Electricity Demand Forecasting

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With the globally increasing electricity demand, its related uncertainties are on the rise as well. Therefore, a deeper insight into load forecasting techniques for projecting future electricity demands becomes imperative for business entities and policymakers. The electricity demand is governed by a set of different variables or “electricity demand determinants”. These demand determinants depend on forecasting horizons (long term, medium term, and short term), the load aggregation level, climate, and socio-economic activities. In this paper, a review of different electricity demand forecasting methodologies is provided in the context of a group of low and middle-income countries. The article presents a comprehensive literature review by tabulating the different demand determinants used in different countries and forecasting the trends and techniques used in these countries. A comparative review of these forecasting methodologies over different time horizons reveal that the time series modeling approach has been extensively used while forecasting for long and medium terms. For short term forecasts, artificial intelligence-based techniques remain prevalent in the literature. Furthermore, a comparative analysis of the demand determinants in these countries indicates frequent use of determinants like the population, GDP, weather, and load data over different time horizons.

Keywords: demand determinants ; forecasting horizon ; load forecasting ; low and middle income countries

1. Introduction

Technological advancements are changing the shape of the grid by converting a demand-driven power system towards a generation power-driven system. This is essentially due to a multitude of factors including increased penetration of renewable energy resources (RES) and new technologies at the consumer side (electric vehicles, energy storage). This creates uncertainties in terms of future electricity demand. Therefore, the importance of load forecasting has increased multifold for the future grid with limited safety margins and increasing risk levels. However, the rise in global electricity demand is consistent and still expected to grow more than twice the rate of global energy demand [1]. Forecasting in the energy sector is a crucial input for many power system applications of both a technical and managerial nature. These applications range from energy generation (from different renewable and non-renewable resources), energy management at different nodes and sectors, energy pricing, and many others. The primary purpose of having a forecasted load for these applications is to ensure a safe, reliable, and affordable energy supply [2]. Load forecasting has been a research topic for decades, however, due to the eminent changes in the grid, load forecasting is attracting the attention of more researchers today than ever before.

2. Importance of Load Forecasting for Pakistan—A Global Perspective

Electricity demand growth trends in developed economies are now flattening [1]. Meanwhile, the annual demand growth rate in developing economies is four times higher than that in developed economies. Estimated to constitute almost 90% of the global electricity demand by 2040 [1], developing economies, therefore, carry a significant status in the global energy perspective. Such growth in electricity demand needs to be carefully forecasted using robust forecasting methods. Practically, forecasting a non-linear quantity like the electric load is a complicated task and barely achieves 100% accuracy [2]. Resulting inaccuracies in these forecasts can have serious technical and economic impacts. In the long term, for example, the right allocation of resources, asset management, and investments in power infrastructure can be greatly affected by inaccurate forecasts [3].

Similarly, on a very short term horizon, the unit commitment and generators’ availability can have serious impacts following an under or over forecasted load [4]. A resulting inadequacy in capacity planning, loss of load, and outage costs can plunge an already developing economy further into a serious economic crisis [4]. For example, in 2018, Pakistan paid 4.7 billion USD in terms of the idle capacity charges which partly resulted due to inaccurate demand forecasts [5]. Therefore, the right selection of demand determinants, their combinations, and the selection of suitable forecasting models and techniques become important prerequisites for obtaining reliable forecasts. In Pakistan, there exists a

unidirectional causal relationship between its economic growth and electricity demand [6]. Recent economic cooperation between China and Pakistan worth 46 billion USD, i.e., the China–Pakistan Economic Corridor (CPEC), is expected to add 2.5% to Pakistan's current GDP [7]. Consequently, Pakistan's GDP is expected to increase in the future.

In addition to its economic growth, the electricity demand in Pakistan is highly driven by different climatic variables as well. Due to the seasonal variability in its climate zones, the bulk power from the north flows to the country's load centers (north-east and south) in the summer, whereas, in the winter, this bulk power flows from major generation centers in the south to load centers (north-east and south) [8]. Moreover, rising temperatures in the country result in electricity demand growth due to the increasing use of air-conditioning in summer [9]. Today, Pakistan stands amongst 28 countries which are most affected due to climate change [10]. It is estimated that a rise of one-degree Celsius in temperature can result in an additional 109.3 GWh of electrical energy demand in Pakistan [9]. Given the situation and significance of weather variables in load forecasting, it now becomes imperative for forecasters in Pakistan to build forecast models inclusive of its changing climatic conditions.

3. Forecasting Methodologies—Models and Techniques

Based on their forecasting horizons, electricity load forecasts can be broadly categorized into three distinct categories. These categories are:

- Short term load forecasting (STLF)
- Medium-term load forecasting (MTLF)
- Long term load forecasting (LTLF)

STLF is usually carried out over time periods ranging from hours to days or weeks ahead [11]. It helps in facilitating electricity markets for the day ahead planning of the electricity supply, and in demand-side management (DSM) as well [12]. MTLF, on other hand, deals with the forecasting horizons of months to even years ahead [13]. Such forecasts help in revenue assessments, unit maintenance scheduling, and energy trading, etc. [14]. For LTLF, the forecast horizon stretches from roughly five years to even decades ahead [14]. These forecasts provide deeper insight for policymakers and help with the efficient management of assets and effective power systems expansion planning.

4. Conclusions

In this paper, we have reviewed electricity demand forecasting practices (methodologies and determinants) in a group of LMICs and used Pakistan as a reference country for comparison. Numerous studies were found combining different techniques and approaches in attempts to enhance forecasting accuracies. We identified that the selection of forecasting techniques and demand determinants depends on the forecasting horizons and regional dynamics. For LTLF and MTLF, time series modeling was found to be extensively used by researchers. On the other hand, AI-based techniques were mostly used while forecasting for the short term (STLF). Similarly, for LTLF, the GDP, population, and previous load data were the most commonly used demand determinants. For MTLF, the GDP, weather data, and previous load data appeared to be more relevant demand determinants. For STLF, only weather data and past load data were significant.

Amongst the most meaningful studies we considered from Pakistan, 87.5% were on LTLF. When compared with those from LMICs, it was found that no LTLF study from Pakistan used AI-based techniques and only a few used econometric models. Therefore, it is recommended that advanced and more inclusive methodologies (such as AI and econometric modeling techniques) must be used by the forecasters while making forecasting models for Pakistan. The literature on STLF is very limited, with no study found on MTLF, in contrast to LMICs, raising another concern for forecasters in Pakistan to tap on these potential research gaps.

In the end, electricity demand determinants from Pakistan and LMICs were reviewed, analyzed and compared. It was found that when compared to LMICs, LTLF related demand determinants were quite fairly used in the literature from Pakistan. In LMICs, STLF studies extensively incorporated determinants related to weather and load data. However, due to challenges associated with data availability, very limited literature is available in Pakistan which incorporates these data sets. Since no meaningful study on MTLF has yet been produced in Pakistan, it was also suggested that MTLF related demand determinants must be used while producing medium-term forecasts for Pakistan. Finally, with the rise of RES in the country's energy mix, it is also concluded that forecasters in Pakistan must adapt to net-load forecasting techniques instead of the usual forecasting methods in the future.

Authors have reviewed and compared forecasting practices in Pakistan within the context of developing countries. We have explored the different dimensions of electricity load forecasting, including electricity forecasting horizons, methodologies, and demand determinants. For the country selection process, we used a robust criterion and finally selected four different parameters as a basis for comparison. However, this criterion can be made stricter in the future by introducing additional parameters to those already used. This will result in more precise results and hence a deeper insight into the subject as well. Moreover, any future extension of this work may also include comparing forecasting practices in a developed/developing country with or within other developed/developing countries.

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