



Design of Anti-interference Control System for Vacuum Packaging Machine Based on Wireless Network

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Abstract. In order to improve the anti-interference control ability of vacuum packaging machine, the design method of anti-interference control system of vacuum packaging machine based on wireless network is put forward. The system design is divided into anti-interference control algorithm design and hardware design of vacuum packaging machine. The parameter distribution model of anti-interference control of vacuum packaging machine is constructed. The output voltage, power and potential field of vacuum packaging machine are taken as the control constraint parameters. The difference between the output phase current of the vacuum packaging machine is calculated, the saturation function is constructed to analyze the control decision variables of the vacuum packaging machine, the sampling output voltage stabilizing characteristic quantity and PWM duty cycle are taken as the modulation parameters, the equivalent mechanical power and equivalent electromagnetic power of the vacuum packaging machine are calculated, and the network output design of the anti-interference control system of the vacuum packaging machine is carried out in the wireless network. The hardware design of anti-interference control system of vacuum packaging machine is carried out by using FPGA. The test results show that the output stability of anti-interference control of vacuum packaging machine is good and the robustness of motor control is strong.

Keywords: Wireless network · Vacuum packaging machine · Anti-interference · Control system

1 Introduction

The control system of vacuum packaging machine is a motor system which uses permanent magnet and transducer to carry out multi-channel servo synchronous conversion. In the design of vacuum packaging machine, due to the instability of output power, the stability of output power of vacuum packaging machine is not good, so it is necessary to adjust and optimize the output power of vacuum packaging machine [1]. Combined with the output parameter adjustment method of vacuum packaging machine, the parameter stability analysis is carried out. It is of great significance in the design and application of vacuum packaging machine to establish the parameter self-tuning model of vacuum packaging machine, to improve the output stability of vacuum packaging machine, and to study the control method of vacuum packaging machine [2].

At present, the control methods of vacuum packaging machine are mainly based on fuzzy neural network control method and BP control method. Based on fuzzy PID adaptive parameter adjustment model, the output stability control of vacuum packaging machine is carried out to improve the stability of motor control, but the output power gain of anti-interference control of vacuum packaging machine is not good [3]. In order to solve the above problems, this paper puts forward the design method of anti-interference control system of vacuum packaging machine based on wireless network. The system design is divided into anti-interference control algorithm design and hardware design of vacuum packaging machine. The parameter distribution model of anti-interference control of vacuum packaging machine is constructed. The sampling output voltage stabilizing characteristic quantity and PWM duty cycle are used as modulation parameters. Combined with fuzzy PID control method, the output robustness control of vacuum packaging machine is carried out [5]. The equivalent mechanical power and equivalent electromagnetic power of vacuum packaging machine are calculated, the self-tuning method of motor output is carried out by using the optimal parameter adjustment method, the transient stability of vacuum packaging machine is adjusted based on the method of terminal voltage average analysis, the anti-interference control law of vacuum packaging machine is optimized, and the anti-interference control system of vacuum packaging machine is optimized with FPGA. Finally, the simulation test and analysis are carried out, it draws the conclusion of validity.

2 Equivalent Circuit Analysis and Control Constraint Parameters of Anti-interference Control of Vacuum Packing Machine

2.1 Equivalent Circuit Analysis of Anti-interference Control of Vacuum Packaging Machine

In order to optimize the anti-interference control of vacuum packaging machine, it is necessary to construct the parameter distribution model of anti-interference control of vacuum packaging machine. Taking the output voltage, power and potential field of vacuum packaging machine as the control constraint parameters, the control parameters are optimized and adjusted, the equivalent circuit model of anti-interference control of vacuum packaging machine is established, and the primary side circuit and secondary side circuit are used for electromagnetic coupling adjustment [6]. The electromagnetic coupling control model of anti-interference control of vacuum packaging machine is established, and the equivalent circuit of anti-interference control of vacuum packaging machine is obtained as shown in Fig. 1.

According to Fig. 1, the output conversion control model of vacuum packaging machine is constructed by using "T" equivalent, and the output power of vacuum packaging machine is adjusted adaptively by using the transient stability analysis method of generator power angle combined with the parameters such as output power, electromagnetic torque and power gain of the motor, the constraint parameter model is established [7], and the electromagnetic torque coupling control of vacuum packaging

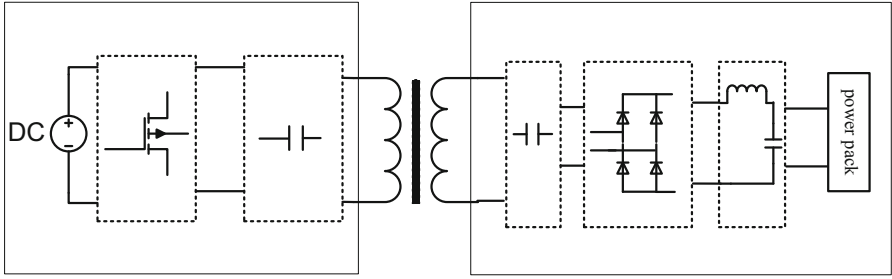


Fig. 1. Equivalent circuit of anti-interference control of vacuum packing machine

machine is carried out by using the method of virtual synchronous control. The coupling parameter model is obtained:

$$NI = \pi l_w(2r_r + 2l + l_w)J_{cu}k_fk_c \tag{1}$$

Among them, the power output transfer coefficient of vacuum packaging machine represents the generation of excitation voltage. For example, $k_c = 2/3$, combined with feedback gain adjustment method, the output magnetic flux of vacuum packaging machine is obtained as follows:

$$B_g = \frac{F_m}{A_g \mathfrak{R}} \tag{2}$$

Wherein, F_m is the proportional integral control parameter of reactive power loop, A_g is the air gap area of winding, and \mathfrak{R} is the phase angle of rotor reference voltage. The difference between the output phase current of the vacuum packaging machine is calculated, the saturation function is constructed to analyze the control decision variables of the vacuum packaging machine, the equivalent circuit model is established, and the optimal control design of the motor is carried out [8].

2.2 Control Constraint Parameter Analysis

Combined with the analysis method of inertia response characteristics of motor system, the inertia characteristics and frequency response of the calculated system are calculated, and the magnetic field capacitance and winding capacitance of motor are obtained [9], and the fuzzy parameters of continuous compensation control of vacuum packaging machine are satisfied.

$$\omega L_{lp} - \frac{1}{\omega C_p} = 0 \Rightarrow C_p = \frac{1}{\omega^2 L_{lp}} \tag{3}$$

$$\omega L_{ls} - \frac{1}{\omega C_s} = 0 \Rightarrow C_s = \frac{1}{\omega^2 L_{ls}} \tag{4}$$

By analyzing the inertia characteristics of the vacuum packaging machine system, combined with the electromagnetic coupling compensation control method, the impedance of each part of the vacuum packaging machine is as follows:

$$Z_3 = R_{eq} + Z_s \quad (5)$$

$$Z_2 = \frac{Z_m(R_{eq} + Z_s)}{Z_m + R_{eq} + Z_s} \quad (6)$$

$$Z_1 = \frac{Z_m + R_{eq} + Z_s}{Z_p(Z_m + R_{eq} + Z_s) + (R_{eq} + Z_s)Z_m} \quad (7)$$

Wherein

$$Z_p = R_p + jX_p = R_p + j(\omega L_{lp} - \frac{1}{\omega C_p}) \quad (8)$$

$$Z_s = R_s + jX_s = R_s + j(\omega L_{ls} - \frac{1}{\omega C_s}) \quad (9)$$

$$Z_m = j\omega L_m \quad (10)$$

The equivalent conversion of rotor voltage and stator and rotor current is carried out, and MUR1620CT is used as regulator to adjust the output coupling of vacuum packaging machine [10]. The inertia gain of synchronous motor is obtained as follows:

$$G_V = \left| \frac{R_{eq} Z_2}{Z_3 Z_1} \right| = \left[(ac - bd)^2 + (bc + ad)^2 \right]^{-\frac{1}{2}} \quad (11)$$

The output stability of the vacuum packaging machine is controlled according to the combined estimation method of the stator voltage and the rotor voltage, and the saturation tracking error of the output voltage of the vacuum packaging machine is as follows:

$$\frac{R_{eq}}{Z_3} = \frac{R_{eq}}{R_{eq} + Z_s} \quad (12)$$

The output robustness control of the vacuum packaging machine is carried out in combination with the fuzzy PID control method by constructing an error compensation function to perform the output steady-state adjustment of the vacuum packaging machine, the sampling output voltage stabilizing characteristic amount and the PWM duty ratio as the modulation parameters, and combining the fuzzy PID control method to carry out the output robustness control of the vacuum packaging machine [11].

3 Optimization of Anti-interference Control Algorithm for Vacuum Packaging Machine

3.1 The Control Parameters Are Adjusted Adaptively

The equivalent mechanical power and equivalent electromagnetic power of vacuum packaging machine are calculated. The optimal parameter adjustment method is used to self-adjust the motor output, and the output power of electromagnetic torque of vacuum packaging machine is adjusted adaptively. The method of small signal disturbance transfer is used to control the motor torque [12]. The optimal regulation model of rotor current and voltage of vacuum packaging machine is obtained as follows:

$$F_m = \frac{B_r l_m}{\mu_0 \mu_{r1}} \quad (13)$$

$$A_g = l_s \frac{\beta \pi}{p} (r_r + l_g) \quad (14)$$

$$\Re = \frac{1}{\mu_0 l_s \beta \pi / p} \left(\frac{1}{\mu_{r1}} \int_{r_r - l_m}^{r_r} \frac{d_r}{r} + \int_{r_r}^{r_r + l_g} \frac{d_r}{r} + \frac{1}{\mu_{r2}} \int_{r_r + l_g}^{r_r + l_g + l_w} \frac{d_r}{r} \right) \quad (15)$$

Wherein the vacuum permeability of the electromagnetic coupler of the vacuum packaging machine is $\mu_0 = 4\pi \times 10^{-7} / \text{m}$, μ_{r1} and μ_{r2} are the magnetic permeability of the permanent magnet and the winding of the vacuum packaging machine. The self-adaptive inversion control method is adopted to calculate rotor resistance, stator, rotor equivalent self-inductance and mutual inductance, and the reverse potential and phase current of the motor are respectively expressed as:

$$R = R_{dc} + \frac{\psi}{3} \Delta^4 R_{dc} \left(\frac{I'}{\omega \cdot I} \right) \quad (16)$$

$$\psi = \frac{5p^2 - 1}{15} \quad (17)$$

$$\Delta = \frac{d_{eff}}{\delta_0} \quad (18)$$

$$R_{dc} = 4\rho \frac{N \cdot MLT}{\pi \cdot Str \cdot d_c^2} \quad (19)$$

$$\delta_0 = \sqrt{\frac{1}{\pi f_{sw} \mu_0 \delta}} \quad (20)$$

Where the $\omega = 2\pi f$. The self-inductance of the phase winding is introduced, the input saturation error of the vacuum packaging machine is regarded as the uncertainty,

and the anti-saturation compensation is carried out on the whole vacuum packaging machine to realize the self-adaptive regulation of the control parameters [13].

3.2 Control Law Optimization

Under the condition of limiting the steady state error, the optimal control model of the vacuum packaging machine is constructed, the output resistance of the vacuum packaging machine and the coupling damping moment of the motor are described as follows:

$$R_{eq} = 8V_0^2 / (\pi^2 P_L) \quad (21)$$

The piecewise saturation function is used to suppress the disturbance inside and outside the boundary layer:

$$\frac{Z_2}{Z_1} = \frac{Z_m(R_{eq} + Z_s)}{Z_p(R_{eq} + Z_m + Z_s) + Z_m(R_{eq} + Z_s)} \quad (22)$$

Wherein

$$a = 1 + \frac{R_s}{R_{eq}} \quad (23)$$

$$b = \frac{X_s}{R_{eq}} \quad (24)$$

$$c = 1 + \frac{R_p R_m + X_p X_m}{R_m^2 + X_m^2} + \frac{R_p(R_{eq} + R_s) + X_p X_s}{(R_{eq} + R_s)^2 + X_s^2} \quad (25)$$

$$d = \frac{R_m X_p - R_p X_m}{R_m^2 + X_m^2} + \frac{X_p(R_{eq} + R_s) - R_p X_m}{(R_{eq} + R_s)^2 + X_s^2} \quad (26)$$

The self-rounding process of the motor output is carried out by adopting an optimized parameter adjusting method, and the transient stability regulation of the vacuum packaging machine is carried out based on the method of the terminal voltage average analysis, and the torque output of the vacuum packaging machine can be expressed as:

$$T_{em} = \frac{\pi k_f k_c k_1 k_\beta B_r l_m l_s l_w (2r_r + 2l_g + l_w) J_{cu}}{\ln\left(\frac{r_r + l_g + l_w}{r_r - l_m}\right)} \quad (27)$$

$$k_1 = 1 - \frac{1}{0.9[r_r / (\beta p (l_g + l_w))]^2 + 1} \quad (28)$$

$$k_\beta = \frac{\alpha(\beta, k_c)}{k_c} \quad (29)$$

finally, the output power loss of the vacuum packaging machine is obtained as follows:

$$P_{loss} = I_p^2(R_p + R_{cp} + 2R_{IGBT}) + I_s^2(R_s + R_{cs} + 2R_{don}) \quad (30)$$

The optimized motor control laws are:

$$\begin{aligned} f_0(\mathbf{X}) &= w_p P_1(\mathbf{X}) + w_v V_t(\mathbf{X}) + w_c C(\mathbf{X}) \\ &+ \frac{1}{\varepsilon} [f_u(1 - T_{em}/T_{em}^*) \\ &+ f_u(1 - \omega_r^{\max}/\omega_r^*) + f_u(B_{sy}/B_{sy}^{knee} - 1)] \end{aligned} \quad (31)$$

The ε is a small constant, and the method of least square optimization is used to obtain the optimized section vector $f_u(\chi)$:

$$f_u(\chi) = \frac{1}{1 + e^{-\sigma\chi}} \quad (32)$$

Based on the method of terminal voltage average analysis, the transient stability of vacuum packaging machine is adjusted, and the anti-interference control law of vacuum packaging machine is optimized, and the control function is optimized:

$$F(x) = \sum_{q=1}^Q e_q^T e_q = \sum_{q=1}^Q \sum_{k=1}^m e_{kq}^2 = \sum_{i=1}^N v_i^2 \quad (33)$$

The self-adaptive linear weighting is adopted to realize the optimized anti-interference control of the vacuum packaging machine.

4 System Hardware Design

On the basis of the above control algorithm design, the hardware of the system is taken together. The anti-interference control system of vacuum packaging machine adopts FPGA as the main control chip, designs the source protection module of the anti-interference control system of vacuum packaging machine, constructs the grounding resistance measurement module to carry on the output conversion control of the anti-interference control system of vacuum packaging machine, and adopts the method of DC constant current output control. The bus transmission of the anti-interference control system of the vacuum packaging machine is carried out, and the information security baseline configuration of the anti-interference control system of the vacuum packaging machine is carried out by using the RS485 bus monitoring method. The hardware structure of the system is shown in Fig. 2.

With the method of integrated design, the information security baseline configuration and man-machine interactive interface design of the anti-interference control

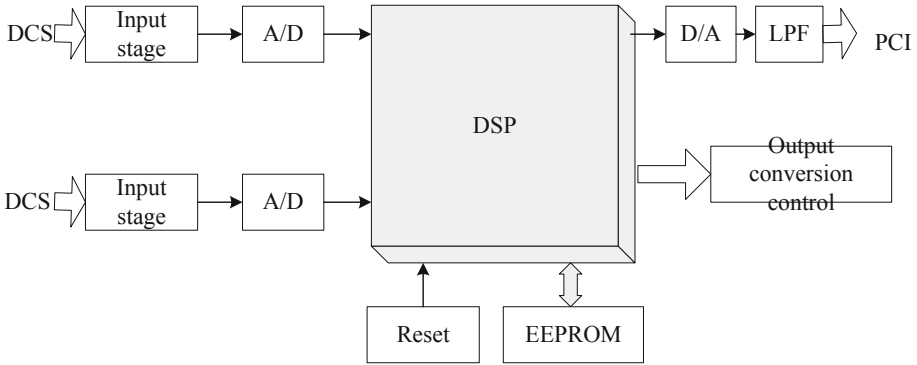


Fig. 2. Hardware structure of the system

system of the vacuum packaging machine are realized in the ROM, and the hardware design of the system is shown in Fig. 3.

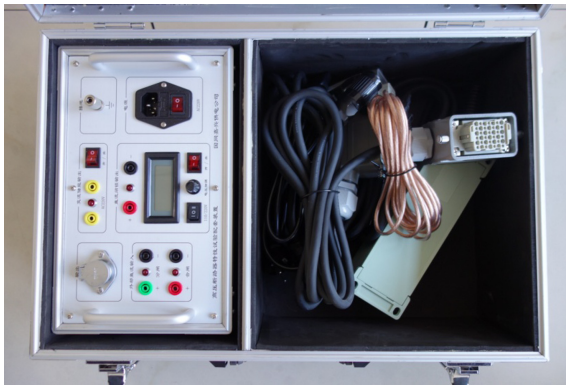


Fig. 3. System hardware design

5 Simulation Test Analysis

In order to test the application performance of the method in the anti-interference control of the vacuum packaging machine, the experiment test is carried out. The input voltage of the vacuum packaging machine is 240 V, the potential observation value is 480 V, the average voltage of the terminal voltage is 120 V, the output current of the motor is 50 A, the rated torque is 0.24 N. m, The initial power is 300 KW, the reference speed and the feedback speed are $G_0(s)e^{-\tau s} = \frac{1}{55s+1} e^{-122s}$ and the permeability $\mu_0 = 4\pi \times 10^{-7}$ H/m, according to the simulation environment and the parameter setting, the anti-interference control of the vacuum packaging machine is carried out, and the output power angle is tested, and the result is shown in Fig. 4.

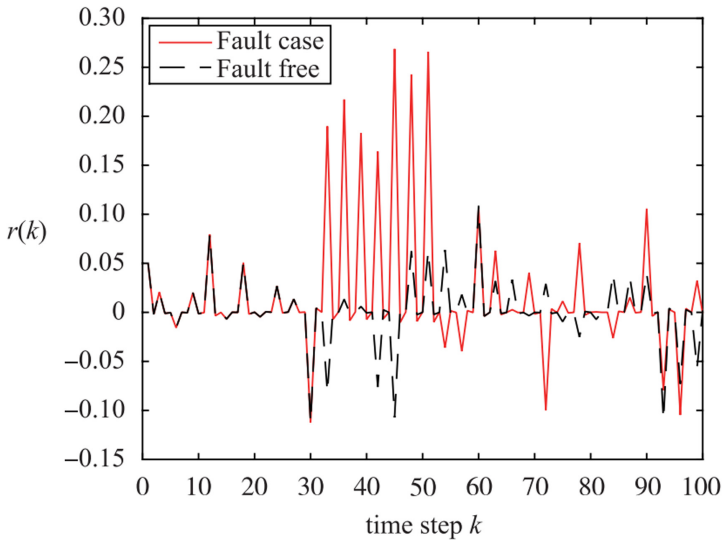


Fig. 4. Output power angle of vacuum package machine

The analysis of Fig. 4 shows that the convergence of anti-interference control of vacuum packaging machine is good, the gain of output power angle is large, the output voltage stabilizing characteristic quantity and PWM duty cycle are tested, and the results are shown in Fig. 5.

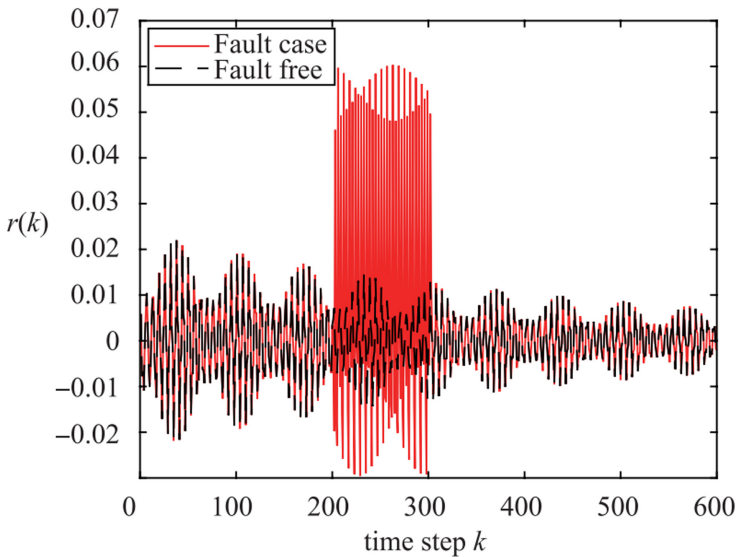


Fig. 5. Output steady voltage characteristic quantity and PWM duty cycle

The analysis of Fig. 5 shows that the anti-interference control of vacuum packaging machine is carried out in this paper, which improves the output power and efficiency, and has good robustness. The output gain of the motor is further tested, and the results are shown in Table 1. The analysis Table 1 shows that the output gain of the anti-interference control of the vacuum packaging machine by this method is higher.

Table 1. Output gain test (unit: dB)

Iterations	Proposed method	Reference [3]	Reference [4]
100	35.4	17.2	23.2
150	33.5	18.1	26.3
200	45.2	21.3	28.5
250	51.2	24.4	29.1

6 Conclusions

In this paper, the output power regulation and the optimization control of the vacuum packaging machine are carried out, and the parameter stability analysis is carried out in combination with the output parameter adjustment method of the vacuum packing machine, and the design method of the anti-interference control system of the vacuum packaging machine based on the wireless network is put forward, the output robustness of the vacuum packaging machine is controlled by combining the fuzzy PID control method, the equivalent mechanical power and the equivalent electromagnetic power of the vacuum packaging machine are calculated, The transient stability regulation of the vacuum packaging machine is carried out based on the method of the terminal voltage average analysis, and the anti-interference control law optimization design of the vacuum packaging machine is realized. The hardware design of anti-interference control system of vacuum packing machine is carried out by using FPGA. In this paper, the anti-interference control of vacuum packing machine is carried out in this paper, and the output power and efficiency are improved, and the method has good robustness.

Fund Projects. General Project of Beijing Education Commission, Design and Implementation of a Vacuum Packaging Machine Based on Single Chip Microcomputer Touch Screen (KM201810858001).

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