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Genetic Algorithm-Based Model for Short-Term Load Forecasting in Isolated Microgrids

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INTRODUCTION & AIM

In recent years, power demand forecasting has gained considerable attention from power generation and marketing companies. Energy demand forecasting is a key element for determining policies to be followed by companies and governments. Nowadays, various simulation tools, engineering, and methods based on artificial intelligence are used for the optimal forecasting of electricity demand. Forecasting has also become indispensable because of the integration of smart grid systems into current energy systems and the penetration of renewable energy sources, making this process more complex, requiring more innovative techniques, and increasing the impact of demand prediction on aspects such as the planning, operation, and safety of electricity systems [1]–[5].

In the implementation of the electricity demand forecasting model, three different time horizons were considered. The first, short-term time horizon usually ranges from one hour to one week; the second, medium-term projections range from one week to one year; and the third, long-term forecasts are applied to time intervals from one year to ten years [6]. When the forecast horizon is small, social and economic conditions have no significant influence. An adequate forecast can be achieved based on the climate and customer consumption habits.

Demand forecasting is a widely studied topic owing to its importance. The electricity demand curve varies over time because it depends on several parameters such as weather conditions, time of day, geographical area, and type of load. Electricity demand, by consumption type, can be broadly classified into residential, industrial, and commercial.

METHOD

In Cuba, demand forecasting in isolated systems in tourist development areas has traditionally been carried out using two methods based on models supported by software oriented by the National Electric Load Dispatch (CNC for its acronym in Spanish) of Electric Union (UNE for its acronym in Spanish), the only electricity service provider in the country.

- Lectura software, based on the moving average method, was the first one used.
- The ANADEM software is based on a neural network algorithm. This method was developed by the National Electric Load Dispatch and is currently recommended.

The use of both methods in the prediction of demand in isolated microgrids in the tourist development areas in Cuba has shown that they do not always achieve the necessary accuracy in the forecast, which causes difficulties in the economic operation of generation sources. On the other hand, other prediction models were studied. However, none was found to be available and applicable to the operating conditions of these systems.

The forecasting error is given as the difference between the actual and predicted values according to Equation (1).

$$e(t) = y_r(t) - y_p(t) \qquad (1)$$

Where:

e(t) : Forecasting error.

y_r (t) : True value of the variable (real demand).

y_p (t) : Forecasted value of variable (forecasted demand).

Equation (2) provides the mean absolute percentage error (MAPE), which is widely used by the scientific community.

$$MAPE = \frac{1}{N}\sum_{t=1}^{N}\left(\frac{|y_r(t)-y_p(t)|}{y_r(t)}\right)\cdot 100\% \qquad (2)$$

Where:

N: Is the number of forecasted variables.

RESULTS & DISCUSSION

The National Electroenergy System extends throughout the archipelago. However, there are six isolated electrical systems in islands or key geographic locations, five of which belong to tourist poles located on the country's coasts: Cayo Largo del Sur, Cayo Santa María, Cayo Coco - Cayo Guillermo, Cayo Paredón (still under construction without tourist exploitation), and Cayo Romano–Cayo Cruz, where hotel facilities of different chains predominate. At these poles, generation is currently carried out conventionally using diesel and fuel oil generators. The sixth system is located in the special municipality of Isla de la Juventud, which has an important presence of renewable energy sources and very different characteristics from the previous five.

Table 1.

Mapping indicator of the proposed model runs applied to demand forecasting in the Cayo Coco - Cayo Guillermo system.

Run	1	2	3	4	5
Forecast date	26/12/19 Thursday	9/11/19 Saturday	20/08/19 Tuesday	06/05/19 Monday	06/03/19 Wednesday
Medium temperature (°C)	26.1	27.5	27.5	28	25
Activity level (HDO)	5936	6120	7489	6901	7024
MAPE (%)	**2.83%**	**4.84%**	**8.04%**	**3.26%**	**9.33%**
Time (minutes)	6.3	7.9	5.0	3.9	3.8
Forecasted Energy. (MWh per day)	266	277	303	295	280
Real Energy (MWh per day)	261	269	329	303	308
Energy deviation (%)	**1.9%**	**3.0%**	**7.8%**	**2.6%**	**9.3%**

Table 1.

Mapping indicator of the performance of proposed model applied to demand forecasting in Cayo Romano - Cayo Cruz system.

Run	1	2	3	4	5
Forecast date	10/07/2022 Sunday	20/08/2022 Saturday	15/09/2022 Thursday	04/10/2022 Tuesday	09/11/2022 Wednesday
Medium temperature (°C)	28.9	29.5	27.9	27.7	25.2
Activity level (HDO)	Low	Low	High	High	High
MAPE (%)	**6.80%**	**5.29%**	**3.01%**	**4.95%**	**5.51%**
Time (minutes)	0.2	0.3	0.2	0.2	0.2
Forecasted Energy. (MWh per day)	27	27	31	30	34
Real Energy (MWh per day)	26	28	31	31	36
Energy deviation (%)	**5.10%**	**1.20%**	**1.00%**	**3.80%**	**4.60%**

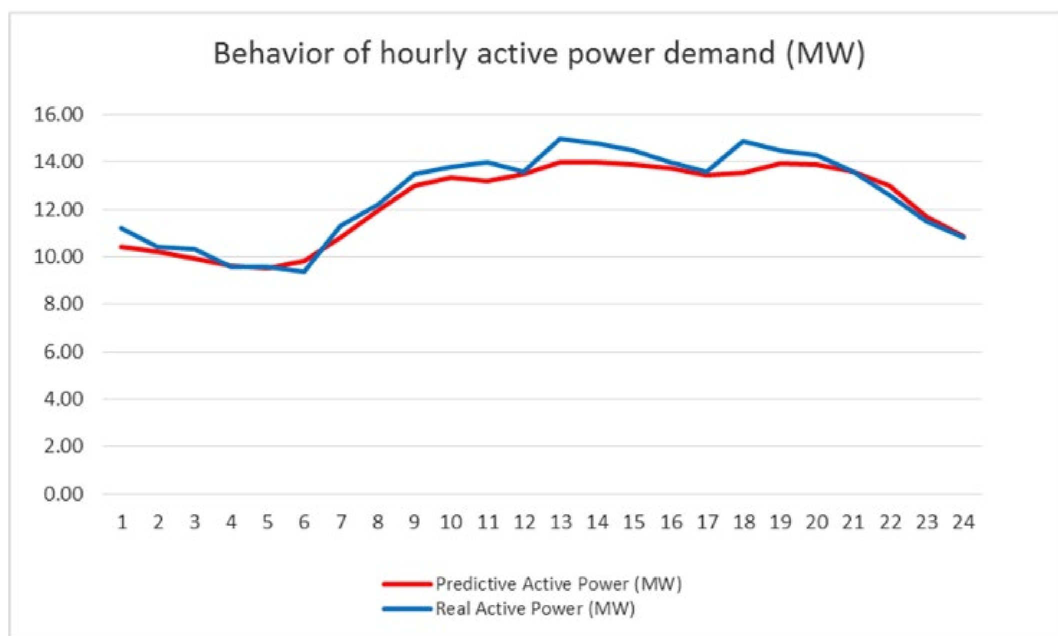

FIGURE 1. Demand prediction plots obtained with the proposed model on a random day. Monday, May 6, 2019, in the Cayo Coco - Cayo Guillermo system.

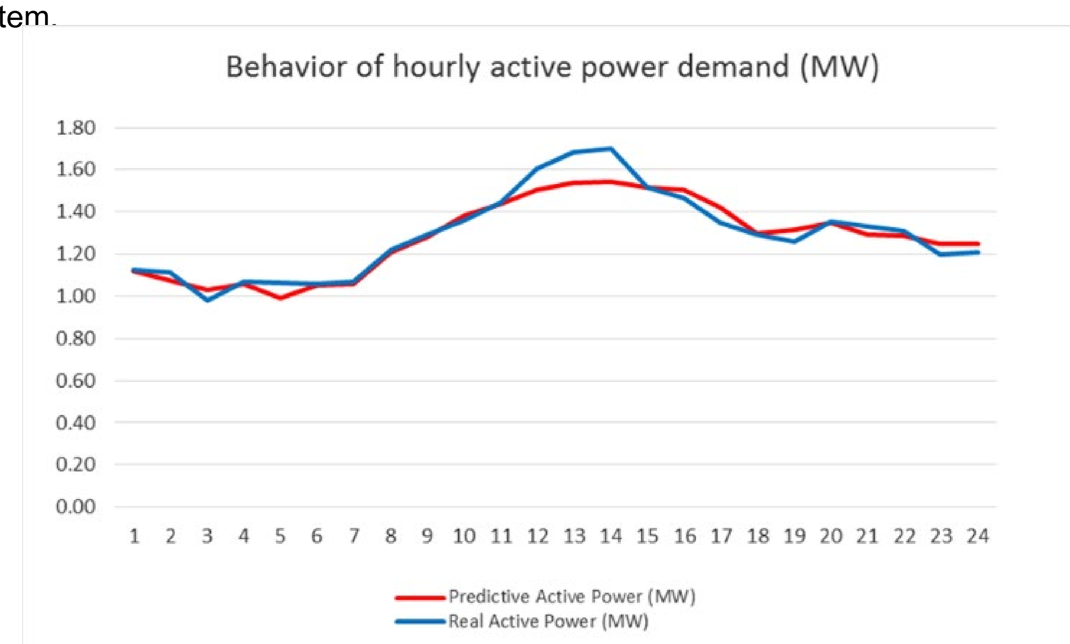

FIGURE 2. Demand prediction plots obtained with the proposed model on a random day. Thursday, September 15, 2022, in the Cayo Romano - Cayo Cruz system.

CONCLUSION

The two software packages currently used for electric demand forecasting in isolated systems do not achieve acceptable accuracy in all and under all forecasting conditions, although on certain days, they can obtain better accuracies.

The proposed demand prediction model has proven to be an effective tool for the proposed purpose because it achieves good accuracy between the actual and predicted behavior of the demand, evaluated using the mean absolute percentage error (MAPE) indicator. This indicator was less than 10% on all days analyzed in both isolated systems. On the other hand, the predicted energy in no case exceeds a 10 % deviation concerning the real energy produced, which is particularly important when forecasting the operating conditions of the generation systems. The proposed model can be implemented through the design of a computational tool, using the programming structures of the Global Optimization Toolbox: Genetic Algorithm and Direct Search, MATLAB software version 2024ª.

FUTURE WORK / REFERENCES

Considering the results obtained and the limitations identified, several opportunities for future work emerge. One possible direction is the integration of additional forecasting techniques, such as deep learning models (e.g., LSTM and GRU neural networks), hybrid optimization approaches, or ensemble learning, with the goal of further improving prediction accuracy under different operating and climatic conditions.

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