International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 35 العدد
Part 1 المجلد
October 2024 اكتوبر

تم استلام الورقة بتاريخ: 2024/9/28م وتم نشرها على الموقع بتاريخ: 31/ 2024/10م

Application of Artificial Neural Networks and Fuzzy Logic Methods for Short-Term Load Forecasting of the Western Libyan Electric Network

http://www.doi.org/10.62341/aoat1919

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Abstract:
This research paper investigates the application of artificial neural networks (ANNs) and fuzzy logic methods for short-term load forecasting in the Western Libyan Electric Network. Historical hourly load data collected during the year 2023 by the General Electricity Company of Libya (GECOL). The study aims to develop accurate and reliable load forecasting models to support efficient grid operation and resource planning. Historical load data and meteorological variables are utilized to train and evaluate the forecasting models. The performance of the ANNs and fuzzy logic methods is compared, and the suitability of each approach for load forecasting in the Western Libyan Electric Network is assessed. The results demonstrate the effectiveness of both ANNs and fuzzy logic methods in short-term load forecasting, providing valuable insights for electricity providers and policymakers in the region.

Keywords: neural' networks, fuzzy logic, load forecasting.

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تطبيق شبكات العصب الاصطناعي وأساليب المنطق الضبابي لتوقع الحمل على المدى القصير لدى شبكة كهرباء غرب ليبيا

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الملخص:

يتناول هذا البحث تطبيق الشبكات العصبية الاصطناعية وطرق المنطق الضبابي للتنبؤ بالأحمال قصيرة المدى في شبكة كهرباء غرب ليبيا.تم جمع بيانات الأحمال بالساعة التاريخية خلال عام 2023 من قبل الشركة العامة للكهرباء في ليبيا(GECOL) . تهدف الدراسة إلى تطوير نماذج دقيقة وموثوقة للتنبؤ بالأحمال لدعم تشغيل الشبكة بكفاءة وتخطيط الموارد.يتم استخدام بيانات الأحمال التاريخية والمتغيرات الجوية لتدريب وتقييم نماذج التنبؤ.تتم مقارنة أداء الشبكات العصبية الاصطناعية وطرق المنطق الضبابي، وتقييم مدى ملاءمة كل نهج للتنبؤ بالأحمال في شبكة كهرباء غرب ليبيا.توضح النتائج فعالية كل من الشبكات العصبية الاصطناعية وطرق المنطق الضبابي في التنبؤ بالأحمال قصيرة المدى، مما يوفر رؤى قيمة لمقدمي الكهرباء وصناع السياسات في المنطقة.

الكلمات المفتاحية: الشبكات العصبية الاصطناعية ، المنطق الضبابي، التنبؤ بالأحمال.

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Introduction

Accurate demand forecasting plays a pivotal role in developing reliable and secure strategic operating plans for the power system. Predicting electricity usage trends is crucial for effective long-term planning, especially amid today's evolving energy landscape. The nature of demand projections varies depending on the intended analyses and required precision [1].

Power load forecasting can be categorized into mid-term, long-term, and short-term projections. Mid-term and long-term forecasting occurs annually or monthly and serves as baseline data for developing long-range operational strategies. Short-term forecasting transpires hourly [2].

Accurate load forecasting plays a crucial role for power system energy management [3] Load forecasting has gained considerable attention as a prominent research area in electrical engineering in recent years. However, it is widely recognized that load forecasting presents inherent difficulties and complexities [4].Short-term load forecasting involves predicting the energy demand for a period ranging from one hour to one week. This forecasting technique serves several purposes, including assisting energy system operators in carrying out efficient energy management operations and enhancing power system planning. These operations and plans encompass activities such as energy procurement, unit commitment, minimizing spinning reserve capacity, and optimizing transmission and distribution operations (T&D) [5].

The (ANNs) technique attempts to analyze the relationship among loads and other influential factors such as weather and customer usage behavior by using experience and observations to perform the forecasting function where knowledge is supplied by real data[6].

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The application of fuzzy logic in short-term load forecasting involves utilizing weather data, including temperature, humidity, and wind speed. On the other hand, the expert system approach is a rule-based technique for load forecasting that leverages the knowledge and logic of a power system operator to formulate mathematical equations for predictions. Fuzzy logic is a form of multi-valued logic that allows for intermediate values to describe conventional concepts, such as yes or no and true or false. It extends the principles of Boolean logic and finds applications in digital circuit design. One of the advantages of fuzzy logic is that it does not require a precise mathematical model to map inputs to outputs, nor does it rely on precise inputs [6].

LOAD FORECAST

Load forecasting techniques are employed by power utilities to predict the quantity of power required to meet demand and provide insights into current and future load requirements. This practice finds numerous practical applications, such as energy procurement and generation, load management, contract assessment, and infrastructure planning. Over the past few years, load forecasting has emerged as a significant research domain within the field of electrical engineering [7].

- **Long-term Forecasting**

Long-term forecasting refers to the prediction of future events, trends, or conditions that extend over an extended period, typically beyond one year. It involves analyzing historical data, identifying patterns, and applying mathematical and statistical models to project future outcomes. Long-term forecasting is commonly used in various fields, including economics, finance, demographics, climate science, and business planning [8].

- **Medium- term Forecasting**

Medium-term forecasting refers to the prediction of future events, trends, or conditions within a time frame that typically ranges from

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a few months to a year or two. It lies between short-term forecasting (which focuses on immediate or near-future predictions) and long-term forecasting (which extends beyond a year) [3].

- **Short-term Forecast**

Load forecasts sometimes concentrate on predicting peaks, which of course are very important, because peak load determines the maximum demand on total equipment in any particular period. To minimize overall cost on an incremental cost basis, a comprehensive short-term forecast must predict the entire load pattern throughout the range of the forecast load times.
Must be brought-on or dropped-off the line to take care of hour-to-hour and day-to-day changes due to weekday industrial load, Friday loose, evening lighting and cooking, weather changes affecting "heating" or "cooling" load, etc.[9].

Methodology

This paper examines a proposed action plan for utilizing neural network models and fuzzy logic in short-term forecasting, taking into account the structure and types of data, including daily hourly load data, seasonal hourly load data, and identifying the most suitable model for these structures. Additionally, the inclusion of hourly temperature data in the model for system studies is explored. The following steps outline the proposed working plan :
1. Data collection will involve gathering load, temperature, and time variation data for the year 2023 from the General Electric Company of Libya (GECOL) and weather data from Weather Underground (WUGD).
2. The collected data will be organized in a manner that aligns with the input and output requirements of the model structure.

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3. A Neural Network model will be developed that accommodates the input variables. This will involve selecting appropriate hidden layers and neurons that yield the lowest forecast error.
4. The input and target data will be appropriately arranged for the training and testing process, in line with the modeling and development of the proposed Adaptive Neural-Fuzzy Inference System (ANFIS) predictor.
5. A careful selection of cases will be made for studying using the best possible model, which includes all data variables such as load and temperature. The results will be discussed and analyzed.
In this study MATLAB program is used for load forecast using Neural Networks and fuzzy logic.

- **ARTICIAL NEURAL NETWORK**

Artificial neural networks (ANNs) are computational models characterized by densely interconnected adaptive processing units. These networks implement fine-grained parallelism and are capable of simulating nonlinear or dynamic systems. One of their key features is adaptability, where learning from examples replaces traditional programming methods for problem-solving. Similar to the human brain, neural networks process information through a network of highly interconnected processing elements, or neurons, operating in parallel within a distributed system. In such systems, knowledge is represented in a distributed manner rather than localized, with no single processing element holding a consistently unique meaning [3].
A learning rule is a method for updating the weights associated with artificial neural networks (ANNs). Supervised learning (also known as learning with a teacher or associative learning) is a type of learning rule that requires two components for training a set of patterns. These components consist of an input vector and a target vector (desired output). The target vector is used during the

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learning process for comparison to the network output produced by the particular input vector of the training pair. When the output vector does not equal the target vector, an error is produced.
Figure (1) shows that, There the network is adjusted, based on a comparison of the output and the target, until the network output matches the target.

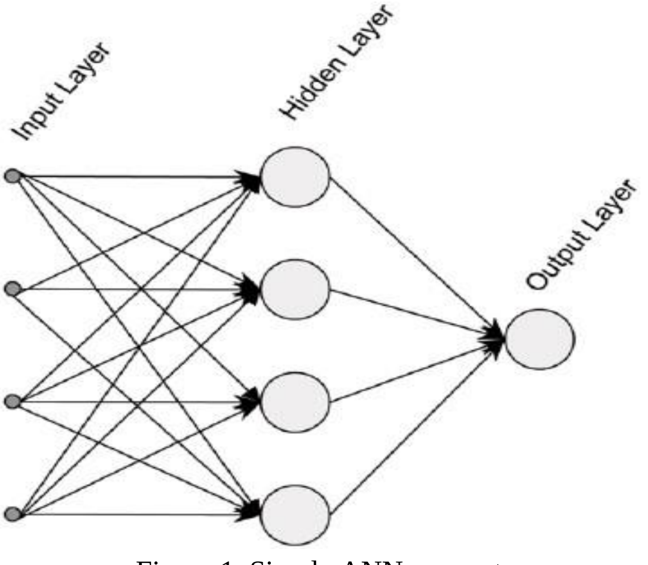

Figure 1. Simple ANN concept

ANN training basically consists on determining the network parameters such as weights and others, that allow achieving the desired objective based on the available training sets. Usually, multi-layer feed forward neural networks are trained in a supervised manner. Back-propagation is used as the training method here [10].
The neural network structure including the size of the hidden layer is chosen from several known structures. The chosen structure is the one that provides the best network performance in terms of

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minimum error, which is obtained by the difference between the network output and the target (Actual load).

Examination of load shapes for different day-types indicates that working days, weekends and holidays should be treated. Hence, these types are treated as distinct groups of load and weather data, using year of hourly historical load and weather data. The data for each day is first normalized, grouped and averaged out according to the calendar day type.

To evaluate the performance of the neural networks model, the mean absolute error (MAE) , should calculated, which are defined as follows[11]:

$$MAE = \frac{1}{n}\sum_{i=1}^{n} \frac{l_i^{actual} - l_i^{forecast}}{l_i^{actual}} * 100\% \qquad (1)$$

Where n is the number of samples; l_i^{actual} is i^{th} the actual electricity load; $l_i^{forecast}$ is the i^{th}predicted load .

- **Fuzzy Logic**

The process of short-term load forecasting with fuzzy logic involves several steps. First, we need to define the linguistic variables and their corresponding membership functions. These membership functions determine the degree to which an input variable belongs to a particular fuzzy set, allowing us to express the vagueness of the information.

Next, we construct a set of fuzzy rules that relate the linguistic variables to the load forecast. These rules are typically derived from expert knowledge or historical data analysis. Each rule consists of an antecedent (if-portion) and a consequent (then-portion), specifying the relationship between the input variables and the load forecast output.

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Once we have the fuzzy rule base, we can use fuzzy inference techniques to compute the load forecast. Fuzzy inference involves applying the fuzzy rules to the input data, combining the fuzzy sets and their membership functions to generate fuzzy outputs. These fuzzy outputs are then aggregated and defuzzified to obtain a crisp load forecast value.

Fig.2 shows the whole structure of fuzzy logic system included input, reasoning rules and the proposed output. The inference rules relate the input to the output and every rule represents a fuzzy relation.

Fuzzification is used in order to express the fuzziness of data, in this study an arrangement is made of fuzzy subsets for different inputs and outputs in complete universe of discourse as membership functions.

The inputs taken for Short-Term Load Forecasting (STLF) are (Time, last day load, and Temperature), as shown in figure 2 [12].

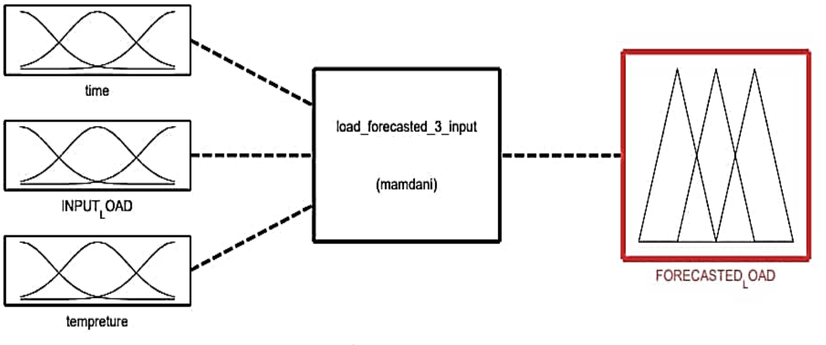

Figure 2: fuzzy logic structures

Case Studies and Results

In order to implement short-term load forecasting, 24 hours of load data is considered, as shown. For each hour, the load amount and corresponding temperature are provided. These data are used as

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input for training an Artificial Neural Network (ANN) model, as well as for the inputs of the proposed fuzzy logic approach.

In this case the data for the whole seasons is model training, (winter, spring, summer, and autumn) of the year.

Considering short term load forecasted for a winter day the results is shown in Table (1) and in Figure (3a, b).

Table (1): Testing results for one day

Time	Temperature	Actual load	Forecast load (ANN)	Forecast load (fuzy logic)	MAE ANN	FL
1	9	3390	3056	3602	9.85	6.25
2	9	3148	3087	3584	1.93	13.85
3	9	2948	3073	3584	4.24	21.57
4	9	2922	2989	3584	2.29	22.65
5	9	2876	2898	3584	0.76	24.61
6	7	2999	2923	3337	2.53	11.27
7	9	3415	3321	3615	2.83	5.85
8	12	3757	3561	3405	5.21	9.35
9	13	3851	3237	3434	15.94	10.82
10	15	3906	3982	3657	1.94	6.37
11	16	4061	4181	3796	2.95	6.52
12	16	4074	4173	3797	2.43	6.79
13	17	4223	4282	3646	1.93	12.73
14	14	4255	4261	3685	0.14	13.39
15	18	4150	4168	3750	0.43	9.63
16	17	4001	4017	3973	0.39	0.69
17	15	4069	4109	3669	0.98	9.84
18	14	4133	4013	3582	2.90	13.33
19	12	4226	3920	3615	7.24	14.45
20	11	4498	4514	3777	0.35	16.02
21	10	4191	4880	3573	16.43	14.74
22	8	4104	4202	3739	2.38	8.89
23	8	3926	3993	3742	1.70	4.68
24	9	3558	4049	3648	13.79	2.52

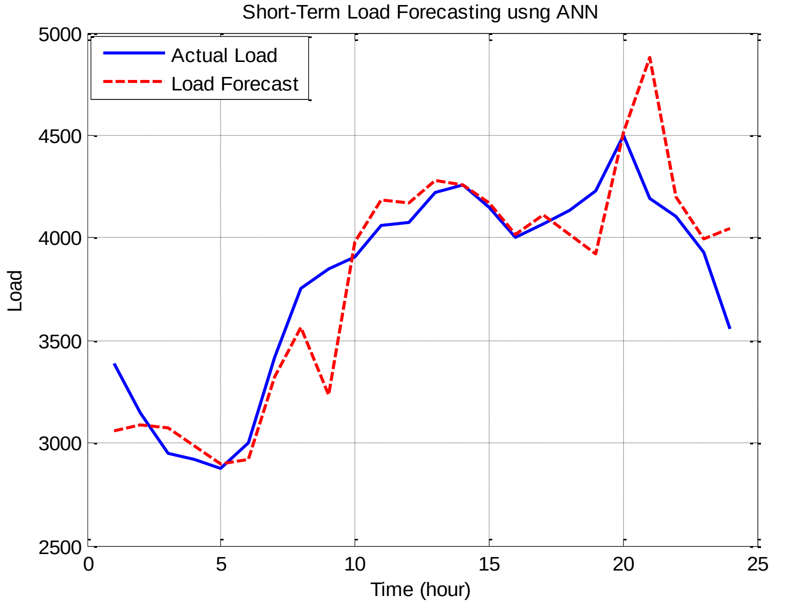

Figure 3 a load curve in winter day

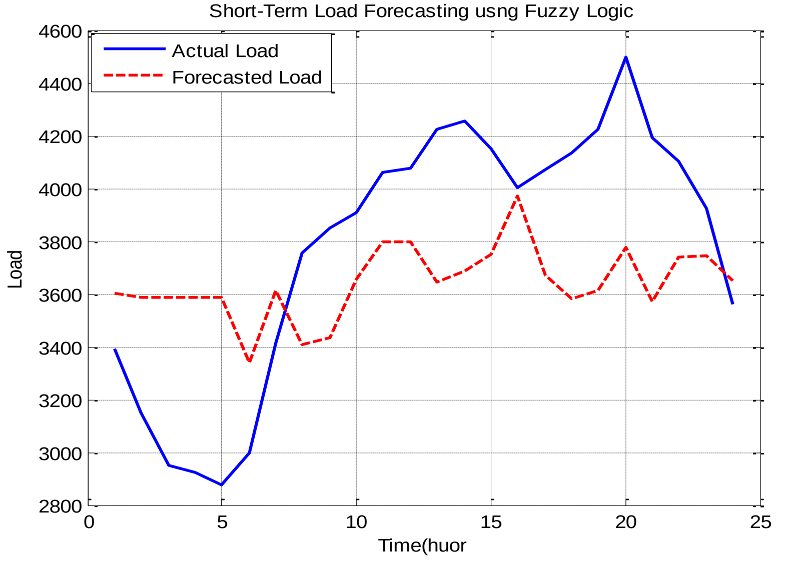

Figure 3 b load curve in winter day

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As a discussion for this case the results shown in figure (3a , b) show that the load curve plotted which is the comparison between the actual load and the forecasted load.

The results obtained from the fuzzy logic and Neural Network are compared with actual load , In general From the curve ,it is observed that Neural Network load curve is very close to the actual load curve presents a very good results for forecast.

Considering short term load forecasted for a summer day the results is shown in Table2 and in Figure (4 a, b).

Table (2): Testing results for one day

time	Temperature	Actual load	Forcast load (ANN)	Forcast load (fuzzy logic)	MAE	
					ANN	FL
1	33	2677	2497	2920	6.72	9.07
2	34	2563	2545	2861	0.70	11.62
3	33	2465	2488	2772	0.93	12.45
4	38	2382	2185	2791	8.27	17.17
5	38	2440	2287	2895	6.27	18.64
6	38	2401	2452	2828	2.12	17.78
7	36	2572	2878	2927	11.89	13.80
8	37	2813	2885	3038	2.55	7.99
9	38	2967	2975	3051	0.26	2.83
10	38	3078	3067	3051	0.35	0.87
11	40	3307	3169	3081	4.17	6.83
12	40	3373	3285	3081	2.60	8.65
13	29	3466	3410	3019	1.61	12.89
14	28	3528	3457	3045	2.01	13.69

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15	28	3387	3337	3031	1.47	10.51
16	27	3328	3391	3060	1.89	8.05
17	25	3527	3508	3141	0.53	10.94
18	24	3540	3474	3163	1.86	10.64
19	23	3544	3415	3183	3.64	10.18
20	23	3780	3534	3081	12.81	18.49
21	23	3683	3613	3113	1.90	15.47
22	23	3530	3579	3189	1.38	9.66
23	23	3304	3410	3230	3.20	2.23
24	22	3027	3184	3179	5.18	5.02

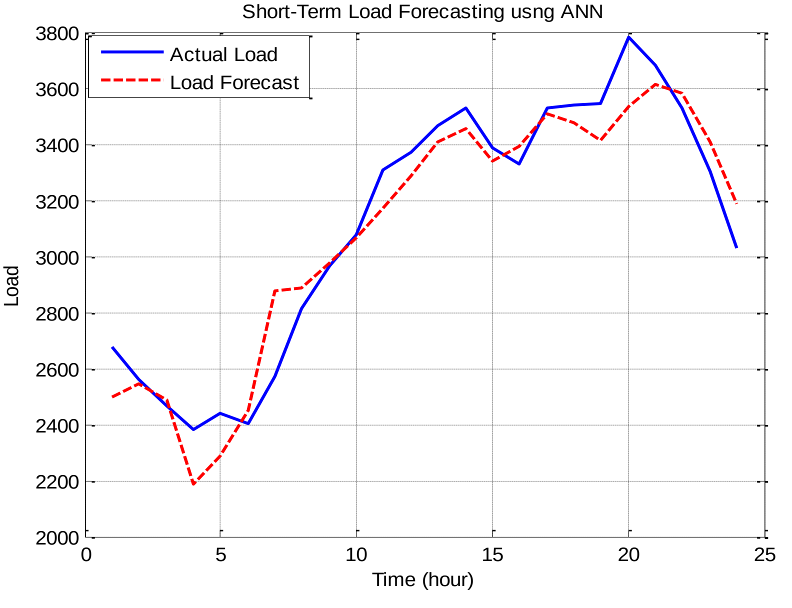

Figure 4 a load curve in summer day

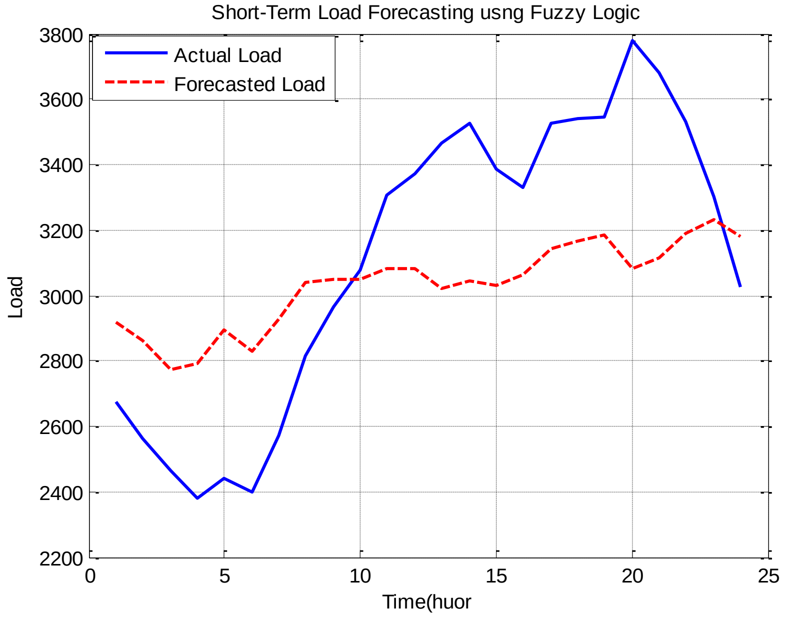

Figure 4 b load curve in summer day

As a discussion for this case the results shown in figure (4a,b) show that the load curve plotted which is the comparison between the actual load and the forecasted load.

The results obtained from the fuzzy logic and Neural Network are compared with actual load , In general From the curve ,it is observed that Neural Network load curve is very close to the actual load curve presents a very good results for forecast.

Conclusion

The application of Artificial Neural Networks (ANNs) and Fuzzy Logic methods for short-term load forecasting of the Western Libyan Electric Network offers a promising solution to enhance the accuracy and reliability of load forecasting in the region.

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By leveraging the capabilities of ANNs, which excel at recognizing complex patterns in data, and Fuzzy Logic, which enables handling uncertainty and linguistic variables effectively, this approach can effectively model the intricate relationships between various factors influencing electricity consumption.
Furthermore, the utilization of ANN and Fuzzy Logic methods underscores the commitment to leveraging innovative technologies to modernize the energy sector, enhance operational efficiency, and promote sustainable practices in power management.
In conclusion, the integration of Artificial Neural Networks and Fuzzy Logic methods for short-term load forecasting in the Western Libyan Electric Network represents a significant step towards achieving a more efficient, reliable, and sustainable energy infrastructure in the region.

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