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HAM: A HYBRID ALGORITHM PREDICTION BASED MODEL FOR ELECTRICITY DEMAND

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ABSTRACT

Based on the rapid development of digital signal processing technology and computers, computational intelligence (CI) becomes an object of study fields of fundamental and applied research of interest to researchers recently. Research that exploits a number of further processing techniques are the subject of CI information technology, including artificial neural networks, genetic algorithms, fuzzy logic, evolutionary computation, or a combination of these techniques, known as hybrid technology. The purpose of this study is to develop a prediction model based CI to improve the accuracy of prediction of the demand for electricity. Method combination of several algorithms in search of optimum value will be developed to overcome the premature convergence on the model predictions. The data will be used to measure the performance of the hybrid model is data electrical energy needs of Indonesia. Average prediction errors will become a reference in selecting the right model for the planning of the electrical energy needs of the next few years in Indonesia. The results showed: 1) performance computational intelligence-based prediction models that utilize the capabilities of the hybrid algorithm is superior to the single algorithm-based predictive models. 2) The accuracy of the prediction model based hybrid algorithm (HAM) can reach 97%, exceeding the level of the previous model's accuracy.

Keywords: *Computational Intelligence, Hybrid Algorithm, Prediction Model.*

1. INTRODUCTION

In determining future energy development, Indonesia has been using LEAP (Long-range Energy Alternatives Planning System) to analyze projected needs and long-term energy supply. In analyzing the various possibilities of socioeconomic and technological development in the future, the Ministry of Energy and Mineral Resources uses two scenarios, namely: BAU (Business As Usual) and KEN scenario (National Energy Policy) [9].

As one of the alternatives in the development of future technologies, hybrid algorithm model (HAM) is the development of computational intelligence-based prediction methods that can be used to analyze the needs of electric energy in Indonesia. This model can be used to analyze the projected long-term electrical energy needs and the provision by using a variety of scenarios.

The estimation error can be avoided in a single algorithm-based predictive models when the number of variables increases. This drawback can be overcome by using a hybrid algorithm (HAM). By HAM expected to find forecasting electricity demand more accurately which can be used in planning long-term electricity needs.

The accuracy of prediction models is a major concern in this study because a huge influence on the operational cost savings of electric energy supply. Various efforts have been made by previous researchers to enhance the performance of the prediction model, among others, tried to set the variable model, using some kind of algorithm to explore and exploit the advantages of each type of algorithm.

In this study, the developed algorithm is the Nelder Mead as a classic algorithm by exploiting its ability to explore the optimum solution for a limited search area, as well as combining it with genetic algorithm as a modern algorithm for its ability to determine the area where the best solutions are.

The discovery of the best solutions is increasingly allowing the presence of excess owned by the two algorithms. As a consequence, the level of accuracy of prediction models getting up.

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2. FORECASTING METHODS

In previous studies, a single algorithm approach to forecasting long-term electricity needs have been made by Ozturk and Ceylan [1] and Azadeh et al. [2]. A single algorithm (i.e. Genetic algorithms, GA) have been used as a tool of optimization for complex problems involving many variables or involve a combination of linear and nonlinear equations.

As an optimization tool, GA attempted to improve performance that leads to the optimal solution. However, these models still have not found the best solution which is marked with an error rate prediction is still relatively high and the number of iterations is large [3]. Although GA is faster to find areas in which the global optimum is, but require a long time and a lot number of iterations to find the right local optimum solution.

Method combination of GA with local search can speed up the search to find a global optimum solution. Some additional heuristics in GA can increase the rate of convergence of the algorithm and find a better solution.

Performance of GA can be measured by using the mechanisms to exploit and explore the search space. Extensive exploration of the search space can guide the search for a decent local and global optimum area, while exploiting mechanisms help in finding optimal solutions in a fast calculation time [3].

Hybrid mechanism that combines the capabilities of exploitation and exploration of the search space can be implemented with modern algorithms (in this case GA) and guides the direction the search by classic algorithms (such as Nelder Mead).

The Nelder Mead's (NM) simplex method is one of the most popular derivative-free optimization algorithms in the fields of engineering, science, and statistics. NM simplex algorithm is widely used because of its simplicity and fast convergence. This method converges really well with small scale problems of some variables. However, for large scale problems with multiple variables, it does not have much success.

In a study by Pham [5] as a solution to improve the NM simplex algorithm in terms of the convergence rate and the convergence speed, the quasi-gradient method was introduced. The author has succeeded to obtain the significant improvement of the method compared to the original simplex method.

In three dimensions, the simplex are a tetrahedron, and in two dimensions, it is a triangle. This method evaluates the objective function in each iteration at trial points. The location of a trial point is dependent on the function values of the vertices and the earlier trial points.

In order to find a new point to improve the worst vertex, the simplex is altered using reflection, reflection and expansion, contraction, and multiple contractions [6].

The Nelder-Mead`s simplex method contributed towards stronger exploitation capabilities to achieve a global optimum solution in an effective way.

However, the processes of reflection, expansion, contraction and multiple contractions or shrinking needs a high computational cost in term of iterations and decrease on the capabilities of existing Nelder-Mead's simplex method.

In order to minimize the computational cost, we proposed the improved Nelder-Mead simplex by combined the GA with small iteration. Solution from GA used as the initial point for NM.

3. RESEARCH PURPOSES

The purpose of this study is to develop electricity demand forecasting model based on a modern hybrid algorithm (GA) and the classic local search algorithm (Nelder Mead). To achieve this, three specific objectives are:

- To formulate the objective function in the hybrid algorithm model (HAM) that can reduce electricity demand forecast errors using linear and nonlinear equations.
- To overcome premature convergence and local optimality problem through a combination of genetic algorithm and extended Nelder Mead.

The research is focused on "benchmarking" by doing a comparison of forecasting results using the proposed models and other methods. The main indicator for the comparison of the model is accurate.

4. CONTRIBUTIONS

Outputs from this research is the hybrid algorithm optimization techniques that can be considered as a new technique which offers the opportunity to improve the performance of the electricity demand forecasting model.

- A good forecasting model has a major effect on the operating costs of electric power supply system which is sensitive to forecasting error.

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- Electric utilities can save millions of dollars for even a small reduction in the average forecasting error. Forecasting accuracy holds the potential for huge savings when used to control operating costs and planning decisions such as the allocation of fuel, transmission and unit commitment.
- Fluctuations in supply and demand changes in weather conditions during peak demand situations can cause energy prices to rise by a factor of ten or more. In this situation, forecasting is essential for utility companies in operational decisions and good planning.
- Forecasting precision can help reduce the occurrence of equipment failure and blackout because estimates may prevent overloading on time.

5. METHODOLOGIES

Methods in "HAMfP" (Hybrid Algorithm Model for Prediction) includes the mathematical formulation and description of the algorithm used to calculate electricity demand.

5.1 Model Formulation.

Mathematically the relationship between the demand for electricity with the operational variables that influence can be expressed by equation 5.1 to 5.4 as follows:

$$KL1 = \lambda 0 + \lambda 1 \log x1 + \lambda 2 \log x2 + \lambda 3 \log x3 + \lambda 4 \log x4 \quad (5.1)$$

This equation states the logarithmic linear relationship between:

- Demand for electricity (KL1), in units of Tera Watt hour (TWh) with a variety:
  - Total population (x1), in units of millions of people
  - Gross domestic product (GDP = x2), in units billion US Dollar
  - Import (x3), in units of billion US dollars, and
  - Export (x4) in units billion US Dollar.

Meanwhile: λ0, λ1, λ2, λ3, λ4,... λn is the model parameters will be calculated using a hybrid algorithm (HAMfP). The algorithm will determine how much of the significance of these parameters in influencing the demand for electricity in Indonesia each year.

Electricity demand can also be expressed by non-linear relationships, such as exponential (KL2), quadratic (KL3), and combined (mixed) between linear and nonlinear (KL4) [7].

- Exponential (KL2):

$$KL2 = \lambda 1 + \lambda 2\ x1^{\lambda 3} + \lambda 4\ x2^{\lambda 5} + \lambda 6\ x3^{\lambda 7} + \lambda 8\ x4^{\lambda 9} \quad (5.2)$$

- Quadratic (KL3),

$$KL3 = \lambda 1 + \lambda 2\ x1^{\lambda 3} + \lambda 4\ x2^{\lambda 5} + \lambda 6\ x3^{\lambda 7} + \lambda 8\ x4^{\lambda 9} + \lambda 10\ x1\ x2 + \lambda 11\ x1\ x3 + \lambda 12\ x1\ x4 + \lambda 13\ x2\ x3 + \lambda 14\ x2\ x4 + \lambda 15\ x3\ x4 \quad (5.3)$$

- Mixed (KL4)

$$KL4 = \lambda 1 + \lambda 2 * \exp(\lambda 3 + \lambda 4\ x1 + \lambda 5\ x2 + \lambda 6\ x3 + \lambda 7\ x4) \quad (5.4)$$

Parameters of each of the four mathematical models will be computed using HAMfP to know which model is more precise or more accurate in predicting the demand for electricity.

5.2 HAMfP Descriptions

Hybrid algorithm will calculate the fitness value of the objective function obtained at each iteration. This value is the minimum individual solutions (global minima) that can be achieved when convergent. If targeted search is the declared value error between the actual data and the predicted results, then under ideal conditions this value is zero. But these ideal conditions are difficult to achieve, or in other words, it is difficult to achieve 100% accuracy rate. The objective function for electricity demand model is expressed by a mathematical equation as follows [7]:

$$S = \sum_{i=1}^{n} (KL_{actual} - KL_{prediction})^2 \quad (5.5)$$

Steps in hybrid algorithms (HAMfP) generally follow the flow as a flowchart in Figure 1.

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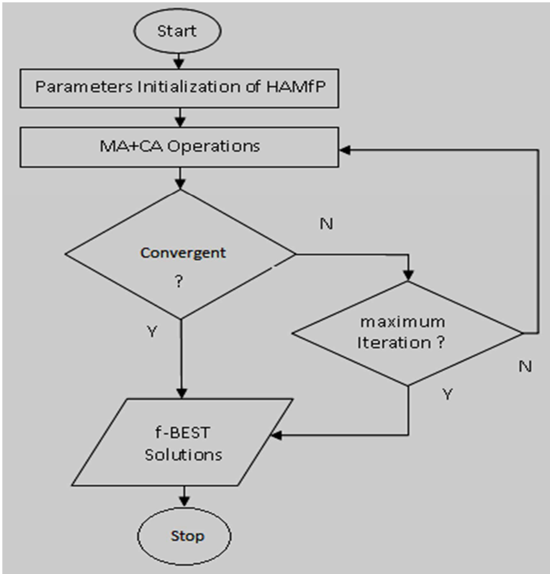

Figure 1. HAMfP Steps

MA is Modern Algorithm, CA is Classical Algorithm, while f-BEST is the global minimum solution values.

In general, the steps in Modern algorithm (MA) can be divided into six steps which are: (i) initialization, (ii) encode the individuals, (iii) crossover and mutation, (iv) decode the individuals, (v) evaluation of fitness, (vi) check stopping criteria.

To initialise the algorithm, every variable of an individual will be randomly generated within their defined range. The range of the initial population will have to cover the entire space of possible solutions.

The 'children' solutions will be first generated by crossover process which all the variables of an individual solution will be clustered and converted into a binary form.

Different crossover methods such as one-point, two-point, and uniform crossover, have different rules on how the children solutions inherit the characteristics from their 'parents'. In this study, uniform crossover is used for 40 bits of each individual.

The mutation process will prevent the premature convergence on poor solutions. The mutation operator involves an arbitrary bit in a genetic sequence having a probability to be changed from its original state. That is to flip some random part of the genetic sequence from '0' to '1' or from '1' to '0'.

After crossover and mutation, the individuals will be converted back to real form. The solution obtained from MA is returns as initial point (x0) for extended Nelder Mead (CA) local search algorithm.

The evaluation step focuses on the application demands. In this study, MSE, RMSE, MAD, and MAPE are used as the fitness evaluation functions to measure the least error (f-BEST) between the actual electricity demand and the forecasting values.

The reproduction process will repeat until one of the stopping conditions is met. Usually, the ending criteria will be one of the following:

1. A solution is found that satisfies the minimum criteria (convergent).
2. A fixed number of generations (maximum iteration) is reached.

6. EXPERIMENTAL RESULTS

6.1 Getting Data into HAMfP

Data for HAMfP is very important because it is necessary to test the performance of the model in the calculation of the value of the parameter. The parameters to be calculated consist of independent variable data and its effect on the dependent variable.

The independent variables include population data, the GDP data, the data import and export. The data obtained from legitimate sources that provide data for use in research [10]. These sources like Enerdata, BPS (Central Bureau of Statistics), ASEAN Outlook, and the Energy and Mineral Resources Agency.

Table 6.1 presented the normalized data for HAMfP. If the preprocessing data have been conducted before estimation, all constants that are used in normalized data should be recalculated to obtain the original data.

6.2 Simulation Results

Experiment using the normalized data is conducted to estimate parameter value that can minimize error. HAMfP was obtained the f_BEST values as shown in Table 6.2. All of the parameters (λ1, λ2, λ3, λ4, λ5, λ6, and λ7) were used to measure the accuracy of prediction.

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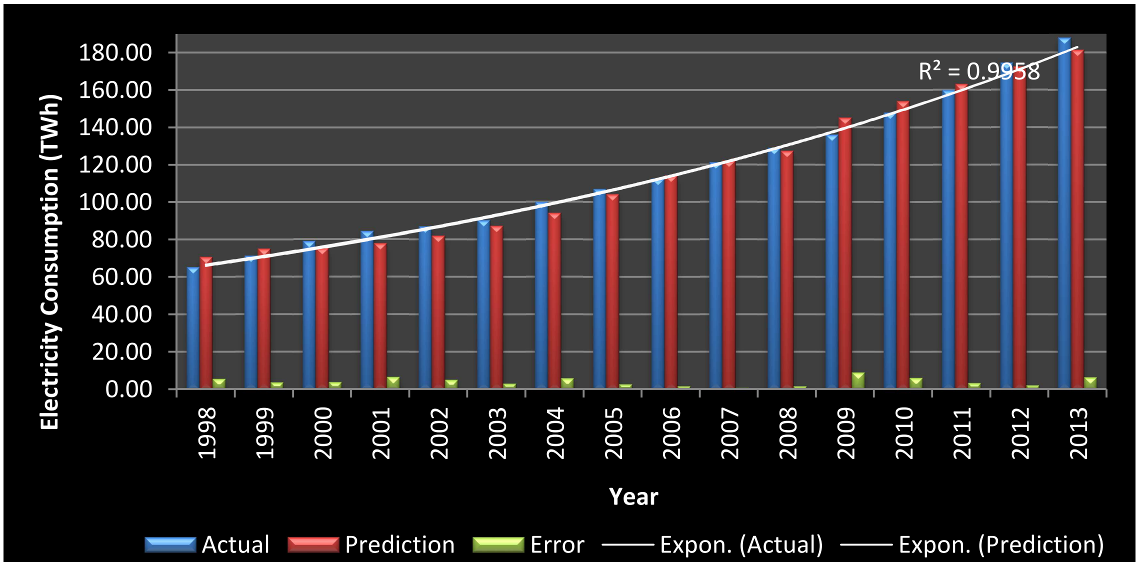

Figure 2. Electricity Prediction by KL4(mixed)

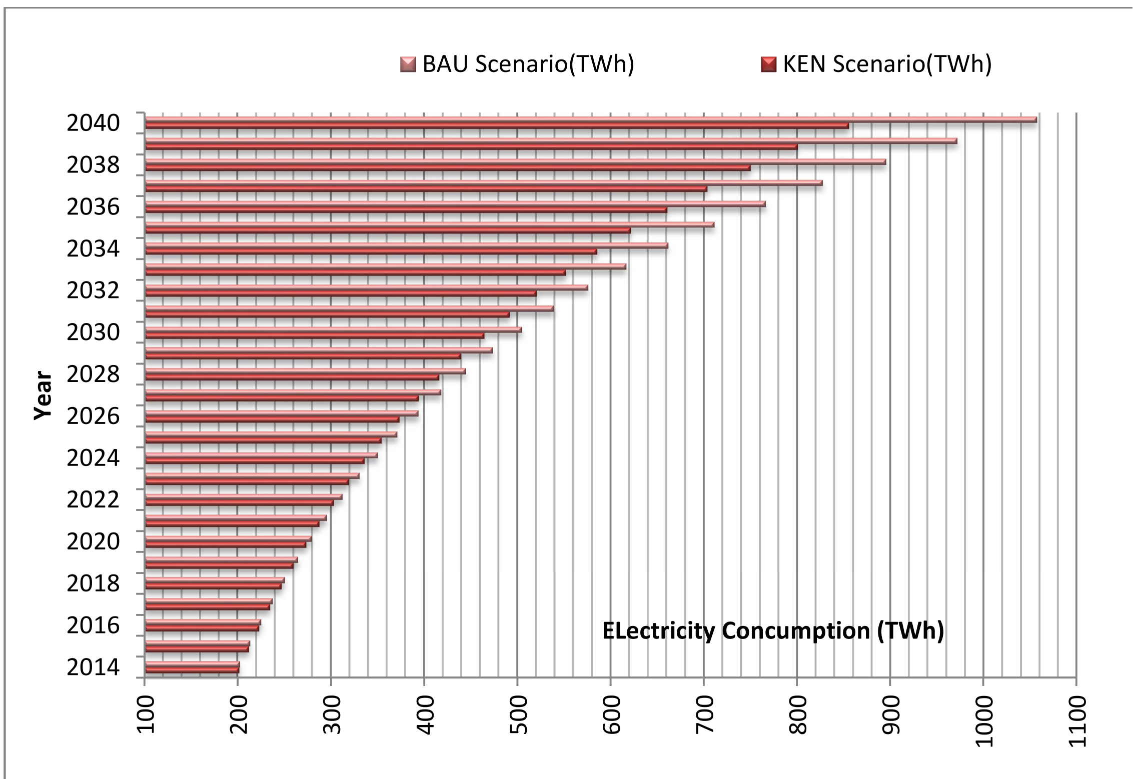

Figure 3. Projection of Electricity Consumption

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Table 6.1 Electricity demand and variables

KL (actual)	x1	x2	x3	x4
0.072	0.225	0.116	0.030	0.054
0.078	0.228	0.170	0.026	0.053
0.087	0.225	0.182	0.037	0.068
0.093	0.228	0.177	0.034	0.062
0.096	0.232	0.215	0.034	0.063
0.099	0.235	0.258	0.036	0.067
0.110	0.238	0.282	0.051	0.079
0.118	0.242	0.314	0.063	0.094
0.124	0.245	0.400	0.067	0.111
0.133	0.248	0.475	0.082	0.125
0.142	0.251	0.562	0.142	0.151
0.150	0.264	0.593	0.106	0.128
0.163	0.269	0.676	0.120	0.137
0.176	0.274	0.770	0.135	0.147
0.192	0.279	0.878	0.152	0.158
0.207	0.284	1.001	0.170	0.169

Table 6.2 Parameter values

λ1	λ2	λ3	λ4	λ5	λ6	λ7
-0.15788	0.038462	0.15413	7.1705	-0.17077	0.26535	1.5171

The parameters values from Table 6.2 are substituted into (5.4) to calculate the KL4. KL4 (Mixed Model) is better than others model (logarithmic, exponential and quadratic) as indicated by the MAPE.

Electricity demand prediction during 1998-2013 using those parameters is shown in Figure 2. As can be seen, the Figure 2 visualizes the comparison between actual and predicted values in electricity demand prediction. It is depicted that the values produced by the HAMfP are fitted the actual electricity consumption in most of the testing period.

To visualize the HAMfP projection, the graphical results provided in Figure 3. From the figure, the long-term electricity demand projections using the BAU (Business As Usual) and KEN (National Energy Commission) are illustrated. This scenario is based on the assumption of national economic growth [9].

The scenario used by the ministry of energy and mineral resources (ESDM) assuming economic growth of 7.2% for the BAU and 6% for KEN.

Based on these assumptions, the HAMfP projection of electricity demand for 2014 to 2040 is provided in Figure 3.

The visual result of convergence rate that obtained from simulations is provided in Figure 4.

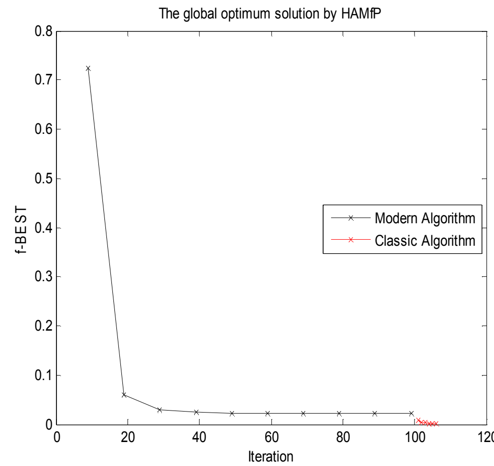

Figure 4. Convergence rate of HAMfP

From the figure, it is depicted that HAMfP experienced the strength in terms of convergence. The performance of the proposed model by measuring the level of accuracy using MAPE, MSE, RMSE, MAD as shown in Table 6.3.

Table 6.3 Level of Accuracy of Proposed Model

Model	MAPE	MSE	RMSE	MAD	Accuracy (%)
KL1 (log)	3.629	31.313	5.596	4.939	96.371
KL2 (exp)	2.488	15.756	3.969	3.385	97.512
KL3 (quad)	10.114	281.885	16.789	13.765	89.886
KL4 (mixed)	2.277	0.852	0.923	4.279	97.723

6.3 Evaluate Relativeness to Some Benchmarks

In 2012, Piltan et al [8] proposed linear and nonlinear models based on evolutionary algorithms to estimate the electricity consumption function in Turkey.

They used the four fitness functions (MSE, RMSE, MAD and MAPE) in the evolutionary algorithms and data from Ozturk and Ceylan [1].

The different linear and nonlinear models which were used for the estimation of electricity demand functional in Turkey using evolutionary algorithms (PSO and RCGA) are Logarithmic model in addition to Exponential and Quadratic models and

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Mix models as the improvement of Ozturk and Ceylan [1] results.

The best final results of the hybrid approach and also the best results of Piltan et al.[8] are shown in Table 6.4.

Table 6.4 The best results of Piltan at al.[8]

Methods	Models	Fitness Functions (%)			
		MAPE	RMSE	MSE	MAD
PSO	Mix	91.33	33.70	34.76	59.48
	Quad	84.56	42.41	44.17	89.22
	Log	7.48	4.54	4.63	5.90
RCGA	Mix	57.01	62.81	66.75	88.45
	Quad	209.24	148.17	166.47	118.48
	Log	8.31	4.71	4.46	6.43

One can see in Table 6.3 and Table 6.4 that using PSO and RCGA as an optimize for industrial electricity demand forecasting systems reduced the error rates on the average of 5-6%, which is the significant improvement on the existing previous models.

But with the use of hybrid algorithms model for prediction (HAMfP), the improvements reached the error rates on the averages of 2.2 – 4.2%. These improvements justified the use of the hybrid algorithm (HAM) as far as the error rates are concerned.

In the HAM, Logarithmic (Log), Quadratic (Quad) and Mix models were used for the estimation of electricity demand in Turkey as they were used in Piltan et al.[8] and Ozturk et al. [1]. In this study, Turkey's industrial electricity consumption is the function of gross domestic product, import and export. The four fitness functions of error rate impact on the results can be seen in this experiment.

The best final results of the hybrid modern algorithm and classical approach can be compared to the RCGA and PSO approaches in Piltan et al [8] Their best result has 4.46% of error with Log model and MSE fitness function, whereas the HMCA has less error percentage of 0.8459 using Log model.

The MA+CA algorithm is better than PSO and RCGA, whereas with the Quad model, the results of hybrid algorithm are better than other algorithms. The best forecasting model with optimum parameters can be expressed by substituting the optimal parameter values into Log and Quad models using MAD fitness function of error rate.

In further evaluation of the performance, the HMCA must be benchmarked with the state-of-the-arts models, which include PSO, RCGA, and hybrid (GA+PSO) models. The results of the two models as stated before is conducted and shown in Table 6.5. Table 6.5 presents the comparison of HMCA models with hybrid GA and PSO uses data in Ozturk and Ceylan [1] for industrial electricity consumption.

Table 6.5 Benchmarked HAMfP with Other Hybrid Models

Methods	Models	Fitness Functions (%)			
		MAPE	RMSE	MSE	MAD
GA+PSO	Mix	63.62	96.64	9340.7	81.60
	Quad	72.05	108.88	11855	92.42
	Log	4.94	5.99	35.94	6.33
MA+CA	Mix	8.57	7.12	50.83	4.17
	Quad	7.76	5.01	25.09	3.77
	Log	1.73	1.01	1.03	0.84

Table 6.5 shown that using PSO, GA as an optimize for industrial electricity demand forecasting systems reduced the error rates on the average of 4.9371%, but with the use of hybrid modern and classical algorithms (HMCA), the improvements reached the error rates on the averages of 1.73.

7. CONCLUSION

Demonstrate the effectiveness of HAMfP for the data on electricity demand, both table and graphical results is provided.

As can be seen, the KL4 (mixed) model outperforms the other model when the accuracy achieved was 97.723%.

Besides prediction accuracy, the error rate, which is relative to MAPE, MSE, RMSE and MAD are also in a good agreement which indicate the superiority of KL4 (mixed) model.

In some benchmark, the HAMfP reach the significant improvements which justified the use of the hybrid modern and classical algorithms (HAM) as far as the error rates are concerned.

Based on the extensive experiments and obtained results, it appears that the proposed HAM is more accurate than the conventional approach. In the proposed HAM, improved hybrid algorithms and normalizing of available data and variables have more effect towards the forecasting process, therefore, the obtained results proved to have the best accuracy.

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8. FUTURE WORK

The experimental results indicated that the proposed hybrid approach could achieve a higher quality performance than single algorithm optimisation. However, the classical algorithm presented in this study can be improved by using other techniques to estimate the demand parameters more accurately. The improved simplex method can converge at least ten times faster than the conventional simplex local search method. This type of improvement can be a good topic of future research.

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