Research Article

A Hybrid Forecasting Model Based on Bivariate Division and a Backpropagation Artificial Neural Network Optimized by Chaos Particle Swarm Optimization for Day-Ahead Electricity Price

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In the electricity market, the electricity price plays an inevitable role. Nevertheless, accurate price forecasting, a vital factor affecting both government regulatory agencies and public power companies, remains a huge challenge and a critical problem. Determining how to address the accurate forecasting problem becomes an even more significant task in an era in which electricity is increasingly important. Based on the chaos particle swarm optimization (CPSO), the backpropagation artificial neural network (BPANN), and the idea of bivariate division, this paper proposes a bivariate division BPANN (BD-BPANN) method and the CPSO-BD-BPANN method for forecasting electricity price. The former method creatively transforms the electricity demand and price to be a new variable, named DV, which is calculated using the division principle, to forecast the day-ahead electricity by multiplying the forecasted values of the DVs and forecasted values of the demand. Next, to improve the accuracy of BD-BPANN, chaos particle swarm optimization and BD-BPANN are synthesized to form a novel model, CPSO-BD-BPANN. In this study, CPSO is utilized to optimize the initial parameters of BD-BPANN to make its output more stable than the original model. Finally, two forecasting strategies are proposed regarding different situations.

1. Introduction

The price of electricity is not only related to the interests of the market participants but also affected by many aspects of the relevant society and the economy. Thus, the price of electricity has been the subject of considerable research. Accurate forecasting of electricity price is of great significance, both for government regulatory agencies and for public power companies. However, the electricity prices exhibit large fluctuations, and the characteristics of the electricity prices in various electricity markets are notably different. Therefore, it is notably difficult to predict all of the electricity prices using only one model. As indicated by Anbazhagan and Kumarappan, in general, the forecasting errors for the electricity price vary from approximately 5% to 36%, which are relatively high compared with the forecasting errors for

the electricity load (usually in the range from 1% to 3%). Thus, there is still an urgent demand for exploiting new electricity price forecasting models to improve the electricity price forecasting accuracy [1].

Existing forecasting models for the electricity price can be categorized by different classification criteria. Two criteria are adopted frequently, that is, forecasting models based classification and forecasting horizons based classification. According to the former classification criterion, the electricity price forecasting models can be generally classified into three categories [2]: (i) the stochastic models, (ii) the causal forecasting approaches, and (iii) the artificial intelligence based methods. According to the latter criterion, forecasting models for electricity price consist of three types: the short-term, the midterm, and the long-term models. However, as is known, most forecasting models cannot be sorted into

a single category by the forecasting models based classification rule because increasing numbers of hybrid or combined models are being developed to obtain electricity price results with superior performance. Therefore, this paper will survey and summarize the previous electricity price forecasting models according to their forecasting horizons. The short-term electricity price forecasting is usually known as the day-ahead electricity price forecasting. During the recent few decades, a large number of day-ahead electricity price forecasting models have been exploited for their importance in establishing bidding strategies for the spot market [3]. A two-stage model derived from panel cointegration and a particle filter was proposed by Li et al. [4] to forecast the day-ahead electricity data of Pennsylvania, New Jersey, Maryland (PJM). Zhang et al. [5] presented the performance of a hybrid approach composed of the wavelet transform (WT) method, the autoregressive integrated moving average (ARIMA) model, the least squares support vector machine (LSSVM), and the particle swarm optimization in forecasting the day-ahead electricity price of New South Wales, Australia. The WT and ARIMA algorithms were also used by Tan et al. [6] to build a hybrid model with the generalized autoregressive conditional heteroskedasticity to examine the day-ahead electricity price forecasting performance of PJM and Spain. A day-ahead price forecasting model, which was constructed by a feature selection approach and a cascaded neural network algorithm, was developed by Amjadi and Keynia [7] to perform an electricity price survey in Spain and Australia. Several other day-ahead electricity price forecasting models can be found in [8–15]. Accurate midterm electricity price forecasting is essential in assisting the market players to define their contracts and hedging policies. Horizons for midterm electricity price forecasting usually last from one month ahead to six months ahead. Yan and Chowdhury [16] presented a hybrid forecasting model of the midterm electricity clearing price on the basis of the LSSVM and autoregressive moving average with external input models. A multiple support vector machine approach was also applied by the same two authors [17] to the electricity market clearing price forecasting by using the PJM interconnection data. Compared to the short-term and midterm electricity price forecasting tasks, the long-term electricity price forecasting is conducted on a much wider horizon to provide the market players with the ability to make expansion plans. Pao [3] adopted an artificial neural network model to survey the long-term electricity price forecasting results on the European Energy Exchange market. However, studies regarding the long-term electricity price forecasting are relatively few compared to the number of studies on short-term and midterm electricity price forecasting due to the relatively long forecasting horizons required.

The accuracy of electricity price forecasting is affected by many factors, such as historical price, temperature, and load, among which the effect of load on electricity price forecasting is quite significant. Much of the relevant literature attempted to improve the accuracy of the electricity price by considering the impact of electricity load on the electricity price. For example, Lin et al. [18] regarded the load as one of the inputs to the enhanced probability neural network proposed in their

paper to demonstrate its performance in the electricity price forecasting. Load was also contained in the input variables of the enhanced radial basis function network proposed by Lin et al. [15]. Singhal and Swarup [19] also used the historical load and forecasted load as inputs to the artificial neural network models to obtain the electricity price forecasting results. Although the specific models used in these studies are different, these studies have one factor in common: the impact of the load on the electricity price in these studies was embodied by directly using the load as one of the input variables and the electricity price as the output variable, rather than to transform both electricity demand and price into a new variable. Based on this idea of transformation, a new hybrid electricity model is proposed in this paper.

2. Backpropagation Artificial Neuron Network (BPANN)

An artificial neural network is widely used to validate the underlying relationship between the relevant dependent and independent variables. The advantage of the use of neural networks compared to the traditional methods lies in their capacity to analyze complicated patterns quickly with a low error. In addition, in neural networks, no assumptions are required regarding the characteristics of the underlying distribution of the data [20]. Among all of the neural networks, the backpropagation artificial neural network (BPANN) is the most frequently used neural network. The basic BPANN consists of three parts: the input layer part, the hidden layer part (or middle layer part, as one or more layers can be contained in this part), and the output layer part. Generally, the number of neurons in the input layer and in the output layer is determined according to the desired input variables and output variables, respectively, while there is no fixed rule to choose the number of the neurons in the hidden layer part. For a BPANN with N neurons $x_1, x_2, \dots, x_N$ in the current layer, the output y_k of the k th neuron in the adjacent next layer is expressed as

$$y_k = f \left(\sum_{i=1}^N w_{ik} x_i - b_k \right), \quad (1)$$

where w_{ik} is the weight connection from the neuron i of the current layer to the neuron k of the adjacent next layer, b_k is the threshold of the k th neuron, and $f(\cdot)$ is the activation function, which usually consists of three types [21]:

(i) $f(\cdot)$ is the linear function defined as

$$f(x) = x; \quad (2)$$

(ii) $f(\cdot)$ is the logistic sigmoid (logsig) function defined as

$$f(x) = \frac{1}{1 + \exp(-x)}; \quad (3)$$

(iii) $f(\cdot)$ is the hyperbolic sigmoid (tansig) function defined as

$$f(x) = \frac{2}{1 + \exp(-2x)} - 1. \quad (4)$$

To validate the performance of a BP neural network, the sample data are usually divided into three parts: the training data, the validation data, and the testing data. If there are M input-output pairs in the training data in total and the number of the neurons in the output layer is K , then the objective function of the BPANN is given by

$$E = \frac{1}{2M} \sum_{i=1}^M \sum_{j=1}^K (do_j^i - ao_j^i)^2, \quad (5)$$

where do_j^i and ao_j^i are the desired and actual outputs, respectively, of the j th neuron obtained by the i th input-output pair.

In the operation process of the BPANN, the weight is updated according to the gradient descent rules expressed as follows [22]:

$$\begin{aligned} b_k(i+1) &= b_k(i) - \frac{\eta \partial E}{\partial b_k} \\ w_{ik}(i+1) &= w_{ik}(i) - \frac{\eta \partial E}{\partial w_{ik}}, \end{aligned} \quad (6)$$

where η is the learning rate parameter. In this paper, BPANN has three layers, the weights and thresholds of which are denoted by w_1 , b_1 and w_2 , b_2 . The activation function of first layer is a logistic sigmoid function, and that of the second layer is a linear function.

3. Bivariate Division BPANN (BD-BPANN)

In Section 1, it is mentioned that electricity price and demand have a closed relationship. In addition, Singhal and Swarup obtained the result that the price forecasting values using the neural network model indicate that the electricity price in the deregulated markets is strongly dependent on the trend in the load demand and the clearing price [19]. Therefore, to promote the accuracy of price forecasting, a bivariate division model based on BPANN, the price databases, and the demand databases is proposed. This hybrid approach skillfully transforms both of the two variables, demand and price, into one, as denoted by DV, using the dividing principle. This principle can be shown as

$$DV = \frac{\text{Demand}}{\text{Price}}. \quad (7)$$

Next, a sample matrix of DV is used to obtain the parameters of BPANN, which will provide the forecasting values of DV. Meanwhile, the network of electricity demand is also obtained by training its BPANN. Eventually, the electricity price forecasting values can be calculated using the following simple formula:

$$\text{Price}_{\text{forecasting}} = \frac{\text{Demand}_{\text{forecasting}}}{\text{DV}_{\text{forecasting}}}. \quad (8)$$

Details of BD-BPANN can be shown by these steps.

Step 1. Obtain the values of DV by using $DV = \text{Demand} / \text{Price}$.

Step 2. Perform preprocessing of the training set of electricity demand using the following formula:

$$\begin{aligned} \text{Data}_{\text{Training Set}} &= \frac{\text{Data}_{\text{Training Set}} - \min(\text{Data}_{\text{Training Set}})}{\max(\text{Data}_{\text{Training Set}}) - \min(\text{Data}_{\text{Training Set}})}. \end{aligned} \quad (9)$$

In addition, the testing set will be mapped by

$$\text{Data}_{\text{Testing Set}} = \frac{\text{Data}_{\text{Testing Set}} - \min(\text{Data}_{\text{Training Set}})}{\max(\text{Data}_{\text{Training Set}}) - \min(\text{Data}_{\text{Training Set}})}. \quad (10)$$

Note that the inputs and the outputs of the training sets and testing sets themselves are column vectors.

Step 3. Use $\text{Data}_{\text{Training Set}}$ to train the BPANN and obtain $\text{BPANN}_{\text{Demand}}$.

Step 4. Obtain the mapping values of the inputs of $\text{Data}_{\text{Testing Set}}$ through

$$\begin{aligned} \text{Output}_{\text{BPANN}_{\text{Demand}}} &= \text{BPANN}_{\text{Demand}} \left(\text{inputs of} \right. \\ &\quad \left. \text{the demand part of Data}_{\text{Testing Set}} \right). \end{aligned} \quad (11)$$

Step 5. Obtain the forecasting values by postprocessing of the output by

$$\begin{aligned} \text{Demand}_{\text{Forecasting}} &= \text{Output}_{\text{BPANN}_{\text{Demand}}} \times \left(\max(\text{Data}_{\text{Training Set}}) \right. \\ &\quad \left. - \min(\text{Data}_{\text{Training Set}}) \right) \\ &\quad + \min(\text{Data}_{\text{Training Set}}). \end{aligned} \quad (12)$$

Step 6. Replace the electricity demand with DV values and repeat Steps 2–5 to obtain the forecasting values of the DVs.

Step 7. Obtain the forecasting price by

$$\text{Price}_{\text{Forecasting}} = \frac{\text{Demand}_{\text{Forecasting}}}{\text{DV}_{\text{Forecasting}}}. \quad (13)$$

Figure 1 shows the specific process of BD-BPANN.

4. Chaos Particle Swarm Optimization BD-BPANN (CPSO-BD-BPANN)

The particle swarm optimization (PSO) algorithm was first developed by Kennedy and Eberhart [23] as a population-based optimization approach. In a PSO system, there are multiple candidate solutions, and each solution is named a “particle.” Each particle is captured by two factors: the velocity and the position.

FIGURE 1: BD-BPANN method.

4.1. Chaos Particle Swarm Optimization (CPSO). In a standard PSO, at iteration $t + 1$, for the k th particle, its velocity (v_k) and the position (x_k) are updated by [24]

$$\begin{aligned} v_k^{t+1} &= w v_k^t + c_1 \times \text{rand1} \times (P_k - x_k^t) + c_2 \\ &\quad \times \text{rand2} \times (P_g - x_k^t), \\ x_k^{t+1} &= x_k^t + v_k^{t+1}, \end{aligned} \quad (14)$$

where w is the inertia weight, rand1 and rand2 are two independent random variables drawn from a uniform distribution with range $[0, 1]$, and c_1 and c_2 are positive constant parameters that are known as the learning parameters. The remaining two variables P_k and P_g denote the personal best position of the k th particle in history and the current global best position, respectively; that is, by substituting these two values into the predetermined objective function, the optimal values of the k th particle and the whole particles can be obtained.

Although the standard PSO is widely applied in the parameter optimization field, it had disadvantages of easily remaining in the local optimization of the parameters, and its convergence speed is slow. As indicated by Singhal and Swarup [19], the use of the chaos will accelerate the convergence speed due to the nonrepetitive nature of chaos. Thus, the chaotic PSO (CPSO) algorithm is adopted in this paper to obtain the optimal parameter values with a higher convergence speed. The improvement of the CPSO algorithm over the standard PSO is that it initializes the position of the particles by the following formula:

$$x_{i+1} = \mu x_i (1 - x_i), \quad i = 1, 2, \dots, n, \quad (15)$$

where μ is the control variable located in the range (2, 4].

4.2. CPSO-BD-BPANN. In the classical training process of an artificial neuron network, especially for that of BPANN, the initial parameters, w_1 and w_2 along with b_1 and b_2 , often, are random matrices or vectors and consequently easily fall into the local optimal solution [25]. Chaos particle swarm optimization (abbreviated as CPSO) is an effective artificial algorithm that has the ability to achieve global optimization. CPSO is based on the basic concept of particle swarm optimization and the theory of chaos. In this paper, CPSO is used to achieve the best initial parameters of the BPANN. The improved network outperforms the previous one and has an improved ability to determine the global optimal parameters, with a lower probability of overfitting and a higher forecasting accuracy. Main steps of this CPSO-BPANN are described as follows.

Step 1. Reshape the parameters w_1 , w_2 and b_1 , b_2 of the BPANN to one vector and denote the length of the vector by n .

Step 2. Perform the initialization of the CPSO's swarm, whose length is n .

Step 3. Choose the fitness evaluation of CPSO to be the mean squared error (MSE):

$$MSE = \frac{(\text{Vector}_{\text{Actual}} - \text{Vector}_{\text{Network Output}})^2}{\text{Length}_{\text{Vector}_{\text{Actual}}}}. \quad (16)$$

Step 4. Execute the optimizing process of the CPSO and obtain the best swarm.

Step 5. Reshape the best swarm into four parameters of the network, and then reconstruct the BPANN by using these optimal matrices and vectors. The resulting network is called CPSO-BPANN.

Next, the BD-BPANN will replace the BPANN's part of the CPSO-BPANN. The process of the new forecasting model is as follows.

Step 1. Obtain the values of DV by using $DV = \text{Demand} / \text{Price}$.

Step 2. Perform the preprocessing of the training set of the electricity demand using the following formula:

$$\text{Data}_{\text{Training Set}} = \frac{\text{Data}_{\text{Training Set}} - \min(\text{Data}_{\text{Training Set}})}{\max(\text{Data}_{\text{Training Set}}) - \min(\text{Data}_{\text{Training Set}})}. \quad (17)$$

And the testing set will be mapped by

$$\text{Data}_{\text{Testing Set}} = \frac{\text{Data}_{\text{Testing Set}} - \min(\text{Data}_{\text{Training Set}})}{\max(\text{Data}_{\text{Training Set}}) - \min(\text{Data}_{\text{Training Set}})}. \quad (18)$$

Note that the inputs and outputs of the training sets and the testing sets are column vectors.

Step 3. Construct the BPANN based on the structure of the data.

Step 4. Reshape the parameters, w_1 , w_2 and b_1 , b_2 , of the BPANN into one vector, and denote the length of the vector as n .

Step 5. Perform the initialization of the CPSO's swarm, whose length is n .

Step 6. Choose the fitness evaluation of CPSO as the mean squared error (MSE):

$$MSE = \frac{(\text{Vector}_{\text{Actual}} - \text{Vector}_{\text{Network Output}})^2}{\text{Length}_{\text{Vector}_{\text{Actual}}}}. \quad (19)$$

Step 7. Execute the optimization process of the CPSO and obtain the best swarm.

Step 8. Reshape the best swarm into four parameters of the network, and then reconstruct the BPANN, consequently named as CPSO-BPANN, by using these optimal matrices and vectors.

Step 9. Use $\text{Data}_{\text{Training Set}}$ to train the CPSO-BPANN to obtain $\text{CPSO-BPANN}_{\text{Demand}}$.

Step 10. Obtain the mapping values of the inputs of $\text{Data}_{\text{Testing Set}}$ through

$$\begin{aligned} \text{Output}_{\text{CPSO-BPANN}_{\text{Demand}}} &= \text{CPSO-BPANN}_{\text{Demand}} (\text{inputs of the demand} \\ &\quad \text{part of } \text{Data}_{\text{Testing Set}}). \end{aligned} \quad (20)$$

Step 11. Obtain the forecasting values by postprocessing of the output by

$$\begin{aligned} \text{Demand}_{\text{Forecasting}} &= \text{Output}_{\text{CPSO-BPANN}_{\text{Demand}}} \\ &\quad * (\max(\text{Data}_{\text{Training Set}}) - \min(\text{Data}_{\text{Training Set}})) \\ &\quad + \min(\text{Data}_{\text{Training Set}}). \end{aligned} \quad (21)$$

Step 12. Replace the electricity demand with DV and repeat Steps 2–11 to obtain the forecasted values of the DVs.

Step 13. Obtain the forecasted price by

$$\text{Price}_{\text{Forecasting}} = \frac{\text{Demand}_{\text{Forecasting}}}{\text{DV}_{\text{Forecasting}}}. \quad (22)$$

Figure 2 schematically shows the entire process of the new model.

5. Numerical Results

In this section, the electricity price and demand will be used to test the models of CPSO-BD-BPANN, BD-BPANN, CPSO-BPANN, and BPANN. To begin, the source of data, the forecasting principle, and the cases that must be studied are introduced. Next, cases 1 and 2 are researched specifically with data provided in tables and figures. Finally, the remaining cases are studied, and, consequently, evaluation of the models is performed by comparing the forecasting accuracy, calculation time, and stability.

5.1. Data Selection, Forecasting Principles, and Case Studies. In Data Selection section, the source of the electricity data and certain properties of the data will be briefly introduced. Because a comparison is performed among these models, it is necessary to establish certain principles, which will be mentioned in the section Forecasting Principles. Eventually, to obtain the overall forecasting effectiveness of each model, this paper chooses five cases to illustrate the overall forecasting results calculated by the four models considered.

5.1.1. Data Selection. The electricity price and demand of Victoria of Australia in 2008 are chosen as the database under consideration in this paper. In each day of this database, there are 48 observation points, each representing half-hours. Figure 3 shows the schematic diagram of the electricity price, and Figure 4 shows the schematic diagram of the demand.

It is obvious that demand data are more regular than the electricity price data.

5.1.2. Forecasting Principles

Principle 1. This new forecasting model, whose lifespan is one day, will be updated by reconstructing and training new samples when it has provided 48 forecasting values.

Principle 2. The four-hour points will be used to forecast the price of the next half-hour.

Principle 3. The number of neurons in the hidden layer of the CPSO-BPANN is 3.

Principle 4. The points of the previous 21 days of the target day, a total of 1008 half-hour values, construct the training set.

Principle 5. In this paper, the forecasting result of the BPANN is the best result among the 10 times the forecasting results are obtained; this best BPANN is abbreviated as b-BPANN.

Principles 1–4 are schematically shown in Figure 5.

5.1.3. Study Cases. There are five cases in this paper. The purpose of case 1 is to explain the proposed model by forecasting only one day specifically. The other cases concentrate on the forecasting effectiveness of the proposed model and a comparison among the new CPSO-BD-BPANN and CPSO-BPANN and the original b-BPANN. The evaluation criterion of the models is mean absolute percent error (MAPE), which can be expressed as

$$\text{MAPE} = \frac{|y_{\text{models}} - y_{\text{actual}}|}{y_{\text{actual}}} \times 100\%. \quad (23)$$

And it must be pointed out that elements of all columns except the first column are MAPEs which is dimensionless in Tables 4, 5, 6, 7, and 8. The details of each case are presented in Table 1.

5.2. Study of Case 1. In this case, each step, as mentioned in Section 4, will be clearly presented through figures and tables to understand the main concept of this proposed model. First, electricity price, demand, and the value of DV (as described in Section 3) are presented in Figure 6.

The electricity demand clearly has more regularity in the data than those of price and DV. In addition, the fact that the volatility of price and DV do not exhibit distinct differences is also observed. Next, the results of the BD-BPANN will be presented in Table 2 and Figure 7.

In Table 2, units of demand and price are Hmk/h and \$/Mwh, respectively. The symbol “*” represents the time spots, a total of 27 points, for which BD-BPANN outperforms b-BPANN. The symbol “†” represents the reverse situation to that of the symbol “*.” The symbol “‡” represents the results of the average and the variance of each column (except the first column). Specifically, in these 48 time spots, the best forecasting MAPE of demand is 0.05% at 10:30 of this day, and the worst MAPE is 6.06% at 1:00. The average value, the variance, and average forecasting MAPE of the electricity demand obtained through b-BPANN are 5645.0323, 555.27757, and 1.38%, respectively. Similarly, the best forecasting value of the DV whose MAPE is 1.25% is at 11:30 of June 9 in 2008, and the worst performance of forecasting occurred at 2:30. The average value, variance, and average forecasting MAPE of the DV which b-BPANN calculates are 222.68, 88.982, and 11.24%, respectively. To

FIGURE 2: CPSO-BD-BPANN method.

TABLE I: Cases' information.

Case	Testing days	Sample (training) days	Numbers of samples	Marks
1	June 9, 2008	May 19–June 8, 2008	1008	Example
2	March 10, 2008	February 18–March 9, 2008	1008	Spring
	March 11, 2008	February 19–March 10, 2008	1008	
	March 12, 2008	February 20–March 11, 2008	1008	
	March 13, 2008	February 21–March 12, 2008	1008	
	March 14, 2008	February 22–March 13, 2008	1008	
	March 15, 2008	February 23–March 14, 2008	1008	
	March 16, 2008	February 24–March 15, 2008	1008	
3	June 9, 2008	May 19–June 8, 2008	1008	Summer
	June 10, 2008	May 20–June 9, 2008	1008	
	June 11, 2008	May 21–June 10th, 2008	1008	
	June 12, 2008	May 22–June 11, 2008	1008	
	June 13, 2008	May 23–June 12, 2008	1008	
	June 14, 2008	May 24–June 13, 2008	1008	
	June 15, 2008	May 25–June 14, 2008	1008	
4	September 15, 2008	August 25–September 14, 2008	1008	Autumn
	September 16, 2008	August 26–September 15, 2008	1008	
	September 17, 2008	August 27–September 16, 2008	1008	
	September 18, 2008	August 28–September 17, 2008	1008	
	September 19, 2008	August 29–September 18, 2008	1008	
	September 20, 2008	August 30–September 19, 2008	1008	
	September 21, 2008	August 31–September 20, 2008	1008	
5	December 8, 2008	November 17–December 7, 2008	1008	Winter
	December 9, 2008	November 18–December 8, 2008	1008	
	December 10, 2008	November 19–December 9, 2008	1008	
	December 11, 2008	November 20–December 10, 2008	1008	
	December 12, 2008	November 21–December 11, 2008	1008	
	December 13, 2008	November 22–December 12, 2008	1008	
	December 14, 2008	November 23–December 13, 2008	1008

FIGURE 3: Electricity prices in the period from May 19 to June 9.

FIGURE 4: Electricity demand in the period from May 19 to June 9.

FIGURE 5: Forecasting Principles 1-4.

make a comparison between b-BPANN and BD-BPANN, the output of b-BPANN, that is, the price forecasting values obtained by only using b-BPANN, is also presented in Table 2. 0.52% is the best MAPE of b-BPANN at 16:30, and 42.39% is the worst MAPE obtained when utilizing b-BPANN to forecast electricity price occurred at 2:30. In addition, the average value, variance, and average forecasting MAPE of the price are 30.903, 16.482, and 15.30%, respectively. Furthermore, the best performance of BD-BPANN occurred at 20:30, with a forecasting MAPE of 0.56%; meanwhile, 39.00% is the worst MAPE of this new forecasting method. The average forecasting MAPE of the price calculated by BD-BPANN is 13.25%, which is less than that of the classical method.

Figure 7 shows the forecasting results of b-BPANN and BD-BPANN and the actual electricity price. It is clear that BD-BPANN is superior to BPANN because the green points (forecasted values of BD-BPANN) are closer to the blue curve (actual price) than the red rectangles.

Next, the consequence of using CPSO-BD-BPANN is described as follows. In Table 3, units of demand and price are Hmk/h and \$/Mwh, respectively. The forecasting MAPE of the demand obtained by CPSO-BPANN ranges from 0.12% at 15:00 to 4.55% at 1:00, and the CPSO-BPANN's average forecasting MAPE of the demand is 1.23%, which is less than 1.38%, the result of the b-BPANN. At 22:30, the best DV forecasted value, whose MAPE is 0.009%, appears. The worst MAPE of DV reaches 41.94% at 8:30, with the average value of the MAPE of DV calculated by CPSO-BPANN of 10.79%, which is still less than the 11.24% obtained using b-BPANN only. In the end, the final model, CPSO-BD-BPANN, is used to forecast the electricity prices of June 9 in 2008. Additionally, to enable a comparison between CPSO-BPANN and CPSO-BD-BPANN, the results of CPSO-BPANN, that is, to calculate the forecasting values of price by only using CPSO-BPANN, are also presented in Table 2. 0.23% is the best MAPE of CPSO-BPANN at 8:00, and 42.64% is the worst

FIGURE 6: Schematic diagram of the electricity price demand and DV.

FIGURE 7: BPANN and BD-BPANN methods for case 1.

TABLE 2: Results of BD-BPANN.

Hour	Actual demand	Forecasting demand (BPANN)	MAPE (demand)	Actual DV	Forecasting DV (BPANN)	MAPE (DV)	Actual price	Forecasting price (BPANN)	MAPE (price, BPANN)	Forecasting price (BD-BPANN)	MAPE (price, BD-BPANN)	Improvement
0:00	5414.8	5442.3104	0.51%	240.8	215.49331	10.50%	22.49	27.594881	22.70%	25.25512481	12.29%	10.40% *
0:30	5253.18	5284.0131	0.59%	265.4	232.03984	12.58%	19.79	22.490634	13.65%	22.77200803	15.07%	-1.42% †
1:00	5606.09	5266.4948	6.06%	261.4	248.91589	4.76%	21.45	21.258555	0.89%	21.15772899	1.36%	-0.47% †
1:30	5419.17	5339.1006	1.48%	276.5	247.95654	10.32%	19.6	22.055641	12.53%	21.53240496	9.86%	2.67%
2:00	5239.77	5235.039	0.09%	307.1	261.63496	14.82%	17.06	21.746225	27.47%	20.00894253	17.29%	10.18% *
2:30	5070.66	5112.8046	0.83%	386.2	280.15216	27.46%	13.13	18.772312	42.97%	18.25009901	39.00%	3.98%
3:00	4911.51	5134.0262	4.53%	373.2	291.94975	21.77%	13.16	15.194394	15.46%	17.5853074	33.63%	-18.17%
3:30	4797.44	4829.5796	0.67%	355.9	288.04488	19.06%	13.48	14.110274	4.68%	16.76676069	24.38%	-19.71%
4:00	4715.03	4753.9841	0.83%	393.9	290.25239	26.31%	11.97	15.899535	32.83%	16.3787943	36.83%	-4.00%
4:30	4668.43	4646.7215	0.47%	396.6	293.38185	26.03%	11.77	15.2975	29.97%	15.83847612	34.57%	-4.60% †
5:00	4692.85	4754.847	1.32%	384	293.45887	23.58%	12.22	14.34174	17.36%	16.2027717	32.59%	-15.23%
5:30	4758.21	4832.7262	1.57%	347.6	292.35656	15.89%	13.69	15.517764	13.35%	16.53024745	20.75%	-7.40%
6:00	4912.88	4924.456	0.24%	326.4	284.52861	12.84%	15.05	16.922151	12.44%	17.3074197	15.00%	-2.56%
6:30	5003.4	5140.7882	2.75%	357.9	280.17246	21.72%	13.98	19.766599	41.39%	18.34865658	31.25%	10.14%
7:00	4960.1	5143.8833	3.71%	331.3	288.59885	12.90%	14.97	19.594035	30.89%	17.8236444	19.06%	11.83% *
7:30	5117.18	4938.0315	3.50%	311.6	282.69038	9.29%	16.42	19.072568	16.15%	17.46798557	6.38%	9.77%
8:00	5318.34	5357.6693	0.74%	257.9	278.11501	7.83%	20.62	21.63026	4.90%	19.26422207	6.58%	-1.68%
8:30	5495.88	5525.5037	0.54%	212.9	245.17048	15.14%	25.81	24.91201	3.48%	22.53739351	12.68%	-9.20% †
9:00	5642.2	5629.6762	0.22%	188.2	203.71598	8.25%	29.98	31.321237	4.47%	27.63492669	7.82%	-3.35%
9:30	5710.65	5771.7986	1.07%	177.6	177.64214	0.04%	32.16	35.888593	11.59%	32.49115641	1.03%	10.56%
10:00	5768.91	5738.3228	0.53%	169.3	161.25699	4.74%	34.08	37.976947	11.43%	35.58495464	4.42%	7.02%
10:30	5824.49	5827.4595	0.05%	173.7	159.3596	8.26%	33.53	39.714597	18.44%	36.56798612	9.06%	9.38%
11:00	5875.85	5875.5412	0.01%	175	168.03384	4.00%	33.57	39.576878	17.89%	34.96641707	4.16%	13.73% *
11:30	5921.07	5914.5372	0.11%	179.8	177.5588	1.25%	32.93	38.320271	16.37%	33.31030251	1.15%	15.21%
12:00	5913.02	5965.4175	0.89%	181.7	184.585	1.58%	32.54	37.36692	14.83%	32.3179965	0.68%	14.15%
12:30	5895.12	5903.9873	0.15%	188.2	180.62093	4.04%	31.32	35.282581	12.65%	32.68717122	4.37%	8.29%
13:00	5946.73	5898.7832	0.81%	181.7	186.44404	2.62%	32.73	33.633542	2.76%	31.63835756	3.34%	-0.57% †
13:30	5914.24	6046.6289	2.24%	170.5	178.24	4.55%	34.69	34.40681	0.82%	33.92408544	2.21%	-1.39%
14:00	5856.43	5895.5677	0.67%	187.9	162.70022	13.43%	31.16	37.333873	19.81%	36.23576938	16.29%	3.52%
14:30	5849.54	5824.1822	0.43%	191.9	182.44249	4.90%	30.49	33.800372	10.86%	31.92338672	4.70%	6.16% *
15:00	5887.96	5915.1964	0.46%	183.1	187.82561	2.56%	32.15	31.37679	2.41%	31.49302427	2.04%	0.36%
15:30	5890.44	5984.3436	1.59%	168.5	179.66382	6.60%	34.95	34.276918	1.93%	33.30856348	4.70%	-2.77%
16:00	5979.28	5932.6459	0.78%	146.3	159.13812	8.80%	40.88	37.643712	7.92%	37.27985404	8.81%	-0.89% †
16:30	6233.19	6118.3096	1.84%	138.9	134.84939	2.93%	44.87	45.104528	0.52%	45.37143043	1.12%	-0.59%
17:00	6581.07	6525.8842	0.84%	103.9	129.07518	24.17%	63.31	49.75938	21.40%	50.55878385	20.14%	1.26% *
17:30	6822.35	6874.8221	0.77%	77.35	95.021935	22.85%	88.2	73.377177	16.81%	72.34984345	17.97%	-1.16% †

TABLE 2: Continued.

Hour	Actual demand	Forecasting demand (BPANN)	MAPE (demand)	Actual DV	Forecasting DV (BPANN)	MAPE (DV)	Actual price	Forecasting price (BPANN)	MAPE (price, BPANN)	Forecasting price (BD-BPANN)	MAPE (price, BD-BPANN)	Improvement
18:00	6742.56	6946.8078	3.03%	84.82	83.750475	1.26%	79.49	94.148773	18.44%	82.94648873	4.35%	14.09% *
18:30	6595.51	6653.9664	0.89%	107.9	87.440297	18.96%	61.13	74.163976	21.32%	76.09725325	24.48%	-3.16% †
19:00	6362.9	6441.8524	1.24%	138.1	108.96495	21.12%	46.06	60.105859	30.49%	59.11857523	28.35%	2.14%
19:30	6299.54	6159.9071	2.22%	141.5	147.50474	4.24%	44.52	51.411757	15.48%	41.76073974	6.20%	9.28%
20:00	6203.49	6230.2734	0.43%	142.7	150.18509	5.22%	43.46	40.316111	7.23%	41.48396847	4.55%	2.69% *
20:30	6085.82	6113.2257	0.45%	149.5	150.97197	1.01%	40.72	41.213382	1.21%	40.49245619	0.56%	0.65%
21:00	5937.52	5988.264	0.85%	166.5	153.18458	8.00%	35.66	39.223883	9.99%	39.09181919	9.62%	0.37%
21:30	5772.1	5910.8892	2.40%	189.4	168.13084	11.25%	30.47	38.878744	27.60%	35.15648301	15.38%	12.22%
22:00	5584.53	5727.8769	2.57%	178.4	192.49561	7.89%	31.3	32.765402	4.68%	29.755883	4.93%	-0.25% †
22:30	5421.07	5546.936	2.32%	209.9	177.50303	15.42%	25.83	33.122254	28.23%	31.24980994	20.98%	7.25% *
23:00	5605	5380.5298	4.00%	189.4	210.78249	11.31%	29.6	26.070365	11.92%	25.52645485	13.76%	-1.84% †
23:30	5484.05	5586.3543	1.87%	220.2	186.35301	15.35%	24.91	30.340156	21.80%	29.97726871	20.34%	1.46% *
Average	5645.03	5666.4993	1.38%	222.7	202.50737	11.24%	30.9	33.627043	15.30%	32.15269162	13.25%	2.05% ‡
Variance	555.278	556.16377	1.31%	88.95	61.797993	7.83%	16.48	16.42647	10.62%	15.36874818	10.98%	8.04%

MAPE of the CPSO-BPANN used to forecast electricity price, which occurred at 2:30. In addition, the average MAPE CPSO-BPANN is 14.18%, which is better than that of the b-BPANN of 15.30%. In the end, the final model in this paper is used to forecast the electricity price of June 9 in 2008. At 10:00 on this day, the new model yields the best forecasting MAPE, which is only 0.36%. On the contrary, at 2:30, the worst performance of CPSO-BD-BPANN, with a MAPE of 43.07%, arises. The average MAPE obtained by CPSO-BD-BPANN of this day is 12.31%, which is less than that calculated by CPSO-BPANN. However, there are 28 time spots, that is, the symbol “*” in Table 3, where the effectiveness of CPSO-BD-BPANN is better than that of CPSO-BPANN. Figure 8 graphically shows the results presented in Table 3.

Overall, it is not difficult to determine that CPSO-BD-BPANN has the best effectiveness among the models of b-BPANN, BD-BPANN, CPSO-BPANN, and CPSO-BD-BPANN. Further, the fact that BD-BPANN outperforms CPSO-BPANN, whose calculating time is much longer than that of BD-BPANN, explains why BD-BPANN is more efficient than CPSO-BPANN, which is an optimal artificial neural network under the same conditions, including calculating capacity and language of debugging.

5.3. Study of Case 2. The primary objective of this part is testing the effectiveness of models in spring, rather than explaining the details of the methods, as was performed in case 1. This section will present the effectiveness of each method, as measured by MAPE. Tables 4 and 5 present a comparison between the b-BPANN method and the CPSO-BD-BPANN and that between CPSO-BPANN and BD-BPANN. It is obvious that CPSO-BD-BPANN performs better than b-BPANN in all of the spring week except March 11. In March 10, March 13, March 14, and March 16, BD-BPANN is more efficient than CPSO-BPANN, and the overall effectiveness of BD-BPANN is still better than that of CPSO-BPANN in this randomly selected spring week. The results indicate that this sample transformation, named bivariate division, of the input of b-BPANN is more effective than a complex process using an artificial intelligent algorithm, CPSO in this paper, to obtain the best initial parameters of the network.

Specifically, on March 10, CPSO-BPANN exhibited its best MAPE, 0.18%, at 5:30 and obtains its worst one, 103.16%, at 17:00. 1.16% is the minimal MAPE of BD-BPANN at 9:00; in contrast, at 14:30, BD-BPANN exhibits its maximum MAPE, 56.10%, of this day. The best MAPE of another model, CPSO-BD-BPANN, is 0.0002% at 8:30 and the worst MAPE for this model reaches 46.52% at 14:30 on this spring day. On the next day of this week, March 11, CPSO-BPANN exhibits its best forecasting performance, with a MAPE of 0.02% at 12:30, and the method exhibited a maximum MAPE, 45.55%, at 17:00. Meanwhile, the smallest MAPE of BD-BPANN is 0.09% at 22:00, and its maximum one is 42.89% at 7:00. 0.17% is the best forecasting error by using CPSO-BD-BPANN, which exhibited its worst MAPE of 38.52% at 7:00. On March 12, the MAPE of CPSO-BPANN ranges from 0.04% at 9:00 to 35.03% at 7:00; that of BD-BPANN reaches its smallest MAPE value, 0.02%, at 11:30 and its

maximum one, 43.40%, at 17:00; and CPSO-BD-BPANN exhibited its best forecasting effectiveness, with a MAPE of 0.2%, at 19:30, and its worst one, 34.21%, at 17:00. On the fourth day of this spring week, b-BPANN optimized by the CPSO algorithm obtains its minimal MAPE, whose value is 0.08% at 3:30 and its maximum one, 74.99%, at 19:30; the forecasting MAPE of BD-BPANN changes from its smallest value 0.34% at 17:00 to its largest one 62.31% at 15:00 of this day; the final proposed approach, CPSO-BD-BPANN, exhibited its best forecasting effectiveness at 4:00, with a MAPE of 0.23%, and its worst effectiveness at 15:00, with a MAPE of 56.86%. On March 14, CPSO-BPANN exhibited its minimum MAPE of this day of 1.59%, at 21:30, and its largest MAPE of 178.85%, at 19:30; simultaneously, the MAPE of BD-BPANN and CPSO-BD-BPANN ranges from 3.08% at 5:30 and 0.73%, respectively, at 22:00 up to 71.38% and 71.74% for BD-BPANN and CPSO-BD-BPANN, respectively, at 15:00. For the next day, March 15, 0.0003% is the minimum MAPE forecasted by CPSO-BPANN at 3:00, and 52.19% at 21:30 is the maximum one; BD-BPANN exhibited its best forecasting performance with a MAPE of 0.36% at 6:00 and its worst one with a MAPE of 43.13% at 21:30; using CPSO-BD-BPANN, its minimum MAPE, 0.34%, and its maximum one, 41.14%, appear at 22:30 and 21:30, respectively. On the last day of this week, the minimum MAPE of CPSO-BPANN is 0.18% at 4:00 and the largest one of this method is 62.99% at 14:30; simultaneously, the MAPE of both of the new models, BD-BPANN and CPSO-BD-BPANN, changes from 0.06% at 4:30 and 13:00, respectively, to values of 67.56% and 62.48% for BD-BPANN and CPSO-BD-BPANN, respectively, at 14:30. The results indicate that BD-BPANN and CPSO-BD-BPANN both exhibit better forecasting effectiveness than does CPSO-BPANN, especially in the aspect of stability, considering that both BD-BPANN and CPSO-BD-BPANN do not exhibit an extreme MAPE beyond 100%. Figures 9 and 10 show the results of these 4 forecasting methods through the comparison with the actual price and errors of the forecasting values. Thus, the CPSO-BD-BPANN and BD-BPANN methods outperform CPSO-BPANN and the original b-BPANN.

5.4. Results Analysis and Models Evaluation. In this section, the results of the proposed models of cases 3–5 are presented in Tables 6, 7, and 8. Next, each season's average MAPE of CPSO-BD-BPANN, BD-BPANN, CPSO-BPANN, and b-BPANN is presented in Table 9. Simultaneously, the forecasting values of these approaches are also illustrated in pictures. Finally, each of the models will be evaluated through three aspects: forecasting accuracy, calculating time, and stability.

5.4.1. Results Analysis. Table 6 collects the forecasting values calculated by CPSO-BD-BPANN and BD-BPANN. Each column refers to result of each method on different days of summer. For June 9, the lowest MAPE is 0.36% at 10:00 when using BD-BPANN, which also exhibited the highest MAPE, 43.70%, at 2:30 on this day. The forecasting MAPE of BD-BPANN on June 10 ranges from 0.02% at 3:00 to 44.62% at 8:30. On June 11, the MAPE values of BD-BPANN ranged

TABLE 3: Results of CPSO-BD-BPANN.

Hour	Actual demand	Forecasting demand (CPSO-BPANN)	MAPE (demand)	Actual DV	Forecasting DV (CPSO-BPANN)	MAPE (DV)	Actual price	Forecasting price (CPSO-BPANN)	MAPE (price, CPSO-BPANN)	Forecasting price (CPSO-BD-BPANN)	MAPE (price, CPSO-BD-BPANN)	Improvement
0:00	5414.8	5492.2153	1.43%	240.8	219.57536	8.80%	22.49	26.880519	19.52%	25.01289458	11.22%	8.30%
0:30	5253.18	5306.663	1.02%	265.4	243.41062	8.30%	19.79	23.418112	18.33%	21.8012801	10.16%	8.17%
1:00	5606.09	5350.7844	4.55%	261.4	267.36513	2.30%	21.45	20.436447	4.73%	20.01302299	6.70%	-1.97%
1:30	5419.17	5549.2508	2.40%	276.5	246.77087	10.77%	19.6	23.108165	17.90%	22.49201997	14.76%	3.14%
2:00	5239.77	5139.7849	1.91%	307.1	259.74285	15.43%	17.06	21.551401	26.33%	19.78979409	15.99%	10.34%
2:30	5070.66	5082.3405	0.23%	386.2	270.54802	29.94%	13.13	18.729147	42.64%	18.7853548	43.07%	-0.43%
3:00	4911.51	4955.8072	0.90%	373.2	336.4826	9.84%	13.16	14.119062	7.29%	14.72827195	11.92%	-4.63%
3:30	4797.44	4789.1308	0.17%	355.9	297.47988	16.41%	13.48	14.636359	8.58%	16.09900721	19.43%	-10.85%
4:00	4715.03	4778.4144	1.34%	393.9	285.25176	27.58%	11.97	15.798302	31.98%	16.75156848	39.95%	-7.96%
4:30	4668.43	4700.7516	0.69%	396.6	298.37235	24.77%	11.77	14.555668	23.67%	15.75464871	33.85%	-10.19%
5:00	4692.85	4720.5633	0.59%	384	289.67213	24.57%	12.22	14.408606	17.91%	16.29622854	33.36%	-15.45%
5:30	4758.21	4764.3251	0.13%	347.6	319.21548	8.16%	13.69	15.334222	12.01%	14.92510684	9.02%	2.99%
6:00	4912.88	4884.1285	0.59%	326.4	313.75764	3.88%	15.05	17.408772	15.67%	15.56656418	3.43%	12.24%
6:30	5003.4	5199.2274	3.91%	357.9	311.08704	13.08%	13.98	19.288571	37.97%	16.71309538	19.55%	18.42%
7:00	4960.1	5168.1909	4.20%	331.3	334.2254	0.87%	14.97	17.91098	19.65%	15.46319001	3.29%	16.35%
7:30	5117.18	4922.7543	3.80%	311.6	296.53318	4.85%	16.42	18.762677	14.27%	16.60102342	1.10%	13.16%
8:00	5318.34	5297.6919	0.39%	257.9	290.00561	12.44%	20.62	20.57195	0.23%	18.26754984	11.41%	-11.18%
8:30	5495.88	5547.3933	0.94%	212.9	302.2374	41.94%	25.81	25.67494	0.52%	18.35442365	28.89%	-28.36%
9:00	5642.2	5674.7367	0.58%	188.2	218.76175	16.24%	29.98	31.919947	6.47%	25.94025953	13.47%	-7.00%
9:30	5710.65	5767.462	0.99%	177.6	203.63688	14.68%	32.16	36.591638	13.78%	28.32228561	11.93%	1.85%
10:00	5768.91	5795.6082	0.46%	169.3	169.44063	0.10%	34.08	38.313277	12.42%	34.20435895	0.36%	12.06%
10:30	5824.49	5821.0626	0.06%	173.7	164.75679	5.15%	33.53	39.638414	18.22%	35.33124535	5.37%	12.85%
11:00	5875.85	5838.2803	0.64%	175	167.62649	4.23%	33.57	38.044351	13.33%	34.82910338	3.75%	9.58%
11:30	5921.07	5908.7385	0.21%	179.8	185.71187	3.28%	32.93	37.171662	12.88%	31.81669919	3.38%	9.50%
12:00	5913.02	5935.1334	0.37%	181.7	176.38607	2.93%	32.54	35.834762	10.13%	33.64853796	3.41%	6.72%
12:30	5895.12	5890.3105	0.08%	188.2	174.95423	7.05%	31.32	35.028453	11.84%	33.66772215	7.50%	4.34%
13:00	5946.73	5896.7971	0.84%	181.7	183.04082	0.74%	32.73	33.400088	2.05%	32.21574978	1.57%	0.48%
13:30	5914.24	6031.6281	1.98%	170.5	175.40448	2.88%	34.69	35.102752	1.19%	34.38696758	0.87%	0.32%
14:00	5856.43	5921.8544	1.12%	187.9	155.72492	17.14%	31.16	37.676124	20.91%	38.02765926	22.04%	-1.13%
14:30	5849.54	5825.7947	0.41%	191.9	179.74411	6.31%	30.49	33.492881	9.85%	32.41160238	6.30%	3.55%
15:00	5887.96	5880.9772	0.12%	183.1	193.4568	5.63%	32.15	32.229431	0.25%	30.39943415	5.44%	-5.20%
15:30	5890.44	5957.7337	1.14%	168.5	173.90229	3.18%	34.95	34.471827	1.37%	34.25908615	1.98%	-0.61%
16:00	5979.28	5922.67	0.95%	146.3	152.40082	4.20%	40.88	38.232693	6.48%	38.86245512	4.94%	1.54%
16:30	6233.19	6108.8388	1.99%	138.9	127.597	8.15%	44.87	45.338569	1.04%	47.87603855	6.70%	-5.66%
17:00	6581.07	6619.2217	0.58%	103.9	119.09502	14.57%	63.31	49.906215	21.17%	55.5793317	12.21%	8.96%
17:30	6822.35	6799.2178	0.34%	77.35	92.64065	19.77%	88.2	69.094306	21.66%	73.39345962	16.79%	4.87%

TABLE 3: Continued.

Hour	Actual demand	Forecasting demand (CPSO-BPANN)	MAPE (demand)	Actual DV	Forecasting DV (CPSO-BPANN)	MAPE (DV)	Actual price	Forecasting price (CPSO-BPANN)	MAPE (price, CPSO-BPANN)	Forecasting price (CPSO-BD-BPANN)	MAPE (price, CPSO-BD-BPANN)	Improvement
18:00	6742.56	6848.7633	1.58%	84.82	88.597835	4.45%	79.49	90.229561	13.51%	77.30170033	2.75%	10.76% *
18:30	6595.51	6704.684	1.66%	107.9	79.521754	26.30%	61.13	81.428552	33.21%	84.3125764	37.92%	-4.72% †
19:00	6362.9	6425.7627	0.99%	138.1	115.19771	16.61%	46.06	60.10706	30.50%	55.78029774	21.10%	9.39%
19:30	6299.54	6270.3806	0.46%	141.5	148.37372	4.86%	44.52	41.978859	5.71%	42.26072192	5.07%	0.63% *
20:00	6203.49	6217.1247	0.22%	142.7	152.30635	6.70%	43.46	40.572231	6.64%	40.81986587	6.07%	0.57%
20:30	6085.82	6108.2877	0.37%	149.5	154.24126	3.20%	40.72	40.786703	0.16%	39.60216314	2.75%	-2.58% †
21:00	5937.52	5882.9523	0.92%	166.5	160.28586	3.73%	35.66	39.121866	9.71%	36.70287807	2.92%	6.78% *
21:30	5772.1	5914.9629	2.48%	189.4	168.41194	11.10%	30.47	34.602221	13.56%	35.12199356	15.27%	-1.71% †
22:00	5584.53	5668.5092	1.50%	178.4	178.40287	9.31E-05	31.3	28.618536	8.57%	31.7736434	1.51%	7.05% *
22:30	5421.07	5528.3863	1.98%	209.9	177.88209	15.24%	25.83	30.635709	18.61%	31.07893729	20.32%	-1.72% †
23:00	5605	5365.2112	4.28%	189.4	214.68836	13.38%	29.6	25.656578	13.32%	24.99069397	15.57%	-2.25%
23:30	5484.05	5522.2096	0.70%	220.2	193.76899	11.99%	24.91	30.594098	22.82%	28.49893352	14.41%	8.41% *
Average	5645.03	5660.4733	1.23%	222.7	208.90924	10.79%	30.9	33.091943	14.18%	31.80895055	12.31%	1.87% †
Variance	555.278	558.35349	1.18%	88.95	70.212986	8.96%	16.48	16.238851	10.18%	16.02614904	11.05%	8.87% †

TABLE 4: Results of case 2 study (b-BPANN and CPSO-BD-BPANN).

Hour	March 10th		March 11th		March 12th		March 13th		March 14th		March 15th		March 16th	
	b-BPANN	CPSO-BD-BPANN	b-BPANN	CPSO-BD-BPANN	b-BPANN	CPSO-BD-BPANN	b-BPANN	CPSO-BD-BPANN	b-BPANN	CPSO-BD-BPANN	b-BPANN	CPSO-BD-BPANN	b-BPANN	CPSO-BD-BPANN
0:00	55.44%	7.46%	14.17%	9.22%	2.34%	4.31%	20.55%	7.49%	20.36%	9.93%	28.58%	1.52%	12.15%	6.10%
0:30	31.35%	8.98%	10.63%	6.50%	2.78%	5.20%	10.41%	0.31%	6.78%	5.36%	38.38%	10.32%	3.89%	3.49%
1:00	38.33%	13.33%	11.16%	7.30%	9.88%	4.53%	2.93%	7.04%	10.79%	13.78%	23.89%	12.20%	5.55%	2.32%
1:30	108.10%	25.31%	13.98%	4.02%	19.37%	15.83%	27.59%	15.12%	20.41%	15.74%	5.86%	2.99%	12.65%	4.53%
2:00	20.34%	10.06%	3.22%	7.88%	9.94%	10.43%	23.37%	0.49%	23.58%	6.45%	7.77%	3.03%	16.46%	8.15%
2:30	130.12%	20.47%	0.42%	4.57%	14.58%	12.16%	7.97%	3.46%	2.55%	1.68%	10.11%	3.24%	5.31%	3.74%
3:00	40.77%	10.86%	13.79%	6.05%	3.44%	3.86%	8.84%	0.92%	8.17%	4.49%	11.74%	1.31%	4.33%	2.08%
3:30	104.40%	7.55%	4.97%	10.16%	11.90%	15.35%	12.21%	4.55%	0.14%	11.79%	21.14%	4.66%	4.11%	5.05%
4:00	61.59%	9.50%	0.98%	6.40%	0.09%	11.57%	8.28%	0.23%	7.61%	15.41%	14.58%	7.37%	5.25%	2.94%
4:30	58.41%	1.35%	1.30%	9.50%	13.03%	16.51%	10.94%	15.72%	9.48%	15.86%	9.37%	10.26%	5.05%	0.62%
5:00	54.34%	0.46%	25.21%	27.51%	16.67%	19.95%	19.37%	20.07%	23.34%	28.35%	0.33%	14.06%	4.13%	2.63%
5:30	32.75%	1.08%	11.04%	16.77%	0.58%	3.49%	2.68%	2.48%	8.39%	7.63%	28.09%	6.26%	5.50%	0.86%
6:00	30.99%	3.47%	6.40%	2.46%	4.16%	8.47%	6.18%	4.94%	13.20%	10.82%	8.64%	7.71%	5.89%	2.83%
6:30	33.37%	4.88%	15.31%	17.33%	23.12%	23.16%	12.07%	6.91%	31.10%	31.18%	6.05%	13.79%	6.74%	2.55%
7:00	23.60%	5.03%	48.47%	38.52%	52.12%	25.99%	25.81%	19.02%	17.13%	26.12%	35.61%	7.82%	5.94%	5.10%
7:30	7.75%	10.65%	11.05%	0.60%	5.60%	3.25%	12.28%	2.11%	3.86%	12.56%	12.22%	18.31%	5.46%	15.17%
8:00	23.85%	0.53%	19.84%	9.93%	11.56%	1.79%	2.83%	14.63%	29.62%	22.20%	12.21%	29.46%	11.15%	19.01%
8:30	15.81%	0.00%	3.20%	6.40%	0.40%	0.22%	2.80%	10.34%	12.23%	7.99%	7.25%	24.89%	10.27%	13.56%
9:00	8.94%	1.81%	13.48%	13.76%	1.97%	1.80%	11.34%	16.34%	24.53%	28.72%	11.82%	23.65%	8.18%	5.53%
9:30	0.68%	8.68%	13.68%	9.21%	25.92%	27.21%	7.12%	5.58%	21.52%	15.42%	23.71%	32.89%	4.41%	2.04%
10:00	9.01%	0.22%	13.11%	9.32%	32.04%	28.01%	8.16%	0.83%	12.87%	9.96%	2.45%	10.40%	15.34%	17.25%
10:30	8.67%	7.54%	15.43%	13.78%	11.51%	11.07%	19.60%	21.61%	15.57%	32.45%	4.36%	0.69%	7.17%	6.91%
11:00	4.54%	3.91%	18.13%	20.31%	3.67%	7.83%	11.89%	16.93%	15.97%	4.44%	21.61%	22.52%	14.64%	18.62%
11:30	14.22%	5.61%	0.06%	4.38%	3.14%	10.95%	12.78%	22.71%	6.18%	4.36%	10.97%	19.79%	5.55%	1.72%
12:00	40.90%	32.98%	15.79%	20.73%	9.76%	3.15%	7.86%	3.28%	17.19%	9.44%	15.25%	11.30%	3.06%	12.98%
12:30	27.06%	13.71%	5.24%	13.65%	23.55%	23.95%	5.99%	14.70%	4.43%	11.02%	6.40%	17.59%	0.33%	3.29%
13:00	24.90%	26.18%	3.29%	19.07%	5.07%	2.36%	1.42%	8.81%	40.47%	40.29%	13.67%	19.87%	1.43%	0.06%
13:30	76.27%	32.56%	1.64%	13.75%	7.83%	6.45%	20.08%	13.82%	1.47%	6.23%	10.36%	18.36%	2.41%	1.38%
14:00	5.55%	13.52%	8.32%	9.91%	2.08%	2.83%	31.66%	25.50%	10.06%	8.32%	1.22%	18.63%	27.96%	31.03%
14:30	67.44%	46.52%	8.83%	8.00%	7.01%	8.19%	39.03%	41.66%	35.00%	19.18%	13.66%	27.83%	64.85%	62.48%
15:00	275.01%	21.44%	3.85%	14.52%	2.06%	3.19%	64.22%	56.86%	77.53%	71.74%	0.55%	28.32%	58.96%	9.27%
15:30	140.17%	39.46%	2.46%	8.12%	4.67%	2.01%	59.51%	37.15%	54.91%	61.27%	19.68%	22.68%	46.08%	45.91%
16:00	22.53%	31.77%	2.11%	7.28%	12.93%	6.16%	3.16%	24.04%	7.48%	6.27%	13.50%	14.99%	33.87%	42.40%
16:30	49.13%	3.70%	8.21%	0.17%	10.79%	7.43%	26.38%	29.84%	51.92%	39.73%	8.69%	17.06%	39.04%	16.39%
17:00	32.38%	36.38%	35.70%	27.04%	33.98%	34.21%	11.48%	1.16%	53.53%	7.61%	3.99%	16.83%	19.09%	19.86%
17:30	152.50%	30.58%	7.55%	1.25%	14.54%	11.39%	2.11%	14.73%	74.38%	7.48%	9.39%	6.66%	20.16%	19.11%
18:00	55.64%	10.84%	9.87%	1.70%	5.31%	12.30%	23.01%	24.50%	6.92%	20.01%	29.19%	0.63%	10.86%	17.08%
18:30	9.43%	0.43%	8.67%	5.72%	11.43%	15.25%	38.11%	18.02%	33.94%	11.71%	27.80%	15.95%	5.05%	2.85%

TABLE 4: Continued.

Hour	March 10th		March 11th		March 12th		March 13th		March 14th		March 15th		March 16th	
	b- BPANN	CPSO-BD- BPANN	b- BPANN	CPSO-BD- BPANN	b- BPANN	CPSO-BD- BPANN	b- BPANN	CPSO-BD- BPANN	b- BPANN	CPSO-BD- BPANN	b- BPANN	CPSO-BD- BPANN	b- BPANN	CPSO-BD- BPANN
19:00	0.66%	9.04%	0.58%	6.25%	4.35%	7.51%	9.02%	20.59%	32.56%	16.98%	34.77%	10.45%	16.17%	21.01%
19:30	30.95%	14.70%	24.17%	26.81%	8.60%	0.20%	21.32%	20.31%	35.33%	18.28%	64.81%	20.12%	3.79%	21.08%
20:00	4.80%	13.48%	4.14%	6.46%	4.98%	15.79%	13.21%	3.86%	9.53%	11.38%	31.15%	12.71%	4.20%	8.13%
20:30	14.59%	1.63%	0.47%	11.25%	3.94%	13.22%	19.12%	20.42%	9.74%	8.94%	15.06%	11.43%	15.44%	6.44%
21:00	6.65%	5.52%	13.03%	5.98%	3.73%	4.38%	12.70%	6.54%	15.23%	17.62%	25.41%	1.02%	10.97%	14.88%
21:30	31.61%	16.28%	13.15%	21.97%	17.37%	22.68%	9.55%	11.21%	5.88%	9.71%	22.25%	41.14%	23.23%	23.66%
22:00	4.86%	17.70%	5.09%	0.39%	22.19%	12.16%	23.92%	4.29%	5.51%	0.73%	48.24%	18.65%	5.01%	1.15%
22:30	43.17%	2.93%	10.85%	4.14%	32.82%	28.93%	14.42%	16.26%	15.59%	12.23%	13.65%	0.34%	1.99%	1.04%
23:00	18.92%	2.22%	16.53%	13.11%	24.69%	14.87%	3.06%	4.85%	1.58%	8.21%	28.98%	3.30%	8.65%	10.58%
23:30	27.50%	1.04%	7.37%	9.75%	8.07%	1.10%	3.30%	0.92%	15.37%	14.19%	37.81%	0.58%	6.38%	2.45%
Mean	43.33%	12.36%	10.54%	10.81%	11.70%	11.10%	15.87%	13.40%	20.02%	16.28%	17.75%	13.45%	12.79%	11.40%
Std.	49.79%	11.90%	9.22%	8.06%	10.76%	8.72%	13.35%	11.84%	18.06%	14.05%	13.29%	9.64%	14.18%	12.86%

TABLE 5: Results of case 2 study (CPSO-BPANN and BD-BPANN).

Hour	March 10th			March 11th			March 12th			March 13th			March 14th			March 15th			March 16th		
	CPSO-BPANN	BD-BPANN		CPSO-BPANN	BD-BPANN		CPSO-BPANN	BD-BPANN		CPSO-BPANN	BD-BPANN		CPSO-BPANN	BD-BPANN		CPSO-BPANN	BD-BPANN		CPSO-BPANN	BD-BPANN	
0:00	24.84%	7.68%		11.00%	10.90%		1.19%	0.20%		13.93%	9.23%		6.57%	5.93%		9.85%	4.47%		11.20%	5.79%	
0:30	3.97%	6.62%		11.81%	8.95%		5.67%	0.14%		1.60%	2.32%		18.90%	8.18%		6.47%	10.29%		4.84%	5.44%	
1:00	10.89%	12.39%		9.81%	11.63%		11.43%	3.46%		4.46%	3.15%		30.53%	9.04%		9.75%	10.12%		10.15%	3.53%	
1:30	43.24%	29.28%		14.46%	8.34%		16.35%	17.88%		17.41%	14.99%		18.26%	11.95%		18.06%	5.55%		10.02%	10.60%	
2:00	8.82%	11.14%		5.26%	6.67%		16.49%	13.42%		8.60%	1.41%		24.53%	10.87%		17.65%	4.76%		13.13%	10.52%	
2:30	24.27%	25.43%		2.12%	4.11%		16.42%	15.51%		4.84%	1.22%		37.32%	4.88%		14.36%	1.02%		1.68%	2.19%	
3:00	10.35%	14.93%		13.20%	9.72%		11.65%	4.03%		0.58%	4.57%		41.35%	3.10%		3.31E-05	1.89%		0.38%	0.85%	
3:30	1.24%	3.19%		1.64%	10.06%		20.59%	18.19%		0.08%	6.57%		48.48%	11.47%		2.08%	4.17%		1.28%	2.74%	
4:00	4.07%	11.62%		1.63%	8.41%		13.82%	12.88%		1.42%	3.05%		50.32%	12.51%		2.94%	3.19%		0.18%	1.38%	
4:30	1.73%	10.50%		2.59%	5.66%		15.30%	18.45%		16.66%	14.25%		58.04%	11.31%		5.51%	5.95%		0.74%	0.06%	
5:00	3.82%	9.62%		26.84%	29.81%		21.57%	21.21%		21.31%	19.48%		55.06%	20.70%		8.89%	8.59%		0.24%	1.05%	
5:30	0.18%	6.04%		16.35%	9.77%		6.18%	4.89%		4.43%	8.77%		29.33%	3.08%		10.77%	14.16%		1.04%	0.92%	
6:00	8.54%	4.65%		1.36%	10.10%		5.62%	11.51%		8.07%	5.32%		10.05%	23.27%		0.67%	0.36%		1.89%	0.08%	
6:30	7.65%	2.86%		19.30%	20.07%		17.10%	14.21%		6.47%	9.54%		44.25%	29.30%		7.99%	8.26%		2.81%	0.76%	
7:00	7.80%	2.31%		43.34%	42.89%		35.03%	39.22%		23.57%	19.97%		10.96%	6.97%		15.49%	20.04%		2.03%	0.43%	
7:30	6.89%	10.37%		5.12%	1.42%		6.19%	2.99%		0.90%	1.45%		25.48%	11.00%		8.35%	10.67%		9.00%	10.59%	
8:00	2.66%	3.66%		20.24%	15.58%		9.43%	8.69%		11.98%	13.45%		23.35%	24.39%		22.27%	21.40%		13.98%	14.70%	
8:30	3.05%	2.89%		2.03%	4.01%		6.92%	10.64%		8.17%	5.79%		19.30%	6.85%		21.01%	17.20%		12.23%	12.43%	
9:00	2.26%	1.16%		7.45%	19.91%		0.04%	2.09%		15.56%	15.37%		31.05%	24.43%		15.61%	8.50%		9.17%	9.22%	
9:30	10.48%	7.50%		20.38%	6.20%		27.06%	28.82%		3.63%	8.60%		31.39%	18.20%		21.27%	26.97%		4.76%	4.46%	
10:00	5.32%	4.34%		14.48%	13.36%		21.69%	17.97%		10.87%	1.38%		26.45%	18.38%		11.12%	9.89%		15.55%	14.01%	
10:30	10.36%	11.26%		13.92%	12.93%		1.87%	5.03%		18.15%	28.11%		38.69%	18.89%		20.57%	0.68%		4.74%	7.05%	
11:00	11.33%	6.91%		14.35%	19.48%		6.16%	3.50%		8.11%	14.30%		30.56%	19.16%		5.19%	18.60%		16.05%	17.81%	
11:30	11.92%	10.42%		11.68%	6.03%		5.05%	0.02%		14.52%	12.38%		20.98%	9.67%		12.05%	16.89%		8.33%	12.70%	
12:00	39.24%	36.91%		6.74%	25.63%		0.17%	3.34%		9.86%	12.17%		2.97%	13.19%		8.54%	15.92%		6.15%	11.48%	
12:30	10.27%	14.18%		0.02%	11.06%		26.01%	27.82%		10.20%	14.66%		15.52%	5.54%		2.37%	12.21%		1.90%	3.77%	
13:00	26.71%	10.66%		3.41%	0.18%		3.61%	12.88%		6.51%	10.00%		20.31%	33.87%		0.20%	14.10%		0.95%	6.47%	
13:30	34.96%	26.82%		3.12%	13.24%		6.51%	15.07%		6.38%	6.90%		73.27%	5.40%		0.83%	14.00%		4.27%	8.93%	
14:00	16.67%	13.80%		6.39%	9.31%		1.39%	8.02%		21.17%	16.98%		87.29%	7.33%		2.27%	12.63%		31.34%	30.79%	
14:30	43.77%	56.10%		7.96%	6.63%		8.46%	16.93%		41.29%	40.22%		19.65%	17.94%		12.88%	22.76%		62.99%	67.56%	
15:00	74.23%	16.29%		1.32%	14.35%		1.49%	8.73%		54.92%	62.31%		59.84%	71.38%		9.31%	23.32%		47.70%	9.33%	
15:30	3.02%	35.42%		7.13%	8.44%		6.71%	4.47%		68.29%	53.43%		39.37%	59.22%		1.79%	15.50%		46.12%	23.08%	
16:00	37.97%	21.15%		9.01%	5.52%		17.96%	3.56%		24.37%	6.58%		22.17%	18.36%		4.90%	9.69%		35.95%	10.88%	
16:30	25.87%	20.25%		15.63%	0.49%		11.67%	10.57%		68.22%	20.05%		8.35%	20.36%		3.02%	11.14%		28.08%	17.43%	
17:00	103.16%	52.47%		45.55%	29.45%		30.19%	43.40%		42.99%	0.34%		66.01%	7.56%		1.77%	13.53%		2.77%	45.72%	
17:30	11.22%	47.06%		2.21%	3.42%		3.64%	2.06%		52.72%	2.37%		77.97%	14.63%		13.21%	1.97%		32.22%	14.49%	
18:00	45.89%	10.40%		3.31%	5.82%		7.45%	8.69%		6.44%	24.83%		128.32%	12.45%		22.66%	4.74%		5.06%	5.22%	
18:30	41.12%	10.72%		1.37%	6.49%		15.47%	19.01%		2.22%	17.09%		8.10%	23.79%		4.50%	12.66%		62.57%	5.01%	

TABLE 5: Continued.

Hour	March 10th			March 11th			March 12th			March 13th			March 14th			March 15th			March 16th		
	CPSO- BPANN	BD- BPANN	CPSO- BPANN	CPSO- BPANN	BD- BPANN	CPSO- BPANN	CPSO- BPANN	BD- BPANN	CPSO- BPANN	CPSO- BPANN	BD- BPANN	CPSO- BPANN	CPSO- BPANN	BD- BPANN	CPSO- BPANN	CPSO- BPANN	BD- BPANN	CPSO- BPANN	CPSO- BPANN	BD- BPANN	
19:00	9.13%	16.77%	5.28%	2.60%	11.20%	10.51%	11.20%	25.85%	38.34%	25.85%	13.67%	15.43%	2.23%	9.20%	19.47%	5.37%					
19:30	18.20%	8.45%	27.32%	24.56%	2.24%	1.96%	2.24%	25.86%	74.99%	25.86%	178.85%	28.94%	37.95%	23.21%	27.88%	0.87%					
20:00	21.36%	21.35%	0.21%	3.48%	4.95%	13.16%	4.95%	10.84%	10.94%	10.84%	29.96%	18.78%	34.45%	16.74%	29.54%	8.69%					
20:30	25.51%	6.41%	2.24%	10.55%	10.06%	10.49%	10.06%	18.69%	13.27%	18.69%	25.38%	13.01%	5.99%	10.33%	17.64%	26.62%					
21:00	3.24%	2.77%	5.90%	8.65%	3.23%	5.09%	3.23%	1.58%	6.94%	1.58%	38.73%	11.07%	7.83%	2.41%	5.65%	1.85%					
21:30	26.63%	11.13%	18.37%	15.87%	19.18%	21.87%	19.18%	19.67%	15.63%	19.67%	1.59%	5.79%	52.19%	43.13%	35.43%	29.07%					
22:00	9.78%	16.58%	1.89%	0.09%	16.09%	9.34%	16.09%	10.64%	11.35%	10.64%	10.45%	5.76%	6.34%	19.69%	5.55%	2.55%					
22:30	3.26%	3.58%	7.81%	0.94%	18.16%	20.26%	18.16%	25.75%	15.32%	25.75%	7.81%	13.00%	13.31%	3.44%	9.06%	2.83%					
23:00	1.58%	7.07%	16.49%	11.25%	16.87%	16.71%	16.87%	4.65%	2.52%	4.65%	22.99%	12.57%	2.40%	6.08%	2.19%	5.73%					
23:30	2.11%	2.18%	9.49%	8.29%	0.52%	3.64%	0.52%	1.18%	2.12%	1.18%	8.88%	11.43%	8.01%	1.11%	3.67%	0.90%					
Mean	17.93%	14.28%	10.39%	10.88%	11.71%	17.34%	17.34%	13.69%	17.34%	13.69%	35.39%	16.05%	10.98%	11.52%	14.16%	10.29%					
Std.	20.16%	12.93%	10.02%	8.59%	9.62%	8.40%	9.62%	12.85%	18.95%	12.85%	32.41%	12.73%	10.40%	8.35%	16.17%	12.57%

FIGURE 8: BPANN and CPSO-BD-BPANN methods for case 1.

from 0.04% at 15:30 to 41.50% at 1:30. On June 12 of this summer week, CPSO-BD-BPANN has the best performance, whose MAPE is 0.04% at 16:00, while BD-BPANN has the worst one, whose MAPE is 35.42% at 6:00. The MAPE of the fifth day in this week, June 13, changes from 0.07% for CPSO-BD-BPANN at 15:30 to 32.36% for BD-BPANN at 17:00. On June 14, the lowest forecasting MAPE of 0.02% for BD-BPANN occurred at 14:00 and CPSO-BD-BPANN exhibited the worst forecasting effectiveness with a MAPE of 31.51% at 00:00. For the last day of this summer week, the MAPE ranges from 0.001% at 13:00 to 49.06% at 6:30, both of which are for BD-BPANN.

Table 7 shows the MAPE computed through using CPSO-BD-BPANN and BD-BPANN to forecast one week of autumn's electricity price. For September 15, the minimum MAPE is 0.14% at 13:00 when using BD-BPANN to forecast price, while CPSO-BD-BPANN exhibited the maximum MAPE of 35.03% at 11:30. The forecasting MAPE of September 16 changes from 0.12% obtained by CPSO-BD-BPANN at 10:00 to 45.48% obtained by BD-BPANN at 18:00. On September 17, the lowest MAPE value of 0.08% at 14:00 and the highest MAPE of 157.45% at 3:00 were both for BD-BPANN. On September 18 of this week, CPSO-BD-BPANN exhibited the lowest MAPE of 0.19% at 11:30,

while its highest MAPE, 29.32% at 6:30, is also the highest in this day. The MAPE of the fifth day, September 19, in this autumn week ranges from 0.96% for CPSO-BD-BPANN at 5:00 to 27.53% for BD-BPANN at 22:00. On September 20, the lowest forecasting MAPE of 0.08% for CPSO-BD-BPANN was observed at 14:30, while the optimized BD-BPANN model exhibited the maximum MAPE of 45.91% at 9:00 of this day. For the last day of this week, the MAPE changes from 0.28% at 9:30 to 43.43% at 23:30, both for BD-BPANN.

Table 8 demonstrates the forecasting values calculated by CPSO-BD-BPANN and BD-BPANN. Each column refers to the result of each method on different days of winter. For December 8, the lowest MAPE is 0.06% at 0:00 when using CPSO-BD-BPANN, while BD-BPANN exhibits the highest MAPE of 35.00% at 5:00 on this day. The forecasting MAPE of December 9 ranges from 0.006% at 12:00 to 34.43% at 1:30 which are calculated through CPSO-BD-BPANN and BD-BPANN, respectively. On December 10, the MAPE of CPSO-BD-BPANN was 0.30% at 0:30 which is the lowest MAPE, while BD-BPANN exhibited the highest MAPE of 25.18% at 23:00. On December 11 of this winter week, CPSO-BD-BPANN has the best performance, whose MAPE is 0.26% at 10:30, while BD-BPANN exhibited the worst MAPE of

FIGURE 9: BPANN and CPSO-BD-BPANN methods for case 2.

FIGURE 10: BD-BPANN and CPSO-BPANN methods for case 2.

TABLE 6: Results of case 3 (CPSO-BD-BPANN and BD-BPANN).

Hour	June 9th		June 10th		June 11th		June 12th		June 13th		June 14th		June 15th	
	CPSO-BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN
0:00	12.29%	11.22%	14.54%	15.41%	20.09%	19.60%	5.11%	8.81%	17.44%	20.99%	31.51%	28.12%	26.39%	27.45%
0:30	15.07%	10.16%	3.03%	4.07%	1.55%	3.61%	6.43%	4.37%	0.61%	1.35%	1.91%	0.57%	12.25%	12.81%
1:00	1.36%	6.70%	5.19%	0.82%	6.88%	5.28%	13.74%	17.28%	5.08%	2.77%	10.94%	12.18%	16.32%	18.37%
1:30	9.86%	14.76%	10.30%	7.93%	40.60%	41.50%	29.19%	29.56%	3.09%	1.12%	13.13%	12.54%	12.66%	12.61%
2:00	17.29%	15.99%	5.11%	9.22%	3.45%	0.48%	6.63%	3.60%	16.53%	16.90%	20.07%	18.27%	4.32%	0.24%
2:30	39.00%	43.07%	13.41%	9.43%	18.89%	27.78%	10.17%	9.08%	5.09%	4.57%	8.05%	5.49%	17.02%	16.14%
3:00	33.63%	11.92%	7.08%	0.02%	19.54%	23.50%	13.50%	17.15%	20.50%	17.30%	2.38E-02	3.64%	16.44%	11.94%
3:30	24.38%	19.43%	16.97%	6.21%	1.46%	6.23%	4.42%	3.21%	10.73%	2.57%	5.73%	6.79%	1.71%	0.66%
4:00	36.83%	39.95%	6.42%	12.90%	6.73%	9.43%	3.34%	14.21%	3.45%	3.99%	29.23%	28.21%	7.72%	8.94%
4:30	34.57%	33.85%	4.79%	14.48%	7.03%	3.57%	7.75%	6.79%	6.03%	11.46%	19.84%	14.09%	6.88%	5.50%
5:00	32.59%	33.36%	1.24%	20.12%	3.84%	1.80%	9.47%	7.78%	6.17%	8.43%	1.03%	1.60%	6.32%	6.10%
5:30	20.75%	9.02%	2.77%	21.97%	0.51%	11.45%	1.09%	2.76%	13.18%	17.09%	8.99%	6.45%	6.29%	5.03%
6:00	15.00%	3.43%	23.02%	37.68%	24.64%	31.48%	30.19%	35.42%	23.10%	30.46%	4.85%	2.71%	27.41%	27.51%
6:30	31.25%	19.55%	5.34%	19.86%	2.15%	2.26%	17.81%	20.12%	2.32%	8.36%	4.45%	7.45%	46.95%	49.06%
7:00	19.06%	3.29%	4.18%	16.84%	15.93%	11.49%	22.88%	22.35%	1.61%	3.32%	8.57%	13.41%	25.85%	27.10%
7:30	6.38%	1.10%	1.80%	21.75%	5.22%	2.06%	14.23%	6.42%	9.71%	20.03%	13.45%	17.33%	28.27%	27.69%
8:00	6.58%	11.41%	3.77%	19.70%	14.58%	1.20%	2.07%	2.36%	13.74%	19.36%	12.43%	9.92%	18.95%	20.68%
8:30	12.68%	28.89%	17.41%	44.62%	14.24%	6.44%	1.85%	10.31%	3.59%	5.15%	17.24%	15.48%	3.42%	0.05%
9:00	7.82%	13.47%	2.75%	3.70%	1.31%	3.05%	7.57%	9.11%	2.73%	8.81%	9.91%	9.81%	18.68%	2.45%
9:30	1.03%	11.93%	0.03%	6.49%	10.61%	12.25%	3.50%	14.89%	0.70%	6.90%	8.42%	9.20%	9.47%	1.94%
10:00	4.42%	0.36%	0.55%	2.07%	2.39%	1.50%	1.33%	8.95%	2.23%	3.81%	2.94%	1.34%	13.35%	13.02%
10:30	9.06%	5.37%	1.42%	1.65%	3.32%	4.14%	6.42%	3.06%	0.65%	2.82%	1.59%	4.06%	5.42%	3.38%
11:00	4.16%	3.75%	1.07%	2.28%	5.15%	7.08%	5.24%	11.44%	4.50%	7.22%	16.90%	22.73%	1.19%	5.85%
11:30	1.15%	3.38%	0.85%	2.95%	22.49%	22.50%	4.41%	10.04%	2.18%	1.61%	6.75%	1.71%	2.79%	3.11%
12:00	0.68%	3.41%	1.14%	1.92%	2.46%	2.31%	8.23%	5.74%	2.91%	2.95%	9.45%	7.11%	4.00%	4.59%
12:30	4.37%	7.50%	0.93%	0.78%	0.06%	0.38%	4.11%	9.18%	4.29%	5.76%	0.19%	0.24%	10.95%	13.49%
13:00	3.34%	1.57%	0.74%	0.94%	6.60%	5.89%	16.90%	22.12%	1.41%	1.95%	1.38%	3.32%	0.07%	1.32E-05
13:30	2.21%	0.87%	4.40%	5.68%	5.32%	5.14%	8.91%	16.25%	3.87%	4.18%	2.72%	6.87%	4.88%	2.82%
14:00	16.29%	22.04%	5.62%	4.47%	3.03%	2.18%	4.84%	12.05%	6.16%	6.49%	0.02%	3.74%	2.56%	4.48%
14:30	4.70%	6.30%	5.88%	4.44%	8.58%	4.56%	5.26%	2.28%	4.96%	4.81%	1.45%	0.56%	14.13%	17.55%
15:00	2.04%	5.44%	5.26%	2.13%	1.38%	0.26%	1.59%	6.79%	6.54%	8.19%	0.63%	1.19%	5.70%	4.69%
15:30	4.70%	1.98%	1.98%	4.84%	1.12%	0.04%	0.32%	6.17%	0.07%	0.59%	1.18%	3.38%	1.35%	3.40%
16:00	8.81%	4.94%	2.93%	5.31%	3.07%	4.59%	0.04%	1.13%	1.67%	2.84%	1.15%	0.14%	14.69%	11.93%
16:30	1.12%	6.70%	6.38%	5.66%	7.86%	7.32%	4.54%	2.86%	2.97%	4.23%	13.74%	12.63%	11.71%	3.39%
17:00	20.14%	12.21%	27.93%	24.94%	12.63%	11.67%	11.90%	9.90%	30.67%	32.36%	17.15%	15.66%	21.65%	17.29%
17:30	17.97%	16.79%	24.37%	13.52%	9.64%	8.30%	24.50%	20.87%	16.07%	16.18%	21.20%	18.14%	21.31%	17.19%
18:00	4.35%	2.75%	7.25%	4.19%	11.60%	14.47%	11.11%	12.84%	1.36%	0.87%	16.36%	18.08%	24.94%	21.02%
18:30	24.48%	37.92%	21.53%	10.06%	9.49%	16.53%	0.60%	7.90%	10.99%	19.32%	12.66%	11.89%	7.53%	2.23%

TABLE 6: Continued.

Hour	June 9th			June 10th			June 11th			June 12th			June 13th			June 14th			June 15th		
	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN
19:00	28.35%	21.10%	28.07%	28.07%	15.35%	21.86%	21.86%	26.74%	7.23%	14.78%	17.96%	17.96%	9.97%	9.97%	3.77%	20.03%	3.15%	20.03%	20.03%	27.97%	27.97%
19:30	6.20%	5.07%	8.98%	8.98%	4.39%	1.88%	1.88%	3.58%	1.09%	11.25%	1.47%	1.47%	6.02%	6.02%	7.00%	3.09%	7.26%	3.09%	3.09%	3.57%	3.57%
20:00	4.55%	6.07%	5.66%	5.66%	10.61%	2.41%	2.41%	3.10%	17.43%	25.56%	8.04%	8.04%	4.89%	4.89%	14.47%	5.53%	18.14%	5.53%	5.53%	10.08%	10.08%
20:30	0.56%	2.75%	0.03%	0.03%	5.08%	0.16%	0.16%	2.40%	2.17%	11.28%	0.12%	0.12%	3.10%	3.10%	3.48%	2.78%	4.83%	2.78%	2.78%	0.47%	0.47%
21:00	9.62%	2.92%	7.59%	7.59%	0.16%	9.37%	9.37%	12.04%	1.76%	0.42%	3.91%	3.91%	2.39%	2.39%	6.45%	2.31%	3.44%	2.31%	2.31%	2.02%	2.02%
21:30	15.38%	15.27%	3.18%	3.18%	0.52%	6.74%	6.74%	5.70%	14.05%	9.54%	0.73%	0.73%	0.73%	0.73%	8.38%	6.23%	6.56%	6.23%	6.23%	2.68%	2.68%
22:00	4.93%	1.51%	12.04%	12.04%	9.76%	2.99%	2.99%	4.80%	8.49%	8.92%	24.36%	24.36%	25.88%	25.88%	3.49%	11.75%	5.67%	11.75%	11.75%	11.21%	11.21%
22:30	20.98%	20.32%	26.80%	26.80%	36.87%	30.95%	30.95%	31.42%	11.34%	6.78%	2.75%	2.75%	8.71%	8.71%	14.17%	15.96%	13.91%	15.96%	15.96%	15.20%	15.20%
23:00	13.76%	15.57%	1.64%	1.64%	6.07%	8.38%	8.38%	8.11%	10.64%	9.74%	14.38%	14.38%	14.31%	14.31%	10.63%	17.02%	8.04%	17.02%	17.02%	17.48%	17.48%
23:30	20.34%	14.41%	10.43%	10.43%	1.99%	4.65%	4.65%	9.48%	30.92%	27.80%	27.24%	27.24%	21.48%	21.48%	9.26%	0.28%	3.88%	0.28%	0.28%	0.10%	0.10%
Mean	13.25%	12.31%	7.79%	7.79%	10.04%	8.85%	8.85%	9.39%	9.09%	11.28%	7.71%	7.71%	9.05%	9.05%	9.18%	11.80%	8.98%	11.80%	11.80%	10.89%	10.89%
Std.	10.98%	11.05%	7.95%	7.95%	10.27%	8.71%	8.71%	9.64%	7.99%	7.86%	7.85%	7.85%	8.18%	8.18%	7.45%	9.60%	7.15%	9.60%	9.60%	10.28%	10.28%

TABLE 7: Results of case 4 (CPSO-BD-BPANN and BD-BPANN).

Hour	September 15th			September 16th			September 17th			September 18th			September 19th			September 20th			September 21st		
	CPSO-BD-BPANN	BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN	BD-BPANN	CPSO-BD-BPANN	BD-BPANN	BD-BPANN
0:00	5.89%	6.47%	9.12%	10.82%	3.18%	3.34%	38.01%	49.29%	24.38%	24.03%	11.09%	12.87%	21.14%	17.37%	24.31%	24.31%	17.37%	24.31%	24.31%	24.47%	
0:30	12.28%	11.54%	3.34%	3.18%	1.94%	1.94%	7.19%	6.37%	19.65%	19.22%	7.71%	6.97%	15.32%	18.37%	6.27%	6.27%	18.37%	6.27%	6.27%	1.34%	
1:00	6.04%	4.70%	1.94%	1.33%	2.71%	2.71%	24.44%	27.91%	4.61%	1.86%	2.57%	1.59%	9.17%	8.00%	10.25%	10.25%	8.00%	10.25%	10.23%		
1:30	27.92%	23.44%	2.71%	5.14%	2.93%	2.93%	24.32%	1.02%	0.29%	2.37%	9.17%	6.75%	10.60%	8.29%	10.82%	10.82%	8.29%	10.82%	8.05%		
2:00	14.64%	15.38%	2.93%	0.77%	10.55%	10.55%	20.77%	20.77%	6.80%	3.59%	6.74%	5.06%	7.38%	7.24%	18.78%	18.78%	7.24%	18.78%	28.54%		
2:30	7.92%	9.38%	10.47%	12.48%	8.07%	8.07%	45.44%	28.57%	6.44%	6.58%	1.37%	0.31%	5.27%	12.40%	3.90%	3.90%	12.40%	3.90%	6.00%		
3:00	0.65%	3.05%	8.07%	9.95%	3.57%	3.57%	30.82%	157.45%	4.03%	0.32%	8.71%	5.12%	1.30E - 01	12.89%	1.13%	1.13%	12.89%	1.13%	3.50%		
3:30	6.53%	14.88%	3.57%	6.88%	16.58%	16.58%	8.49%	8.17%	4.85%	2.17%	13.70%	11.29%	5.08%	4.50%	10.26%	10.26%	4.50%	10.26%	5.11%		
4:00	5.69%	2.62%	16.58%	11.11%	8.77%	8.77%	8.77%	14.59%	2.68%	4.70%	6.82%	4.31%	4.71%	4.04%	3.50%	3.50%	4.04%	3.50%	1.14%		
4:30	9.16%	6.34%	3.76%	3.74%	3.76%	3.76%	6.98%	12.39%	6.06%	5.09%	13.87%	15.43%	7.60%	6.05%	4.73%	4.73%	6.05%	4.73%	3.50%		
5:00	26.52%	29.04%	7.63%	5.61%	7.63%	7.63%	39.20%	39.81%	1.12%	1.70%	0.96%	2.04%	7.45%	5.37%	21.05%	21.05%	5.37%	21.05%	21.75%		
5:30	17.75%	10.57%	10.45%	8.88%	8.88%	8.88%	45.89%	43.71%	2.10%	1.49%	2.53%	2.14%	4.13%	0.64%	3.45%	3.45%	0.64%	3.45%	4.82%		
6:00	11.86%	5.99%	9.41%	8.52%	9.41%	9.41%	26.50%	11.29%	2.40%	3.04%	9.52%	12.08%	5.16%	4.38%	0.36%	0.36%	4.38%	0.36%	0.56%		
6:30	1.85%	9.14%	10.66%	11.85%	16.89%	16.89%	16.89%	11.88%	29.32%	27.94%	11.41%	13.86%	13.99%	11.41%	6.37%	6.37%	11.41%	6.37%	4.31%		
7:00	8.43%	10.06%	7.43%	3.20%	17.99%	17.99%	17.99%	18.09%	25.38%	26.96%	6.25%	8.32%	4.38%	4.88%	0.31%	0.31%	4.88%	0.31%	2.37%		
7:30	2.03%	11.82%	3.41%	3.28%	3.41%	3.41%	6.05%	2.69%	13.10%	7.30%	26.66%	20.51%	10.77%	13.24%	12.64%	12.64%	13.24%	12.64%	14.55%		
8:00	11.58%	1.70%	19.16%	15.89%	19.16%	19.16%	2.23%	1.17%	3.59%	2.33%	6.24%	13.97%	0.78%	1.07%	18.74%	18.74%	1.07%	18.74%	18.12%		
8:30	5.16%	6.26%	33.34%	29.58%	33.34%	33.34%	5.20%	3.24%	0.61%	0.72%	3.91%	1.03%	12.98%	11.25%	7.72%	7.72%	11.25%	7.72%	16.12%		
9:00	15.61%	17.09%	0.86%	2.95%	0.86%	0.86%	0.37%	11.89%	4.35%	3.74%	12.03%	7.08%	45.91%	41.99%	16.27%	16.27%	41.99%	16.27%	14.89%		
9:30	7.76%	8.32%	25.82%	20.82%	25.82%	25.82%	4.24%	3.62%	2.22%	0.66%	4.38%	2.85%	42.98%	88.77%	2.20%	2.20%	88.77%	2.20%	0.28%		
10:00	5.25%	4.92%	0.12%	5.59%	0.12%	0.12%	0.24%	0.57%	6.15%	10.05%	2.55%	5.01%	15.24%	7.51%	10.38%	10.38%	7.51%	10.38%	8.83%		
10:30	13.22%	17.92%	0.67%	0.38%	0.67%	0.67%	4.12%	10.09%	19.27%	18.98%	2.57%	2.90%	2.12%	22.74%	10.85%	10.85%	22.74%	10.85%	3.24%		
11:00	13.18%	15.42%	9.85%	6.12%	9.85%	9.85%	11.56%	11.73%	6.36%	5.90%	4.44%	9.69%	6.84%	2.00%	9.55%	9.55%	2.00%	9.55%	12.77%		
11:30	35.03%	33.29%	11.03%	7.06%	11.03%	11.03%	0.11%	1.51%	0.19%	1.04%	13.12%	9.93%	16.27%	6.53%	9.72%	9.72%	6.53%	9.72%	4.49%		
12:00	10.88%	20.25%	2.89%	0.72%	2.89%	2.89%	7.92%	11.08%	5.37%	6.19%	2.10%	1.37%	8.57%	4.95%	15.08%	15.08%	4.95%	15.08%	8.66%		
12:30	8.75%	14.28%	3.13%	1.86%	3.13%	3.13%	6.87%	7.92%	10.27%	10.16%	6.05%	7.89%	15.56%	18.96%	13.37%	13.37%	18.96%	13.37%	8.47%		
13:00	2.34%	0.14%	14.44%	10.74%	14.44%	14.44%	7.29%	5.48%	2.12%	2.27%	8.66%	6.53%	24.46%	23.35%	18.51%	18.51%	23.35%	18.51%	1.03E - 01		
13:30	1.78%	8.98%	19.81%	20.03%	1.86%	1.86%	1.95%	2.03%	8.43%	10.52%	7.76%	6.05%	0.44%	1.26%	7.78%	7.78%	1.26%	7.78%	1.85%		
14:00	1.07%	4.08%	7.40%	1.99%	6.78%	6.78%	3.23%	0.08%	10.86%	9.11%	4.82%	4.69%	0.29%	2.15%	4.44%	4.44%	2.15%	4.44%	3.95%		
14:30	0.39%	3.63%	4.04%	4.08%	8.88%	8.88%	1.19%	7.44%	2.24%	4.27%	18.04%	16.42%	0.08%	4.57%	6.90%	6.90%	4.57%	6.90%	1.72%		
15:00	10.36%	13.00%	1.35%	1.86%	1.35%	1.35%	18.42%	18.20%	0.98%	1.20%	21.41%	21.38%	12.01%	7.41%	1.12%	1.12%	7.41%	1.12%	5.40%		
15:30	19.09%	21.78%	1.53%	4.93%	1.53%	1.53%	1.09%	1.03%	6.13%	4.06%	8.67%	1.75%	2.88%	7.01%	11.62%	11.62%	7.01%	11.62%	5.91%		
16:00	3.93%	3.47%	6.78%	5.13%	6.78%	6.78%	16.17%	16.66%	13.39%	11.58%	9.55%	6.26%	14.71%	12.20%	5.66%	5.66%	12.20%	5.66%	0.73%		
16:30	4.37%	5.95%	8.88%	11.12%	8.88%	8.88%	6.43%	7.19%	6.39%	8.17%	3.14%	2.03%	3.21%	1.60%	8.81%	8.81%	2.03%	1.60%	3.25%		
17:00	14.36%	12.53%	7.26%	5.85%	7.26%	7.26%	13.74%	12.73%	11.48%	13.18%	1.61%	3.56%	5.26%	0.26%	10.91%	10.91%	3.56%	10.91%	3.15%		
17:30	9.40%	10.90%	18.50%	22.53%	18.50%	18.50%	20.59%	18.95%	4.59%	4.69%	6.24%	8.06%	11.85%	11.74%	7.97%	7.97%	11.74%	7.97%	0.90%		
18:00	13.14%	13.02%	42.96%	45.48%	42.96%	42.96%	4.40%	7.14%	1.94%	7.18%	3.05%	1.98%	21.93%	18.92%	28.97%	28.97%	1.98%	28.97%	21.73%		
18:30	0.19%	0.46%	2.90%	20.41%	0.46%	0.46%	18.36%	13.48%	2.58%	1.34%	1.23%	3.53%	14.28%	13.48%	40.21%	40.21%	3.53%	40.21%	31.12%		

TABLE 7: Continued.

Hour	September 15th			September 16th			September 17th			September 18th			September 19th			September 20th			September 21st		
	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	CPSO-BD- BPANN	CPSO-BD- BPANN	BD- BPANN	
19:00	16.98%	15.98%	17.21%	8.47%	20.24%	34.81%	2.27%	0.23%	23.27%	19.89%	4.24%	19.76%	1.98%	8.02%	6.99%						
19:30	0.93%	1.95%	16.45%	15.46%	1.93%	1.35%	0.42%	0.43%	10.05%	10.76%	19.76%	22.22%	22.22%	2.09%	19.19%						
20:00	10.60%	5.50%	21.41%	10.00%	15.95%	9.62%	1.94%	2.19%	3.10%	3.86%	6.69%	10.93%	10.93%	5.61%	1.38%						
20:30	9.90%	12.03%	8.88%	0.21%	15.96%	7.67%	4.65%	5.04%	7.05%	8.92%	5.52%	2.27%	2.27%	3.74%	6.84%						
21:00	0.61%	0.79%	14.80%	5.02%	6.32%	5.33%	28.73%	27.86%	9.29%	9.20%	8.88%	8.97%	8.97%	5.77%	0.85%						
21:30	26.72%	24.85%	5.86%	13.87%	2.05%	4.87%	10.63%	9.59%	2.21%	2.98%	11.21%	10.84%	10.84%	1.10%	0.50%						
22:00	7.31%	9.89%	7.52%	16.26%	8.62%	10.44%	19.68%	17.82%	27.53%	27.53%	43.17%	39.62%	39.62%	10.09%	6.06%						
22:30	16.30%	14.81%	0.19%	7.47%	17.11%	24.27%	17.60%	10.29%	14.75%	20.32%	12.12%	11.62%	11.62%	8.43%	13.85%						
23:00	17.07%	17.70%	41.61%	45.33%	15.23%	11.43%	21.12%	18.61%	23.00%	21.03%	29.48%	34.99%	34.99%	19.69%	19.85%						
23:30	11.12%	12.03%	17.55%	32.87%	6.37%	3.65%	6.76%	1.91%	6.73%	5.94%	2.01%	7.32%	7.32%	26.69%	43.43%						
Mean	10.20%	10.99%	10.54%	10.56%	12.81%	15.60%	8.26%	7.70%	8.70%	8.40%	11.81%	12.49%	12.49%	10.34%	9.27%						
Std.	7.82%	7.51%	9.88%	10.42%	11.79%	23.83%	7.97%	7.73%	6.76%	6.54%	10.68%	14.72%	14.72%	8.20%	9.38%						

TABLE 8: Results of case 5 (CPSO-BD-BPANN and BD-BPANN).

Hour	December 8th			December 9th			December 10th			December 11th			December 12th			December 13th			December 14th		
	CPSO-BD-BPANN	BD-BPANN		CPSO-BD-BPANN	BD-BPANN		CPSO-BD-BPANN	BD-BPANN		CPSO-BD-BPANN	BD-BPANN		CPSO-BD-BPANN	BD-BPANN		CPSO-BD-BPANN	BD-BPANN		CPSO-BD-BPANN	BD-BPANN	
0:00	0.06%	2.22%		25.83%	20.87%		0.74%	0.85%		10.04%	12.65%		1.05%	2.23%		15.97%	6.53%		11.35%	13.42%	
0:30	3.23%	3.75%		19.02%	23.10%		0.30%	3.02%		0.72%	0.06%		1.91%	6.00%		0.38%	4.70%		11.28%	10.72%	
1:00	13.77%	13.21%		17.97%	22.59%		2.87%	3.66%		3.17%	9.29%		5.60%	2.32%		5.12%	3.04%		8.80%	10.49%	
1:30	18.51%	21.32%		20.64%	34.43%		15.47%	11.02%		8.96%	7.69%		16.17%	15.99%		21.03%	12.86%		20.02%	25.06%	
2:00	4.81%	2.02%		14.35%	3.23%		21.42%	15.07%		11.87%	14.41%		14.56%	16.75%		12.51%	13.34%		6.37%	10.18%	
2:30	0.72%	0.52%		3.54%	5.71%		0.44%	0.77%		5.56%	7.42%		7.96%	9.94%		1.20%	0.72%		0.34%	4.70%	
3:00	10.48%	9.16%		7.70%	4.08%		9.41%	6.50%		7.24%	8.00%		2.23%	2.28%		2.26E - 02	0.17%		112.46%	125.60%	
3:30	2.62%	4.99%		6.51%	3.62%		6.48%	8.27%		1.60%	1.03%		11.53%	10.55%		1.50%	0.17%		74.26%	59.22%	
4:00	1.56%	3.58%		9.30%	11.10%		12.43%	10.73%		16.86%	14.36%		11.29%	8.15%		4.54%	0.99%		29.06%	21.51%	
4:30	1.20%	1.01%		18.14%	12.81%		20.53%	18.80%		20.18%	20.98%		21.04%	17.66%		0.15%	5.28%		12.91%	7.55%	
5:00	33.17%	35.00%		8.63%	11.47%		15.06%	15.26%		1.03%	1.32%		6.17%	2.67%		13.91%	17.84%		16.63%	25.87%	
5:30	15.38%	1.07%		3.24%	2.02%		7.46%	7.35%		5.93%	4.75%		0.97%	0.90%		6.73%	5.51%		4.46%	12.96%	
6:00	9.02%	2.91%		10.52%	10.93%		0.71%	1.37%		7.78%	4.26%		2.48%	1.23%		21.07%	18.85%		15.39%	22.02%	
6:30	6.91%	11.86%		3.24%	6.86%		12.79%	10.68%		9.38%	10.01%		21.02%	21.14%		8.53%	5.27%		17.40%	14.60%	
7:00	4.28%	4.40%		3.72%	5.02%		7.84%	4.69%		13.71%	14.37%		7.94%	7.16%		3.53%	5.37%		20.89%	19.65%	
7:30	0.08%	4.77%		6.39%	4.01%		2.05%	4.64%		5.01%	0.58%		6.24%	4.78%		6.44%	8.03%		7.44%	11.15%	
8:00	14.76%	18.51%		3.79%	5.93%		1.11%	2.83%		8.81%	7.04%		6.47%	5.57%		0.37%	4.56%		7.22%	6.89%	
8:30	4.92%	0.76%		0.96%	0.63%		5.99%	6.13%		3.80%	7.19%		4.24%	7.60%		5.25%	7.04%		7.65%	10.99%	
9:00	2.29%	7.34%		1.46%	2.34%		1.65%	4.86%		0.87%	3.41%		8.87%	4.50%		3.38%	8.50%		2.06%	0.32%	
9:30	1.74%	4.21%		4.91%	3.44%		0.62%	3.25%		5.44%	5.62%		3.04%	2.48%		13.13%	19.49%		1.82%	0.31%	
10:00	1.46%	3.94%		4.48%	4.21%		2.12%	1.72%		3.64%	6.00%		1.05%	1.44%		23.64%	11.59%		2.72%	0.25%	
10:30	4.15%	6.26%		7.52%	7.08%		2.82%	0.96%		0.26%	2.58%		5.33%	8.72%		9.26%	4.55%		1.45%	3.45%	
11:00	4.25%	6.17%		13.80%	12.35%		4.07%	3.38%		2.27%	4.20%		5.59%	6.60%		0.77%	3.44%		2.86%	5.01%	
11:30	5.16%	5.46%		5.55%	9.08%		2.35%	1.24%		5.42%	8.48%		9.11%	13.60%		4.41%	10.46%		4.75%	1.89%	
12:00	1.77%	2.73%		6.45E - 05	2.49%		4.69%	3.08%		4.20%	7.52%		5.62%	7.72%		0.44%	5.57%		1.05%	1.45%	
12:30	12.29%	11.07%		5.68%	3.15%		2.82%	3.10%		11.28%	8.23%		5.60%	1.52%		4.52%	7.67%		1.67%	2.32%	
13:00	18.26%	21.00%		0.84%	0.51%		2.27%	0.78%		2.82%	5.28%		8.41%	6.12%		1.04%	6.31%		1.62%	1.89E - 02	
13:30	8.59%	1.79%		3.35%	3.75%		16.48%	18.46%		1.92%	0.79%		11.38%	9.09%		0.13%	7.95%		0.52%	1.29%	
14:00	4.34%	5.41%		0.80%	1.29%		2.56%	3.53%		3.97%	8.53%		10.53%	11.64%		4.30%	10.51%		1.23%	2.89%	
14:30	5.54%	4.65%		2.05%	0.17%		6.45%	7.27%		1.16%	4.09%		2.67%	0.37%		4.01%	9.69%		2.25%	3.25%	
15:00	5.26%	5.65%		17.18%	16.76%		2.81%	4.03%		2.13%	5.38%		0.95%	3.09%		10.67%	15.61%		1.17%	1.44%	
15:30	3.89%	4.15%		7.28%	3.61%		1.92%	3.48%		8.72%	4.79%		5.24%	1.82%		5.70%	12.24%		2.36%	3.15%	
16:00	3.10%	1.28%		9.41%	7.49%		2.79%	4.74%		2.22%	4.85%		2.07%	0.20%		10.17%	3.74%		2.17%	2.30%	
16:30	4.99%	3.73%		3.47%	4.69%		1.46%	3.10%		12.60%	8.93%		2.81%	2.61%		0.07%	5.94%		1.26%	1.74%	
17:00	0.25%	0.46%		0.16%	1.98%		22.82%	21.97%		5.72%	4.60%		5.29%	3.74%		0.49%	6.20%		3.05%	3.32%	
17:30	1.66%	0.36%		14.73%	14.39%		2.16%	2.18%		7.04%	8.26%		3.78%	6.06%		5.85%	1.92%		2.07%	2.06%	
18:00	0.72%	0.53%		12.37%	9.83%		5.57%	5.65%		2.72%	5.49%		4.37%	1.84%		3.67%	7.56%		0.17%	0.92%	
18:30	11.52%	10.76%		5.00%	5.64%		2.88%	3.42%		0.69%	1.29%		2.41%	0.58%		3.22%	7.98%		1.52%	2.30%	

TABLE 8: Continued.

Hour	December 8th			December 9th			December 10th			December 11th			December 12th			December 13th			December 14th		
	CPSO-BD- BPANN	BD- BPANN		CPSO-BD- BPANN	BD- BPANN		CPSO-BD- BPANN	BD- BPANN		CPSO-BD- BPANN	BD- BPANN		CPSO-BD- BPANN	BD- BPANN		CPSO-BD- BPANN	BD- BPANN		CPSO-BD- BPANN	BD- BPANN	
19:00	8.84%	3.62%		21.07%	19.66%		20.72%	21.37%		15.52%	17.62%		3.60%	0.25%		2.59%	7.34%		0.96%	1.40%	
19:30	7.05%	6.03%		6.94%	3.12%		2.16%	1.94%		2.70%	3.55%		2.30%	0.73%		3.38%	9.06%		4.67%	6.20%	
20:00	12.29%	12.06%		13.50%	9.80%		12.70%	13.59%		4.00%	3.45%		0.26%	3.79%		2.10%	7.33%		6.99%	7.77%	
20:30	6.76%	2.07%		23.08%	21.85%		2.40%	3.77%		19.12%	17.11%		3.28%	5.75%		3.74%	2.19%		1.56%	2.33%	
21:00	2.40%	1.71%		4.71%	4.16%		5.89%	4.97%		12.86%	11.21%		3.31%	1.43%		1.62%	3.73%		6.97%	6.40%	
21:30	8.58%	9.48%		1.17%	2.91%		7.04%	4.60%		6.83%	10.16%		10.23%	12.69%		9.27%	2.27%		2.83%	1.87%	
22:00	23.58%	17.80%		10.44%	10.75%		13.89%	13.30%		11.97%	8.87%		19.88%	18.23%		10.96%	16.63%		4.24%	1.74%	
22:30	0.49%	9.81%		12.83%	13.39%		11.89%	8.76%		0.65%	0.76%		1.99%	4.35%		2.11%	6.38%		23.70%	26.04%	
23:00	30.04%	29.16%		4.91%	8.33%		23.37%	25.18%		3.00%	3.33%		4.19%	0.80%		3.65%	8.03%		27.28%	26.95%	
23:30	2.51%	13.37%		2.37%	1.44%		4.13%	4.05%		2.63%	1.26%		3.22%	5.12%		0.80%	5.87%		1.08%	4.72%	
Mean	7.28%	7.36%		8.43%	8.29%		7.05%	6.95%		6.38%	6.90%		6.36%	6.04%		5.82%	7.44%		10.46%	11.24%	
Std.	7.49%	7.54%		6.73%	7.34%		6.74%	6.20%		5.13%	4.81%		5.22%	5.38%		5.83%	4.72%		19.40%	20.00%	

TABLE 9: Models evaluation.

Season	Evaluation items	b-BPANN	CPSO-BPANN	BD-BPANN	CPSO-BD-BPANN
Spring	Accuracy (MAPE)	18.86%	16.81%	12.68%	12.63%
	Calculating time (seconds)	3.25	88.36	6.81	162.29
	Index of stability	6	2	0	0
Summer	Accuracy (MAPE)	11.26%	11.46%	10.28%	9.67%
	Calculating time (seconds)	3.41	88.03	6.92	161.35
	Index of stability	1	0	0	0
Autumn	Accuracy (MAPE)	11.27%	11.37%	10.72%	10.38%
	Calculating time (seconds)	3.45	88.98	6.99	168.89
	Index of stability	1	1	0	0
Winter	Accuracy (MAPE)	8.61%	7.99%	7.74%	7.40%
	Calculating time (seconds)	3.25	84.36	6.49	159.01
	Index of stability	4	2	1	1
Average	Accuracy (MAPE)	12.50%	11.91%	10.36%	10.02%
	Calculating time (seconds)	3.34	87.4325	6.8025	162.885
	Index of stability	3	1.25	0.25	0.25

FIGURE 11: BD-BPANN and CPSO-BD-BPANN methods for case 3.

20.98% at 4:30. The MAPE of the fifth day in this week, December 12, changes from 0.20% at 16:00 to 21.14% at 6:30, with both computed by BD-BPANN. On December 13, the lowest forecasting MAPE is 0.07%, calculated by the CPSO-BD-BPANN at 16:30, and CPSO-BD-BPANN exhibited the worst forecasting effectiveness, with a MAPE of 23.64% at

10:00 on this day. For the last day of this winter week, the MAPE ranges from 0.17% for CPSO-BD-BPANN at 18:00 to 125.60% for BD-BPANN at 3:00.

Overall, in summer, the average forecasting MAPE of the CPSO-BD-BPANN method is 9.67%, which is less than that of BD-BPANN; the forecasting MPAA of BD-BPANN

FIGURE 12: BD-BPANN and CPSO-BD-BPANN methods for case 4.

in autumn, 10.72%, is larger than that of CPSO-BD-BPANN, 10.38%. Similarly, in winter, CPSO-BD-BPANN forecasts the electricity price more accurately than the original method, BD-BPANN; the MAPE of CPSO-BD-BPANN of 7.40% is less than the MAPE of BD-BPANN of 7.74%. Overall, CPSO-BD-BPANN outperforms BD-BPANN 12 times: June 10, June 11, June 12, and June 13 in the summer, September 15, September 16, September 17, and September 20 in autumn, and December 8, December 11, December 13, and December 14 in winter. In contrast, BD-BPANN outperforms CPSO-BD-BPANN 9 times. However, as summarized above, CPSO-BD-BPANN is a better forecasting model than BD-BPANN. Figures 11, 12, and 13 show the results of the new approaches, the actual values, and the forecasting errors.

5.4.2. Models Evaluation. In the above portion of 5.4, the results of both proposed forecasting models of cases 3, 4, and 5 were presented in tables and figures. These results indicate that CPSO-BD-BPANN outperforms BD-BPANN in the aspect of accuracy. Furthermore, to test the forecasting effectiveness of CPSO-BD-BPANN and BD-BPANN, this paper compares both of them with b-BPANN and CPSO-BPANN in the aspects of forecasting accuracy, calculation time, and stability. In this study, the forecasting accuracy is measured by MAPE, and the index of stability of the models is the number of points of the forecasting MAPE that exceed 100%; that is, a model can be regarded as a relatively stable

model when the index of stability is relatively low. The unit of calculation time is one second. Table 9 presents the results of the evaluation of the models of b-BPANN, CPSO-BPANN, BD-BPANN, and CPSO-BD-BPANN.

From Table 9, it is obvious that CPSO-BD-BPANN is the best forecasting model when considering accuracy. In the aspect of calculation time, b-BPANN and BD-BPANN significantly outperform the other models. Finally, the last row of this table indicates that the proposed models are better than b-BPANN and CPSO-BPANN regarding forecasting stability. As a result, to forecast the electricity price efficiently, either BD-BPANN or CPSO-BD-BPANN should be selected as the forecasting model. Specifically, when accuracy is the only concern, CPSO-BD-BPANN should be used to forecast the electricity price. However, when the cost of calculation is the only concern, BD-BPANN is the best model because its accuracy is higher than that of BPANN, the forecasting accuracy of which must be less than that of b-BPANN (by the definition of b-BPANN).

6. Our Contribution

- (i) To combine historical price and demand to improve the forecasting of the electricity price, this paper proposed a new variable, known as DV, through a division of one variable by the other, rather than simply regarding them as inputs of a network. In this

FIGURE 13: BD-BPANN and CPSO-BD-BPANN methods for case 5.

approach, multiplication of the forecasted DV and the demand is taken as the final forecasted price, which consequently improves the accuracy of forecasting price than that using the original BPANN.

- (ii) The CPSO algorithm, BPANN, and the concept of bivariate division are combined to form the new models: BD-BPANN and CPSO-BD-BPANN.
- (iii) This paper evaluated the models through three aspects: forecasting accuracy, calculating time, and stability. The evaluation indicated that CPSO-BD-BPANN is a relatively better model when only considering accuracy and that BD-BPANN is a comparatively better model when the cost of calculation should be low, while the accuracy remains high.

7. Conclusions

In this paper, the BD-BPANN method is creatively proposed by combining the concept of bivariate division with BPANN to forecast electricity price more accurately and stably than BPANN does. In four seasons of 2008, the average MAPE of BD-BPANN is 10.36%, which is less than those of BPANN and CPSO-BPANN. Note that BD-BPANN performs better than BPANN and CPSO-BPANN in each season. Next, the CPSO algorithm was applied to optimize the initial

parameters of BD-BPANN to improve the forecasting accuracy. This optimized forecasting model, named CPSO-BD-BPANN, forecasted the price with an average MAPE, 10.02%, in the weeks of the four seasons considered. Additionally, the CPSO-BD-BPANN method outperforms the other approaches in forecasting accuracy. Finally, the evaluation of the models of BPANN, BD-BPANN, CPSO-BPANN, and CPSO-BD-BPANN was performed. This evaluation involved tests regarding accuracy, calculation time, and stability. For the aspect of accuracy, CPSO-BD-BPANN is the best model. The BPANN model, which exhibits an average calculation time of 3.34 seconds, has huge advantages compared with the other models regarding the calculation time. The last test, stability, indicated that the proposed methods, both of which have an index of stability of 0.25, are more stable than the original BPANN and the CPSO-BPANN models, with indices of stability of 3 and 1.5, respectively. These results illustrate that CPSO-BD-BPANN is a superior model to the others when only concerning accuracy. And BD-BPANN outperforms CPSO-BD-BPANN, CPSO-BPANN, and BPANN when calculation time is the crucial factor.

Highlights

The highlights of this paper are as follows: skillful transformation of the electricity price and demand into a new variable, known as DV, rather than only regarding both of

them as inputs of the network; utilization of chaos particle swarm optimization to obtain the relatively improved weights and thresholds of the network, rather than the random ones; proposal of two different forecasting strategies for the user of the model.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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