Research on Multi-point Hopping Communication System in Power Network Based on Information Fusion Model

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Abstract—Multi-source heterogeneous information will cause access burden to the power network, resulting in poor performance of multi-point hop communication. Therefore, a multi-point hop communication system based on information fusion model is designed. The IEC61970/61968 CIM is selected as the integrated bus general data acquisition scheme of the information fusion model. The local-global distributed information fusion mechanism is used to realize the communication of the power multi-point hop communication system. In this paper, the artificial neural network algorithm is used to fuse local information features, and according to D-S evidence theory, the global decision-level fusion is carried out from both the spatial domain and the time domain. Through the information fusion model, the multi-point hop communication information in the power network realizes efficient transmission. The experimental results show that the application of the system in the power network to implement multi-point hop communication, the packet loss rate is less than 0.25%, the transmission delay is less than 30ms, and the communication performance of the power network is improved.

1. Introduction
With the continuous improvement of human living standards, electricity has become an indispensable and important energy in human life and work. The security and effectiveness of power system determine the development of power network. How to run the power network efficiently, safely and economically is the most important part in power field [1]. At present, the information transmission and processing technologies of power networks lag behind the growth rate of the scale of power grids, and the phenomenon of repeated collection of the same information and isolation of part of the data of power grids is likely to occur, which leads to the long or missing transmission time of the edge data of power networks and affects the control decision of power systems [2-3].

Multi-point hop communication is the main communication technology in power network. Multi-point hop communication is easy to cause high packet loss rate. Information fusion technology can effectively integrate multi-source information in a comprehensive and accurate manner, and facilitate efficient transmission in power network [4]. An efficient multi-point hopping communication system is an important way to solve the problems existing in current power information system. Information fusion model can solve the problem of repeated collection of information and edge data isolation [5]. Based on the hierarchical, self-organizing and adaptive intelligence technology of information fusion technology, the model is applied to the multipoint hopping communication system of power grid.
2. Power Network Multipoint Hop Communication System

2.1. Overall System Structure
The overall structure diagram of the multipoint hop communication system based on the information fusion model is shown in Figure 1.

![Overall system structure](image)

As can be seen from Fig. 1, the multi-point hopping communication system of power network adopts the information fusion model to send the multi-point information of the internal and external of power network to the MCU main control module after multi-level and multi-class processing, and then sends the main control module to the RF transceiver module, and realizes the multi-point hopping communication of data through antenna [6].

The MSP430 series MCU F1491 of TI Company is selected as the main control chip of the system, and the nRF905 of Nordic Company is selected as the RF transceiver module of the system to realize wireless data transceiver [7]. Using RS-232 interface to connect and communicate with PC, RS-485 communication interface can meet the connection requirements of different instruments in power system, choose high-gain external antenna or PCB antenna to realize long-distance multi-point hopping communication in power network.

2.2. Information Fusion Model
The information fusion model can combine the information of local space and temporal redundancy characteristics of different media, different modes and different sources, and make the information in the multi-hop communication system of the power grid consistent and comprehensive through effective information combination rules [8], so as to realize the successful communication of multi-hop communication of the power grid. Artificial Neutral Network (ANN) algorithm is applied to local information feature fusion, D-S evidence theory is applied to global decision level fusion, and information in different parts of the power network is efficiently transmitted through information fusion model. The overall structure of the information fusion model is illustrated in Figure 2.
The local information fusion part is used to describe and explain the state features of power system [9]. The global information fusion part fuses the state features obtained from the local information fusion part and outputs them through effective decision making. Because different information fusion parts have different information types and fusion targets, different fusion methods are needed.

ANN fusion method can make use of the mapping relationship between identity and observation parameters of multi-hop communication system to mark the required information. D-S evidence theory is an efficient intelligent technology fusion method, which applies artificial intelligence method to explain and obtain state and assistant decision [10].

After the original information is collected by the information fusion model, the operation state of power network is described by preprocessing, and the complete and accurate feature state is judged by complementary fusion and redundant fusion. The model can effectively correlate the result of data fusion with the operation mode of power network [11], and realize multi-point hopping communication by using the rules of power network communication. The optimization strategy and communication state evaluation are realized by knowledge fusion, and the communication strategy and optimization strategy are effectively demonstrated by suggestion and phenomenon explanation.

2.3. General-purpose Information Integration Bus

The rapid collection and processing ability of power network information is an important part of the information fusion model in the multi-point hop communication system. IEC61970/61968 CIM is selected as the integrated bus general data acquisition scheme of the information fusion model. The IEC61970CIS interface standard is used as the data access interface standard of the information fusion model. Through the TAO/ACE platform with a language-based distributed environment, the end-to-end multi-hop communication configuration of the power network can be effectively realized [12]. The power general information integration bus frame diagram is shown in Figure 3.
The services provided by the application service layer of the information integration bus include selecting GDA universal data access service, using HSDA high-speed data access service as power real-time database access service, using scalable SVG graphics to provide conversion service, and XML import and export service of data files.

General Standard for Data Access Forms of Heterogeneous Information Conversion as an Information Integration Bus [13], Using Pluggable Access as an Application for Legacy Resource Databases. Through the application service layer of the information integration bus, the access burden of the upper fusion center caused by multi-source heterogeneous information can be reduced and the edge data transmission time can be reduced.

2.4. ANN Algorithm and D-S Evidence Theory

2.4.1 ANN Algorithm

The ANN algorithm is selected as the feature fusion algorithm of the information fusion model, and the feature obtained by multiple sensors is set as the input of ANN. After neural network training, the initial pattern recognition and the inference knowledge stored in the weights and thresholds of pattern classification can be realized by sending the fusion results to the decision level.

A three-layer neural network is used to achieve feature-level fusion, and the error of feature fusion is used to modify the threshold $\theta$ and the network weight $(\lambda_{ij}, T_{ij})$ to make it fall along the gradient direction. The input node, hidden node and output node of the neural network are represented by $y_j$, $x_j$ and $o_l$ respectively.

The sigmoid function is selected as the incentive function $\delta_{kl}$ of the hidden layer of the network, and the linear function is selected as the function $x_{kl}$ of the output layer of the network. The iterative formula of the neural network weight coefficient is as follows:

$$\lambda_{ij}(k+1) = \lambda_{ij}(k) + \mu \delta_{kj}x_{kl}(1)$$

The neural network output layer error formula is as follows:

$$E = (x'_{kl} - x_{kl})y_j(\text{net}_{kl})\left(1 - y_j(\text{net}_{kl})\right)$$

The error formula of hidden layer of neural network is as follows:

$$E_l = y_j(\text{net}_{kl})\left(1 - y_j(\text{net}_{kl})\right)\Sigma_i \delta_{kl}l$$

The BP neural network can not converge when there are local minimum points. The weighted factor $\alpha$ is introduced into the neural network to avoid the oscillation and accelerate the convergence of the neural network.

![General information integration bus framework](image-url)
In the above formulas, $\alpha$ and $\mu$ represent the weighting factor and step size respectively, and $0 < \alpha$, $\mu < 1$.

The mean square error of neural network can be obtained by using $E(w)$ to express the average value of all training samples as follows:

$$E(w) = \sum (x'_{kj} - x_{kj})^2 / 2(4)$$

### 2.4.2 D-S Evidence Theory

Decision-level recognition framework based on neural network output is represented by $(R_1, (R_2), (R_3))$, neural network training BP network sample output is not 1 or 0, usually between 1 and 0 rational number. D-S evidence theory is used to solve the uncertainty problem. D-S evidence theory can set the output of neural network as independent evidence [15], making it become multipoint hopping communication state reliability allocation.

$U$ denotes the set of domains in which all possible values of $X$ are included and all the elements of $U$ are incompatible. In this case, the recognition framework of $X$ is represented by $U$, and the $2^U$ power set of $U$ is the set of all subsets of $U$.

**Definition 1:** Function $n$:

When $2^U \to [0,1]$ satisfies the $n(\emptyset) = 0$ and $\sum n(R) = 1$ conditions, the basic probability assignment of $R$ is $n(R)$, and the function $n$ effectively shows that the given conditions support the conclusion $R$.

**Definition 2:** Identifying box $U$:

The likelihood function $1 - \text{Bel}(\overline{R})$ of $R$ is expressed in terms of $pl(R)$ and the degree of determination of non-$R$ is expressed in terms of $\text{Bel}(\overline{R})$. The formula is as follows:

$$pl(R) = 1 - \text{Bel}(\overline{R})(5)$$

At this point, $R$'s trust interval is represented by $\text{Bel}(R)$, $pl(R)$.

$R_1, \cdots, R_k$ and $B_1, \cdots, B_t$ represents the set elements of $n_1$ and $n_2$ on $2^U$, which are independent of each other in basic probability, respectively.

$$K_1 = \sum n_1(R_i) n_2(B_j) < 1(6)$$

Then:

$$n(c) = \frac{\sum n_1(R_i) n_2(B_j)}{1 - K_1}, \forall C \subset U C \neq \emptyset(7)$$

In equation (7), $K_1$ represents the conflict factor.

Based on formula (7), the output of feature set can be effectively fused in both space and time domains. By using the information fusion model, multi-hop communication information in power network can be transmitted efficiently, so as to improve the fusion performance of the information fusion model, reduce the rate of misjudgement, and solve the problem of repeated collection of information and isolation of edge data.

### 3. Experimental Results And Analysis

#### 3.1. Experiment Platform

In order to validate the communication effectiveness of the multipoint hopping communication system based on information fusion model, a power network environment is simulated by Matlab, and programmed by Java language. Figure 4 shows the experimental platform:
Through the experimental platform, the number of nodes in the power network is set to 100, each node contains 10 neighbor nodes, and the number of channels in the power network is 30. According to the number of different nodes and the size of different communication data packets, the throughput rate, packet loss rate, and transmission delay of multi-point hop communication are used as experimental indicators to test the communication performance of the system in this paper.

3.2. Throughput test under different number of nodes

Under different number of nodes, test the communication throughput rate of the system in this paper for 60 seconds. The test result is shown in Figure 5.

![Throughput Test](image)

**Fig. 5 Communication throughput rate under different number of nodes**

It can be seen from the experimental results in Figure 5 that when the number of statistical nodes is 30, 50, 100, the communication throughput range of the multi-point hop communication tested by this system is 350kbit/s~550kbit/s. It shows that the system in this paper can still maintain high communication efficiency when the number of nodes is different.

3.3. Packet loss rate test under different number of nodes

Under different number of nodes, the communication packet loss rate of the communication system in this paper is tested for 60 seconds, and the test result is shown in Figure 6.
It can be seen from the experimental results in Figure 6 that when the number of statistical nodes is 30, 50, 100, the communication packet loss rate of the multi-point hop communication tested by the system in this paper is all lower than 0.25%. It shows that the system in this paper can still maintain a low communication packet loss rate when the number of nodes is different.

### 3.4. Transmission Delay Test Under Different Number Of Nodes

Under different number of nodes, test the transmission delay of 60 seconds of communication of the system in this paper, and the test result is shown in Figure 7.

It can be seen from the experimental results in Figure 7 that when the number of statistical nodes is 30, 50, and 100, the transmission delays of the multi-point hop communication tested by this system are all less than 30ms. It shows that the system in this paper can still maintain a low transmission delay when the number of nodes is different, which effectively verifies the effectiveness of the multi-point hop communication using the information fusion model in this paper.

### 3.5. Throughput Test with Different Packet Sizes

Set the number of nodes to 100 and test the communication throughput of the system for 60 seconds under different packet sizes, as shown in Figure 8.

It can be seen from the experimental results in Figure 8 that when the number of statistical nodes is 100, 200, and 300, the throughput rates of the multi-point hop communication tested by this system are all lower than 600kbit/s. It shows that the system in this paper can still maintain a low throughput when the number of nodes is different, which effectively verifies the effectiveness of the multi-point hop communication using the information fusion model in this paper.
The experimental results in Fig. 8 show that when the packet size is 100M, 200M, 500M, the throughput of the system is still in the range of 350kbit/s ~ 550kbit/s. Once again, the system in this paper can maintain a high communication efficiency in different packet sizes.

3.6. Packet Drop Rate Test Under Different Packet Sizes
Set the number of nodes to 100, and test the 60 second packet loss rate of the system communication under different packet sizes. The test results are shown in Figure 9.

![Packet loss rate for different packet sizes](image)

Fig. 9 Packet loss rate for different packet sizes

The experimental results in Figure 9 show that when the packet size is 100M, 200M and 500M, the packet loss rate is still less than 0.25%, which shows that the system can keep a low packet loss rate.

3.7. Transmission Delay Test Under Different Packet Sizes
Set the number of nodes to 100 and test the 60 second transmission latency of the system communication in this article with different packet sizes, as shown in Figure 10.

![Transmission delay for different packet sizes](image)

Fig. 10 Transmission delay for different packet sizes

The experimental results in Figure 10 show that when the size of the statistical packets is 100M, 200M, 500M, the transmission delay of the multi-hop communication is less than 25ms. It is shown that the system can maintain low transmission delay even when the packet sizes are different.

3.8. Communication Performance Test with White Noise
Set the number of nodes to 100, add 0-50dB white noise into the power communication network, test the performance of the system with white noise. The statistical results are shown in Table 1.

| White noise (dB) | Throughput rate (kbit/s) | Packet loss rate (%) | Transmission delay (ms) |
|------------------|--------------------------|----------------------|------------------------|
| 5                | 486.5                    | 0.07                 | 12                     |
| 10               | 476.2                    | 0.08                 | 14                     |
| 15               | 471.8                    | 0.09                 | 15                     |

Tab. 1 Communication performance of the system with white noise
Table 1  Experimental results show that the proposed system can maintain high performance of multipoint hopping communication with different white noise levels. Moreover, the increase of white noise has little effect on the communication performance of the system, which shows that the system has high robustness.

4. Conclusion
The application of multi-point hopping communication system in smart grid communication can effectively improve the self-healing and self-organization of power network. The application of information fusion model in multi-point jump communication system of power grid can improve the reliability, integrity and accuracy of data acquisition, and solve the problem of large amount of data in emergency. The simulation experiment validates that the system can improve the timeliness of power network data communication, make power network data collection and data communication more efficient and reliable, and can effectively reduce packet loss rate and improve the performance of power network multi-hop communication.

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