A New Approach to the Implementation of Multivariable Information Transfer Models of Smart Sensors for Ubiquitous Power Energy Internet of Things

Shiyu Chen1,*, Bin Li2, Wei Sun1, Lei Wang2, Lin Li1 and Dewen Zhang1
1State Grid Heilongjiang Electric Power Co., Ltd. Electric Power Research Institute, Harbin 150001, China
2State Grid Heilongjiang Electric Power Co., Ltd. Harbin 150001, China

*Corresponding author: uniquecharm@live.cn

Abstract. As an important cornerstone of the construction of the energy Internet, the ubiquitous power Internet of Things is of great significance for improving the overall efficiency and social efficiency of the power grid, and promoting the development of emerging services that meet the needs of users. The thesis first elaborates the basic concepts and characteristics of the ubiquitous power Internet of Things, and analyzes its system architecture in detail; secondly, discusses the key technologies of the ubiquitous power Internet of Things from three aspects: smart chips, 5G and LPWA, and Internet of Things platform; Third, in order to overcome the influence of the interference of the sensor's mutual sensing area of the Internet of Things on the transmission success rate, it is necessary to design the interference avoidance algorithm of the sensor's mutual sensing area, and propose an Internet of Things based on adaptive link equalization configuration and inter-code interference suppression. The algorithm for avoiding interference between sensors in the mutual sensing area. The simulation results show that using this method for sensor interference avoidance, the output error rate is lower, the purity of sensor sensing area information is higher, and the anti-interference is better.

1. Introduction

With the rapid expansion of the scale of AC and DC power transmission, the types and numbers of distributed power generation equipment are rapidly increasing, resulting in the continuous increase of the complexity of the power grid, which poses a challenge to the traditional power grid. On the other hand, the development of artificial intelligence technology also puts forward new requirements on the function and operation of the power grid. Therefore, combining the ubiquitous Internet of Things technology to build the existing power system into a ubiquitous power Internet of Things is the development trend of the future power energy system, and it is also the most urgent and important task of the State Grid at the current stage. At present, there are relatively few researches on the ubiquitous power Internet of Things at home and abroad, and the research on the integrated energy system has many similarities with the ubiquitous power Internet of Things. Jeremy Rivkin believes that a future energy system that integrates new energy technology and information technology has the following characteristics: 1) Clean energy is the main primary energy; 2) Support for ultra-large-scale distributed
power generation and distributed energy storage system access; 3) Realize wide-area energy sharing based on Internet technology; 4) Support the electrification of transportation systems.

With the gradual promotion and application of advanced technologies such as artificial intelligence, 5G, and the Internet of Things, traditional power grids need to further integrate their own data and information resources, participate in the construction of new infrastructure, and create a ubiquitous power Internet of Things. The construction of network source coordination for the ubiquitous power Internet of Things is based on Internet thinking, playing the pivotal role of the power grid, promoting the coordination of strong smart grid and the ubiquitous power Internet of Things, forming a platform for network source coordination and friendly interaction [1].

2. Overview of Ubiquitous Power Internet of Things

The ubiquitous power Internet of Things refers to the real-time interconnection and dynamic interaction between enterprises, equipment and personnel involved in the entire process of power system generation, transmission, transformation, distribution, and utilization. The ubiquitous power Internet of Things has the dual attributes of network and control, and has the advantages of real-time, high efficiency, reliability and tolerance. It is essentially a combination of Internet of Things technology, big data, cloud computing, artificial intelligence and other information technology and power technology. It can be regarded as an upgrade and expansion of the cyber-physical system in the energy Internet. It is mainly composed of data collection equipment such as sensors and computers. It is composed of physical equipment such as computing equipment and transformers, and integrates advanced technologies such as information collection and transmission, data computing and processing, and equipment control decision-making into physical systems such as power-related equipment to realize the interconnection and interconnection of people and things in the power system. Interactive. The technical architecture of the ubiquitous power Internet of Things includes the perception layer, network layer, platform layer and application layer (see Figure 1). The perception layer uses various high-precision smart sensors, smart energy meters, etc. to collect data and respond to related instructions in the entire process of transmission, transmission, transformation, distribution, and use. The network layer is based on advanced wireless communication technologies such as high-throughput satellites and 5G for high-speed, real-time and reliable data transmission. At the platform layer, data information is processed uniformly through the data centre, the Internet of Things management centre, etc., and the cloud platform is used for data storage and sharing. The application layer is the key goal for the construction of the ubiquitous power Internet of Things architecture [2]. The data information processed by the platform layer is used to provide decision support for grid dispatching and maintenance, power sales enterprises, users, etc., and combined with related power technologies to promote clean energy consumption, to further ensure the safe and stable economic operation of the power grid.

Figure 1. Ubiquitous power IoT technology architecture
3. Key technologies of ubiquitous power Internet of Things

3.1. Smart chip
With the continuous development of the power system, more and more metering, protection, conversion, control, monitoring, power consumption and other equipment are connected to the power system. The operation of various power equipment generates a large amount of data. At present, most on-site data acquisition equipment is still Transmission-based industrial acquisition devices have poor data reliability and low accuracy, which also makes the terminal equipment less intelligent. Miniature smart sensors and smart terminals based on smart chips can fully solve this problem, with high precision and low power. With the characteristics of energy consumption, miniaturization, and intelligent computing, on the one hand, it can complete the collection, extraction and transmission of equipment information; on the other hand, through local edge computing, it can realize terminal intelligence and complete local self-control, so that there is no need to only have telemetry and shaking like traditional equipment. Letter function without remote control function [3].

3.2. 5G and LPWA
The transmission of massive power data requires an integrated communication network. The power system is widely distributed and often involves complex environments such as mountains, forests, and ice fields, making it difficult for the communication network to cover all of it, and it is difficult to transmit on-site data. There are two types of mainstream technologies for the Internet of Things: one is wired network technology based on industrial Ethernet and power carrier, and the other is wireless network technology based on 5G and low-power wide area network (LPMA). In the ubiquitous power Internet of Things, data is widely distributed, highly decentralized, some are not easy to supply power, difficult to connect, and the collection frequency is low. The traditional wired network communication technology is difficult to apply. Therefore, the modern communication technology based on wireless networks is the realization of ubiquitous power things. The main means of network communication.

3.3. IoT platform
Ubiquitous power Internet of Things as an information platform in the information power system, through the analysis and mining of a large amount of data information, data information that is valuable for power information can be captured and used. As a basic information platform, the Internet of Things platform should have the ability to integrate data and information processing in order to realize functions such as wind and solar forecasting, power system fault diagnosis, and artificial intelligence. At present, many high-tech enterprises in China have designed endless IoT platforms, such as Baidu's "Tangong" intelligent IoT platform; mobile company's "one net" IoT platform; Ali's "link" IoT integrated data platform, etc. The listing provides a strong foundation for the construction of a ubiquitous power Internet of Things platform [4].

4. IoT sensor information optimization model algorithm

4.1. Complex sensor information perception channel model under the Internet of Things
Assuming that the minimum distance of nodes in the complex sensor information sensing area under the Internet of Things is d, the maximum likelihood estimation method is used to construct the complex sensor information sensing channel model under the Internet of Things, and the position of the nth sensor node is \( n \in \Omega_n, n = 1, 2, ..., N \). Using the adaptive link equalization position method, the effective distribution set of IoT sensor nodes is obtained as \( Y = [y_1, y_2, ..., y_N] \), and the sampling sample \( X(\eta), \forall \eta \in \Omega_\eta \) of the sensor's information perception. The useful information sequence in the next frame of data received by the complex sensor node is:
\[ \sigma^2_{\eta} = E\left[ \hat{x}(\eta) - x(\eta) \right]^2, \eta \in \Omega_{\eta} \]  

(1)

Among them, \( \hat{x}(\eta) \) is the minimum mean square error estimate of \( x(\eta) \). Assuming that the maximum time interval of sensor network information sensing multipath components under the Internet of Things is \( T_{\text{max}} \), under the channel equalization configuration, the maximum vector combination set of the received signals of the information sensing area of the Internet of Things sensor is:

\[ X = DW + Z \]  

(2)

Under complex multipath conditions, the output IoT transmission channel model is:

\[ |s(f)| = A \sqrt{\frac{1}{2k}} \left[ |cv_1 + cv_2|^2 + |sv_1 + sv_2|^2 \right] \]  

(3)

In the formula, \( A(t) \) is the output signal amplitude of the sensor network information sensing channel under the Internet of Things, \( f_0 \) is the initial frequency of information sampling in the sensing area, \( k = BT \) is the modulation frequency, \( B \) is the multipath gain, considering the Internet of Things routing node Optimized deployment of complex sensor nodes in the Internet of Things based on packet switching, and the optimal deployment structure model of channels and sensor nodes in the information perception area \( [S_{i-1}, S_i] \) is expressed as:

\[ p_k(S_k - S_{i-1}) + p_{k+1}(S_i - S_k) = p_i(S_i - S_{i-1}) \]  

(4)

Through quantization and decomposition of multiple independent fading channels, the quantized and equalized transmission channel model is obtained as:

\[ R'_\eta(k) = E[q_\eta(k)q_\eta^T(k)] \leq \text{diag} \left\{ \Delta_\eta^2(k,1)/4, \Delta_\eta^2(k,2)/4, ..., \Delta_\eta^2(k,p)/4 \right\} = R'_\eta(k) \]  

(5)

According to the above analysis, there is a multipath effect in the complex sensor information sensing channel model under the Internet of Things, which generates inter-symbol interference, and requires interference avoidance design.

4.2. Channel equalization design

The baud interval equalization configuration method is used to perform the equalization processing of the complex sensor sensing channel under the Internet of Things, and the channel impulse response of the mutual sensing of the sensors under the Internet of Things can be expressed as:

\[ h(t) = \sum_i a_i(t)e^{j\theta_i(t)}\delta(t - iT_\eta) \]  

(6)

Where \( \theta_i(t) \) is the multipath offset of each branch, where \( \theta_i(t) \) has a positive correlation with the channel's sensing information sampling frequency \( f_0 \). For space diversity, the baud interval equalization control method is used to obtain the complex sensor channel equalization under the Internet of Things. The impulse response is described as:

\[ h(\tau, t) = \sum_{i=1}^{N_i} a_i(t)e^{j\theta_i(t)}\delta(t - \tau_i(t)) \]  

(7)
Under multipath interference, under the complex sensor distribution model, the radial distance of the spatial array element distribution of the sensor node is \( d \), and the signal receiving model of the complex sensor mutual sensing under the Internet of Things is:

\[
x_m(t) = \sum_{i=1}^{I} s_i(t) e^{j \omega t} + n_m(t), -p + 1 \leq m \leq p
\]

(8)

The mutual sensing channel of complex sensors under the Internet of Things is adaptively expanded, and distortion compensation is performed according to the sampling characteristic sequence of the baud interval to realize the channel equalization design [5].

5. Simulation results

According to the principle of perceived similarity, OPNET is used to simulate the scheme in this paper, and the simulation parameters are shown in Table 1.

| Simulation parameters | Number of deployed nodes | Deployment area | Routing Protocol | Number of available channels | Transmission distance adjustment |
|-----------------------|--------------------------|-----------------|------------------|----------------------------|-------------------------------|
| Value                 | 50                       | 3×10km          | AODV             | 1/3                        | 500m/1500m                    |

Among them, 3×10km means that the node is deployed in the range of 3km×10km. Power adjustment is regarded as communication distance adjustment, and two scenarios are used for comparative experiments: scenario1, the network is not divided into layers, the node communication distance is 500m, and the number of available channels is 1; scenario2, the network is divided into 3 layers, and the node communication adjustment distance is 500/1000/1500m, 3 available channels, the corresponding results of the experiment are given below. Figure 2 shows the comparison of the total number of bits of successfully received data corresponding to the networks in the two scenarios. In the figure, the ordinate is the number of bits received per s b, and the abscissa represents the simulation time in min. It can be seen that the network throughput under different channels and power levels after network layering is significantly increased compared with the network throughput of a single power level, which shows that multi-channel and multi-power levels have brought network capacity improvements [6].

![Figure 2. Network throughput comparison chart](image-url)
Figure 3 shows the comparison between the average transmission hops and transmission delay of data packets in the network. The number of experimental simulation nodes is only 50, which is equivalent to a small part of the entire network. The average number of hops for data packets in this small range is reduced from 8 hops to 7 hops, and the delay is also significantly shortened. It can be seen that the expansion is the entire long chain. In sensor networks, the number of hops required for data packets will be reduced considerably. Finally, good real-time network transmission can be obtained [7].

Figure 3. Average number of data transmission hops

6. Conclusion
Based on the topology and routing levels of network construction, this paper proposes an optimization plan for the construction of a ubiquitous power Internet of Things transmission network, and takes a city’s transmission network as an example to construct a network model. At the network topology level, it proposes an edge addition based on node weights. Optimization strategy, after adopting the optimization strategy proposed in this paper and the traditional random strategy to expand the network capacity, the network connectivity and communication efficiency are simulated after random failures and deliberate attacks. The final simulation results show that the optimization strategy proposed in this paper is effective It has obvious advantages to improve the robustness of the network.

Acknowledgments
This work was supported by Science and Technology Project of SGCC (Research on Low-temperature Resistance Characteristics and Evaluation Technology of New Sensors for Power Transmission and Transformation).

References
[1] Jaeseung, L., Yunsick, S., & Jong, P. Lightweight sensor authentication scheme for energy efficiency in ubiquitous computing environments. Sensors, 16(12) (2016) 2044.
[2] Santos, J., Rodrigues, J. J. P. C., Casal, J., Saleem, K., & Denisov, V. Intelligent personal assistants based on internet of things approaches. IEEE Systems Journal, 12(2) (2018) 1793-1802.
[3] Ejaz, W., Naeem, M., Shahid, A., Anpalagan, A., & Jo, M. Efficient energy management for the internet of things in smart cities. IEEE Communications Magazine, 55(1) (2017) 84-91.
[4] Liu, Y., Tong, K. D., Mao, F., & Yang, J. Research on digital production technology for traditional manufacturing enterprises based on industrial internet of things in 5g era. The International Journal of Advanced Manufacturing Technology, 107(3) (2020) 1101-1114.
[5] Mashal, I., Alsaryrah, O., Chung, T. Y., Yang, C. Z., Kuo, W. H., & Agrawal, D. P. Choices for interaction with things on internet and underlying issues. Ad Hoc Networks, 28(5) (2015) 68-
90.

[6] Silva, B. N., Khan, M., & Han, K. Internet of things: a comprehensive review of enabling technologies, architecture, and challenges. IETE Technical Review, 35(2) (2018) 205-220.

[7] Hu, W., Li, H., Yao, W., & Hu, Y. Energy optimization for wsn in ubiquitous power internet of things. International Journal of Computers, Communications & Control (IJCCC), 14(4) (2019) 503-517.