CLAIMS

1. A thermal load prediction method for facilitate efficient scheduling of boiler steam usage, comprising:

configuring a plurality of prediction states and error thresholds respectively corresponding to the plurality of prediction states, and forming a prediction model corresponding to a target steam user;

calling the prediction model to predict first thermal load magnitudes respectively corresponding to a plurality of testing time periods, wherein the target steam user uses boiler steam in the plurality of testing time periods;

determining, according to the first thermal load magnitudes respectively corresponding to the plurality of testing time periods, relative prediction errors respectively corresponding to the plurality of testing time periods;

forming a state transition probability matrix according to the relative prediction errors respectively corresponding to the plurality of testing time periods and the error thresholds respectively corresponding to the plurality of prediction states, and determining a state confidence probability of each prediction state of the plurality of prediction states in each future time period of future time periods according to the state transition probability matrix;

calling the prediction model to predict second thermal load magnitudes respectively corresponding to the future time periods, wherein the target steam user uses the boiler steam in the future time periods; and

for the each future time period, determining a thermal load range corresponding to the each future time period, according to each second thermal load magnitude of the second thermal load magnitudes corresponding to the each future time period, the state confidence probability of the each prediction state in the each future time period, and the error thresholds respectively corresponding to the plurality of prediction states, wherein the target steam user uses the boiler steam in the each future time period; and

scheduling the operation of the boiler steam according to the thermal load range with minimum difference between supply and demand of the target steam user.

2. The method according to claim 1, wherein

the step of determining, according to the first thermal load magnitudes respectively corresponding to the plurality of testing time periods, the relative prediction errors respectively corresponding to the plurality of testing time periods comprises:

acquiring actual thermal load magnitudes respectively corresponding to the plurality of testing time periods, wherein the target steam user uses the boiler steam in the plurality of testing time periods; and

calculating the relative prediction errors respectively corresponding to the plurality of testing time periods through the following formula (1):

$$E_i = \frac{F_i - f_i}{f_i};$$

wherein Ei represents a relative prediction error of the relative prediction errors corresponding to an ith testing time period of the plurality of testing time periods, Fi represents an actual thermal load magnitude of the actual thermal load magnitudes corresponding to the ith testing time period of the plurality of testing time periods, and fi represents a first thermal load magnitude of the first thermal load magnitudes corresponding to the ith testing time period of the plurality of testing time periods.

3. The method according to claim 2, wherein

the step of forming the state transition probability matrix according to the relative prediction errors respectively corresponding to the plurality of testing time periods and the error thresholds respectively corresponding to the plurality of prediction states, and the step of determining the state confidence probability of the each prediction state in the each future time period according to the state transition probability matrix comprises:

determining a trusted prediction state of trusted prediction states corresponding to each testing time period of the plurality of testing time periods according to the relative prediction errors respectively corresponding to the plurality of testing time periods and the error thresholds respectively corresponding to the plurality of prediction states;

determining a number of times of state transitions respectively corresponding to prediction state transition types according to the trusted prediction states respectively corresponding to each two adjacent testing time periods of the plurality of testing time periods;

determining a state transition probability corresponding to each prediction state transition type of the prediction state transition types according to the number of times of the state transitions corresponding to the each prediction state transition type;

forming the state transition probability matrix by using the state transition probability corresponding to the each prediction state transition type;

determining an initial probability matrix of the plurality of prediction states in a current time period; and

determining confidence probabilities of the plurality of prediction states in the future time periods according to the initial probability matrix and the state transition probability matrix.

4. The method according to claim 3, wherein

the step of determining the confidence probabilities of the plurality of prediction states in the future time periods according to the initial probability matrix and the state transition probability matrix comprises:

calculating the confidence probabilities of the plurality of prediction states in the future time periods through the following formula (2);

$$X(n)=X(0)*P^{n} \qquad (2);$$

wherein X(n) represents a confidence probability matrix of the plurality of prediction states in an [nth future time period of the future time periods, wherein a cut-off time point of the current time period is taken as a starting time point in the nth future time period, X(0) represents the initial probability matrix corresponding to the current time period, and P represents the state transition probability matrix; and

for the each future time period, extracting the confidence probabilities of the plurality of prediction states in the future time periods from the confidence probability matrix corresponding to the each future time period.

5. The method according to claim 4, wherein

the plurality of prediction states comprise: an extreme overestimate state, an overestimate state, a normal state, an underestimate state, and an extreme underestimate state; wherein

a first error threshold corresponding to the extreme overestimate state is more than 10%;

a second error threshold corresponding to the overestimate state is more than 5% and less than or equal to 10%;

a third error threshold corresponding to the normal state is more than −5% and less than or equal to 5%;

a fourth error threshold corresponding to the underestimate state is more than or equal to −10% and less than −5%; and

a fifth error threshold corresponding to the extreme underestimate state is less than −10%.

6. The method according to claim 3, wherein

the plurality of prediction states comprise: an extreme overestimate state, an overestimate state, a normal state, an underestimate state, and an extreme underestimate state; wherein

a first error threshold corresponding to the extreme overestimate state is more than 10%;

a second error threshold corresponding to the overestimate state is more than 5% and less than or equal to 10%;

a third error threshold corresponding to the normal state is more than −5% and less than or equal to 5%;

a fourth error threshold corresponding to the underestimate state is more than or equal to −10% and less than −5%; and

a fifth error threshold corresponding to the extreme underestimate state is less than −10%.

7. The method according to claim 2, wherein

the plurality of prediction states comprise: an extreme overestimate state, an overestimate state, a normal state, an underestimate state, and an extreme underestimate state; wherein

a first error threshold corresponding to the extreme overestimate state is more than 10%;

a second error threshold corresponding to the overestimate state is more than 5% and less than or equal to 10%;

a third error threshold corresponding to the normal state is more than −5% and less than or equal to 5%;

a fourth error threshold corresponding to the underestimate state is more than or equal to −10% and less than −5%; and

a fifth error threshold corresponding to the extreme underestimate state is less than −10%.

8. The method according to claim 1, wherein

the step of determining, according to the each second thermal load magnitude corresponding to the each future time period, the state confidence probability of the each prediction state in the each future time period, and the error thresholds respectively corresponding to the plurality of prediction states, the thermal load range corresponding to the each future time period, wherein the target steam user uses the boiler steam in the each future time period comprises:

determining a maximum confidence probability from confidence probabilities of the plurality of prediction states in the future time periods;

determining a prediction state of the plurality of prediction states corresponding to the maximum confidence probability as a target prediction state; and

determining, according to an error threshold of the error thresholds corresponding to the target prediction state and the each second thermal load magnitude corresponding to the each future time period, the thermal load range corresponding to the each future time period, wherein the target steam user uses the boiler steam in the each future time period.

9. The method according to claim 8, wherein

the step of determining, according to the error threshold corresponding to the target prediction state and the each second thermal load magnitude corresponding to the each future

time period, the thermal load range corresponding to the each future time period, wherein the target steam user uses the boiler steam in the each future period comprises:

calculating an upper critical value and a lower critical value corresponding to the each future time period, wherein the target steam user uses the boiler steam in the each future time period through the following formula (3):

$$y=Y/(1+e) \quad (3);$$

wherein y represents the upper critical value or lower critical value corresponding to the each future time period, Y represents the each second thermal load magnitude corresponding to the each future time period, and e represents an upper extremum or a lower extremum of the error threshold corresponding to the target prediction state; and

determining, according to the upper critical value and the lower critical value, the thermal load range corresponding to the each future time period, wherein the target steam user uses the boiler steam in the each future time period.

10. The method according to claim 9, wherein

the plurality of prediction states comprise: an extreme overestimate state, an overestimate state, a normal state, an underestimate state, and an extreme underestimate state; wherein

a first error threshold corresponding to the extreme overestimate state is more than 10%;

a second error threshold corresponding to the overestimate state is more than 5% and less than or equal to 10%;

a third error threshold corresponding to the normal state is more than −5% and less than or equal to 5%;

a fourth error threshold corresponding to the underestimate state is more than or equal to −10% and less than −5%; and

a fifth error threshold corresponding to the extreme underestimate state is less than −10%.

11. The method according to claim 8, wherein

the plurality of prediction states comprise: an extreme overestimate state, an overestimate state, a normal state, an underestimate state, and an extreme underestimate state; wherein

a first error threshold corresponding to the extreme overestimate state is more than 10%;

a second error threshold corresponding to the overestimate state is more than 5% and less than or equal to 10%;

a third error threshold corresponding to the normal state is more than −5% and less than or equal to 5%;

a fourth error threshold corresponding to the underestimate state is more than or equal to −10% and less than −5%; and

a fifth error threshold corresponding to the extreme underestimate state is less than −10%.

12. A non-transitory readable medium, comprising execution instructions, when a processor of an electronic device executes the execution instructions, the electronic device performing the method according to claim 1.

13. The non-transitory readable medium according to claim 12, wherein

the step of determining, according to the first thermal load magnitudes respectively corresponding to the plurality of testing time periods, the relative prediction errors respectively corresponding to the plurality of testing time periods comprises:

acquiring actual thermal load magnitudes respectively corresponding to the plurality of testing time periods, wherein the target steam user uses the boiler steam in the plurality of testing time periods; and

calculating the relative prediction errors respectively corresponding to the plurality of testing time periods through the following formula (1):

$$E_i = \frac{F_i - f_i}{f_i};$$

wherein E_i represents a relative prediction error of the relative prediction errors corresponding to an i^{th} testing time period of the plurality of testing time periods, F_i represents an actual thermal load magnitude of the actual thermal load magnitudes corresponding to the i^{th} testing time period of the plurality of testing time periods, and f_i represents a first thermal load magnitude of the first thermal load magnitudes corresponding to the i^{th} testing time period of the plurality of testing time periods.

14. The non-transitory readable medium according to claim 13, wherein

the step of forming the state transition probability matrix according to the relative prediction errors respectively corresponding to the plurality of testing time periods and the error thresholds respectively corresponding to the plurality of prediction states, and the step of determining the state confidence probability of the each prediction state in the each future time period according to the state transition probability matrix comprises:

determining a trusted prediction state of trusted prediction states corresponding to each testing time period of the plurality of testing time periods according to the relative prediction errors respectively corresponding to the plurality of testing time periods and the error thresholds respectively corresponding to the plurality of prediction states;

determining a number of times of state transitions respectively corresponding to prediction state transition types according to the trusted prediction states respectively corresponding to each two adjacent testing time periods of the plurality of testing time periods;

determining a state transition probability corresponding to each prediction state transition type of the prediction state transition types according to the number of times of the state transitions corresponding to the each prediction state transition type;

forming the state transition probability matrix by using the state transition probability corresponding to the each prediction state transition type;

determining an initial probability matrix of the plurality of prediction states in a current time period; and

determining confidence probabilities of the plurality of prediction states in the future time periods according to the initial probability matrix and the state transition probability matrix.

15. The non-transitory readable medium according to claim 14, wherein

the step of determining the confidence probabilities of the plurality of prediction states in the future time periods according to the initial probability matrix and the state transition probability matrix comprises:

calculating the confidence probabilities of the plurality of prediction states in the future time periods through the following formula (2);

$$X(n)=X(0)*P^n \qquad (2);$$

wherein X(n) represents a confidence probability matrix of the plurality of prediction states in an n^{th} future time period of the future time periods, wherein a cut-off time point of the current time period is taken as a starting time point in the n^{th} future time period, X(0) represents the initial probability matrix corresponding to the current time period, and P represents the state transition probability matrix; and

for the each future time period, extracting the confidence probabilities of the plurality of prediction states in the future time periods from the confidence probability matrix corresponding to the each future time period.

16. The non-transitory readable medium according to claim 12, wherein

the step of determining, according to the each second thermal load magnitude corresponding to the each future time period, the state confidence probability of the each prediction state in the each future time period, and the error thresholds respectively corresponding to the plurality of prediction states, the thermal load range corresponding to the each future time period, wherein the target steam user uses the boiler steam in the each future time period comprises:

determining a maximum confidence probability from confidence probabilities of the plurality of prediction states in the future time periods;

determining a prediction state of the plurality of prediction states corresponding to the maximum confidence probability as a target prediction state; and

determining, according to an error threshold of the error thresholds corresponding to the target prediction state and the each second thermal load magnitude corresponding to the each future time period, the thermal load range corresponding to the each future time period, wherein the target steam user uses the boiler steam in the each future time period.

17. The non-transitory readable medium according to claim 16, wherein

the step of determining, according to the error threshold corresponding to the target prediction state and the each second thermal load magnitude corresponding to the each future time period, the thermal load range corresponding to the each future time period, wherein the target steam user uses the boiler steam in the each future period comprises:

calculating an upper critical value and a lower critical value corresponding to the each future time period, wherein the target steam user uses the boiler steam in the each future time period through the following formula (3):

$$y=Y/(1+e) \qquad (3);$$

wherein y represents the upper critical value or lower critical value corresponding to the each future time period, Y represents the each second thermal load magnitude corresponding to the each future time period, and e represents an upper extremum or a lower extremum of the error threshold corresponding to the target prediction state; and

determining, according to the upper critical value and the lower critical value, the thermal load range corresponding to the each future time period, wherein the target steam user uses the boiler steam in the each future time period.

18. The method according to claim 1, wherein

the plurality of prediction states comprise: an extreme overestimate state, an overestimate state, a normal state, an underestimate state, and an extreme underestimate state; wherein

a first error threshold corresponding to the extreme overestimate state is more than 10%;

a second error threshold corresponding to the overestimate state is more than 5% and less than or equal to 10%;

a third error threshold corresponding to the normal state is more than −5% and less than or equal to 5%;

a fourth error threshold corresponding to the underestimate state is more than or equal to −10% and less than −5%; and

a fifth error threshold corresponding to the extreme underestimate state is less than −10%.

19. An electronic device, comprising: a processor, a memory, and a bus; wherein the memory is configured to store execution instructions, the processor and the memory are connected through the bus, and when the electronic device runs, the processor executing the execution instructions stored in the memory to cause the processor the perform the method according to claim 1.

20. A thermal load prediction apparatus for facilitate efficient scheduling of boiler steam usage, comprising:

a processor coupled with memory, the processor programmed to:

configure a plurality of prediction states and error thresholds respectively corresponding to the plurality of prediction states, and the pre-processing module configured to form a prediction model corresponding to a target steam user;

call the prediction model to predict first thermal load magnitudes respectively corresponding to a plurality of testing time periods, wherein the target steam user uses a boiler steam in the plurality of testing time periods; and the model calling module configured to call the prediction model to predict second thermal load magnitudes respectively corresponding to future time periods, wherein the target steam user uses the boiler steam in the future time periods;

determine, according to the first thermal load magnitudes respectively corresponding to the plurality of testing time periods, relative prediction errors respectively corresponding to the plurality of testing time periods;

form a state transition probability matrix according to the relative prediction errors respectively corresponding to the plurality of testing time periods and the error thresholds respectively corresponding to the plurality of prediction states, and the state probability determination module configured to determine a state confidence probability of each prediction state of the plurality of prediction states in each future time period of the future time periods according to the state transition probability matrix; and

for the each future time period, determine a thermal load range corresponding to the each future time period, according to the each second thermal load magnitude corresponding to the each future time period, the state confidence probability of the each prediction state in the each future time period, and the error thresholds respectively corresponding to the plurality of prediction states, wherein the target steam user uses the boiler steam in the each future time period, and

schedule the operation of the boiler steam according to the thermal load range with minimum difference between supply and demand of the target steam user.