Research on ADRC for Strong Magnetic Resonance Coupling System

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Abstract: Aiming at strong magnetic resonance coupling system(SMRCS), this paper has built the system of wireless power transmission under the control of the classic PID, and then an ADRC(Active Disturbance Rejection Control) is designed to replace the traditional PI controller in the system to enhance the anti-jamming performance and the accuracy of identification.The controller is composed of three parts: tracking differentiator, extended state observer and nonlinear combination. The simulations of two control system have been carried out in this paper. The two groups of control methods are analyzed and compared, and the results of simulation show that the ADRC has the advantages of strong anti-interference ability, high accuracy of identification, good robustness and simple algorithm.It is suitable for the control of the wireless power transmission under the strong magnetic resonance coupling system.

1 INTRODUCTION

Wireless transmission technology is a hot topic in the field of energy transmission in recent years. The technology of wireless power transmission is mainly based on inductive mode at this stage. Through the magnetic field of high frequency to create energy transfer channel between power supply instrument and electric appliance, to transmit power in a non-contact way，Compared with the traditional contact mode, the non-contact mode is safe, reliable and low cost (Zhai yuan, 2014). It can overcome the unfavorable environmental factors and so on. In recent years, the research on wireless power transmission in strongly coupled resonant systems has attracted more and more academic attention. In the strong magnetic resonance coupled radio power transmission system, because the two resonant links are added, the order of the whole system is increased, and the transmission law of the electric energy is different from the former electromagnetic induction (Han Jingqing, 2008).

A wireless transmission system consisting of four coils is established in the literature, and the output voltage is adjusted by the traditional PID control to keep the output signal constant. In order to identify and control the relative parameters of secondary side through the primary side, the phase of the voltage and current of the primary coil is obtained by mutual inductance model, and the mutual inductance and the magnitude of the load impedance are obtained. Get the function relationship between the input voltage to the output voltage through the related parameter identification.we construct the Buck converter to adjust the input voltage.Because the input and output of Buck converter can be obtained by the relevant primary side, there is no need to construct other measuring circuit. It reduces costs and improves reliability (Bai Mingxia, 2010). In addition, the traditional PI controller in the system is replaced by ADRC in this paper. By comparing the output signals, datas and images after the replacement of the system, it highlights the better correction and anti-interference function of the ADRC.

2 THE SMRCS UNDER TRADITIONAL PI CONTROL

2.1 Proposed technical scheme

A radio energy transmission system under typical strong magnetic coupling resonant mode consists of 4 coils, one of which is a transmitting coil, one is a receiving coil, and the other are two resonant coils. The input signal through the energy conversion, then converting electrical energy into magnetic energy by

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the transmitting coil .The first resonant coil receives the converted magnetic energy and transmitted it to second resonant coils by means of wireless transmission (Wang Wenhu, 2015). Finally, the energy of the second resonant coils is received by the receiving coil and subjected to magnetoelectric conversion. The magnetic energy is then converted into electrical energy and transferred to electrical equipment after adjustment. This is the principle of strong magnetic coupling resonance (Wang Zhaoan, 2013).

When the mutual inductance, load size and other variables change between the resonant coils, the output signal of the system will change accordingly. The mutual inductance of the resonance coil and the magnitude of the load can be identified by measuring the phase between the current and voltage in the transmitting coil, and other predetermined parameters can be measured ahead of time (Zhang Xinghui, 2014). The output signal can be controlled by changing the input signal of the inverter, so as to keep it stable (Zhu Cheng, 2014). The function of changing the input signal of the inverter bridge can be achieved by adjusting the Buck circuit. When the mutual inductance between coils or transformer load changed ，the constant output voltage of the system can be realized by reasonably changing the duty cycle of the Buck converter. The whole block diagram of the strong magnetic coupling system is shown in the following figure (Wang Yu, 2013).

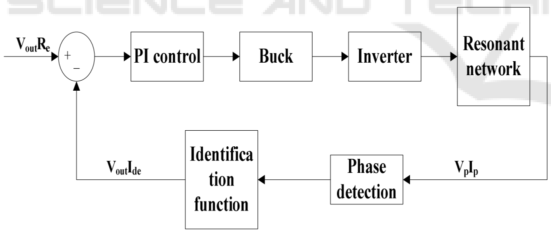

Figure 1: The system structure diagram

2.2 Derivation of output voltage formula

In the strong magnetic coupling resonance system for wireless power transmission, when the system frequency is low, the coil radiation loss resistance Rra and ohmic loss resistance Rr in the system can be neglected (Hu Jian, 2014).

It is assumed that the resonant angular frequency of the system is W0，the transmitter coil current is Ip, voltage is Vp, the phase between the two angles is alpha, the time difference between the current and voltage is △t, It is assumed that the mutual inductance between the transmitter and the resonant coil 1 is Mps, and the mutual inductance between the receiver and the resonant coil 2 is Mrl.

Mutual inductance between resonant coils can be derived:

$$M_{sr}=M_{rl}M_{ps}\sqrt{\frac{w_0}{w_0 L_p L_L - L_L V_p sin w_0 \Delta t/Ip}} \tag{1}$$

The equivalent load impedance can be deduced :

$$R_{ac}=\frac{w_0 L_L V_p cos w_0 \Delta t}{w_0 L_p - V_p sin w_0 \Delta t / I_p} \tag{2}$$

The input equivalent voltage of the inverter is assumed to be Vi.The output voltage of the strong magnetic coupling resonance system is as follows:

$$V_o=\frac{L_L M_{sr} R_{ac}}{M_{ps} M_{rl}\sqrt{(R_{ac}^2 + w_0^2 L_L^2)}} V_i \tag{3}$$

From the upper model, the mutual inductance changes between the coils will cause the output voltage of the strong magnetic coupling resonance system to change accordingly. On the other hand, other component parameters can be set as fixed quantities or derived according to relevant step detection. When the output voltage of the system is changed, a BUCK circuit can be set to adjust the output voltage. By adjusting the duty cycle, the output voltage is stabilized at a constant value (Liu Keyi, 2014).

Assuming that the duty ratio of the BUCK converter circuit is D, the expression of the final output voltage is obtained:

$$V0=\frac{D L_L M_{sr} R_O \pi^2}{M_{ps} M_{rl}\sqrt{(\pi^4 R_0^2 + 64 w_0^2 L_L^2)}} E_{dc} \tag{4}$$

On the basis of the BUCK transform circuit, the PI controller is added to detect and correct the error between the actual output voltage and the artificially given voltage .It can adjust the duty cycle of the BUCK circuit,to ensure that the actual output voltage is generally stable at an ideal constant value.

2.3 Experimental study under PI control

MATLAB is used to build the system simulation circuit, and a real-time dynamic resistor is added into the system as the interference signal. When changing the value of the load or mutual inductance，As can be seen from the figure below, the PI controller can basically adjust the duty cycle, so that the output voltage of the system is always stable near a constant value. But the graphic fluctuation is frequent, and the system anti-interference ability is poor.

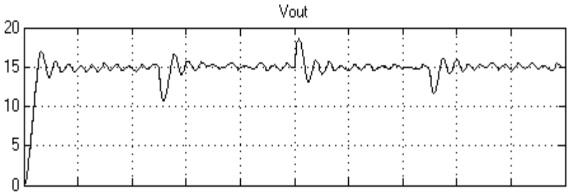

Figure 2: Output voltage waveform when load changes

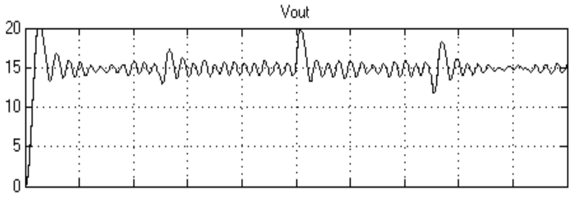

Figure 3: Output voltage waveform when mutual inductance is changed

3 THE SMRCS UNDER ADRC CONTROL

3.1 The basic structure and algorithm of ADRC

The ADRC is composed of three parts: tracking differentiator(TD), extended state observer(ESO) and nonlinear combination(NLC). In ADRC, the transition process for parameter input is implemented by TD, which allows for smooth input signals and get the corresponding differential signals. As the core part of the ADRC, the ESO is used to reconstruct the object model by double channel compensation, which makes the uncertain and nonlinear system deterministic and linearized (Liu Keyi, 2014). By measuring the controlled object through ESO, both the values of each state variable and the right side estimation of the controlled object equation, that is, the disturbance estimation, can be measured. Take the output of TD and the state variable given by ESO, estimate the error between them, and get the error of the state variable.

3.2 Design of ADRC

The block diagram of ADRC is shown in the following figure. G (s) is the whole transfer function of the strong magnetic coupling resonance system.

Adjust the related parameters and components of the ADRC simulation circuit, add it to the system and replace the PI controller in the original system after encapsulation.

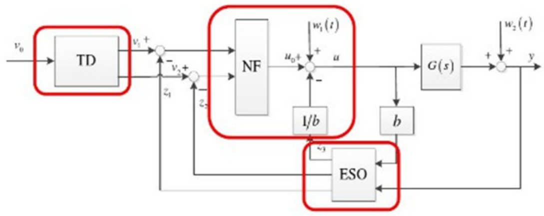

Figure 4: ADRC block diagram

3.3 Experimental study of ADRC

The parameters of the simulation circuit and ADRC are adjusted(Bagus Manhawan, 2000). When the parameters of the system are basically stable and able to work properly， Through the control variable method, the parameter identification under the load change and mutual inductance change are studied respectively.Make sure that changes are consistent with the changes in traditional PI controls (B C KUO, 1989).

When changing the value of the load or mutual inductance， as can be seen from the figure below, the ADRC can basically adjust the duty cycle, so that the output voltage of the system is always stable near a constant value. And the graphic fluctuations are basically eliminated. The system anti-interference ability also be better.

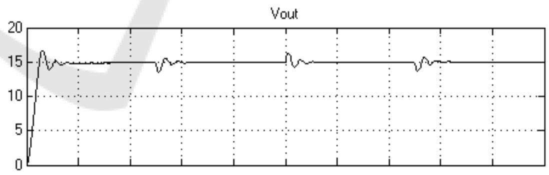

Figure 5: Output voltage waveform when load changes

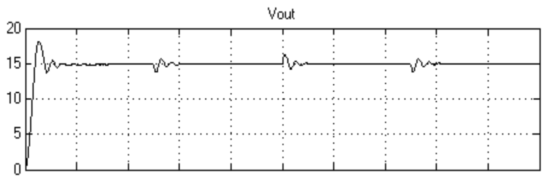

Figure 6: Output voltage waveform when mutual inductance is changed

4 COMPARISON OF PID CONTROL AND ADRC

The experimental results show that the strong magnetic coupling resonance system with ADRC has the following characteristics as compared with the traditional PID controller.

1. When the load or mutual inductance of the system changes, the feedback detection mechanism in the system can detect this change by the phase angle of the coil voltage and current. The two controllers can complete the corresponding parameter identification. But the system parameter identification under ADRC is more accurate and closer to the actual given value.

2. When the system related parameters are changed, the output voltage of system is calculated by the controller, and it is always stabilized near a constant value by changing the duty ratio of the BUCK circuit. The two controllers can basically complete the correction function. But the output voltage fluctuation of the system under traditional PID controller is larger. The output fluctuation of the system under ADRC is smaller, and it has stronger anti-interference ability.

3. The amplitude and overshoot of output voltage fluctuation with ADRC are smaller . It can be seen from the following table.

Table 1: Comparison of load changes

	Maximum amplitude /V	Overshoot /%
PID	18.1	20.7
ADRC	16.4	9.3

Table 2: Comparison of mutual inductance changes

	Maximum amplitude /V	Overshoot /%
PID	23.1	30.3
ADRC	17.7	18

Through the comparison, the ADRC can not only realize the correction and adjustment function of the traditional PID controller, but also make the system have better identification function and stronger anti-interference ability. It has the function of optimizing the system.

5 CONCLUSIONS

In this paper, the wireless power transmission of a strong magnetic coupling system under the control of ADRC is studied.And it is compared in detail with the results of a same system under the control of the traditional PID controller.To prove that compared with the traditional PID controller, it has better correction function and anti-interference ability. In the experimental research, the ADRC algorithm is added, and the traditional PID controller is replaced by the ADRC. It greatly improves the parameter identification ability of system, and the identification result is more accurate. It can eliminate the output voltage fluctuations caused by the disturbance, so that the system output voltage remained stable.

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