centrally managed to limit every consumer to 1.5 kW. In this approach, roughly 15,000 high-load residential customers might be curtailed at peak periods, shedding a load of approximately 50 MW. Depending on the communication mechanisms, the AMI system could be implemented in different ways. The most important benefit of AMI is the decrease of 11kV and the accompanying distribution losses.

4.5. Early Closure of Shops

In 2010, the National Energy Summit decided on the closing of markets and shops at 8:00 PM to reduce, in particular, the use of lights and air conditioners during peak hours. At that time, in 8 DISCOs, 388 11 kV feeders were catering supply to shopping centers and markets with an aggregate load of 1111 MW; the early closure of shops resulted in substantial DSM gain (PEPCO Evaluation 2010).

4.6. Replacement of Incandescent Bulbs with Energy Saver (CFL'S)

Lighting loads account for approximately 25% of the total load in the household, commercial, and industrial sectors. The replacement of 30 million IBs with CFLs, having an average consumption of 21.5 W per lamp, targeted an estimated reduction in peak demand by about 1094 MW, which was undertaken during the period 2010–2014 (source: ADB) [5].

4.7. National Energy Efficiency and Conservation Authority NEECA

In 2016, the National Energy Conservation Centre (ENERCON) was transformed into the National Energy Efficiency and Conservation Authority (NEECA) [13]. The NEECA provides the governance framework that can facilitate national efforts and reinvigorate wide-scale adoption of sound energy efficient practices, and it has been entrusted with a wide range of regulatory responsibilities [13].

4.8. Punjab and Sindh Energy Efficiency and Conservation Agency

The Punjab Energy Efficiency and Conservation Authority (PEECA) was founded in 2016 to implement energy efficiency and conservation policies and practices in Pakistan's Punjab province [12]. On similar lines, the Sindh Energy Efficiency and Conservation Authority (SEECA) was formed in Sindh in August 2022.

5. Assessment of DSM as a Viable Solution

According to a credible study of ENERCON (now NEECA), the following sector-wise savings were estimated (Table 2).

Table 2. Energy Savings in various sectors in Pakistan [14].

Sector	Building	Industry	Agriculture	Transport	Average
Potential Saving %	30	25	20	20	25

The potential of DSM in the building and industry sectors is significant; by applying DSM techniques, efficiency can be increased and losses can be reduced.

Some of the specific techniques (already in use or that need intensification) that will result in potential savings are listed below.

- **Power Factor:** The overall efficiency of power utilization is maintained with reduction in the load of motors through power factor correction of industrial and agricultural loads by installing capacitors that result in potential savings.

- **LED Lights:** Lighting contributes approximately 25% of the load in buildings. As a priority measure, it is imperative to undertake the conversion of lighting loads to LED starting with government buildings and public lighting.
- **Energy Efficient Distribution Transformers to be implemented by Utilities:** Installation of energy efficient distribution transformers with reduced power losses.
- **Good Quality Material with Monitoring and Implementation by the Pakistan Standards and Quality Control Authority:** Use of good quality material, e.g., for cables and accessories, wires, switches, holder, fans, and lamps, decreases the losses and demand. A poor quality fan consumes on average 20 watts extra while a poor quality cable consumes on average 8 watts extra.
- **Inverter type air conditioners:** The introduction of inverter type air conditioners would be a significant measure to decrease demand, with only inverter type ACs recommended to be imported.
- **Energy Audit:** The NEECA, PEECA, SEECA, and Utilities should arrange energy audits of industries and commercial complexes starting from government buildings. The utilities need to establish DSM cells to institutionalize DSM activities and energy audits.
- **ESCO:** To institutionalize energy savings, ESCOs (energy service companies) should be established and promoted in order to facilitate the prospective consumers.
- Replacing old and inefficient tube-well motor pumps and shifting the load pattern to use TOD meters. Presently, the efficiency of the pumps is stated to be only 30% of the standard equipment.
- An ENERCON study indicated that saving energy is possible by switching to high-efficiency motors, especially for heavy continuous load applications.

6. Conclusions and Recommendations

Pakistan has suffered major energy challenges due to a lack of planning, population growth, and outdated infrastructure. Even so, the ongoing 5GW shortfall and future demand could be compensated for by managing the current resources, optimizing infrastructure, effective planning, strong financing, and collaboration with the private sector and international agencies. DSM might be a unique solution to minimize utility consumption if the strategies mentioned above are implemented. Long-term strategies are necessary to implement these processes, and the results will improve the current energy crisis. In addition, the success of DSM may be achieved through consumer awareness programs, which will help consumers better understand the energy management system, such as the reasons for load shedding. These numerous enhancements will contribute to the ultimate objective of a better load management system.

- Conserving energy and improving efficiency in using energy resources via technological advancements and improvements in institutional capacity has become critical. Without a complete shift towards energy conservation and efficiency, all efforts will fail.
- The government needs to establish energy development funds dedicated to energy conservation and develop a well-established system to facilitate investments in energy savings.
- The most effective and crucial missing element of DSM in Pakistan is the lack of policy framework and implementation mechanism, which need to be developed with a priority for institutionalizing demand-side management in Pakistan and to achieve realistic tangible results.

Author Contributions: A.C.: Concept, assessment, drafting and critical revision. M.A.U., N.H.M., drafting, analysis and critical revision, F.U.S.: Formal analysis. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was approved by the Institutional Review Board of NED University of Engineering and Technology.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data is available upon request.

Conflicts of Interest: The authors declare no conflict of interest.

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