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OPTIMIZATION OF RADIO ENERGY TRANSMISSION SYSTEM EFFICIENCY BASED ON GENETIC ALGORITHM

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Abstract. In order to better understand the efficiency optimization problem of radio energy transmission systems, the author proposes a genetic algorithm based research on efficiency optimization of radio energy transmission systems. The author first addresses the issue of improving the efficiency of magnetic coupled radio energy transmission. On the basis of ensuring a certain transmission distance and voltage gain, the system is mathematically modeled using coupling circuit theory, and mathematical expressions such as transmission efficiency, transmission distance, and voltage gain are obtained as the objective functions of the algorithm. Secondly, the impact of metal obstacles on the transmission system was analyzed. Design a radio energy transmission compensation circuit, and through simulation, obtain three transmission system parameter schemes that meet the objective function and constraint conditions. Finally, the multi-objective genetic algorithm is used to optimize the system parameter design and obtain the optimal combination of transmission system parameters, with coupling coefficient k=0.1818 and mutual inductance coefficient M=23.165×10^{-5}H. Using multi-objective genetic algorithm, the algorithm has a fast convergence function in terms of the number of iterations, a non dominated function solution, and Pareto graphs have verified that the numerical value (3) in the text is the optimal combination design for the transmission system.

Key words: Genetic algorithm, radio energy transmission, electromagnetic coupling

1. Introduction. The wireless energy transmission network is a planar self-organizing network architecture, where the nodes within the network are wireless power supply devices. For example, sensors in wireless sensor networks and robots in robot football matches can be regarded as nodes of a wireless energy transmission network. Each node has three functions, namely energy transmission, energy reception, and energy relay. For limited nodes distributed within a certain spatial range, electrical energy is emitted from the transmitting node and transmitted one-on-one through several relay nodes to reach the receiving node. A power transmission link is formed between the transmitting node and the receiving node, several transmission links form the network topology of a wireless energy transmission network. Link transmission efficiency: Electric energy passes from the transmitting node to the receiving node through the relay node, and the ratio of the electric energy picked up by the receiving node coil to the electric energy emitted by the transmitting node coil is the transmission efficiency of the link. The efficiency between nodes is related to the mutual inductance between coils. The larger the mutual inductance, the stronger the coupling between coils, and the higher the transmission efficiency. However, the mutual inductance between coils is related to distance, and the larger the distance, the smaller the mutual inductance. Scholars have derived a formula for calculating the mutual inductance between any coil. The author calculates the mutual inductance between nodes based on this formula, and then calculates the efficiency between nodes. The transmission efficiency of adjacent two nodes is multiplied sequentially to obtain the transmission efficiency of the link. Link lifetime: The link of WPTNs dynamically changes based on the electrical energy requirements of nodes in the current network. The period from the formation of the transmission link to the end of energy transmission is called the link lifetime. Self repair ability: The ability of a link to self repair and restore the transmission of electrical energy when a malfunction occurs during transmission and the link cannot function properly. Non crossability: In WPTNs, nodes transmit electricity in a one-to-one transmission mode, and a node can only work in one state. There can be multiple transmission links at the same time, but the transmission links do not cross each other. Threshold electrical energy: Nodes can only participate in the power transmission of WPTNs when their stored energy is above the threshold electrical energy.

When WPTNs establish a link, the receiving node sends an energy request signal outward, and adjacent

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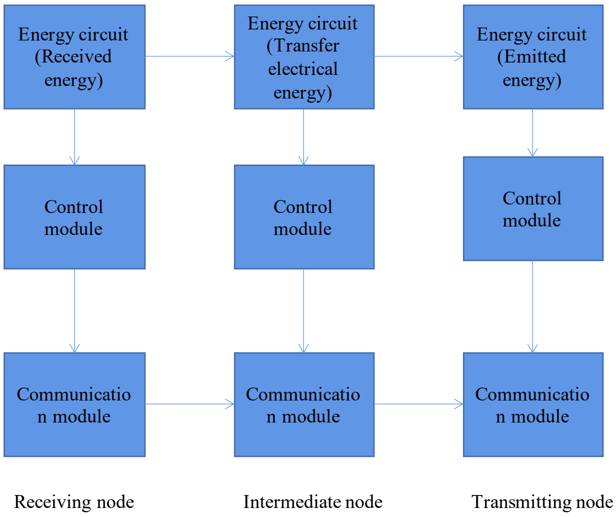

Fig. 1.1: 3 Node Transmission Link.

nodes receive the energy request signal. Based on its own working state and energy storage situation, the receiving node responds by receiving signals from neighboring nodes and selecting one of the many feasible nodes to provide energy. The node consists of three parts: energy circuit, control module, and communication module. The energy circuit has three functions: receiving electrical energy, transmitting electrical energy, and transmitting electrical energy. This means that the node has three working states, and can switch between these three states. However, the node only has one function when working, namely receiving electrical energy, transmitting electrical energy, or transmitting electrical energy. As shown in Figure 1.1, this is a radio energy transmission link composed of three nodes. The control module of the receiving node gives corresponding instructions to the communication module, which sends electricity demand information to surrounding nodes. The communication modules of the relay node and the transmitting node upload the information to their respective control modules. After confirming the connection between the receiving node and the relay node, they respectively control their energy circuits to work in the receiving and transmitting electricity states. The power transmission link between the three nodes is thus established [17, 2].

2. Literature review. In recent years, wireless power transfer (WPT) technology has undergone rapid development. In terms of rescue and medical applications, wireless energy transmission technology is a key technology for robots to achieve continuous, lightweight, and wireless cable limited work in special environments (such as underwater, metal pipelines, human bodies, etc.). There are four main principles of wireless transmission, such as electromagnetic radiation, ultrasonic, magnetic field coupling, and electric field coupling. The magnetic coupling resonance method ensures transmission distance, transmission power, and transmission efficiency in special environments, with relatively small radiation to the surrounding area.

The application of wireless energy transmission technology in specific occasions such as electric vehicle charging, power supply for built-in devices in the human body, and power supply for high-voltage devices is more convenient, safe, and reliable compared to traditional contact based energy transmission technology. Because there is no direct cable connection between its power supply and electrical equipment, there will be no skin breakage or wear. With the continuous development and application of wireless energy transmission technology, this technology is receiving increasing attention from domestic and foreign researchers. Among them, magnetic coupling resonant radio energy transmission technology is a new type of radio energy transmission technology that has been widely applied in recent years, it breaks the contradiction between the transmission efficiency and distance of traditional wireless energy transmission technology. The parameter optimization of the magnetic coupling system is crucial for improving the transmission efficiency of the system. Electromagnetic coupling resonant radio energy transmission utilizes non radiative electromagnetic fields in the near field area to complete electrical energy transmission. On the one hand, compared to electromagnetic induction energy transmission, it has greatly improved the transmission distance, bringing greater freedom for electrical equipment to obtain electrical energy; On the other hand, compared to electromagnetic radiation energy transfer, the energy in the near field area has the characteristic of non radiation, so this technology has good safety, and the design difficulty of the electric energy transmitter and receiver is also reduced. In recent years, WPT has become a research hotspot in domestic and foreign research institutions. Some studies have shown that when the transmission distance is reduced to a certain level, the system is in an overcoupled state. In this state, the system exhibits two 'resonant frequencies', and the power received by the load near these two frequency points is high. This phenomenon indicates that the frequency of the resonant system undergoes splitting in an overcoupled state. Due to the phenomenon of frequency splitting, if the system cannot automatically adjust and track the system's operating frequency, the operating frequency and resonant frequency will definitely be inconsistent, and the system will operate in a non resonant state. The power received by the load shedding will inevitably be very low, which will affect the normal operation of the load when it is lower than the rated power. Therefore, monitoring and controlling the operating frequency of the system is an effective means to improve the load receiving power and efficiency.

Tabataba, P. K. M. et al. proposed through circuit theory modeling analysis that the resonance frequency will shift due to factors such as circuit and environment in radio energy transmission. When in an overcoupled state during transmission, frequency splitting occurs, which affects the consistency of the highest efficiency point and power point, and elucidates the characteristics of radio energy transmission systems [13]. LingzhaoWANG et al. constructed a steady-state circuit model of a wireless transmission system considering the influence of higher-order harmonics, and obtained mathematical formulas for system circuit parameters and state variables through mathematical modeling. By using genetic algorithms, the problem of identifying system circuit parameters is transformed into an optimization problem [15]. Devi, R. R., and others proposed using an improved genetic algorithm to optimize the resonant frequency, coupling coefficient, coil turns, coil radius, capacitance, mutual inductance, and other factors of the transmission system, achieving an energy efficiency of 87 for the capsule robot wireless energy transmission system prototype 6 mV, with a transmission efficiency of 8.02% [5].

The author uses the theory of coupled circuits to analyze the circuit model of wireless energy transmission systems and derives a mathematical formula for the voltage gain coefficient of the coupled circuit. By combining the formula of transmission distance and mutual inductance, a transmission and reception circuit is designed through MATLAB simulation. Under the requirements of transmission efficiency, voltage gain, and coupling coefficient, various parameters of the transmission system circuit are obtained. The multi-objective genetic algorithm was used to optimize the parameters of the radio energy transmission system, verifying the effectiveness of the simulation system parameter design [9, 4].

3. Methods.

3.1. Adaptive frequency tracking WPT system. High frequency power supply is a key issue in magnetic coupling resonant transmission systems, including high-frequency inverter, dual transistor Class E high-frequency resonant, and microsignal power amplification. Although high-frequency inverter has high power and high frequency, its work efficiency is low and its frequency adjustability is poor. The micro signal power amplification system has received more attention and research due to its high work efficiency, easy frequency adjustment, and mature implementation methods. The adaptive frequency tracking WPT system is shown in Figure 3.1.

Using direct digital synthesis (DDS) to generate the source frequency, compared to high-frequency inverter power supplies, it has higher efficiency, higher frequency, and better adjustability [1]. This system uses DSP to control DDS to generate 3.6-5.6 MHz signals as the system's RF signal source. The DDS frequency can reach 20 MHz, and the swing rate of general power operational amplifiers is not enough, resulting in distortion of the output waveform. Therefore, a two-stage current mode amplifier circuit composed of XST13050 is adopted, with a bandwidth of 425MHz, a maximum output current of 0.2 A, and a swing rate of 6.6 kV/us, meeting the design requirements of this system. After wireless transmission, the energy is converted into DC by the AC/DC module, and then transmitted to the load. The load end uses a power detection module to detect the power (Zigbee is selected as the wireless signal transmission device), and then the power and power variables

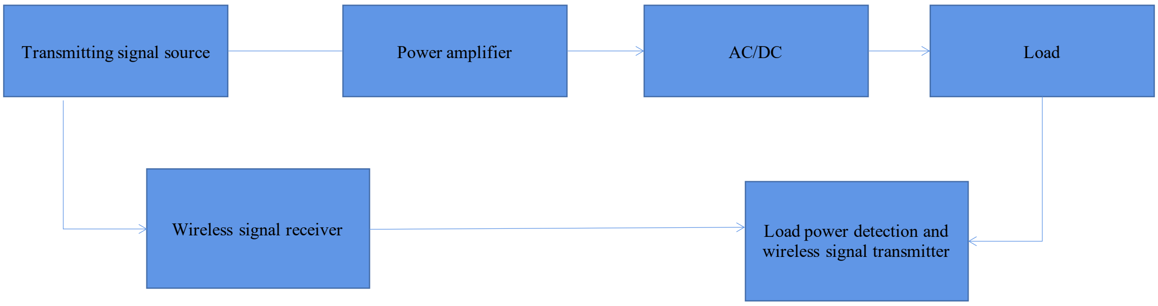

Fig. 3.1: Adaptive frequency tracking WPT system.

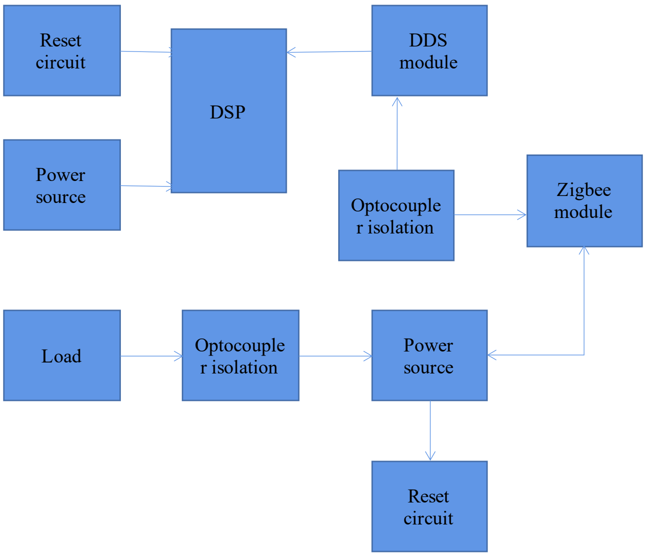

Fig. 3.2: Zigbee hardware circuit.

are transmitted to the Zigbee receiving end through the Zigbee transmitting end, and then to the DSP (the Zigbee receiving end is controlled by the DSP), the DSP immediately triggers an improved genetic algorithm for iterative calculation (calculating the system operation once and generating the corresponding power value), and takes the frequency generated under convergence conditions after 27 iterations as the ideal source frequency for this distance [3].

The wireless communication device in this system adopts Zigbee, with a working frequency of 2550 MHz, a baud rate of 9500, a working channel of Channel20, and a transmission distance of 4 meters. The Zigbee communication module consists of two boards, the transmitter and receiver. The transmitting end and power detection module are both controlled by the load end MCU, and the receiving end is controlled by DSP. The specific hardware circuit is shown in Figure 3.2.

3.2. Modeling and analysis of transmission system. The common resonant radio energy transmission system mainly consists of the following three parts: Power module, resonator module, and load module. The power module is used to generate high-frequency current, thereby driving the transmission coil in the resonator module. The resonator module consists of a transmitting coil, a compensating capacitor at the transmitting end, a receiving coil, and a compensating capacitor at the receiving end. The load module end is composed of high-frequency rectifier and voltage regulator, and the load forms a fork. The high-frequency power supply provides high-frequency current to the transmitting coil through a high-frequency inverter circuit. Due to the

Table 3.1: Setting parameters for each parameter in the simulation coupling circuit diagram.

Parameter	Value (1)	Value (2)	Value (3)
Power and load resistance	11	29.8	7.3
R_{sourco} ;R_{Load}/Ω	0	0	0
Primary inductance L1/H	0.93×10^{-5}	310×10^{-5}	255.08×10^{-5}
Secondary inductance L2/H	0.93×10^{-5}	43.18×10^{-5}	52.637×10^{-5}
Primary and secondary capacitance C_1,C_2/F	245×10^{-8}	245×10^{-8}	245×10^{-8}
Primary and secondary resistance R_1,R_2/ Ω	0.2	0.2	0.2
Coupling coefficients K_1,K_2	0.4	0.2007	0.1818
Mutual inductance coefficient M/H	22.834×10^{-5}	22.834×10^{-5}	23.165×10^{-5}
Frequency f0/Hz	2×10^{12}	52×10^{4}	46×10^{4}

resonance frequency being equal to that of the receiving coil, the circuit in the transmitting coil generates resonance, and its current generates an electromagnetic field of the same frequency that is coupled to the receiving coil by the near field. It is then supplied to the load through a rectification circuit to achieve wireless energy transmission [10, 18].

According to the equivalent circuit and KVL law, the circuit equation is listed as follows (3.1):

$$\begin{bmatrix} R_0 + j\omega L_0 j\omega M_{10} \\ j\omega M_{10} R_1 + j\omega L_1 + \frac{1}{j\omega C_1} \end{bmatrix} \tag{3.1}$$

According to equation (3.1), the output voltage gain of the two transmission coil system becomes equation (3.2):

$$s_{22} = \frac{\omega k_{12}\sqrt{L_1, L_2, R_l}}{Z_1'\left(Z_2' + R_L\right) + \omega^2 k_{12}^3 L_1 L_2} \tag{3.2}$$

In the equation, Z represents the equivalent impedance of the entire circuit. When the system is in a resonant state, equation (3.3) can be expressed as:

$$s_{22} = \frac{\omega k_{12}\sqrt{L_1, L_2, R_l}}{R_1\left(R_2 + R_L\right) + \omega^2 k_{12}^3 L_1 L_2} \tag{3.3}$$

3.3. MATLAB simulation data processing. Simulate using MATLAB software Simulink. Under the premise of ensuring transmission efficiency and voltage gain in the simulation diagram, the parameter settings are shown in Table 3.1.

Provide three wireless transmission system design parameters based on simulation experimental values (1)∼(3). The system voltage gain must not be less than 85%. The system coupling coefficient K is 03, and the design parameters should be as close as possible to ensure that the transmission system has a relatively long transmission distance. At the same time, resistors 289, 7.3, and 12 Ω are used as load resistors for three schemes, and the three design objectives are transformed into multi-objective optimization problem models. Based on the multi-objective genetic algorithm proposed above, the three optimization problem models are solved to design a transmission system scheme that meets the objective function. Firstly, set the variation range of each circuit parameter in the system, assuming that the relative variation range of load resistance is [-1.6%, 1.4%]. The relative variation range of other circuit parameters is [-3%, 3%]. Set the population to 110 and the number of iterations to 220 [7, 16]. The multi-objective genetic optimization algorithm can be used to search for the optimal objective function and corresponding optimal circuit parameter scheme that meets the design objectives. The specific objective function is as follows (3.4)-(3.8).

1) Objective function 1:

$$\begin{aligned} s_{22} &= \frac{\omega k_{12}\sqrt{L_1, L_2, R_l}}{R_1\left(R_2 + R_L\right) + \omega^2 k_{12}^3 L_1 L_2} \\ 0.8 < S_{22}' &= \frac{put}{pin} < 1 \end{aligned} \tag{3.4}$$

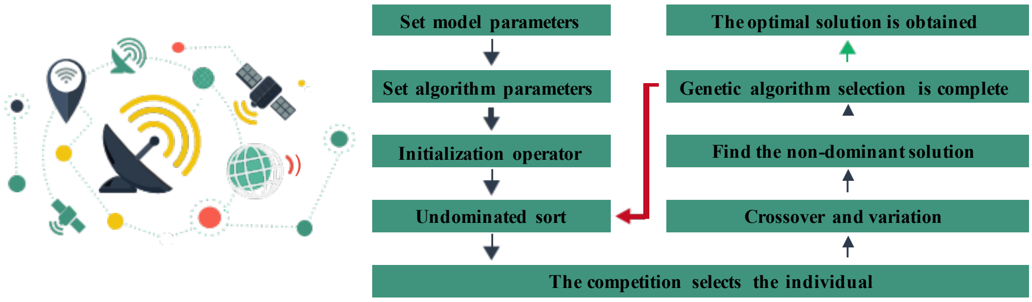

Fig. 4.1: Genetic algorithm process.

2) Objective function 2:

$$M = \frac{\pi \mu n r^4}{2D^3} \tag{3.5}$$

3) Coupling coefficient:

$$k = \frac{M}{\sqrt{L_2 L_1}} < 0.4 \tag{3.6}$$

4) Load resistance:

$$R_L(1 - 0.016) \le R_L(1 + 0.016) \tag{3.7}$$

5) Resistance of primary and secondary circuits:

$$R_2(1 - 0.4) \le R_1 = R_2 = 0.1\Omega \le R_2(1 + 0.4) \tag{3.8}$$

4. Experiments.

4.1. Validation of data validity based on genetic algorithms. Using genetic algorithms to simulate the process of biological evolution through computer simulation for search and evolution, and ultimately seeking the optimal solution. The parameter design and implementation process of the magnetic coupling WPT system based on genetic algorithm proposed by the author is shown in Figure 4.1 [12, 11].

4.2. Algorithm process.

1) Set model parameters, set the number of objective functions and variables; Set the upper and lower limits of model parameters based on constraint conditions.

2) Set the algorithm parameters, including the number of chromosomes included in the solution set (population) to 320, the maximum number of iterations to 210, the mutation rate to 0.2%, and the crossover rate to 0.9%.

3) According to the encoding method, initialize the chromosomes and generate the initial chromosomes completely randomly. The initial group data should generally not be too large or too small, and 25-210 is generally selected, which is conducive to the stable convergence speed of the search [20].

4) Fast non dominated sorting, using non dominated sorting algorithms to layer populations of size n. The set of non dominated individuals is the first level non dominated layer of the population. Then, ignoring these marked non dominated individuals and following the aforementioned hierarchical steps, the first level non dominated layer is obtained. And so on, until the entire population is stratified. The fast non dominated sorting of genetic algorithms reduces computational complexity.

5) The tournament method selects individuals, and the tournament selection strategy selects a certain number of individuals from the population each time, and then selects the best one to enter the offspring

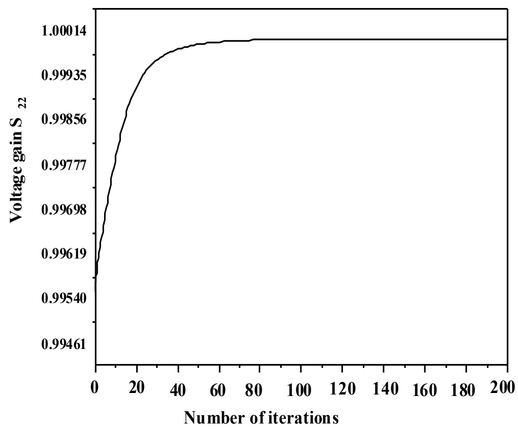

Fig. 4.2: Iterative curve of genetic optimization for system voltage gain coefficient.

population. The competition selection method in genetic algorithm is a return sampling. Repeat this operation until the new population size reaches the original population size. A few yuan tournament is a process of extracting several individuals from the population at once, and then selecting the optimal individual from these individuals and placing them in a set reserved for the next generation of population. Repeat this operation several times as many individuals need to be saved.

6) By using single point mutation and encoding with numerical values and text, methods such as swapping genes at any position with their preceding or following genes or other genes at any position can be used [6, 14]. $r_1 = 2$, then the variation of chromosomes is equation (4.1):

$$[0.2, 0.6, 1.4, 0, 0.5] \to [0.2, 0.3, 1.4, 0.5] \tag{4.1}$$

7) Crossing, using two point crossing, first determines the crossing position of two parental chromosomes. The operation of forming a child chromosome from a part of the paternal chromosome and a part of the other paternal chromosome obtains two offspring chromosomes, also known as single point crossing.

Selected two paternal chromosome formulas (4.2):

$$\begin{aligned} &[0.2, 0.6, 1.4, 0, 0.5][0.4, 0.23, 0.43, 0.9, 0.8]_{(10)} \\ &r_1 = 2, r_2 = 5 \end{aligned} \tag{4.2}$$

So the cross process is equation (4.3):

$$[02, 06, 1.4, 0, 05][04, 023, Q43, 09, Q9] \tag{4.3}$$

Cross Posterior (4.4):

$$[0.2, 0.23, 0.43, 0.9, 0.5][0.4, 0.6, 1.4, 0.8] \tag{4.4}$$

8) Find non repetitive non dominant solutions and combine the population of the previous generation with the population of the current generation after mutation crossover into one population. Adopting an elite selection strategy, it merges the parent population with the offspring population, allowing the next generation's population to be selected from twice the space, thereby preserving all the best individuals and ensuring that certain excellent population individuals are not discarded during the evolution process.

4.3. Numerical simulation analysis. The numerical simulation analysis is shown in Figures 4.2-4.4.

From the analysis of Figures 4.2-4.4, it can be seen that using the values in Table 3.1 (3) for system parameter design meets the optimal requirements for both the voltage gain coefficient and transmission distance objective

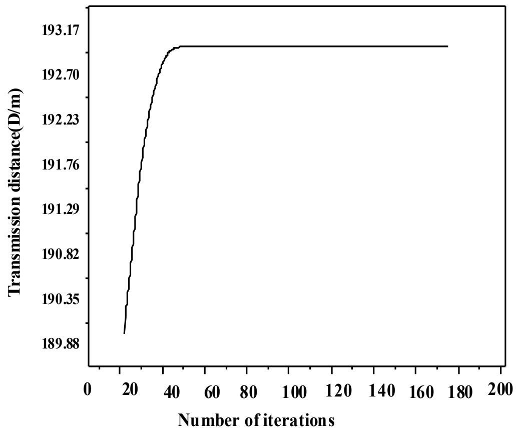

Fig. 4.3: Optimization iterative curve of transmission distance objective function by genetic algorithm.

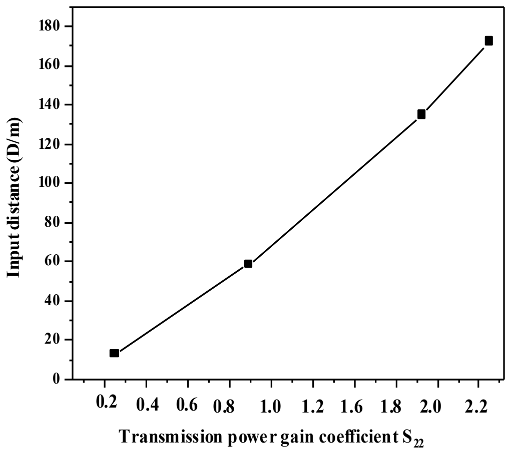

Fig. 4.4: Pareto solution of genetic algorithm optimization objective function.

function of the transmission system. As shown in Figures 4.2 and 4.3, genetic algorithm is used to obtain the iterative curve of the objective function with good convergence, fast convergence speed, and strong search ability. This indicates that the algorithm is effective. The two objective functions in Figure 4.4 are completely in the same direction and have only one non dominant solution [8, 19].

5. Conclusion. The author derived a mathematical formula for the voltage gain of a radio energy transmission system through the theoretical knowledge of coupled circuits, and analyzed the impact of eddy current effect generated when metal obstacles exist on the transmission efficiency of the transmission system. That is, the eddy current effect generated by good conductor obstacles reacts with the impedance of the transmitting and receiving coils, increasing the impedance and thereby affecting the voltage gain coefficient of the transmission system. Then, a circuit model of the wireless energy transmission system was built through MATLAB simulation, and three sets of system parameter values were obtained. When the objective function condition is met: The voltage gain coefficient is not less than 0.9, the transmission distance is ensured as far as possible, and the coupling coefficient is not higher than 0.4. There are also transmission system constraints. Using multi-objective genetic algorithm, the algorithm's iteration function converges quickly, there is a non dominated function solution, and Pareto graph validates that the value (3) in Table 3.1 is the optimal combination design for the transmission system.

REFERENCES

[1] W. G. Bin, Z. Y. Fan, W. Chao, W. X. Chuang, M. Jun, L. Xiao-Dong, and Z. Li, *Multi-level peer-to-peer collaborative optimization of smart energy system based on big data analysis*, in Journal of Physics: Conference Series, vol. 1965, IOP Publishing, 2021, p. 012145.

[2] I. S. Bulut and H. Ilhan, *Energy harvesting optimization of uplink-noma system for iot networks based on channel capacity analysis using the water cycle algorithm*, IEEE Transactions on Green Communications and Networking, 5 (2020), pp. 291–307.

[3] J. Cui, H. Li, D. Zhang, Y. Xu, and F. Xie, *Multi-objective optimization of hydro-viscous flexible drive for dynamic characteristics using genetic algorithm*, Industrial Lubrication and Tribology, 73 (2021), pp. 1003–1010.

[4] T. Delebarre, V. Gras, F. Mauconduit, A. Vignaud, N. Boulant, and L. Ciobanu, *Efficient optimization of chemical exchange saturation transfer mri at 7 t using universal pulses and virtual observation points*, Magnetic Resonance in Medicine, 90 (2023), pp. 51–63.

[5] R. R. Devi and T. Sethukarasi, *An energy-efficient routing based on a hybrid improved whale artificial ecosystem optimization algorithm in wsn*, Concurrency and Computation: Practice and Experience, 34 (2022), p. e6639.

[6] G. Liu, Y. Qin, M. Li, Y. Liu, J. Zheng, X. Liu, and Y. Yin, *Performance analysis and optimization of a pemfc-caorc system based on 3d construction method of thermodynamic cycle*, Energy Conversion and Management, 247 (2021), p. 114730.

[7] J. Liu, F. Zhang, C. Cattand, H. Yang, and S. Wanqing, *Optimization of atp system based on quantum secure communication and its tracking control strategy*, Shock and Vibration, 2021 (2021), pp. 1–13.

[8] A. Mahrooghi and E. Lakzian, *Optimization of wells turbine performance using a hybrid artificial neural fuzzy inference system (anfis)-genetic algorithm (ga)*, Ocean Engineering, 226 (2021), p. 108861.

[9] R. K. Prasad and T. Jaya, *Intelligent spectrum sharing and sensing in cognitive radio network by using aroa (adaptive rider optimization algorithm)*, International Journal of Computational Intelligence and Applications, 22 (2023), p. 2341007.

[10] S. Sahraeian and F. Emami, *Design and optimization of frequency-tunable terahertz absorbers based on graphene using genetic algorithm*, Optical Engineering, 61 (2022), pp. 067105–067105.

[11] K. Sheelavant and R. Sumathi, *Correlative dynamic mapping based optimization (cdmo) for optimal allocation in cognitive radio sensor network*, Revista Gesto Inovao e Tecnologias, 11 (2021), pp. 3955–3973.

[12] P. Shi, Y. Qin, Y. Cao, H. Zhao, R. Gao, and S. Liu, *Topology optimization of metamaterial microstructure for wireless power transfer with high power transmission efficiency*, Journal of Magnetism and Magnetic Materials, 537 (2021), p. 168228.

[13] F. S. Tabataba, P. Rouhani, and M. Koolivand, *Energy efficiency optimization for amplify and forward relay networks with channel estimation errors*, Telecommunication Systems, 76 (2021), pp. 541–552.

[14] C. Tang, B. Xue, and L.-X. Wang, *Optimization design of shaped charge based on improved genetic algorithm*, in IOP Conference Series: Materials Science and Engineering, vol. 1043, IOP Publishing, 2021, p. 042034.

[15] L. Wang and R. Chou, *Energy efficiency research of decode-and-forward two-way simultaneous wireless information and power transfer full-duplex relay system*, Journal of Signal Processing, 38 (2022), pp. 806–815.

[16] B. Wu and S. Zhang, *Energy management strategy for dual-motor two-speed transmission electric vehicles based on dynamic programming algorithm optimization*, SAE International Journal of Electrified Vehicles, 10 (2021), pp. 19–32.

[17] G. Xia, J. Chen, X. Tang, L. Zhao, and B. Sun, *Shift quality optimization control of power shift transmission based on particle swarm optimization–genetic algorithm*, Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 236 (2022), pp. 872–892.

[18] Z. Yan, D. Yin, L. Chen, and W. Shen, *Research on the torsional vibration performance of a cvt powertrain with a dual-mass flywheel damper system*, Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 236 (2022), pp. 1144–1154.

[19] S. Zhang, Y. Zheng, and G. Li, *Research on distribution center layout optimization based on genetic algorithm*, in Journal of Physics: Conference Series, vol. 1976, IOP Publishing, 2021, p. 012010.

[20] G. Zhou, R. Liu, Z. Zhang, C. Yang, and H. Ding, *Optimization of diesel engine dual-variable geometry turbocharger regulated two-stage turbocharging system based on radial basis function neural network-quantum genetic algorithm*, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, (2021), pp. 1–17.

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