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FEES Control Strategy based on Pulse Load of Ship Power System

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Abstract

The flywheel energy storage system is studied to realize the power compensation of the pulse load and the suppression of the system frequenc y fluctuation. The speed of flywheel drive motor is controlled by the rotor flux vector control method to reduce the charging time and process disturba nce. When the pulse load starts to cause the power shortage and the frequency fluctuation of the ship, the flywheel device will enter the discharge mode to supply power to the pulse load with the diesel engine. Flywheel energy storage system with freque ncy converter inside, can achieve ac-dc-ac conversion, to the pulse load stable power supply purposes. The flywheel energy storage and discharge model suitable for ship system is constructed by Matlab/ Simulink platform, and the simulation results show that system can urgently meet the power supply of pulse load, thus speeding up the ship's power grid frequency fluctuation and self-healing.

Keywords

Ship Area Power Distribution System; Flywheel Energy Storage System; Impulse Load; Frequency Fluctuations; Self-healing of Faults.

1. Introduction

The navigation and combat environment of ships in the ocean is harsh, especially the short-term high-power equipment such as laser weapons and radar carried by ships[1]. When starting, the required energy density is high and the power is high, which often leads to a great change in the load of the distribution power system in the ship area, which will cause the speed change of the generator set, resulting in the instantaneous power imbalance of the ship power system and a great fluctuation in the frequency.

The reliability of ship power system depends to a great extent on whether the power grid can continuously and effectively supply power to the load, so the structure of ship power grid is particularly important to the reliability of ship power system. For a long time, domestic and foreign ships have adopted dry-fed hybrid power grid structure to supply power to ships, but these traditional forms of ship power grid are not enough to meet the reliability requirements for large ships and ships.

In order to ensure that important loads such as ship's main power and pulse load do not lose power at the critical moment, the regional distribution power system of the ship needs to activate standby energy storage to quickly respond to the instantaneous high power demand of pulse load and maintain the stability of system frequency[2]. The reserve capacity can be determined according to the number of units in the system, the capacity and the reliability of the system, which is generally 5%~10% of the maximum load. Compared with chemical battery energy storage, pulse power technology is a technology that stores energy and then releases it instantly with high pulse power. It is widely used in high-tech fields and national defense and military affairs. Flywheel energy storage system (FESS) can be used as pulse power supply because of its high instantaneous power[3]. The flywheel energy storage technology can make the flywheel speed reach the rated speed in a few minutes. It has the advantages of high energy storage density, long service life, fast charging, environmental protection and high efficiency, and is expected to become a new generation of energy storage equipment[4]. For example, the Tokamak device of IPP Research Institute in Germany uses flywheel energy storage as pulse power supply. When the power shortage occurs in the ship system, the flywheel energy storage technology can provide emergency power for the side thrust load and pulse load on the ship, and suppress the large frequency fluctuation fault of the ship.

At present, there are few modeling studies on practical application of flywheel energy storage system. Literature[5] introduces flywheel energy storage device to solve the problem of output power fluctuation of wind turbine, and optimizes its control strategy.Literature [6] introduces flywheel energy storage device to improve the quality of users' electricity consumption. The case shows that this device can effectively solve the influence of voltage and frequency disturbance within a few milliseconds. [7]The control strategy of flywheel energy storage system with bidirectional DC/DC is adopted, and the simulation verification of flywheel system charging and discharging is carried out.

Reference [8] puts forward PWM pulse width modulation of driving inverter on flywheel control strategy, and simulation analysis shows that the control effect is significantly improved.

Based on the above research status, this paper designs a flywheel energy storage system which mainly includes three modules: converter, driving motor and flywheel. When the active power output by the ship generator set can't meet the needs for the ship power grid; the fluctuating active power is used as the control signal for the flywheel motor converter of drive the flywheel energy storage device of discharge. On the contrary, when the ship is stable, charge the flywheel device for the next discharge. When the flywheel is charged, the current hysteresis control mode of the rotor flux oriented vector control system is adopted, and the Cuk chopper circuit is adopted in the discharge process to prevent the voltage drop caused by the flywheel speed drop. According to the above design, the charging and discharging characteristics of the flywheel energy storage device are simulated and analyzed on the Matlab/simulink simulation platform, and the correctness and effectiveness of the control strategy of the flywheel energy storage system at the start of pulse load are verified.

2. Application Analysis of Flywheel Energy Storage System

2.1 Frequency Fluctuation of Power System in Ship Area

The ship regional distribution power system supports the ship electric propulsion in the form of all-electric ship, and the generator is the only active power source in the system[9]. Regional power distribution divides the whole ship into multiple power supply areas, and uses multiple power supply modes to combine power supply, which is the main development direction of military ship power system at present[10].

The frequency variation of ship system has great influence on the stable operation of power system. When the frequency decreases, the speed will decrease, which will affect the output power and efficiency of the motor, and lead to the reduction of the system voltage level. When the frequency increases, it will lead to serious overload of propulsion motor and reduce its service life. Large-scale frequency change will also cause serious load imbalance among ship generator sets, resulting in power loss of ship power grid. According to the requirements of the classification society of ship power system, when the prime mover is a diesel engine that suddenly loads or unloads a large load, the instantaneous frequency change of the power grid shall not exceed 10%, and the stability time shall not exceed 5s. At present, the main means of frequency adjustment in ship power system is the speed regulation system of generator prime mover, and PID algorithm is commonly used to control throttle actuator to adjust the fuel supply of diesel engine[9]. This speed regulation method is suitable for frequency deviation caused by small load change. The power shortage and frequency fluctuation range caused by the start and stop of the ship's pulse load are large, so it is difficult to recover the system frequency in a short time by the function of the governor.

2.2 Pulse Load Job Analysis

As shown in Figure 1, for example, it is assumed that a working cycle time of pulse load is t, the power of impulse load is $3P_0$, the duration is t/3, the power of no-load is P_0 and the duration is 2t/3.

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When the voltage and power factor of naval power grid are constant, the pulse loss is proportional to the power quadratic, and the energy loss of one cycle is:

$$\Delta W_{cu} = C(3P_0)^2\frac{t}{3} + CP_0^2\frac{2t}{3} = \frac{11}{3}CP_0^2 t \tag{1}$$

If there is a backup energy supply, it will not cause impact power when the pulse load is started. In the same time t, the average power$P_d = \frac{5}{3}P_0$, then the energy loss in a cycle is:

$$\Delta W_{cu}^{`} = C\left(\frac{5}{3}P_0\right)^2 t = \frac{25}{9}CP_0^2 t \tag{2}$$

It can be seen from the above formula that the energy loss can be reduced by 24.2% after the pulse load is balanced. The higher the peak value of the impact, that is, the higher the unbalance degree of the load, the more the energy loss will be reduced after the balance.

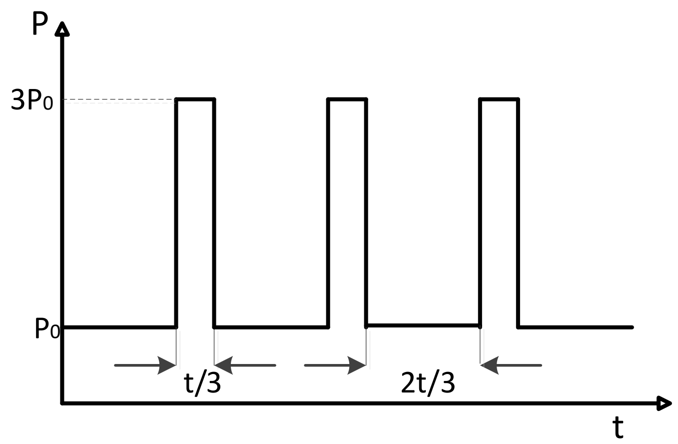

Figure 1. Load diagram of power system with impulse load

2.3 Configuration Scheme of Flywheel Energy Storage System

The installation of flywheel energy storage system is divided into centralized configuration and distributed configuration[5]. Although less flywheel can be used in centralized configuration, the demand for capacity has to be increased, which makes it difficult to realize. The distribution is to install flywheel energy storage devices for each generator, so that the capacity of a single flywheel energy storage device will not be large, and the flywheel devices can release electric energy in a targeted manner.

The 6.6kV medium voltage AC distributed power supply system is adopted in the regional distribution power system of ships, with a rated power of 60Hz. The ship is equipped with four main generator sets, and the pulse loads of the ship mainly include side propulsion motor, radar load and laser load. As the capacity of the ship system is smaller than that of the land power grid, when the electric equipment such as the ship side thruster and pulse load start and stop, the system load will be greatly increased, resulting in power shortage and frequency deviation. Therefore, the flywheel energy storage system is installed for the ship side thruster, radar and laser respectively. The regional distribution power system of ships with impulse load is shown in Figure 2.

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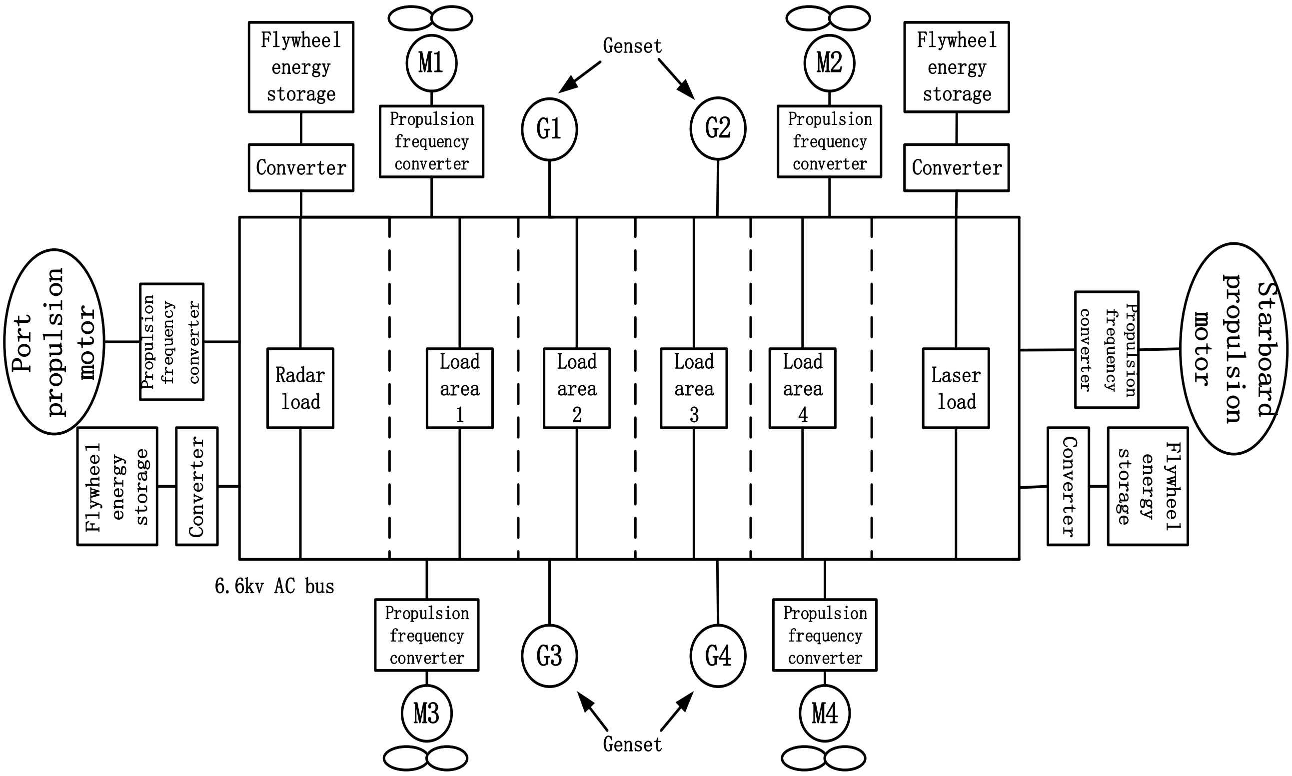

Figure 2. Distribution power system of ship area with impulse load

3. Scheme Design of Ship Flywheel Energy Storage System

3.1 Working Principle of Flywheel Energy Storage System

The power grid of the ship transmits power to the flywheel energy storage system through the power converter. The driving motor works in the motor state, and the electric energy is converted into rotational kinetic energy. The flywheel keeps rotating in a vacuum environment with little friction, and the motor rotor consumes electric energy and continuously increases its rotating speed to the rated speed. Then, the flywheel keeps rotating speed in vacuum with minimal loss by its own inertia, and is in the energy keeping mode. When the pulse load start signal is received, the flywheel device is triggered to start discharging the load, and the driving motor works in the generator state. The flywheel energy storage system outputs electric energy through the converter, and the device has its own inverter, which can achieve the purpose of fast and stable power supply for pulse load. According to the input, storage and output of flywheel energy storage system, the working process of flywheel energy storage system can be divided into three working modes, namely charging mode, holding mode and power generation mode[11].

The moment of inertia of the flywheel is an important physical quantity in the whole device. When the flywheel rotates, the kinetic energy is related to the moment of inertia, which is proportional to the diameter and mass of the flywheel.

The kinetic energy when the flywheel rotates is:

$$E = \frac{1}{2} J\omega^2 \tag{3}$$

Where.,ω is the angular velocity, rad/s, and J is the moment of inertia of the flywheel,kg · m^2

The energy ΔE that can be released or stored by the flywheel energy storage system is:

$$\Delta \mathrm{E} = \frac{1}{2}\mathrm{J}\omega^2 - \frac{1}{2}\mathrm{J}{\omega_L}^2 \tag{4}$$

Where, ω_L is the lowest speed of flywheel energy storage system in charge and discharge cycle, rad/s. Usually, the maximum rated speed ω_H is twice the rated minimum speed ω_L, that is $\omega_H = 2\omega_L$. At that time $\omega = \omega_H \Delta \mathrm{E}_{max}$, the flywheel reached the designed maximum energy storage:

$$\Delta \mathrm{E}_{max} = \frac{1}{2}\mathrm{J}(2\omega_L)^2 - \frac{1}{2}\mathrm{J}{\omega_L}^2 = \frac{3}{2}\mathrm{J}{\omega_L}^2 \tag{5}$$

From the above formula, it can be seen that increasing flywheel speed ω is one of the effective means to increase flywheel energy storage, but the cost of high-power and high-speed flywheel energy storage system is very high. In engineering applications, steel rotor flywheel with rotating speed below 10 000 r/min is the main energy storage.

The moment of inertia of the flywheel is:

$$\mathrm{J} = \frac{GD^2}{4g} \tag{6}$$

Where G is the weight of the rotor, D is the inertia diameter of the rotor, g=9.18m/s is the acceleration of gravity.

The power of flywheel energy storage system is:

$$\mathrm{P} = \frac{d\Delta E}{dt} \tag{7}$$

Where p is the power of flywheel energy storage system, w.

According to formula (2-2):

$$\mathrm{P} = \frac{d\Delta E}{dt} = \frac{d\Delta}{dt}\left(\frac{1}{2}\mathrm{J}\omega^2 - \frac{1}{2}\mathrm{J}\omega^2\right) = J\omega\frac{d\omega}{dt} \tag{8}$$

Considering the pulse load of ships, a single flywheel drive motor with a rotating speed of 5,000 r/min and a total energy storage of 1kwh is selected in this paper. According to the formula, it can be known that the flywheel moment of inertia is 10kg $\cdot m^2$

3.2 Selection of Flywheel Motor

Permanent magnet motors have the following advantages:

1) The working principle of surface permanent magnet synchronous motor is similar to that of concealed pole synchronous motor.

2) Permanent magnet of permanent magnet synchronous motor has no excitation loss, high power factor, and noise and spark generated by brush and slip ring can be avoided[12].

3) Permanent magnet synchronous motor can realize more energy storage under the condition of smaller weight and less occupied space.

Therefore, the surface permanent magnet synchronous motor is used as the driving motor of flywheel energy storage system.

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3.3 Topology of Flywheel Energy Storage System

The flywheel energy storage system is mainly composed of converter, driving motor and flywheel. The AC/DC rectifier circuit is composed of six diodes, and IGBT fully controlled devices V1-V7 and diodes D1-D7 form a DC/AC inverter circuit. Capacitors C1 and C2, inductors L1 and L2, diodes D7, D8 and V7 form a Cuk chopper circuit. S switch has two connection ports, charging port 1 and discharging port 2. The circuit diagram of flywheel energy storage energy conversion is shown in Figure 3.

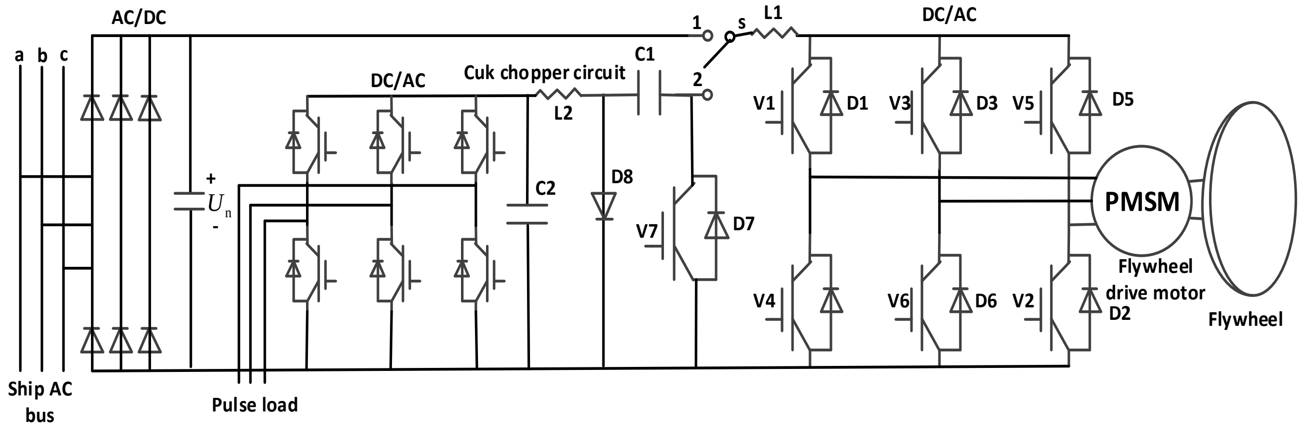

Figure 3. Circuit diagram of energy conversion of flywheel energy storage system

4. Vector Control of Flywheel Drive Motor

The flywheel drive motor control method requires fast response and high precision. Among the commonly used $i_d = 0$ vector control methods, the vector control method is adopted[13]. Because of the existence of permanent magnets, the permanent magnet synchronous motor does not need exciting current, and the electromagnetic torque of the motor is directly proportional to the stator shaft current. By controlling this current, the electromagnetic torque of the permanent magnet synchronous motor can be adjusted, thus achieving the purpose of controlling the motor speed.

A converter is installed in the flywheel device, and PWM converter is the hub of energy exchange between ship power grid and flywheel system, flywheel system and pulse load. By means of rectifier inverter and pulse width modulation technology, the converter drives the motor to transform the state between the motor and the generator. On the one hand, AC-DC conversion of flywheel energy storage system is realized in charging and discharging state, on the other hand, DC side voltage of converter is maintained at a certain constant value[14]. Through the coordinated control of the converter, the energy can flow from the power grid to the flywheel and then to the pulse load.

4.1 Mathematical Model of Flywheel Drive Motor

The flywheel drive motor adopts the vector control method $i_d = 0$ of AC motor, which decomposes the three-phase stator winding current of the motor into the torque current component and the excitation current component of the main magnetic field. Firstly, the voltage and flux linkage equations of flywheel drive motor in dq two-phase rotating coordinate system are obtained by clark coordinate transformation and park transformation in the three-phase stationary abc coordinate system where the stator three-phase windings are located, that is, the mathematical model of permanent magnet synchronous motor in rotating dq coordinate system is obtained. In addition, ideally, flywheel drive motor has no damping winding on rotor and permanent magnet has no damping effect. Then the stator winding voltage equation of permanent magnet synchronous motor is:

$$\mu_d = R_s i_d + p\psi_d - \omega\psi_q \tag{9}$$

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$$\mu_q = R_s i_q + p\psi_q + \omega\psi_d \tag{10}$$

Flux linkage equation:

$$\psi_d = L_d i_d + \psi_f \tag{11}$$

$$\psi_q = L_q i_q \tag{12}$$

Torque equation:

$$T_e = n_p\left(\psi_f i_q + \left(L_d - L_q\right) i_d i_q\right) \tag{13}$$

Because the hidden pole permanent magnet synchronous motor is adopted, if there is$L_d = L_q$, then:

$$T_e = n_p \psi_f i_q \tag{14}$$

Equation of motion:

$$T_e = T_L + J\omega p / n_p \tag{15}$$

Where:, $\mu_d, \mu_q$is the dq axis component of the motor side voltage; $i_{d,}i_q$ is dq component of stator current; ψ_{fd}, ψ_{qf} is dq axis component of stator flux linkage; L_d, L_q is the dq axis component of stator inductance; ψ_f is air gap flux; T_e is electromagnetic torque; n_p is polar logarithm; p = d/dt is a differential operator .

4.2 Flywheel Drive Charging Vector Control Strategy

As shown in Figure 2, when the flywheel energy storage system is charging, the switch S is set at the charging terminal 1, and the flywheel drives the motor to run electrically. The alternating current with constant voltage and frequency of the ship's power grid is rectified into direct current by six freewheeling diodes, and then the rectified direct current passes through the DC/DC step-down chopper circuit, and the current tracking hysteresis PWM inverter control of the flywheel motor side converter is carried out by the vector control system oriented according to the rotor magnetic field[15], which transmits alternating current with adjustable voltage and frequency to the driving motor to drive the flywheel to run.

The flywheel side converter adopts the current hysteresis vector control technology oriented according to the rotor magnetic field to control the motor speed. After the deviation between the ideal speed n^* and the actual speed n passes through the PI link of the speed regulator ASR, the given value i_q^* of the Q-axis stator current component proportional to the electromagnetic torque is output. Because of the vector control mode $i_d^* = 0$, the reference excitation current of the motor D-axis is equal to 0, and then the ideal given value i_{abc}^* of the three-phase current is obtained after the dq coordinate system is converted to the abc coordinate module. The current hysteresis comparison tracker module compares the given value i_{abc}^* of the ideal current with the actual current i_{abc} and outputs the driving PWM signal to the inverter bridge to control the motor operation.

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The structure of current hysteresis tracking modulation vector control system is shown in Figure 4. According to the mathematical model of the driving motor in the dq coordinate system, the vector control system mainly includes the space coordinate transformation module, the speed PI regulator and the current hysteresis tracking PWM modulation module.

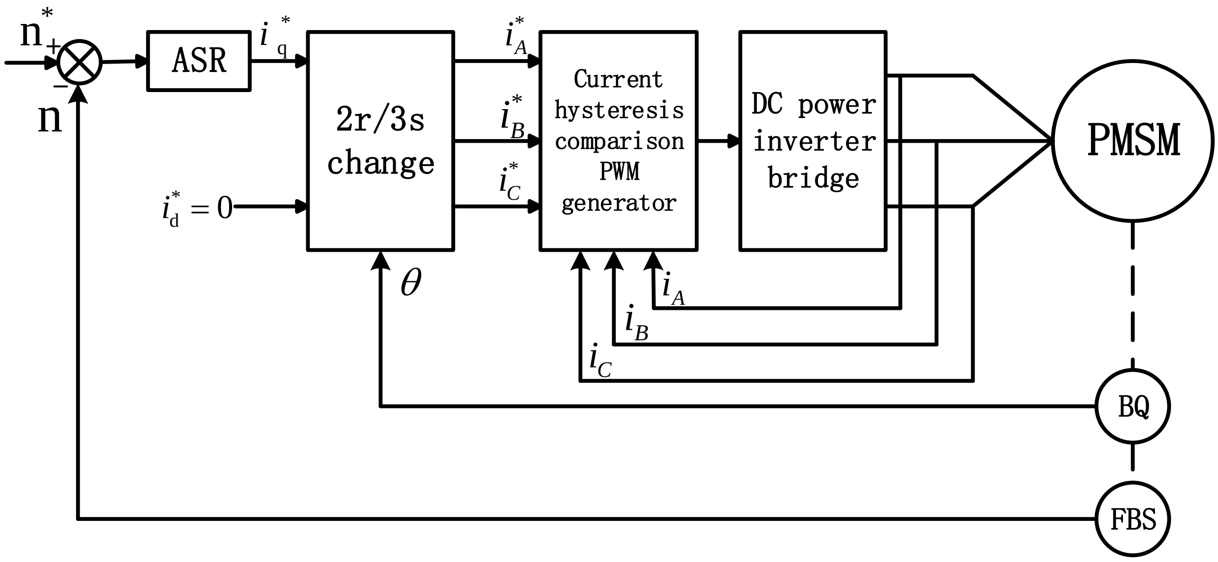

Figure 4. Block diagram of current hysteresis tracking control of flywheel energy storage system

4.3 Discharge Vector Control of Flywheel Energy Storage System

In the flywheel energy storage system shown in Figure 2, when the flywheel energy storage system discharges, the switch S is set at the discharge terminal 2. At this time, the flywheel device is used as the power supply, and the rotational kinetic energy is converted into electric energy. The flywheel drives the motor to generate electricity and run, and after passing through the three-phase full-bridge uncontrollable rectifier circuit, the terminal voltages are generated at both ends of the Cuk circuit. With the decrease of flywheel speed, the output voltage amplitude of the generator varies. If only the freewheeling diodes connected in parallel at both ends of the fully controlled IGBT in the three-phase bridge circuit of the energy converter are rectified, the DC voltage will gradually decrease with the decrease of motor speed, and there will be great pulsation[16].

To solve the above problems, Cuk chopper circuit is introduced into the system to stabilize the output voltage of flywheel motor. The schematic diagram of CU chopper circuit is shown in Figure 5, where, L_1, L_2 is the energy storage inductor, V is the controllable switching device, VD is the freewheeling diode, C is the coupling capacitor for energy transmission, and C2 is the filter capacitor. The turn-on and turn-off of the controllable device V is equivalent to forming a switch S to alternately switch between points A and B, so its equivalent circuit diagram is shown in Figure 6.

During this t_{on} period, the controllable device V is turned on, and E, L_1,V form a path, and the input current i_1 stores energy in the inductor L_1. The voltage of the capacitor C makes the diode turn off in reverse, and R, L_2 C and V form a path. The discharge current i_2 of the capacitor C stores energy in the inductor L_2 and supplies power to the load.

During this t_{off} period, the controllable device V is turned off, at this time, the diode VD is turned on, and E, L_1,C and VD form a path. The power supply E and the inductor L_1 charge the capacitor C. At the same time, the inductor L_2 supplies power to the load through R, L_2,VD circuits.

When the equivalent circuit analysis is adopted U_c, the average value of capacitor voltage is set u_c, T is the switching period and $\alpha = \frac{t_{on}}{T}$ is the on duty ratio, and when the value of capacitor C is large enough, the voltage drop caused by capacitor can be ignored. When the switch S is closed at point A, the voltage at point A is 0, and the voltage at point B is $-u_c$. When the switch S is closed at point B,

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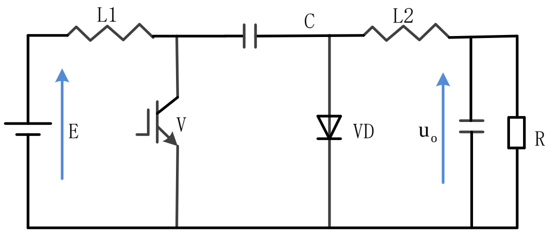
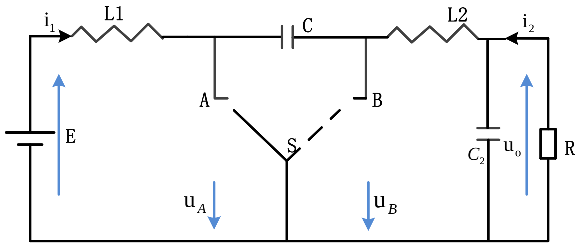
the voltage at point B is 0, and the voltage at point A is u_c. Thus, the average voltage at point A and point B in a period can be obtained $U_A = \frac{t_{off}}{T} U_C$, $U_B = -\frac{t_{on}}{T} U_C$, and the average voltage of inductor L1 and inductor L2 is zero. It can be seen that E=U_A, $U_o = -U_B = \frac{t_{on}}{T} U_C$,nd the relationship between output voltage and power supply voltage is$U_o = \frac{\alpha}{1-\alpha} E$, and the purpose of voltage step-up and step-down can be achieved by controlling the on duty ratio.



(a) Cuk chopper circuit diagram



(b) equivalent circuit diagram of CUK chopper circuit

Figure 5. Cuk chopper circuit principle analysis diagram

According to the working principle of the circuit, no matter during t_{on} or t_{off}, the storage and transmission of energy are carried out in two switching periods and two loops at the same time, both of which can supply energy from the input end to the output end, and the input and output currents can be guaranteed to be smooth only by selecting large enough capacitors and inductors. Compared with the traditional step-up and step-down circuit, Cuk chopper circuit has obvious advantages. There are inductors in the input and output sections, and its input power supply current and output load current continuously have no step change. The polarity of the output voltage is opposite to that of the input voltage, and the output voltage can be lower or higher than the input voltage, which is conducive to filtering the input and output[17]. Therefore, in order to stabilize the output voltage at the load side, Cuk chopper circuit is used to control the discharge voltage of flywheel motor.

The Cuk circuit in the topology diagram 2 of flywheel energy storage system consists of diodes C1 and C2, inductors$L_1 L_2$, transistors V7 and diodes D8. In the control scheme, the closed-loop link is selected on the DC voltage at the output side. In a PWM working cycle, a constant DC voltage can be output by changing the turn-on and turn-off of IGBT V7 through the PID regulation principle. This control scheme can obtain better output performance. Finally, the electric energy is output through the three-phase inverter bridge to meet the requirement of keeping the pulse load running on the ship.

5. Analysis of Simulation Results

5.1 Section Headings

During the charging process, the speed of the driving motor is mainly controlled, in order to obtain faster charging speed and better anti-interference ability. Assuming that in an ideal situation, there is no extra loss, delay and power loss. In the simulink simulation platform, the vector control speed regulation system of flywheel drive motor is built. The simulation system includes permanent magnet

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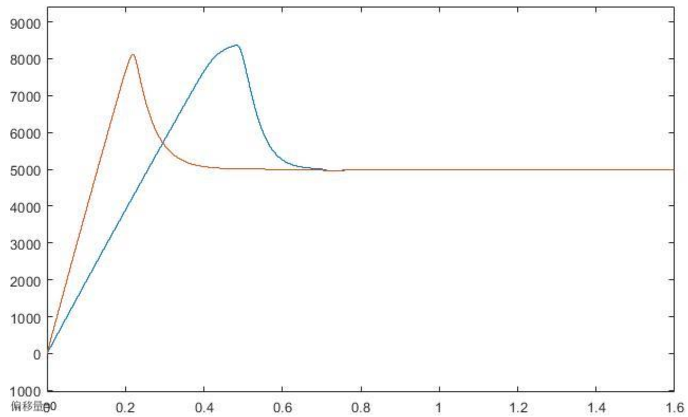
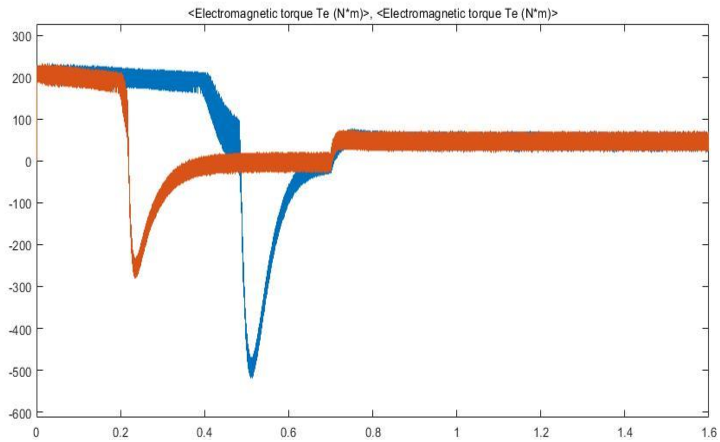
synchronous motor, DC link braking unit, inverter model, speed controller and current hysteresis controller.

Due to the large moment of inertia of the actual flywheel, it often takes several minutes or even ten minutes for the flywheel speed to reach the given value in practical application. In order to save time, the moment of inertia set in the simulation process is small so that the driving motor can reach the given value faster. The simulation parameters of flywheel energy storage system are: motor rated voltage 1000V, stator phase resistance 0.2, stator phase inductance 0.5mh, motor pole pair P=4, flywheel moment of inertia $\mathrm{J} = 0.1\mathrm{kg} \cdot cm^2$, and the system starts at a given speed $\mathrm{n} = 5000\mathrm{r/min}$ with no load.

The red curve in Figure 5 and Figure 6 is the waveform obtained by current hysteresis tracking control, and the blue curve is the simulation waveform obtained by traditional control method.



(a) The speed curve of the driving motor during charging



(b) The simulation curve of the motor torque of the driving motor.

Figure 6. Charging curve of flywheel drive motor

As can be seen from the above figure, the red curve shows that when the current tracking hysteresis control method is adopted, when the motor speed rises to a given speed, the overshoot of 0.2s is 3100r/min, and then it reaches a given speed of 5000 r/min within 0.3s. When the motor runs to 0.7s, $50\ \mathrm{N \cdot m}$ loads are suddenly applied to the motor. After the load is applied, it can be seen from Figure 6 that the current and torque of the motor also increase, and the rotating speed drops to 4,975 r/min. After the current hysteresis tracking adjustment, the rotating speed of the motor recovers to 5,000 r/min within 0.05s, and there is no out-of-step phenomenon. Compared with the traditional control method of blue curve, the flywheel drive motor has smaller overshoot in the process of speed increase, shorter time to reach the specified speed, reduced charging time, and smaller torque ripple of the motor, so the noise during charging is smaller and the anti-disturbance ability is stronger.

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5.2 Analysis of Discharge Simulation Results

In the discharge simulation, the DC bus voltage is taken as the research object, in order to make the flywheel energy storage system have a deeper discharge margin in the process of energy release, and Cuk chopper circuit is used to improve the problem of output power quality degradation caused by flywheel speed reduction. When the flywheel energy storage system works in discharge mode, the electric energy provides AC power for the pulse load through inverter-chopper-inverter.

In order to simplify the system model, the series superposition method of DC voltage source and AC voltage source with long period is adopted to simulate the process that the output electromotive force of flywheel motor decreases with the speed decreasing, and the accuracy of the system model is not affected. The red curve in Figure 7 shows the output DC voltage waveform obtained by Cuk chopper circuit, and the blue curve shows the DC voltage waveform not output by Cuk chopper circuit.

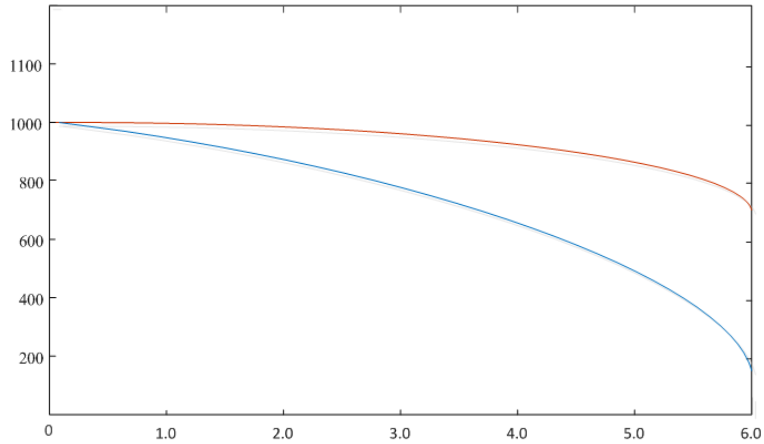

Figure 7. Simulation curve of current bus voltage

It can be seen from fig. 7 that the output power of flywheel energy storage system is stable at about 700V when DC voltage is output by Cuk chopper circuit for six seconds, and the voltage pulsation is small. Compared with DC voltage without Cuk chopper circuit, the voltage drop is smaller after the same discharge time, which meets the simulation requirements. It is verified that the Cuk chopper circuit proposed in this paper is helpful to improve the discharge depth of the system.

6. Conclusion

When the power shortage of the ship is caused by the start-up of pulse load, the flywheel energy storage system is used to compensate the power supply to suppress the frequency fluctuation of the system, so as to prevent the fault or quickly heal itself after the fault. Based on Simulink simulation module, a simulation model of charge and discharge of flywheel energy storage system suitable for ship regional distribution power system is established. The simulation results show that the flywheel energy storage system controlled by current hysteresis tracking has better charging effect, faster response and stronger anti-interference ability, and the connection of Cuk chopper circuit in the discharging process can effectively prevent the voltage drop caused by the flywheel speed drop, and can quickly and effectively meet the pulse load power supply. On the basis of the following paper, it can be improved in the converter circuit design to realize the multi-directional flow of energy.

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