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Research on the Novel Non-Contact Power Supply System Tuning Methodology based on Fuzzy Neural Network Theory under the Random Load Condition

Yaping Yang

Xi'an Aeronautical University, Xi'an 710077, China
xayangyaping@126.com

Abstract

In this paper, we combine the literature review and technique reports to conduct research on the novel non-contact power supply system tuning methodology based on fuzzy neural network theory under the random load condition. Power supply by non-contact way could increase the flexibility of electrical equipment, eliminates the traditional power supply methods of safe hidden trouble and makes up for the traditional power supply methods because of the existence of electrical connections of the lack of divination. The background harmonic separation of qualitative method is detecting system side and user side common connection point for the size of the harmonic distortion effect. The genetic algorithm with adaptive system, cellular automata, chaos theory and artificial intelligence is considered for the next decade computing technology has a significant impact on the key technology which is adopted by our research to optimize the proposed system. Mathematical analysis and dynamic load change can lead to circuit reactance, so system will deviate from the resonance state. The experimental simulation proves the feasibility and robustness of our proposed methodology. In the near future, more related research will be conducted to optimize and modify the current method.

Keywords: *Non-Contact Power Supply System; Tuning Methodology; Fuzzy Neural Network; Random Load Condition; Structure Optimization; Network Topology*

1. Introduction

Contactless power supply technology is a kind of based on electromagnetic coupling induction principle comprehensive utilization of the modern power and electronics technology, magnetic coupling technology, high power energy conversion high frequency transformation technology, with the aid of modern control theory and method, has realized the non-contact way from static electricity grid to the new technology of mobile power supply [1-2]. Power supply by non-contact way, increase the flexibility of electrical equipment, eliminates the traditional power supply methods of safe hidden trouble, makes up for the traditional power supply methods because of the existence of electrical connections of the lack of divination. Therefore, non-contact power supply technology is a kind of safe, reliable and generally flexible access to new technology of electric power. Based on the separable transformer induction coupling contactless power transfer technology, we could overcome the direct contact wires for electrical power transmission mode of the traditional power supply disadvantage. Reduces the power supply system of high frequency electromagnetic pollution to the environment, and avoid the problem of agency wear and carbon deposition, etc. Therefore its special environment safety is of great significance. Transmission efficiency of non-contact power supply system and power is relatively low, and increase the transmission efficiency of the system is the inevitable requirement of energy saving [3]. The power supply system realizes the comprehensive compensation current is the key technique to generate and control.

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The stand or fall of comprehensive compensation current detection method of the system and the compensation effect of three-phase system balance effect has a great influence [4-5]. Active current separation is a common electric current detection method. The detection method using phase-locked loop and low pass filter, when grid voltage frequency deviation of phase-locked loop can't accurate detection, low pass filter will lead to delay. With the rapid development of modern society and the ongoing marketization of electric power, the power quality problem is more and more causes the attention of power system and users, especially all kinds of power electronic devices and the wide application of nonlinear electric equipment brings serious harmonic pollution problem. Harmonic current injection, will reduce the power grid in the same line (or near feeder) the other users on the power quality, serious when will cause power quality and the relevant dispute. Background harmonic separation of qualitative method is detecting system side and user side common connection point for the size of the harmonic distortion effect. If the system side is big, the influence of side thinks that system as the main harmonic source. On the other hand, argues that the user side as the main harmonic source. The application of fuzzy neural network has been rapid development. This is because the fuzzy neural network has the nonlinear control of fuzzy control is simple and effective with neural network learning and adaptive ability [6]. However, the neural network is still suffering from drawbacks shown as the follows. (1) Optimization of the fuzzy neural network structure, the number of optimization of fuzzy rules, when the system input variable is large, the selection of fuzzy rules space increases sharply, the structure of the corresponding neural network become more and more complicated [7]. (2) The optimization of the fuzzy neural network parameters, that is, a factor before and after optimization of fuzzy rules, the fuzzy rules determine the number of cases, the performance of fuzzy control system is made up of fuzzy rules, the coefficient a decision, it is a multi-parameter optimization problem, using the traditional method is difficult to obtain the global optimal solution [8-10].

In the neural network theory and fuzzy theory research while growing up, neural network and fuzzy theory of the respective shortcomings are also exposed. Though neural network with learning ability and adaptive ability, self-organizing ability, fault tolerance and correction ability wait for an advantage, but it is hard to realize logical thinking, can't get the image thinking into language expression. The fuzzy theory is based on fuzzy logic, can realize the fuzziness of human thought but without the ability to learn, it seems only to have the ability to learn, and fault tolerance ability of neural network technology with fuzzy theory with image thinking and logical reasoning, can brings to the study of physiological school greater harvest, and this combination is bound to produce a new research direction of fuzzy neural network. The genetic algorithm with adaptive system, cellular automata, chaos theory and artificial intelligence is considered for the next decade computing technology has a significant impact on the key technology. Genetic algorithm in pattern recognition, image processing, industrial optimization control, adaptive control, neural networks, machine learning, biological science and social science, and other applications have been successful, and shows its great potential and broad prospect of application research. The application of genetic algorithm in the traditional neural network is mainly manifested in the structure of network learning, network design and the analysis of the network which could be found in the papers [11-13].

In the research community, plenty of algorithms and approaches have been put forwarded. In [14], Han’s research group conduct research on the noncontact power supply for seafloor geodetic observing robot system. They firmly believe that, each stop, equipped with the autonomous underwater vehicles, connected to the cable to provide power and communications facilities. Near the AUV wharf, three or four bottom reference station will be set up to observe the earth. In this system, non-contact power supply needs a battery-powered duration of underwater robot surveillance. Based on separable transformer induction coupling power transmission system of physical model,

the influence factors of transfer efficiency were investigated in theory. Mathematical analysis and dynamic load change can lead to circuit reactance: so system will deviate from the resonance state. With constant excitation power frequency and dynamic reactive power regulating circuit device parameters for adaptive tuning method of combining the features. In [15], Tao's research group conducted research on the inductive coupling power transfer device. They propose that the compensation method is adopted to improve the power factor, will inevitably increase the consumption of non-ferrous metal and the consumption of new electrical equipment. In addition, the compensation device itself will have the power loss, so first should be taken to improve natural power factor method of electrical equipment which will be meaningful.

In this paper, we theoretically analyze the novel non-contact power supply system tuning methodology based on fuzzy neural network theory under the random load condition with sufficient experimental simulation. Resonance frequency and load impedance has important effect on transfer efficiency and the change of the load and circuit parameters can cause the original and deputy while system deviates from the resonance state and thus deteriorating system transmission performance. In order to ensure good capability of transmission system, we must make Man system back to the state of resonance. Designed with constant excitation power frequency and adjusting the parameters of the circuit device combining the adaptive tuning method. Fixed working frequency excitation power supply high. According to the principle of maximum current loop compensation capacitance we should make the system return of resonance state. In the following parts, more theoretical analysis and numerical analysis will be conducted to finalize our research.

2. The Fuzzy Neural Network Theory

2.1. The Fuzzy Neural Network Inverse System

With the deepening of the research on chaos, chaos and its control was found to have the profound theoretical significance and broad application prospect, so chaos and its control research quickly follow up. In the process of the design of the fuzzy system, for obtaining the fuzzy inference rules, the traditional method is to determine with experience, this method is complex and difficult to the determination of the initial structure of fuzzy system involves the extraction of fuzzy rules, the fuzzy partition of input and output space, such as the selection of the initial parameters. Fuzzy neural network is put forward to the abstract language experience expression of fuzzy logic and neural network through learning to obtain the characteristics of the system to blend together [16-19]. In theory than the general fuzzy logic or neural networks more advantages. In the formula one, we define the non-linear system for analysis.

$$y(k) = f(\psi(k)); \quad \psi(k) = \left[y(k-1), ..., y(k-ny) \right]^{\mathrm{T}} \tag{1}$$

According to the complexity of the system to take the corresponding number of chaotic systems, input/output data as a signal of network training teachers, a certain amount of training data can be sufficient incentives to ensure that the trained neural network training data can be gained by numerical experiment repeated trial and error, because the state of chaotic systems has the ergodicity, general training data don't have to be big, and training after the network has not sensitive for the initial state of training data. The following equations illustrate the process of training and modelling.

$$\beta_j = M_{j,1}(x_1) \wedge M_{j,2}(x_2) \wedge \cdots \wedge M_{j,\mathrm{nz}}(x_{nx}) \tag{2}$$

$$y_m(k) = \sum_{j=1}^{M} \left(\beta_j / \sum_{j=1}^{M,N} \beta_j \right) y_j(k) + \sum_{i=1}^{M} \left(\beta_i / \sum_{i=1}^{M,N} \beta_j \right) y_i(k) \tag{3}$$

For the fuzzy neural network learning, the more the more complex the structure parameters the more difficult the global optimization of a fuzzy neural network and in the

large-scale practical application of fuzzy neural network are researched. Due to the possible coupling between fuzzy weight fuzzy system and the related making it harder for system identification efficiency is low [20-21]. In recent years many scholars engaged in research work on this some stratified hierarchical fuzzy neural network system was put forward with detailed systematic description. The figure one shows the structure of the fuzzy neural network.

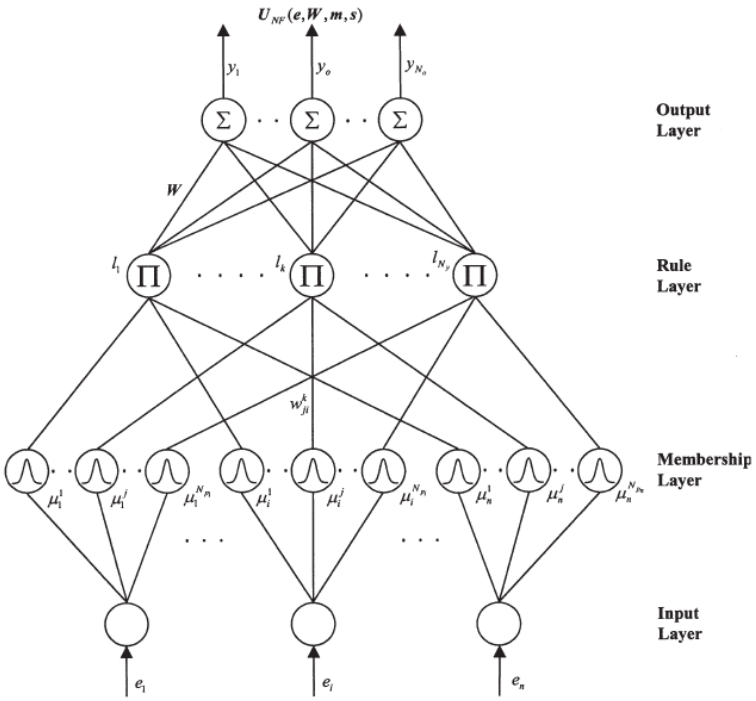

Figure 1. The Demonstration of the Structure of the Fuzzy Neural Network

Fuzzy neural network not only good at using the existing empirical knowledge, and the introduction of neural network learning mechanism, makes the fuzzy neural network at the same time with strong reasoning ability, white adaptable and characteristics of the approximate any continuous nonlinear mapping. Structure identification and parameter estimation at the same time, using the error rate as a pruning strategy, got a more compact structure, but its assumption rules in all input variables Gaussian membership function with the same width with reality which is denoted as the following formula.

$$w_i = a_{0i} + a_{1i}x_1 + a_{2i}x_2 + \cdots a_{mi}x_m, \quad i = 1,2,\cdots n \tag{4}$$

Structure study tried to build a compact by using the method of self-organizing network, the neurons can be dynamically generated and delete, parameter study in alternative learning strategy, first of all, through the study of linear parameter, and then, through the study of nonlinear parameter which will make faster convergence and better generalization performance. Fuzzy algorithm is proved to be a global approximation, is being widely attention and at the same time, it is in forward fuzzy neural network structure through internal information feedback connection to memory system in the past, therefore, can be used to deal with transient problem, and overcome the feedback type dynamic fuzzy neural network to increase the size of the network faults, applicable to the identification of dynamic process which will have a variety of types of the recurrent fuzzy neural network structure. The Gaussian membership function for evaluation is defined as the follows.

$$\mu_{ij}(k)=\exp\left(\frac{\left(x_i(k)+\mu_{ij}(k-1)\theta_i^j-\alpha_i^j\right)^2}{\left(\alpha_i^j\right)^2}\right),\quad i,j=1,2,\cdots n \tag{5}$$

New kind of clustering, including offline training, design optimization, online identification of the steps could automatically determine the number of fuzzy rules, simplified design, speed up the genetic optimization, and has good generalization ability, suitable for online identification with high precision.

2.2. The Fuzzy and Chaotic Systems

In recent years, Chaos control has become a hot research topic goal of chaos control has a lot of a more active research direction is calm chaotic attractor embedded in the unstable periodic orbit. After ten years of development time delay feedback control made some significant achievements of theory and practice and gradually become one of the important control chaos theory methods and technical means in chaos control theory system occupies a pivotal position [22-25]. For any given a finite dimensional system or process, it can be linear or non-linear, discrete or continuous, time-varying or time invariant, not chaos and even stable, concerns is to design a feasible controller, the controlled system to produce chaos phenomenon or enhance the controlled system has existed phenomenon, this is the inverse control of chaos which is also known as the chaos control, chaos generation control or comprehensive, chaos control can solve the problem of the implementation of chaotic source.

Mathematically strict feedback design method, it has already adapted to the low order system adapted to the advantages of high order system. For high order system, according to the controlled chaotic system control target can determine which index of configuration is flexible. In a controlled system allows discretization, and make the controlled system based on the configuration method can also be indirect chaos is applied to simulate the controlled chaotic system control. Controlled system with the combination of the state feedback control mode has three, namely: a controlled linear system and nonlinear state feedback control, the controlled nonlinear system applying linear state feedback control, the controlled nonlinear system applying nonlinear state feedback control [26-27]. Applying nonlinear state feedback of the controlled system of chaos control is the most perfect in theory research, on the application of the most mature methods of applying piecewise linear state feedback of nonlinear control method. With linear or nonlinear boundary conditions of one dimensional linear wave equation on the boundary with a sinusoidal function driver as the controller to control a linear system which was not chaos, chaos, and through the characteristic line method, the analytical solution of the control system, and further on the basis of the theory of total variation and symbol dynamics system.

The system is chaotic proofs are given. Applying linear or nonlinear state feedback of the controlled system input to realize chaos control working in a closed loop mode, the in the noise environment to maintain the desired chaotic motion. Controlled system for open-loop mode by directly applying the linear or nonlinear excitation signal of chaotic motion, how to keep in noise environment depends on the system of anti-interference ability enhancement, but the research has not been reported, at this moment if you can properly part of the introduction of controlled system state feedback, along with linear or nonlinear incentive the desired compound open loop and closed loop control of chaos movement to improve the robustness of chaos movement is a meaningful research topic. In the following figure two, we show the general illustration of the fuzzy and chaotic systems.

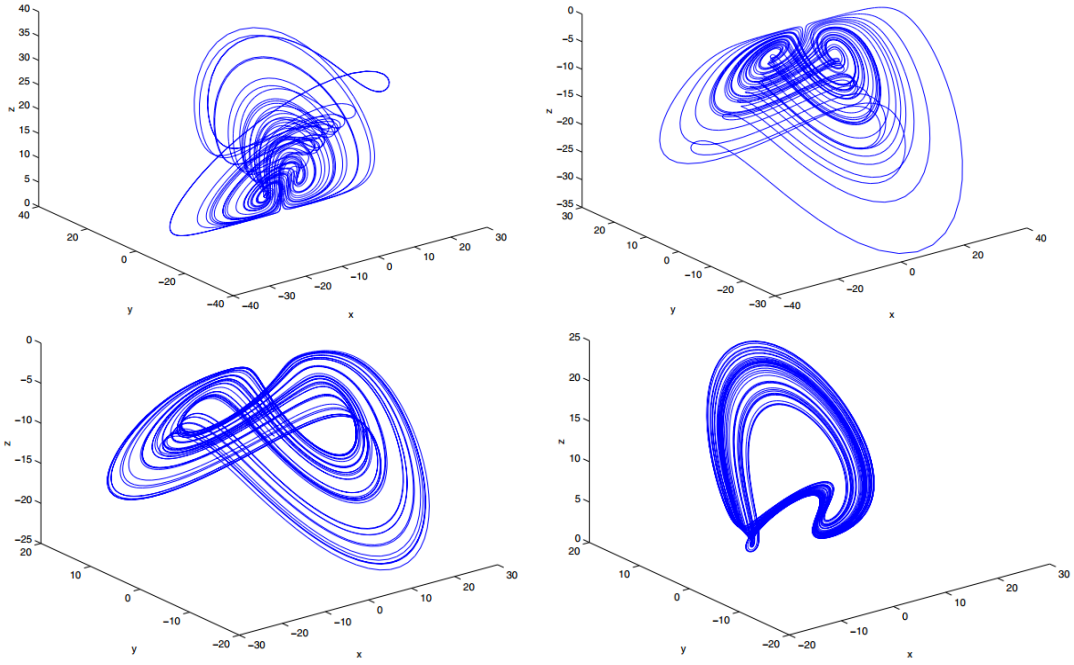

Figure 2. The Illustration of the Fuzzy and Chaotic Systems

3. The Non-Contact Power Supply System Tuning Methodology

3.1. The Principles of Power System Harmonic

In the ideal clean power supply system, the electric current and voltage are the sine wave. In only linear element f in the resistance, inductance and capacitance of the simple circuit, through the current is proportional to the applied voltage, electric current is a sine wave. In the actual power system, because of the existence of nonlinear load, when current flows through and is not a linear relationship between the applied voltages of the load, to form the non-sinusoidal current. Any periodic waveform can be decomposed into a fundamental frequency sine wave with many harmonic frequency of the wave. The causes of harmonic could be summarized as the follows. (1) Transmission and distribution system harmonic generation. In the general transmission and distribution system mainly power transformer harmonic generation, due to the saturation of the transformer core, the nonlinear magnetization curve, combined with design transformer when considering the economy, the choice work flux density in nearly saturated magnetization curve segment, which makes magnetizing current spire waveform, thus containing the odd harmonics [28]. (2) The power quality is not high harmonic generation. Generator with three phase winding on the production is very difficult to do absolutely and absolute core is difficult to achieve uniform and other reasons. Because of the in electric locomotive, aluminum electrolytic tank, the charging device, switching power supply to get more and more widely used, are responsible for a large number of harmonics to grid. As we know, rectifier device adopts the phase shifting control, lacking angle of sine wave is absorbed from the grid, the grid is also part of the left missing angle of bottom chord wave, obviously in the left part contain the amount of harmonic.

Inverter load in order to adapt to variable frequency power supply system simulation test comprehensive electrical characteristics of load demand, in addition to the load components and the cooling efficiency and so on to take the necessary measures, variable frequency simulation load control should be designed as a closed loop automatic control, load loading should be the general load automatic management system setting load value,

power factor and feedback parameters such as accuracy, load protection value, and automatic feedback and correction loading amount, to meet the schedule requirements [29]. To make the electricity equipment better work, need to provide them with different frequency and voltage of power supply. Therefore, in order to meet the demand for power supply, electrical equipment need to hook up all kinds of converter in the power grid, the voltage of power grid transformation to get different frequency and voltage of power supply and ac/dc hybrid power supply system. In the power supply system, due to the nonlinear current transformer, voltage will produce distortion, the distortion of the waveform will affect the work of ac load, serious and even make the system cannot work normally. Frequency conversion device is often used in the equipment such as fan, water pump, elevator, due to the phase control is adopted, the harmonic component is very complex, in addition to containing the integer harmonics, also contains the fractional harmonic, the devices of power generally larger, with the development of frequency control of motor speed, the power grid harmonic caused by more and more.

As researched in the literature reviews, the traditional methodology of detecting the power system harmonic could be summarized as the following equations.

$$P_h = \frac{E_c E_s}{X_c + X_s} \sin\Theta = \frac{X_c X_s}{X_c + X_s} \mathrm{I}_s \mathrm{I}_c \sin\Theta \tag{6}$$

$$Q_h = \frac{E_s}{X_c + X_s} \left(E_s - E_c \cos\Theta \right) \tag{7}$$

Linear load harmonic current is the linear function of the harmonic voltage and harmonic current of nonlinear load is every harmonic voltage of complex function [30-32]. Application of simplified model of harmonic sources and fundamental wave in the power supply voltage phase angle is zero, the real part and imaginary part of harmonic current can be respectively for every harmonic voltage linear polynomial, real and imaginary part of the which caused by the harmonic voltage and harmonic current account for only a very small proportion. Under the condition of the system without background harmonic, the user side harmonic source in common connection point will deteriorate the power quality. But when the system when there is a harmonic source side cannot directly determine the user common connection point for the influence of power quality harmonic sources [33-35]. Assuring the high reliability of system is another key technology is the current distribution of each module. As the parallel module of the system characteristic and parameter is difficult to do the same, will cause uneven module current, large load, the output current large chunk of it may work on the overloading state for a long time, cause the module to improve failure rate. In a parallel power supply system, therefore, need to take some measures to ensure that each module output current equalization, guarantee the system work stably and reliably, give full play to the advantages of parallel power supply. Harmonic positioning can't reflect the user side harmonic source to point the real implications of the harmonic level. So you need to compare the difference between before and after the user side harmonic current injection point of harmonic voltage and harmonic current amplitude which can learn the user side harmonic source inputs to point after harmonic level is to help increase or help decreases. In the following figure three, we demonstrate the basic and traditional ways of preventing the power system harmonic.

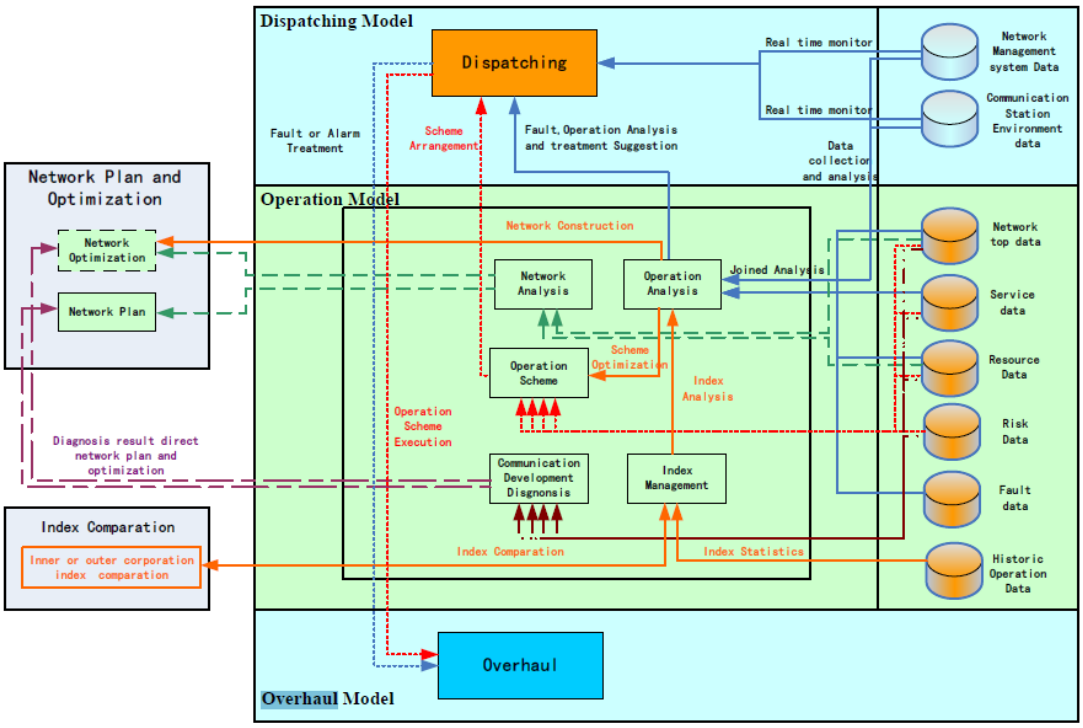

Figure 3. The Traditional Ways of Preventing the Power System Harmonic

3.2. The Non-Contact Power Supply System

Non-contact power supply system of the primary circuit through the resonance in the guide rail is close to the sine wave generated by the coil current, supposed to sinusoidal current of standard here. DC distributed power supply system made up by multiple subsystems and the interaction between subsystems can easily lead to system stability and dynamic performance, and even instability. Usually, the constant power load with the negative impedance of input properties is the main cause of instability in a cascade system Provide effective neutral point, the characteristics of earth transformer is zero sequence impedance is very small, single phase grounding and zero sequence voltage on the earth transformer voltage drop is small. Load can be directly and pick up coil in series through the pickup coil accept energy, but in order to reduce the impedance of the pickup coil itself, increase output power supply current or voltage which can adopt the way. The following figure shows the structure.

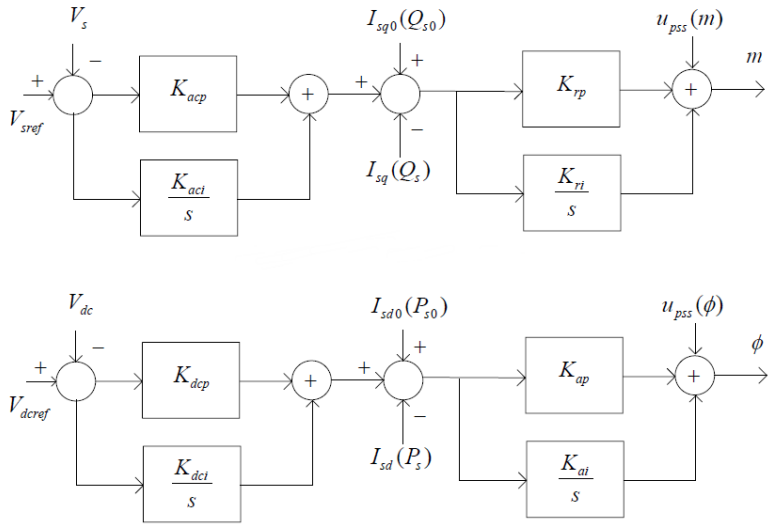

Figure 4. The Structure and Organization of the DC/AC Control

Synchronous rectification buck converter inductor current under arbitrary load conditions are in a state of continuous. System harmonic impedance are greatly influenced by the system short circuit impedance, when the operation mode of fixed, in a short period of time the system harmonic impedance is relatively stable, there will be no big fluctuations, using the measured voltage fluctuation quantity characteristics of current fluctuation quantity ratio of symbols to estimate the harmonic impedance background harmonic, harmonic emission level and system. The transfer function is formulated as the follows.

$$G_{vd} = u_0 / d = U_{in} H(s) \tag{8}$$

$$H(s) = (1 + sR_{cf}C_f) / \left[1 + \frac{R_{Lf}}{R_{Ld}} + s\left(\frac{L_f}{R_{Ld}} + R_{Cf}C_f \right) \right] \tag{9}$$

Due to the constant frequency efficiency and reliability of the system, the rarely used in the system of large capacity, instead, with relatively light mass, high reliability and good maintainability, low operating cost advantage of frequency conversion power supply system. Variable frequency power supply system and constant frequency power supply system of difference is mainly reflected in the change of system frequency range, on the surface of the model test of simulated load to simulate aircraft ac power system comprehensive electrical properties of the load, and the electricity consumption of the power supply system simulation load cases, due to the analog load resistance element in parasitic parameters, the sensitivity of frequency, inductance and capacitance itself shifts in input frequency impedance changes, so in the practice to take measures to eliminate the influence of frequency change. Capacitive load component quality selection of capacitance, automatic pressure sealing of cylindrical metal aluminum shell, with convenient fixed at the bottom of the bolt, lead to use plug-in or polymer bolt type. Internal components with polypropylene film and electrician rolled aluminum foil non-inductive winding way, using the high vacuum impregnation process, to ensure the product's performance.

3.3. The Systematic Description of the Proposed Method

Both the inductive or capacitive circuit can change the characteristics of the circuit by way of compensation. According to the original and deputy while compensation capacitance of different position, non-contact power supply systems are generally divided

into a variety of topological structures. But no matter what kind of topology structure, circuit analysis methods are similar. So this paper does not discuss compensation mode of non-contact power supply circuit. We just assume that circuit is sensitive and type series compensation circuit of the capacitive element. The system is in a state of resonance. The main factors influencing the system efficiency in power transmission with resonance frequency, mutual inductance, resistance load impedance as well as the original. The internal resistance has been unable to change. The materials of mutual inductance and transformer, transformer and the original structure, the relative position of vice edge and other factors are analyzed. Therefore, this article mainly aims at the working frequency of the system are discussed.

This article adopts the method of fixed power frequency adjustable parameters in adaptive tuning. System working process of the high frequency of excitation power supply and remain the same. To ensure the transmission efficiency of the system, by adjusting the value of capacitance compensation. Deviate resonant state of the system in resonant state again. The largest series circuit in resonance when the current in the circuit. By detecting loop current judge whether the system is in a state of resonance. In the figure 5, we illustrate the systematic description of the method.

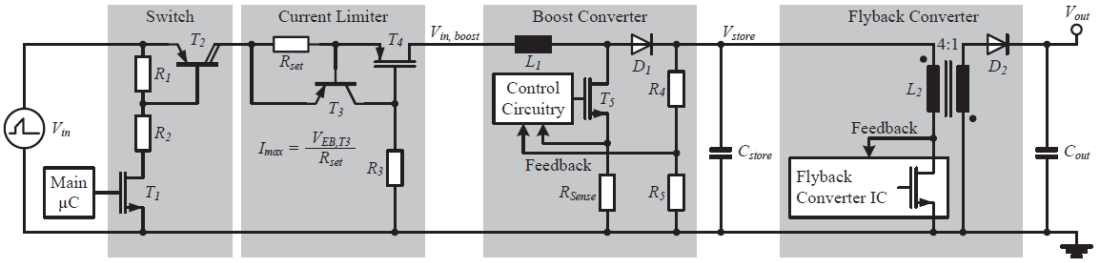

Figure 5. The Systematic Description of the Proposed Methodology

4. Experimental Analysis and Numerical Simulation

In this part, we conduct experimental simulation on the proposed methodology. After the experiment is designed to verify the load change, the effect of the fixed frequency control and combined with dynamic effects after tuning. In the figure 6, we show the systematic structure of the experimental system, in the figure 7, we show the statistical simulation result for the proposed methodology. As reflected from the numerical simulation result, our approach outperforms other state-of-the-art methods.

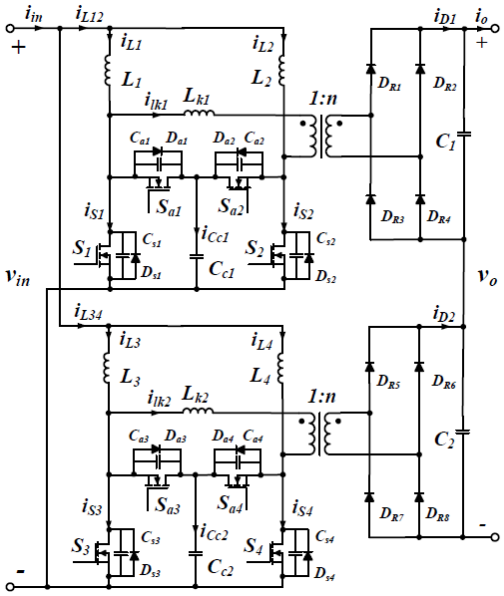

Figure 6. The Systematic Structure of the Experimental System

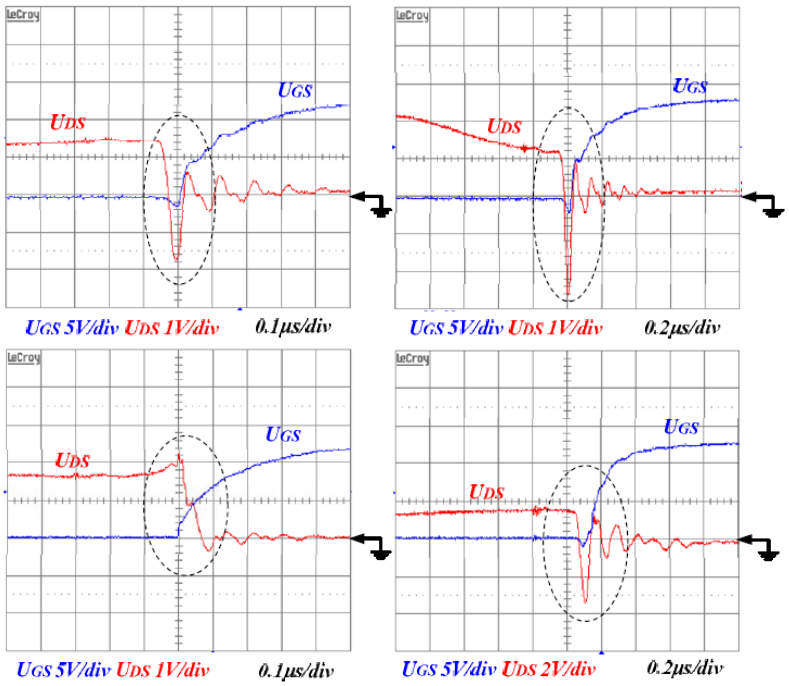

Figure 7. The Statistical Simulation Result for the Proposed Methodology

5. Conclusion and Summary

In this paper, we theoretically analyze the novel non-contact power supply system tuning methodology based on fuzzy neural network theory under the random load condition with sufficient experimental simulation. As the form and development of power market, power supply party must be approved by the high quality of power supply service win the market, at the same time with the participants also became the equality of market management. Harmonic in power network as the main power quality problems, both parties involved is more and more get attention. From the perspective of power

transmission, this paper analyzes the non-contact power supply system in parallel tuned to pick up circuit and serial tuned to pick up circuit of system parameters and the influence of the power transmission capacity. Fixed frequency is presented in this paper the combination of dynamic reactive power control and parameter tuning method, to ensure the working frequency constant of system and makes the switch devices working in soft switch state. Through our research, we could obtain the following conclusions. (1) The power of the harmonic effect on conducted interference on the power cord is more complex, not only associated with the amplitude of harmonic, and its initial phase, harmonic frequency all have relations. (2) For AC/DC hybrid power supply system, in which the DC load caused by the conducted interference is relatively large, if do not take other filtering measures, on the grid can only be articulated smaller dc load, along with the rising of the ac load, can be articulated dc load is increased. (3) For harmonic calculation show that when the power supply does not contain controlled rectifying the conducted interference on the power cord will increases with control angle.

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Author

Yang Yaping, she received her B.E. degree from Tianjin University of Technology and Education of Electric Automation, Tianjing in 1996. She received her M.E. degree from Northwestern Polytechnical University of Power Electronics and Power Drives in 2005. Her current aeras of research interests include Power electronic control technology.