

# Performance Improvement of BPLC Based on Quantum Algorithm For New Energy Micro-grid

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**Abstract:** The channel environment of the new energy microgrid is worse than the traditional power line. On the one hand, the grid connection and switching of a large number of energy terminals in the new energy microgrid will change the impedance characteristics of the power grid and thus affect the transmission characteristics of the power line carrier communication. At the same time, the new energy terminal grid-connected devices make extensive use of power electronic devices, making the noise of the power grid more complicated and greatly different from the noise distribution in the traditional power distribution network, which makes it difficult to detect the carrier communication signal. This article broadband PLC system uses OFDM technology as an effective way to overcome the multipath fading modulation. Although broadband powerline OFDM systems represent the direction of broadband PLC technology, the communications capabilities and quality of service currently provided by the technology are far from broadband telecommunications service standards and require further optimization.

## 1 Introduction

At present, the research on power line carrier communication technology is basically carried out for the traditional distribution network. On the one hand, a large number of energy terminal equipment in the new energy micro-grid will cause the impedance characteristics of the power grid to change and thus affect the transmission of power line carrier communication<sup>1</sup> Characteristics; at the same time, the new energy terminal grid connected equipment uses a large number of power electronic devices that makes the power grid noise is more complex, there is a great difference between the noise and the traditional distribution network in the distribution, impulsive noise occupies a larger proportion of the noise, which makes it difficult to detect the carrier communication signal.

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*State Grid Sichuan electric power company: Research on power line and wireless heterogeneous communication technology for new energy micro grid.*



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Broadband power line communication, referred to as BPLC, is a communication technology that uses medium and low voltage distribution networks as a communication medium to implement integrated services such as data, voice and video transmission. Generally, the communication speed is above 1Mbps, and the frequency range is 1-40MHz. Among the core technologies of broadband PLC, there are orthogonal frequency division multiplexing (OFDM), discrete multitone DMT and spread spectrum modulation, among which OFDM modulation is the most representative, and its application is the most[1-2]. With the increasing speed of smart grid services for PLC communication, the current technology development trend is to use OFDM mode to realize power line carrier communication.

## 2 Analysis of subcarrier allocation scheme for broadband power line OFDM

The OFDM system divides the actual channel into several subcarrier channels, in order to improve the transmission efficiency of the OFDM system, a dynamic resource allocation mode may be adopted to select different modulation modes and allocate different powers for each subcarrier channel according to its own channel conditions, excellent channel selects high modulation mode, poor channel selects low modulation mode, shut down a few very poor channel[3]. With the advent of quantum computing theory, Quantum Genetic Algorithm (QGA) increases the advantages that traditional genetic algorithms do not have, using quantum bits to represent information and expanding the range of population search through the randomness of quantum bit measurement, through the direction of evolution to quickly approximate the optimal solution[4]. Compared with the traditional genetic algorithm, it has the characteristics of less population, less iterative evolution and less likely to fall into local extremum, therefore, this paper uses quantum genetic algorithm to optimize the allocation of broadband PLC subcarriers[5].

On the basis of quantum computation, quantum genetic algorithm expresses the probability amplitude of quantum bits as the encoding applied to chromosomes so that one chromosome can express the superposition of multiple states and realize the update of chromosomes by using quantum logic gates, so as to achieve the goal of optimization. Specific steps include: quantum bit coding, quantum state measurement, individual evaluation, individual evolution and so on.

## 3 Quantum Genetic Algorithm

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(1) Quantum bit code: In genetic algorithm, the chromosome is expressed by definite value, and in quantum genetic algorithm, the chromosome is expressed by quantum bit (qubit). Unlike classical bits, qubits can be in superposition state[6]. A qubit can be represented as:

$$\varphi = \alpha|0\rangle + \beta|1\rangle, \alpha^2 + \beta^2 = 1 \quad (1)$$

Where  $|0\rangle$  and  $|1\rangle$  denote two different quantum states, and  $\alpha$  and  $\beta$  denote the probabilities of the two quantum states, respectively, so a qubit can store and express the information of two states simultaneously. If the gene contains multiple states, you need to convert to binary. Thus a gene that contains  $2^K$  states can be expressed as:

$$q = \begin{bmatrix} \alpha_1 & \alpha_2 & \dots & \alpha_K \\ \beta_1 & \beta_2 & \dots & \beta_K \end{bmatrix} \quad (2)$$

(2) Quantum state measurement: The measurement of quantum states is a measurement of a quantum superposition state by a random variable of 0~1, which causes it to collapse from a probability state to a specific state. The specific process is: randomly produce a number between 0 to 1, if it is greater than the square of the probability amplitude, then the measurement results take 1, otherwise the value of 0. Therefore, by measuring, the qubit of quantum states becomes real valued bits. It can be seen that the measurement of Quantum States has certain randomness, so it can expand the range of population search and reduce the population quantity to a certain extent[7].

(3) Individual evaluation: Individual evaluation and conventional genetic algorithm. That is to say, an appropriate fitness function is set up to evaluate the merits of the current individual.

(4) Individual evolution: Quantum evolutionary operations have two strategies, one is the use of conventional cross evolution operation, and the other is the use of quantum rotation gate strategy. In the quantum theory, the transfer between states is realized through the quantum door transformation matrix, the research shows that the rotation angle of the quantum revolving door can also characterize the evolutionary operation, so that it is convenient to add the information of the best individuals to the evolution, accelerate the convergence of the algorithm[8-9]. Quantum gate evolutionary strategy is used to change the probability of each ground state through the quantum gate acting on the ground state of quantum superposition state or entangled state in order to maintain the diversity of the population and objectively simplify the algorithm itself. Therefore, the evolutionary update method of quantum gates is particularly critical, which is directly related to the performance of the algorithm. According to the characteristics of quantum genetic algorithm, quantum rotation gate  $U$  is chosen to evolve and update, quantum rotation gate is defined as follows:

$$U(\theta) = \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix} \quad (3)$$

In the formula,  $\theta$  is the angle of rotation evolution, and the probability amplitude becomes the quantum evolution after the quantum gate evolution:

$$[\alpha^*, \beta^*]^T = U(\theta_i) \cdot [\alpha_i, \beta_i]^T \quad (4)$$

In the formula,  $[\alpha_i, \beta_i]^T$  is the probability amplitude of the  $i$ th gene in the individual;  $[\alpha_i^*, \beta_i^*]^T$  is the probability amplitude of the  $i$ th gene updated by the quantum rotation gate,  $\theta_i$  is the rotation angle of the quantum gate,

$$\theta_i = \Delta\theta \cdot f(\alpha_i, \beta_i) \quad (5)$$

In the formula,  $\Delta\theta$  is the size of the rotation angle to control the convergence speed of the algorithm;  $f(\alpha_i, \beta_i)$  is the direction of the rotation angle to determine the search direction of the algorithm.  $\Delta\theta$  must be reasonable value, if too large, prone to premature phenomenon; the other hand, if too small, the algorithm search grid is small, too slow, or even at a standstill.  $\Delta\theta$  is defined as a variable related to evolutionary algebra:

$$\Delta\theta = 10 \cdot \exp(-q/n_c)$$

The formula is  $q$  evolution algebra, and  $n_c$  is a constant according to the complexity of optimization problem. In this way, the step size of the search can be adaptively changed.

#### 4 Broadband Powerline Communication Simulation Based on Quantum Algorithm for Subcarrier Allocation

The subcarrier allocation firstly initializes the population, then performs quantum state measurement and individual evaluation, and finally realizes the evolution. The specific algorithm flow is shown in Figure 1. In order to prove the effectiveness of the algorithm in the power line channel environment, according to the modeling method of the channel characteristics of the broadband power line OFDM communication system, 8 user channel models are established, and the channel parameter settings are shown in table 1.

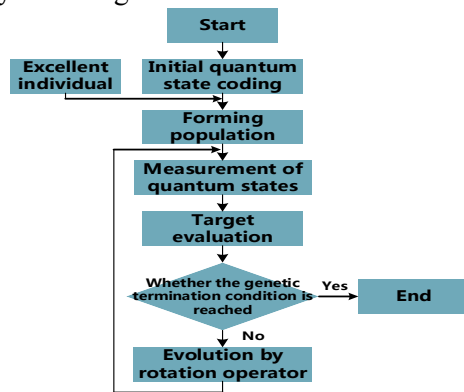
**Table 1** channel simulation parameters

Channel number	Multipath number	Impulse response duration	Initial delay ( $\mu s$ )	Maximum range (head diameter)	Minimum range (end diameter)	Amplitude variable
1	20	2	1	0.003	0.0003	0.9
2	20	1.5	0.5	0.002	0.0002	0.8

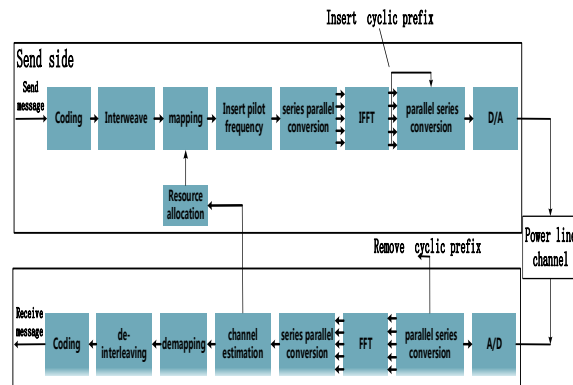
3	10	1	0.5	0.02	0.003	0.8
4	10	1	0.5	0.02	0.003	0.7
5	7	0.7	0.3	0.03	0.004	0.7
6	7	0.7	0.3	0.03	0.004	0.6
7	5	0.5	0.2	0.05	0.005	0.5
8	5	0.5	0.2	0.05	0.005	0.5

Figure 2 shows the transmission characteristics of 8 channels, the selection of 8 channels takes into account the channel conditions under different multipath numbers and fading, and the channel differences among users are obvious. Table 1 shows the other parameters required for the simulation.

It can be seen that in the power line OFDM system, the number of subcarriers is very large, so the sub carrier clustering method is adopted to reduce the complexity of resource allocation. The 10 subcarriers are divided into a cluster, as a resource allocation granularity, so the system only 128 sub carrier clusters to be allocated, greatly reducing the complexity of the allocation of computing. The modulation mode uses M-QAM modulation, and the maximum modulation mode is 1024-QAM. The power spectral density of the signal is selected as -60dBm/Hz according to the HPAV standard.



**Figure1** Resource allocation algorithm

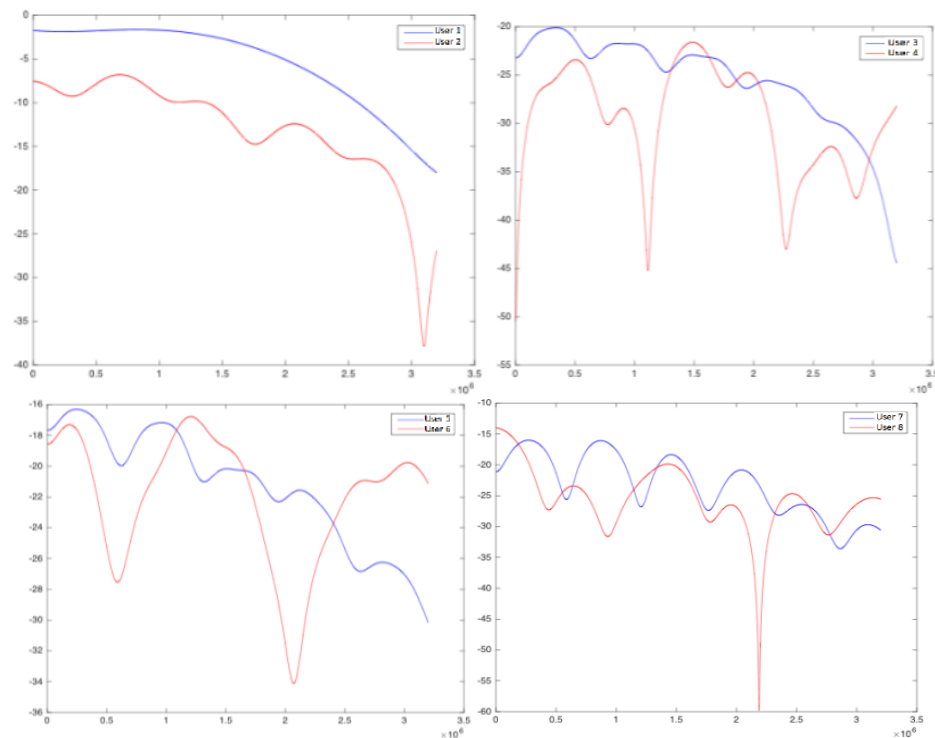


**Figure 2** OFDM based PLC system

Table 2 is the simulation parameter of the power line system OFDM, in which the number of subcarriers is modified appropriately on the reference HPAV standard, selected as 1280, occupying the frequency band from 1 to 30MHz, the main purpose is to facilitate calculation. Multiuser channel transmission characteristic curve as shown in Figure 3.

**Table 2** simulation parameters for resource allocation

Parameter name	Parameter value
Number of subcarriers	1280
Subcarrier cluster	128
Number of users	1, 2, 4, 6, 8
Band range	1~30MHz
Error rate	$10^{-6}$
Power density spectrum of colored background noise	$-120+40*\exp(-f/0.7)$ dBm/Hz
Signal power spectral density PSD	-60dBm/Hz



**Figure 3** Multi-user channel transmission characteristics

## 5 Conclusion

According to the features of the power line channel under the new energy micro-grid environment, the signal transmission model of PLC is established. Due to the shortage of spectrum, the noise interference is serious in some frequency ranges, to avoid these frequency bands and achieve higher signal transmission rate, it is necessary to use the frequency aggregation technology to broaden the frequency band used; at the same time, it is necessary to analyze the acquisition of various types of channel parameters of the PLC and create favorable conditions for improving power line communication performance through networking.

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