Electricity Demand Forecasting: A Pakistans Perspective

Suhail Ahmed Shaikh Nayyar Hussain Mirjat Wajahat Shabbir Korejo Gordhan Das Walasai Abdul Sattar Larik

Arsalan Hussain

***Abstract*—Accurate and realistic electricity demand projection has attained greatest ever importance in overall energy planning. Various methods are found in the literature for electricity demand forecasting ranging from econometric models to statistical tools and the energy models. The demand of electricity in the country has increased along with the number of electricity consumers in Pakistan over last 2-3 decades. However, the countrys energy and power departments capacity to rationally forecast electricity demand and subsequent planning as well as the implementation of developed strategies has not delivered to meet the demand. This paper examines the long-term electricity demand forecasting approaches and specifically reviews the demand projection studies as well as methodologies used in the past. There are mainly five consumer groups identified in the electricity sector of Pakistan i.e. domestic, commercial, industrial, agriculture and other. The growth parameters of each of these groups are pivotal to more accurate electricity demand projection. The Water and Power Development Authority (WAPDA) for nearly 40 years following the independence was responsible for power sector planning. However, following the restructuring of WAPDA, National Transmission and Dispatch Company (NTDC) in coordination with Distribution Companies (DISCOs) undertake electricity demand projection studies. This review finally identifies various loopholes in electricity planning and suggests various parameters and steps which require due consideration for electricity demand forecasting in Pakistan.**

***Index Terms*—Electricity Demand, Forecast, Pakistan, Electricity Crisis**

I. INTRODUCTION

Electricity is now a day considered as an important commodity and most efficient form of secondary energy. Todays civilisation and industries depend heavily on this commodity. As such, electricity is a major source of survival of human society alongside other essential commodities.

Electricity demand in Pakistan has increased with increase in the population and economic growth, but somehow sufficient growth of electricity production could not be witnessed to meet the demand that is why she has to face the load shedding of 8-12 hours a day [1]. The improved lifestyle, as well as the industrial growth, still require more electricity. Since year 2006 and onwards countys enhanced electricity demand could not be met. It is well established that electricity infrastructure planning is mutually related to the demand and Gross Domestic Growth (GDP) especially for a developing country like Pakistan [2]. As such, the electricity demand in the country has increased exceptionally due to GDP growth of 6% per annum for 2002 to 2007. However, with no proper infrastructure planning in power sector resulting in severe power cuts which also caused reduced GDP growth by 2%, unemployment of 0.53 million industrial workers and loss of exports worth $ 1.3 billion in 2010 [3].

The increasing role of electricity in everyday life demands a mechanism to forecast the demand rationally. The electricity demand forecasting models provide the required mechanism. Long term forecasting is also necessary for the better planning of resources utilisation, capacity expansion, grid and network extension. The electricity sector of Pakistan comprises of WAPDA (Water and Power Development Authority), IPPS (Independent Pakistan Power Producer), GENCOs (Generation Companies), KESC (Karachi Electric Supply Company), and PAEC (Pakistan Atomic Energy Commission). National Transmission and Dispatch Company (NTDC), as per its license, is responsible for undertaking load forecasting studies for long-term, as a critical input to the overall electricity infrastructure planning. However, for various reason, the load forecasting studies undertaken by NTDC have not delivered to the expectation to mitigate the ongoing power crisis in Pakistan.

This paper reviews different long-term electricity demand forecasting methodologies and analyses the long-term forecasting exercises undertaken in the past. Section 2 of the paper provides the overview of Pakistan power sector, various long-term electricity demand projection methodologies are discussed in section 3, section 4 provides demand projection undertaken in Pakistan, and section 5 provides discussion and recommendation and finally the conclusion.

II. PAKISTANS POWER SECTOR

The institutional structure of Pakistans power sector is a complex set of various departments with ambiguous and overlapping functions. The key players in Pakistans power sector are shown in Figure 1. WAPDA, PEPCO (GENCOs), PAEC, K-Electric and IPPs are mainly responsible for the generation of electricity, NTDC and CPPA are tasked with power despatch, and related function and DISCOs are responsible for distribution of electricity. Except for K-Electric and IPPs, all other departments mentioned above are working under the umbrella of Ministry of Water and Power. K-electric is the vertically integrated electric company responsible for electricity generation and distribution in Karachi [4].

The electricity consumers in Pakistan are categorised as domestic, commercial, industrial, agriculture and others. The

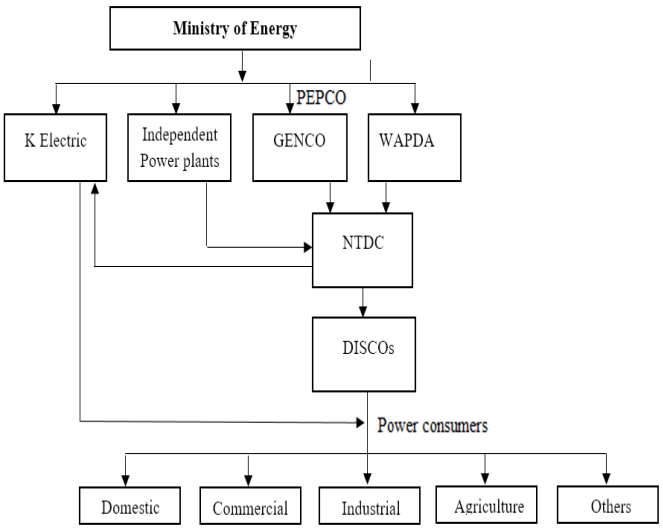

Fig. 1: Overview of Pakistans Power Sector

major chunk of electricity is consumed by the domestic sector followed by industrial sector [5] as shown in Figure 2.

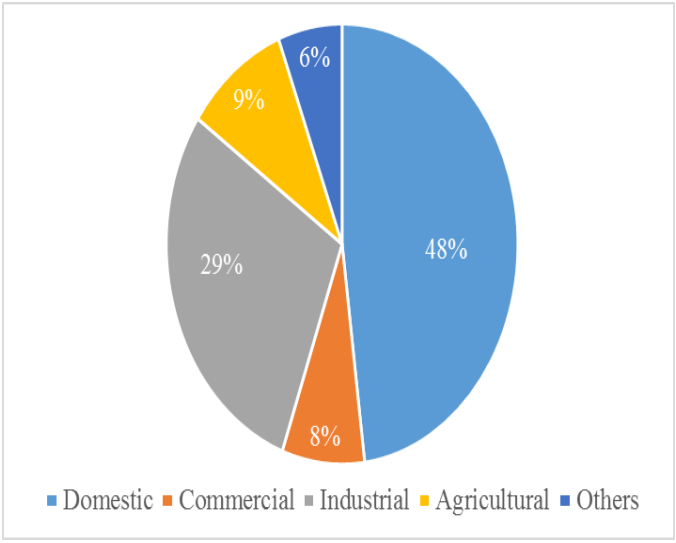

Fig. 2: Electricity consumption by sectors

Table 1 suggests that there is growing electric load base of domestic consumers followed by industrial consumers. It is, therefore, essential that rational load forecasting approaches should be undertaken for each sector of the economy towards cumulative forecasting of the country on long term basis and substantiated with effective planning.

III. LONG TERM ELECTRICITY DEMAND PROJECTION METHODOLOGIES

Various methodologies and approaches are used for projecting the long-term electricity demand at different levels. The electricity demand forecasts are assigned different levels concerning specific time span. Long-term demand forecast spans from 10 years up to fifty years or more, medium term forecast ranges from 5-10 years, and short-term load forecast is generally for a period up to 5 years. Electricity demand projection plays an important role ahead in the electricity generation, transmission and distribution network planning [6]. As such, electricity demand projection is becoming an important feature of overall power system planning since the future development depends on todays predictions.

TABLE 1: ELECTRICITY CONSUMPTION FOR THE PAKISTAN (2009-15) IN GWH

Year	Domestic	Commercial	Industrial	Agriculture	Others	Total
2009-10	31776	5557	19758	9689	10104	76884
2010-11	33675	5726	21147	8972	10668	80188
2011-12	35230	5691	21744	8548	10707	81920
2012-13	34954	5942	22081	7697	10291	80965
2013-14	35439	6304	24117	8290	10440	84590
2014-15	40761	6442	24928	8032	10245	90408
Total	**211835**	**35662**	**133775**	**51228**	**62455.4**	**494955.4**

The electricity demand forecasting methodology can be divided into two groups: Artificial intelligence and Parametric methods.

A. Artificial Intelligence Methods

The artificial intelligence methods are further classified into neural networks, support vector machines [7], genetic algorithms [8], wavelet networks [9], fuzzy logics and expert system methods as shown in Figure 3.

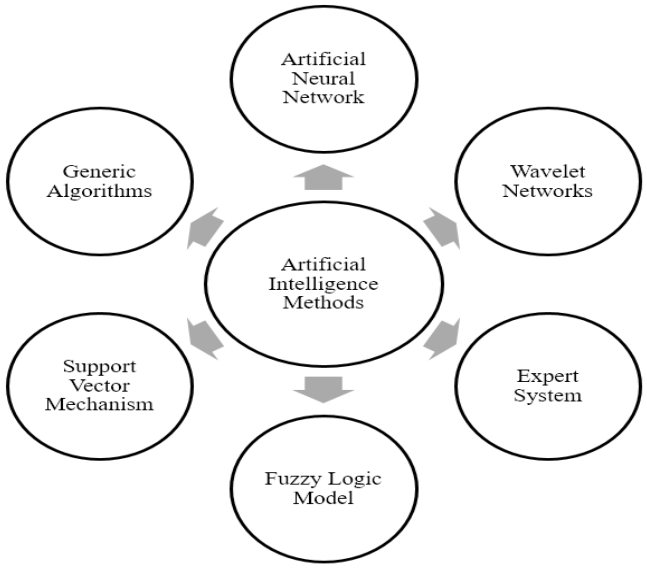

Fig. 3: Artificial intelligence based methods used for long term electricity demand forecasting

The Artificial Neural Networks (ANN) are nonlinear statistical data modelling tools, in which the complex linkages between input and output are modelled whereas, Support Vector Machines (SVM) are the planes that define decision

boundaries. The generic algorithm repeatedly modifies population of individual solutions. Fuzzy logic is used to combine them with a neural network to train ANN and have better load forecasting. Purchasing Power Parity (GDP-PPP) was used and validated by comparing the results with those of MENR.

An expert system emulates the ability of a human expert regarding decision-making. Those are designed for solving complex problems using reasoning, mainly represented as if-then rules rather than through conventional code.

B. Parametric Methods

The parametric methods are related to the load demand and its factors having impact on the model. The parameters are estimated using statistical techniques by analyzing the past load data. Parametric methods can be categorised into three approaches: Trend Analysis, End-use Models and Econometric Models [10] as shown in Figure 4.

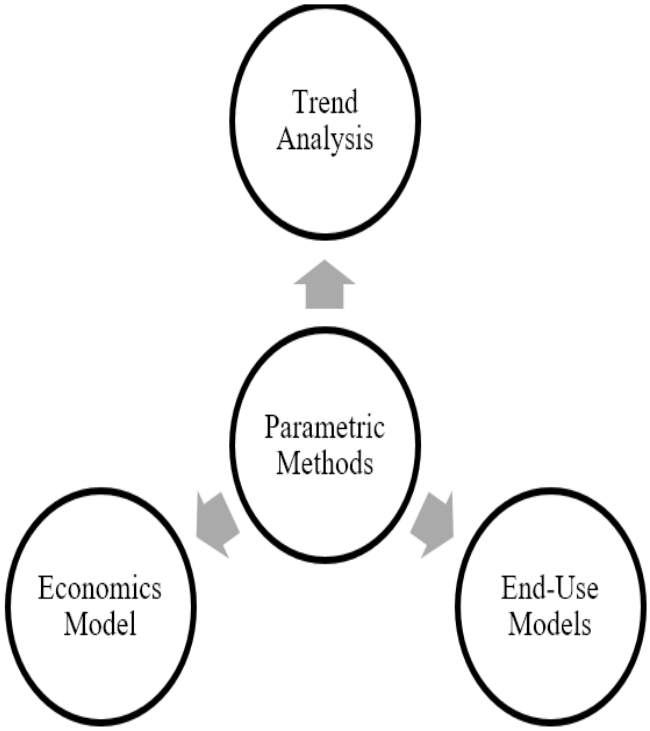

Fig. 4: Parametric methods and their models

The difference between the actual and forecasted values occur due to model structure and unsuitable modelling assumptions [11]. The forecasts based on trend analysis extrapolates the previous times demand trends in the future. The results might be appropriate for shorter time. The econometric models imply a top-down approach for forecasting and are dependent on the link among energy consumption and other variables like GDP, population, price, and number of consumers.

Similarly, end-use models interlink energy consumption with appliances on the basis of use pattern and the industrial sector. These end-use models use the bottom-up modelling approach and generally undertake the disaggregate end-use forecast and consumer survey methods.

IV. POPULAR ELECTRCITY DEMAND FORECASTING MODEL

A brief review of some of the most popular long-term electricity demand projection models is given as under:

A. Time Series Models

The timeseries trend is used to extrapolate the future demand in the Time Series models. Trend analysis extends past consumption of demand towards the future; trending is frequently modified by the assumption, wherein the users keep changing input on the basis of their knowledge of possible future developments which could have impact on the demand [12].

B. Regression Analysis/Models

Regression model analyses the impact of energy consumption on the economic growth by considering both the linear and nonlinear effects. The regression provide a better empirical model than the standard model based on the linear approach. These type of models models are widely used for demand forecasting for medium to long-term time period [7-9]

C. Decomposition Models

Under the energy consumption methodology, the basic parameters are related to the change in level production, structural change, and energy intensity, whereas only last two effects are used in the energy intensity approach [10].

D. Co-integration models

Co-integration models examine the effects of GDP, income, population, number of consumers, and price on energy demand and are used in several countries [11, 13].

E. ARIMA Models (Autoregressive Integrated Moving Averaged

ARIMA (Autoregressive Integrated Moving Averaged) models have been widely used in energy and electricity demand forecasting. Based on statistics and econometrics principles, these models are fitted to time series in order to understand data or to forecast. These models are used where data is non-stationarity, where an initial differencing step can be applied one or more times to eliminate the non-stationarity. These are various studies which have used this class of models for electricity demand forecasting for different time horizon [14, 15].

F. Grey Prediction Models

Due to simplicity and its ability to characterize the unknown system entirely on the basis of few data points, the grey prediction became popular in the recent past [16, 17]. The demand forecasting is a type of grey system problem as only few variables like GDP, income, population are known to affect the demand but how exactly, is not clear. Grey forecasting consists several forecasting models of which GM(1,1) is commonly used for forecasting [18].

G. Input-Output Models

An Input-Output model is used to assess the social and economic development impact on the energy demand in the various sectors of economy. The dominant sectors having higher share in the electricity demand are identified by using Electricity Demand Multiplier (EDM). Alcntara, del Ro [19] developed an inputoutput table (IOT) in order to analyse the consumption pattern in Spain. The table helps in effective utilisation of electricity by increasing energy efficiency. Similarly, IOT is developed for China based on the input output table of the national economy (IOTNE) [20].

H. LEAP Energy Model

The LEAP (Long-range energy alternatives planning) system is an energy accounting modelling tool which matches demand with supply side electricity generation technologies and outlines the system impacts including electricity generation by source, electricity production cost at different discount rates and greenhouse gas (GHG) emission potential.

The methodologies described above are extensively used by various governments and researchers for forecasting electricity demand as shown in Table 2 below.

TABLE 2: DIFFERENT MODELS USED FOR FORECASTING

Methodologies	References	Application	Range of Forecasting Period
Time Series Models	[12]	Israel [21], Asturias-Northern Spain [22], UK [23], New Zealand [24], India [25]	Short and Long-Term
Regression Models	[7-9]	Jannuzzi and Schipper [26], Hongkong [27]	Short and Long-Term
Decomposition Models	[10]	Singapore and Taiwan [28], EU [29], Turkey [30], Iran [31]	Short-term
Co-integration Models	[11, 13]	Pakistan [32], UK [33], Korea [34], Greece [35]	Short-term
ARIMA Models	[14, 15]	Turkey [15], Turkey [17]	Short and Long-Term
Grey Prediction Models	[15, 16, 36, 37]	Taiwan [38], Brazil [39], China [20], Romania [40]	Long-term
Input/output Models	[19, 41]	Brazil [42]	Short, Medium and Long-term
LEAP Model	[43] [44]	China [45], Caribbean [46], Turkey [47]	Short-term

The long-term load demand forecasting methods/models were briefly discussed above. All of these methods can be used to forecast the demand of electricity, but the amount of previous data and such variables which are needed, make them different in accuracy from area to area. Finally, for long-term load forecasting, there should be sufficient input data pertaining the power system. Sometimes different methods can be combined, and results can be compared for the purpose of accuracy

V. LONG TERM ELECTRICITY DEMAND PROJECTIONS OF PAKISTAN

The power sector of Pakistan had witnessed gradual development following independence in 1947 to meet the limited electricity demand. Pakistan inherited a power generation capacity of 60 MW. However, the power sector infrastructure development gained momentum after the 1970s and further improved around early 1990s. But the following years are noticed to show a decline in the progressive curve, and as a result, the power crisis originated [48]. The investments from the 1970s onwards, as per five-year plans, were supported by various studies undertaken from WAPDAs platform over the years and were graciously nanced and technically assisted by a number of international nancial institutions. The methodology of these studies was generally based on statistical or mathematical methods with limited application of energy modeling tools. A summary of these studies undertaken by WAPDA/GOP at the national level is given in Table 3 and their salient features discussed as under:

A. National Transmission and Despatch Company (NTDC) studies

National Transmission and Despatch Company (NTDC) was incorporated in November 1998 is required to undertake medium term and long-term forecast studies on a different time interval. Some of the key studies of NTDC are discussed as under:

Electricity demand forecast based on multiple regression analysis (2014-2037)

The long-term forecast study of NTDC is published annually and takes into account the historical data and future growth scenarios to forecast electricity demand. The study period of the current forecast is 2014 to 2037.In the regression analysis, the study first calculates the elasticity coefficient, and for this purpose econometric software, Eviews is used. In regression analysis, the ordinary least square (OLS) method of estimation is used by utilizing the feature of Eviews. This forecast used past data for 1970-2013 and considers electricity consumption, consumer price index (CPI), tariff, GDP for different sectors of economy, population, number of consumers etc. The forecast presents three different scenarios (low, normal and high) for the period 2014-2037.

Electricity Demand forecast based Power Market Survey

The Power Market Survey (PMS) provides the energy and power projection related to all the DISCOs and the grid stations, that is a type of end-use model. The database includes type of consumer on the basis of grid station and feeder. On the basis of trend analysis of per consumer sale and new requests for connection, the forecasts are made for each of the consumption category. The forecasts in the industrial sector are made by having interview with existing consumer and its trend projections and possible review of the new connection requests. These analyses are repeated for each sub area for each of the years to be forecast. For each sector, the demand is forecasted by using the load and diversity factors and then are summed up to the system-level. The demand cannot be predicted accurately over the long-term future, as PMS is based on the end use mix, projection trend and expansion of consumer plans. In order to predict the impact of changes in different variables and economic development

NTDC uses multiple linear regression model. The techno-economic changes over a longer time are incorporated in the forecasting model to assess their impact in the future. The PMS provides details required for the studies and development of transmission and distribution plan in the electricity sector, as well as the sectoral detail, which are required for assessment of growth rates and impact on load shape curves of the system, distribution companies and the grid stations. PMS also provides appropriate approximation of load growth which shall help in making specific provision for the load shedding [49]. In addition to above these regular studies by NTDC pertaining load forecasting, various national level energy planning effort listed in Table 3 [50] below had also included demand forecast as an essential component of energy planning.

TABLE 3: GOVERNMENT LEVEL STUDIES FOR ANALYSING THE ENERGY SYSTEM EXPANSION

Study	Carried out by	Year	Forecasting Methodology	Remarks
Liefticnk Report	World Bank	1967	Statistical Methods, Linear Programming and Financial Analysis	In this report future load was forecasted till 1985.
RESPAK Model	Energy Wing of Planning Commission	1988	Optimization Planning Framework Model	In this model forecast was prepared for the years 1988-2013.
National Power Plan	Water and Power Development Authority (WAPDA)	1994	System Expansion Plan	National power plan (NPP) covered load forecast, generation and transmission expansion for the period from 1995 to 2018
Energy Security Action Plan	Planning Commission	2005	Past Energy Consumption Trend and Estimated Future Load Growth	Energy security action plan (2005-2030) was announced to ensure secure energy supplies. The plan emphasized increasing electricity generation capacity, from 19,540 MW of electricity to 162,590 MW by the year 2030.
Pakistan Integrated Energy Model (Pak-IEM)	International Resource Group (IRG)	2007	TIMES-VEDA	Pak-IEM model provides analysis of the options Pakistan's energy system to advance over the next 20 years to achieve the growth projections based on 5.6% average GDP up to 2035.
National Power System Expansion Plan (NPSEP)	National Transmission and Despatch Company (NTDC)	2011	System Planning and Production Costing Software (SYPCO)	The load forecast for this study was prepared by the NTDC load forecast team using standard regression methods

B. Academia level Demand Forecasting studies.

Along with government level eorts, there is substantial work done by the researchers on Pakistans energy system, however, this review only takes on account the work whereby electricity demand forecasting been undertaken for national level energy planning as listed in Table 4.

Gul and Qureshi [51] have also forecasted electricity demand through multiple regression analysis, and they observed through LEAP model cumulative growth rate of 8% the electricity demand rise from 68 GWh in 2008 to 368 GWh in 2030. M. Aslam Uqaili [52] have forecasted the electricity demand of Pakistan for study period 2013-2035. Perwez, Sohail [53] have forecasted electricity demand from 2011-2030 which is estimated to be 1312 TWh in 2030. Ishaque [54] have forecasted electricity demand in government policy (GP), demand side management (DSM), and renewable energy (REN) scenarios over the period (2014-2035) which is 303.7 TWh. Except for first study of Table 4 all other studies used LEAP model for demand forecasting in Pakistan.

TABLE 4: NATIONAL LEVEL ENERGY MODELLING EFFORT IN PAKISTAN

Research Tittle	Authors	Years
Modeling Diversified Electricity Generation Scenarios for Pakistan	Gul and Qureshi [51]	2012
Electricity demand and Emission under Different Policy Scenarios for Pakistan	M. Aslam Uqaili [52]	2104
The long-term forecast of Pakistan's electricity supply and demand: Application of long term energy alternative planning	Perwez, et al. [53]	2015
Is it wise to compromise renewable energy future for the sake of expediency? An analysis of Pakistan's long-term electricity generation pathways	Ishaque [54]	2015

VI. CONCLUSION AND RECOMMENDATIONS

Electricity demand forecasting is very crucial to estimate future load and development long term energy plans. Various methods of demand forecasting have been reviewed and discussed in this paper. Pakistan is using only limited demand forecasting methods which do not substantiate to the countrys overall energy planning and resultantly the nation is facing electricity crisis. It is evident from the literature that most of the countries often use multiple forecasting methodologies for rational estimates and accordingly undertake energy planning. As such, Pakistan also requires undertaking institutional capacity building measures focusing electricity demand forecasting so that multiple forecasting estimates may help in sustainable energy planning. Based on this review four steps, which essentially require consideration for rational electricity demand forecasting, are suggested for Pakistans power sector:

Step 1: Accurate and Reliable data

Accurate and reliable past as well as present data is very important for any type of demand forecasting methodology. The essential data include a number of consumers, GDP, past consumption trends and other related information.

Step 2: Technology

The load forecasting methods used in Pakistan are limited and mostly conventional. New methods which are IT based and applied in nature should be considered so that more realistic results may be obtained.

Steps 3: Capacity building

It is very important that concerned professionals from energy and power sector should be trained on latest state of the art forecasting methodologies. This shall not only provide forecasting results on the latest tool but altogether utilize indigenous human capital appropriately.

Steps 4: Planning and Implementation

Following reliable forecasting, the energy planning effort and religious implementation plans/projects can only ensure in meeting the projects electricity demand. It is, therefore, important that there is a level of commitment in every step of delivery in power sector. This study has is an ongoing research on forecasting electricity demand using different energy model. A review of Pakistans power sector, followed a review of forecasting methodologies from literature and those used in Pakistan. Finally, a four-step guideline for realistic forecasting has been recommended in the conclusion of the paper.

REFERENCES

[1] G. D. Valasai, M. A. Uqaili, H. R. Memon, S. R. Samoo, N. H. Mirjat, and K. Harijan, "Overcoming electricity crisis in Pakistan: A review of sustainable electricity options," Renewable and Sustainable Energy Reviews, vol. 72, pp. 734-745, 2017.

[2] F. Jamil and E. Ahmad, "The relationship between electricity consumption, electricity prices and GDP in Pakistan," Energy Policy, vol. 38, no. 10, pp. 6016-6025, 2010.

[3] I. o. P. P. (IPP), "Sate of the economy: pulling back from the Abyss," 2010.

[4] A. Malik, "Power crisis in Pakistan: a crisis in governance?," Pakistan Institute of Development Economics2012.

[5] HDIP, "Pakistan Energy Yearbook 2014," Hydrocarbon Development Institute of Pakistan (HDIP), 2014.

[6] T. Dang Khoa and P. Oanh, "Application of Elman and neural wavelet network to long-term load forecasting," ISEE Journal, vol. 20, pp. 1-6, 2005.

[7] M. A. Badri, A. Al-Mutawa, D. Davis, and D. Davis, "EDSSF: A decision support system (DSS) for electricity peak-load forecasting," Energy, vol. 22, no. 6, pp. 579-589, 1997.

[8] H. Farahbakhsh, V. Ugursal, and A. Fung, "A residential enduse energy consumption model for Canada," International Journal of Energy Research, vol. 22, no. 13, pp. 1133-1143, 1998.

[9] D. Sharma, P. Nair, and R. Balasubramanian, "Residential demand for electrical energy in the state of Kerala: an econometric analysis with medium range projections," in Proceedings of the IEEE power engineering society winter meeting, 2000.

[10] H. Al-Hamadi and S. Soliman, "Long-term/mid-term electric load forecasting based on short-term correlation and annual growth," Electric power systems research, vol. 74, no. 3, pp. 353-361, 2005.

[11] B. Ang, "Decomposition methodology in industrial energy demand analysis," Energy, vol. 20, no. 11, pp. 1081-1095, 1995.

[12] S. C. Bhattacharyya and G. R. Timilsina, "Energy demand models for policy formulation: a comparative study of energy demand models," 2009.

[13] C. Smith, S. Hall, and N. Mabey, "Econometric modelling of international carbon tax regimes," Energy Economics, vol. 17, no. 2, pp. 133-146, 1995.

[14] I. Dincer and S. Dost, "Energy and GDP," International Journal of Energy Research, vol. 21, no. 2, pp. 153-167, 1997.

[15] V. . Ediger and S. Akar, "ARIMA forecasting of primary energy demand by fuel in Turkey," Energy Policy, vol. 35, no. 3, pp. 1701-1708, 2007.

[16] C.-C. Hsu and C.-Y. Chen, "Applications of improved grey prediction model for power demand forecasting," Energy Conversion and management, vol. 44, no. 14, pp. 2241-2249, 2003.

[17] V. . Ediger, S. Akar, and B. Uurlu, "Forecasting production of fossil fuel sources in Turkey using a comparative regression and ARIMA model," Energy Policy, vol. 34, no. 18, pp. 3836-3846, 2006.

[18] L. Suganthi and A. A. Samuel, "Energy models for demand forecastingA review," Renewable and sustainable energy reviews, vol. 16, no. 2, pp. 1223-1240, 2012.

[19] V. Alcntara, P. del Ro, and F. Hernndez, "Structural analysis of electricity consumption by productive sectors. The Spanish case," Energy, vol. 35, no. 5, pp. 2088-2098, 2010.

[20] P. Zhou, B. Ang, and K. Poh, "A trigonometric grey prediction approach to forecasting electricity demand," Energy, vol. 31, no. 14, pp. 2839-2847, 2006.

[21] M. A. Bargur J, "Energy consumption and economic growth in Israel: trend analysis," in energy use management, 1960-1979: Ministry of Energy and Infrastructure.

[22] S. G. Chavez, J. X. Bernat, and H. L. Coalla, "Forecasting of energy production and consumption in Asturias (northern Spain)," Energy, vol. 24, no. 3, pp. 183-198, 1999.

[23] L. C. Hunt, G. Judge, and Y. Ninomiya, "Underlying trends and seasonality in UK energy demand: a sectoral analysis," Energy Economics, vol. 25, no. 1, pp. 93-118, 2003.

[24] P. S. Bodger and H. Tay, "Logistic and energy substitution models for electricity forecasting: a comparison using New Zealand consumption data," Technological Forecasting and Social Change, vol. 31, no. 1, pp. 27-48, 1987.

[25] S. Tripathy, "Demand forecasting in a power system," Energy conversion and management, vol. 38, no. 14, pp. 1475-1481, 1997.

[26] G. D. M. Jannuzzi and L. Schipper, "The structure of electricity demand in the Brazilian household sector," Energy Policy, vol. 19, no. 9, pp. 879-891, 1991.

[27] J. C. Lam, H. L. Tang, and D. H. Li, "Seasonal variations in residential and commercial sector electricity consumption in Hong Kong," Energy, vol. 33, no. 3, pp. 513-523, 2008.

[28] B. Ang and P. Lee, "Decomposition of industrial energy consumption: The energy coefficient approach," Energy Economics, vol. 18, no. 1, pp. 129-143, 1996.

[29] J. Sun, "Energy demand in the fifteen European Union countries by 2010: A forecasting model based on the decomposition approach," Energy, vol. 26, no. 6, pp. 549-560, 2001.

[30] R. Sari and U. Soytas, "Disaggregate energy consumption, employment and income in Turkey," Energy Economics, vol. 26, no. 3, pp. 335-344, 2004.

[31] K. Afshar and N. Bigdeli, "Data analysis and short term load forecasting in Iran electricity market using singular spectral analysis (SSA)," Energy, vol. 36, no. 5, pp. 2620-2627, 2011.

[32] A. M. Masih and R. Masih, "Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error-correction modelling techniques," Energy economics, vol. 18, no. 3, pp. 165-183, 1996.

[33] R. Fouquet, P. Pearson, D. Hawdon, C. Robinson, and P. Stevens, "The future of UK final user energy demand," Energy Policy, vol. 25, no. 2, pp. 231-240, 1997.

[34] Y. U. Glasure, "Energy and national income in Korea: further evidence on the role of omitted variables," Energy economics, vol. 24, no. 4, pp. 355-365, 2002.

[35] G. Hondroyiannis, S. Lolos, and E. Papapetrou, "Energy consumption and economic growth: assessing the evidence from Greece," Energy Economics, vol. 24, no. 4, pp. 319-336, 2002.

[36] A. W. Yao and S. Chi, "Analysis and design of a TaguchiGrey based electricity demand predictor for energy management systems," Energy Conversion and Management, vol. 45, no. 7, pp. 1205-1217, 2004.

[37] A. W. Yao, S. Chi, and J. Chen, "An improved grey-based approach for electricity demand forecasting," Electric Power Systems Research, vol. 67, no. 3, pp. 217-224, 2003.

[38] I. Lu, S. J. Lin, and C. Lewis, "Grey relation analysis of motor vehicular energy consumption in Taiwan," Energy Policy, vol. 36, no. 7, pp. 2556-2561, 2008.

[39] H.-T. Pao and C.-M. Tsai, "Modeling and forecasting the CO 2 emissions, energy consumption, and economic growth in Brazil," Energy, vol. 36, no. 5, pp. 2450-2458, 2011.

[40] V. Bianco, O. Manca, S. Nardini, and A. A. Minea, "Analysis and forecasting of nonresidential electricity consumption in Romania," Applied Energy, vol. 87, no. 11, pp. 3584-3590, 2010.

[41] T. Mu, Q. Xia, and C. Kang, "Input-output table of electricity demand and its application," Energy, vol. 35, no. 1, pp. 326-331, 2010.

[42] M. Arbex and F. S. Perobelli, "Solow meets Leontief: Economic growth and energy consumption," Energy Economics, vol. 32, no. 1, pp. 43-53, 2010.

[43] M. Lazarus, C. Heaps, and P. Raskin, "Long range energy alternatives planning system (LEAP). Reference manual," Boston Stockholm Environment Institute (SEI), Boston, MA, 1995.

[44] S. d. E. S. o. E. SENER, "National Energy Balance 1996 (Balance Nacional de Energa)," Mexico City1997

[45] P. Crompton and Y. Wu, "Energy consumption in China: past trends and future directions," Energy economics, vol. 27, no. 1, pp. 195-208, 2005.

[46] B. M. Francis, L. Moseley, and S. O. Iyare, "Energy consumption and projected growth in selected Caribbean countries," Energy Economics, vol. 29, no. 6, pp. 1224-1232, 2007.

[47] A. nler, "Improvement of energy demand forecasts using swarm intelligence: The case of Turkey with projections to 2025," Energy Policy, vol. 36, no. 6, pp. 1937-1944, 2008.

[48] O. Rauf, S. Wang, P. Yuan, and J. Tan, "An overview of energy status and development in Pakistan," Renewable and Sustainable Energy Reviews, vol. 48, pp. 892-931, 2015.

[49] PEPCO, "Power Market Survey Report," Pakistan Electric Power Company2012.

[50] N. H. Mirjat, M. A. Uqaili, K. Harijan, G. D. Valasai, F. Shaikh, and M. Waris, "A review of energy and power planning and policies of Pakistan," Renewable and Sustainable Energy Reviews, vol. 79, pp. 110-127, 2017.

[51] M. Gul and W. A. Qureshi, "Modeling diversified electricity generation scenarios for Pakistan," in Power and Energy Society General Meeting, 2012 IEEE, 2012, pp. 1-7: IEEE.

[52] N. H. M. Aslam Uqaili, Abdullah Mengal, Khanji Harijan, "Supply Side Initiatives for Overcoming Electricity Crisis in Pakistan," in 14th International Conference on Sustainable Energy Technologies SET 2015 Nottingham, UK, 2015.

[53] U. Perwez, A. Sohail, S. F. Hassan, and U. Zia, "The long-term forecast of Pakistan's electricity supply and demand: An application of long range energy alternatives planning," Energy, vol. 93, pp. 2423-2435, 2015.

[54] H. Ishaque, "Is it wise to compromise renewable energy future for the sake of expediency? An analysis of Pakistan's long-term electricity generation pathways," Energy Strategy Reviews, vol. 17, pp. 6-18, 2017.

AUTHORS

Suhail Ahmed Shaikh
Department of Electrical Engineering
Mehran University of Engineering and Technology
Jamshoro, 76062, Pakistan

Nayyar Hussain Mirjat,nayyar.hussain@faculty.muet.edu.pk
Department of Electrical Engineering
Mehran University of Engineering and Technology
Jamshoro, 76062, Pakistan

Wajahat Shabbir Korejo
Department of Electrical Engineering
Mehran University of Engineering and Technology
Jamshoro, 76062, Pakistan

Gordhan Das Walasai
Department of Mechanical Engineering
Quaid e Awam University of Engineering, Science and Technology
Nawabshah, Pakistan

Abdul Sattar Larik
Department of Electrical Engineering
Mehran University of Engineering and Technology
Jamshoro, 76062, Pakistan

Arsalan Hussain
Department of Electrical Engineering
Mehran University of Engineering and Technology
Jamshoro, 76062, Pakistan