Load balance control method of multi electromechanical transmission system based on dynamic programming

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Abstract. Controlling the load balance of multi electromechanical transmission system is the core and difficulty of metro vehicles. In order to effectively control the load of multi electromechanical transmission system and ensure the load balance of multi electromechanical transmission system. A load balancing control method of multi electromechanical transmission system based on dynamic programming is proposed. By designing the structure of the transmission system filter, the low DC resonant frequency of the inverter is maintained and the grid harmonics with higher order effect are suppressed. The rotor field oriented correction method based on dynamic programming can improve the torque performance of traction electric drive system, control the DC side active damping oscillation, and realize the load balance control of multi electromechanical drive system. The simulation results show that the proposed method avoids the wrong rise of multi electromechanical voltage and the saturation of regulator output caused by inaccurate magnetic field orientation, can effectively control the load of multi electromechanical transmission system, ensure the load balance of multi electromechanical transmission system, and provide an effective reference for the load balance control of multi electromechanical transmission system.

1. Introduction

Multi electromechanical drive system is the core of vehicles and subway. At present, the control technology of electric drive system of subway vehicles in China is monopolized, which seriously affects the development of urban rail transit [1]. At the same time, the use of converter products is not only related to the overall level of national rail transit equipment, but also not conducive to the development of China's urban rail transit industry, which will increase the operation, maintenance and repair costs of metro vehicles in the future.

Power transmission system involves many fields, such as power electronics, motor, microwave control [2]. At present, the multi electromechanical drive converters and control lines of China's science and technology mainly rely on imports for existing lines and new lines. Breaking the monopoly of foreign rail transit equipment suppliers in the subway traction drive market is a serious problem facing China. In the core technology of controlling load balance of multi electromechanical drive system, controlling load balance of multi electromechanical drive system is the core and difficulty of metro vehicles. In order to control load balance of multi electromechanical drive system and obtain further research and development, multi electromechanical drive system analyzes the core control of traction converter and motor system stability of vehicles and metro, a load balancing control method of multi electromechanical transmission system based on dynamic programming is proposed.
2. Load balance control method of multi electromechanical transmission system based on dynamic programming

2.1. Design the structure of transmission system filter
In order to prevent the inductance characteristic curve of the reactor from changing due to the change of current, the parameters of the filter in the DC line in the multi electromechanical transmission system are designed as a hollow structure in order to achieve that the DC measured current will not be affected[3]. DC750V power supply system is designed as the DC side line reactor of traction converter, the inductance value is lower than that of DC1500V power supply system, but the filter support capacitance is designed to be large, and the capacity of the former is basically twice that of the rear. The main purpose of the initial product selection principle is to fully consider the excellent load capacity and small volume characteristics of alumina electrolyte and capacitor, the relatively low use price, as well as the maturity and cost of new films [4]. The operating conditions and filter circuit of metro vehicles can withstand the overvoltage and transient phenomena specified in iec61287 standard, provide the low power impedance required by the inverter, maintain the low DC resonant frequency of the inverter, and suppress higher order effect power grid harmonics. The DC side LC resonant frequency is designed to be less than 25Hz. Set parameters for all vacancies displayed in the calculation process, and set the coefficient of the last term of the characteristic equation in the upper triangle of the table. The Routh stability criterion is used to analyze the stability boundary and region of the system, and provides guidance for the design and further optimization of DC filter parameters of traction converter and the stability control of traction converter system.

2.2. Rotor field orientation correction based on dynamic programming
Firstly, the influence of inaccurate field orientation on the efficiency and pulsation of multi electromechanical drive system is analyzed. The rotor flux shaft component is used to correct the given slip frequency in real time, but the built-in observer needs to calculate the difference of motor current, which is easy to produce vibration during system operation, which is a normal phenomenon. At the beginning, the concept of rotor magnetic field direction correction is that when the rotor magnetic field is correctly oriented, the rotor flux axis component is 0, and the factors affecting the correct orientation are covered by the wavelength, which may be due to the rotor time constant. In order to realize the accurate orientation of the rotor magnetic field of the traction motor and further improve the torque performance of the traction electric drive system, in the practical real-time correction strategy, The precise orientation of rotor magnetic field is realized. The calculation formula of \( u \)-axis component of rotor flux linkage is as follows:

\[
\psi_{ui} = \psi_{ri} \cos \theta - \psi_{ai} \sin \theta \tag{1}
\]

In formula (1), \( i \) represents the rotor time constant; \( u \) represents the rotor flux axis component. Set the module input / output interface to facilitate debugging and parameter correction. The calculation is shown in formula 2 below:

\[
I_{ci} = K_{m}i_{e} \ast /\left[(\tau_{i} + \Delta \tau_{i})(\varphi \dot{i})\right] \tag{2}
\]

In formula (2), \( I_{ci} \) represents the magnetic slip frequency. Correction \( \Delta \tau_{i} \) indirectly changes the slip frequency \( I_{ci} \), so the above two control modes are basically the same, but the latter is very useful for modular programming and design of control program. The slip frequency calculation module and the real-time correction module of rotor magnetic field direction can be designed separately. The I / O interface is configured to facilitate debugging and parameter correction. In the actual transmission control system, the microprocessor adopts various discretization methods to realize the full order rotor flux observer. Therefore, the error discretization calculation error of full order rotor matrix flux linkage radio wave observer will be directly determined by the error discretization calculation accuracy of rotor matrix power exponent and wave function [5]. Therefore, in order to effectively improve the discrete calculation accuracy of various full order discrete rotors and electromagnetic
chain engineering observation devices under the limited application frequency of iterative accuracy calculation, the most direct calculation method is to expand the accuracy calculation coefficient by continuously iterating and improving the power exponent of the discrete matrix and the discrete order value of its function, so as to adopt the high-order Euler discretization method. The digital realization of full order rotor flux observer is completed, and the implementation of rotor field orientation is carried out in this paper. The correction method not only makes effective use of the above improved discrete flux observer, but also avoids the influence of various time constants in low switching frequency applications. Motor torque control ensures the system stability and the correct direction of rotor magnetic field.

2.3. Active damping oscillation at DC side of control load

Through the above analysis of the system instability law, the motor torque control is carried out for the DC side voltage of the system load. The impedance oscillation characteristics of the traction steering converter can show normal impedance oscillation characteristics, and compensate the instability caused by the reduction of attenuation caused by negative impedance. In other words, the high-frequency oscillation of the DC voltage filter can be effectively suppressed and stabilized. The traction converter is equivalent to increasing and shows positive impedance characteristics, so as to weaken the influence of negative impedance on reducing system damping[6]. According to the above control concept, the DC side active damping vibration suppression strategy adopted in this paper is vector control mode under PWM modulation and scalar control mode under single pulse modulation, and DC side active damping vibration suppression under double pulse. The control is basically the same. The control torque is corrected by extracting the oscillation voltage signal of DC capacitor and generating oscillation suppression coefficient [7]. The difference is that the correction method is different. The given torque current is corrected in vector control mode. The given slip frequency is corrected in scalar control mode. Next, the capacitor voltage oscillation component is extracted through the low-pass filter series high pass filter, as shown in Formula 3 below:

$$\Delta o_{vc} = o_{vc} \tau_j E / (\tau_{L2} J + 1)$$  (3)

In formula (3), $\tau_{L2}$ and $\tau_j$ represent the corresponding filtering time constants; $E$ represents the parameters of Laplacian in the filter; $\Delta o_{vc}$ represents the capacitance voltage oscillation component. It is usually a quantitative evaluation index to measure the effect of competitive strategy at each stage. It is an important indicator of the transformation of strategic state direction. Generally speaking, stage decision-making is time-dependent. The decision is made according to the current state. The state transition is driven by time change, and the next decision is made immediately. Because it has the function of dynamic stage planning, it not only separates the current stage indicators from the future stage indicators, but also combines the current stage indicators with the future stage indicators. Therefore, the results of each analysis and decision are selected from the overall perspective of decision-making, which is generally different from the best decision-making in this decision-making stage.

3. Application and analysis

In order to verify the effectiveness of the load balance control method of multi electromechanical transmission system based on dynamic programming. In the MATLAB simulation platform, test a group of transmission motors at different rated speeds. Before and after applying the accurate orientation correction method of different rotor magnetic fields, the current measurement controller displays the waveform curve changes of the output current comparison value and the experimental value. The change of output curve of current controller before application is shown in Figure 1.
According to figure 1, when the motor is within the range of fundamental frequency vector or without fundamental frequency vector magnetic field control, the output voltage of shaft current PI controller corresponding to different speed points and the waveform of shaft feedforward decoupling pre control voltage fluctuate greatly, and the load of transmission system is seriously unbalanced. After testing and applying the rotor field oriented correction driving method in the paper, the corresponding current regulation shows the waveform curve change of the output current, as shown in Fig. 2.

Figure 1. Output curve of current controller before application

Figure 2. Output curve of current controller after application

According to Fig. 2, after applying the method in this paper, during the fundamental frequency vector magnetic field control, the output voltage of the shaft current PI controller corresponding to different speed points and the waveform of the shaft feedforward decoupling pre control voltage fluctuate less, and the load of the transmission system is not unbalanced. Comparing the test results in Fig. 1 and Fig. 2, it can be seen that the output voltage waveform of the current controller obtained without the method in the paper fluctuates greatly, while the output curve of the current controller obtained by the real-time directional correction method of rotor magnetic field in the paper fluctuates significantly less. This shows that the regulator output imbalance of multi electromechanical drive system has been greatly improved, and to a certain extent, the problem of wrong rise of multi electromechanical voltage and regulator output saturation caused by inaccurate magnetic field orientation has been avoided. Therefore, it is concluded that the method in this paper balances the load of multi electromechanical transmission system and can effectively control the load of multi electromechanical transmission system.

4. Conclusion

This paper studies the load balance control method of multi electromechanical transmission system based on dynamic programming, focuses on the core control technology and engineering practice
methods related to the stability of multi electromechanical transmission system, verifies the research results through simulation experiments, and comes to the conclusion that the method in this paper can effectively improve the voltage output imbalance of multi electromechanical regulators. However, due to the large and complex electric drive system of metro vehicles and high requirements for stability and reliability, the close combination of theoretical analysis and engineering practice is needed to ensure the level and performance of the overall design of the system. As its key core, converter and drive control technology is a research direction that is constantly developing and needs to be deeply discussed. In the future, we will continue to study and improve the shortcomings of the method in this paper, so as to provide an effective reference for the load balance control of multi electromechanical transmission system.

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