Scholar Publishing Group
Kinetic Mechanical Engineering
https://doi.org/10.38007/KME.2020.010103
ISSN 2790-2676 Vol. 1, Issue 1: 18-25

Energy Crisis Brought by Construction Machinery and Prevention and Treatment Measures

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Keywords: Construction Machinery, Energy Crisis, Electric Drive, Prevention, Control Measures

Abstract: In recent years, with the continuous breakthrough of computer technology, electronics and automation control technology, electric transmission technology has been rapidly developed and applied in the field of construction machinery. This paper mainly studies the energy crisis brought by construction machinery and prevention measures. In this paper, the overall structure scheme of the test platform is formulated and the topological structure of the composite power system and the loading scheme of the test platform are studied. Then, according to the structural scheme of the test platform, the hardware part of the test platform is selected and matched to complete the construction of the test platform. This paper provides important guidance and reference value for the research and development of electric transmission technology in construction machinery by studying the stability and reliability test of electric transmission system under load mutation.

1. Introduction

With the rapid economic development of our country, the role of construction machinery plays gradually important, and it is widely used in mining, construction and other engineering construction related industries [1]. However, the operation of construction machinery will also bring great environmental pollution problems, including harmful emissions and energy crisis [2]. The engine displacement of construction machinery is large, the working condition is bad, and the fuel consumption is relatively high under the condition of high load. In terms of energy crisis, our country is facing the problem of increasingly severe energy shortage, such as excessive petroleum exploitation, and insufficient exploitation of alternative energy [3-4]. As the energy crisis intensifies, people begin to engage in activities related to energy conservation and emission reduction, and the state also takes various measures to maintain sustainable development [5-6].

The outbreak of the First World War promoted the rapid development and innovation of science and technology, during which electric transmission technology was applied to the military field [7]. At the beginning of the 20th century, the prototype of "little Tramp" armored vehicle was successfully developed, and many scholars began to carry out relevant tests on electric transmission military vehicles [8]. The "Saint-Chamont" tank developed by France is one of the earliest military vehicles to adopt electric transmission system [9]. In the 1960s, the rapid development of semiconductor, rectifier, inverter and other micro electrical appliances, power transmission technology entered a new stage of rapid development. Relevant scholars from Germany, Finland, France and other countries have successfully developed the electric locomotive sample model in the mode of "AC-DC" energy conversion using the technology at that time and conducted performance test research and analysis on it [10]. With the successful application of electric transmission technology in the military field, relevant scholars began to try to apply electric transmission technology to the field of construction machinery, so as to find a new way out for the field of construction machinery in the future development [11]. Caterpillar, as a giant in the world's construction machinery industry, has been conducting research in the field of electric transmission since the end of the 20th century, and has achieved a lot of research results. The research on electric drive vehicles in France mainly focuses on the electric vehicles with independent drive on both sides. In order to study diesel-electric hybrid power, Finland has also built an electric transmission test bench, through which performance testing, control strategy research, fuel consumption and power performance research of the electric transmission system can be conducted [12].

In order to achieve the mechanical engineering technology transformation and upgrading, and effectively solve the problem of energy conservation and environmental protection, both energy-saving sex and maneuverability, the research object of this article is pure electric engineering machinery, study on pure electric power construction machinery composite pattern, fully embody the compound new energy, energy conservation and environmental protection characteristics, can meet the demand of national economic development strategy, has significant environmental, social and economic benefits.

2. Energy Crisis under the Construction Machinery Prevention and Control Measures

2.1. Energy Crisis and Security

In fact, energy security is a concept under dynamic change and development, which has been endowed with different and richer connotations in different historical development stages [13].

Energy security in the narrow and traditional sense is defined from the continuity of energy supply. Energy security focuses on the stable supply of energy. It is believed that a country's energy security is to obtain stable and sustainable energy supply at an acceptable price. Insufficient energy supply or unreasonable fluctuation of energy price will lead to certain energy risks [14]. Therefore, in the previous studies of many scholars, energy supply security is often used to replace energy security [15].

However, with the increase of energy consumption due to the global economic development, there are many problems such as water pollution, Air pollution and so on a series of environmental pollution, the growing global environmental problems make people alert from the economic development, people began to rethink the relationship between energy and environment, that the ecological environment and energy security must be considered an important aspect of the definition of ecological environment be incorporated in the energy security, many scholars will be remit the above three aspects In general, a broader connotation of energy security can be obtained [16-17]. Thus, energy security from the past single focus on the security of supply of traditional energy security concept began to a new energy perspective. The new energy holistic view not only considers the continuity of energy supply and affordability of price, but also involves environmental benefits and sustainable development, and expands the connotation of energy security [18].

In China, energy security is generally understood from two aspects: the stability of supply guarantee and the security of energy utilization. The former refers to the stability of energy supply to meet the survival needs of the country and the people, while the latter refers to the non-threat to the living environment in the process of energy reuse.

For China at the present stage, the rapid economic development makes the energy consumption continue to increase, and the energy import also increases. Moreover, since our country has a great disparity in energy saving technology and energy management with neighboring Japan, the simple and extensive aspects of economic growth make energy consumption in unit GDP much higher than the average level of the main developed countries, and energy waste is relatively serious. Since the 1980s, the contradictions between China's economic development and environmental protection have been increasingly highlighted, and various kinds of environmental deterioration problems have appeared. These environmental problems have appeared in the industrialized stage of developed countries. The contradiction of energy supply and demand and serious environmental pollution in the economic development have all caused the energy risk facing our country in the present stage to become increasingly serious.

2.2. Pure Electric Power System of Construction Machinery

(1) Motor selection

In the selection of composite power drive motor, the following four kinds of motor are generally selected; Dc motor, AC asynchronous motor, switched reluctance motor, permanent magnet synchronous motor, considering technology maturity and reliability and other factors are more widely used in the last three. According to the performance description of the three kinds of motors in Table 1, it can be seen that the power density of the AC asynchronous motor among the three kinds of motors is lower than that of the other two kinds of motors, so it is not considered here. Switched reluctance motor has small size, simple structure and good robustness, wide speed range, high power density, but poor performance at low speed operation, construction machinery in the work of the general speed is low, so this motor is not suitable for construction machinery test bed system. Permanent magnet synchronous motor has high power density, fast dynamic response, high energy utilization rate and low energy consumption, reliable operation, and is more suitable for the construction machinery composite power supply test bed system under various working conditions and frequent switching. In this paper, the rated power of 15KW YGDLC-15 permanent magnet brushless synchronous motor can be used for load test under this working condition.

Table 1. Performance comparison of three common motors

Performance	Alternating current asynchronous machine	Switched reluctance motor	Permanent magnet synchronous machine
Speed	12000-20000	>15000	4000-10000
Power density	Middle	Relatively high	High
Weight	Middle	Light	Light
Volume	Middle	Small	Small
Reliability	High	High	Good

This model of permanent magnet synchronous motor controller is standard with 485 interface, can use USB/485 converter to achieve the computer to set the parameters of the motor controller, also equipped with a removable handheld operation panel (referred to as HMI), Users can directly control motor start, stop, steering, view/modify motor parameters, set motor running frequency, display system status and so on through HMI. Considering the real-time performance of the test process control system and the simplicity of motor control, HMI is chosen to directly control the motor here.

(2) Power battery selection

Power battery as composite construction machinery's main source of power, the power energy management system experimental platform to consider performance parameters are: the power density, energy density and output efficiency, voltage, capacity, internal resistance, and charged state, when performance meet the requirements, also need to consider the temperature of the battery using scope, safety, cost, cycle life and other factors. As the main power source of the composite power system, the choice of power battery affects the performance of the whole test platform. Lithium-ion battery, nickel-metal hydride battery and lead-acid battery are commonly used power batteries in vehicles. The three kinds of power batteries are widely used and the technology is relatively mature. The main performance of the three kinds of power batteries is shown in Table 2 below.

Table 2. Performance comparison of three power batteries

Performance	Lithium battery	Nimh batteries	Lead acid battery
Specific energy	80-130	70-95	20-50
Specific power	200-300	200-300	50-140
Energy efficiency	>95	70	>80
Service life	1000	750-1200	300-400

Lead-acid batteries have short service life, low specific energy, small operating temperature range, and poor low-temperature performance. Therefore, lead-acid batteries are not considered here. Compared with nickel-metal hydride battery, lithium ion battery has high specific energy, high specific power, high energy efficiency, relatively cheap price and a wide range of working temperature. Therefore, lithium battery is selected as the main power source of construction machinery composite power test bench in this paper. More mature and more in the current application and technology of lithium batteries, lithium iron phosphate batteries because of its long service life, the advantages of low cost, safe and reliable and materials are widely used in vehicle power system, can satisfy the performance requirements of power battery test platform, this paper selects the lithium iron phosphate battery as a power battery test platform.

(3) Power battery matching

According to the performance parameters of the motor, the rated voltage of the motor is 288V. In order to keep the voltage level of the power battery and the motor consistent, the rated voltage of the lithium iron phosphate battery is 288V.

If you want to achieve 288V rated voltage, you need N1 batteries in series. If the battery voltage is UBAT, then:

$$N_1 = \frac{V}{u_{bat}} \tag{1}$$

The battery voltage UBAT is 3.2V, and V is the rated voltage of the motor, that is, V =288V. To achieve the rated voltage of 288V, 90 batteries need to be connected in series.

The formula for calculating the maximum supply power of power battery pack is:

$$P_{bat\max} = \frac{kN_1C_1u_{bat}}{1000} \tag{2}$$

K is the discharge rate of power battery. Here, the maximum discharge rate is 2C. C1 indicates the capacity of a unit. The maximum power supply of the battery should be greater than 15.79 KW. Only when the capacity of the ultracapacitor is insufficient, the power battery can be used to drive the power battery alone. It can be calculated from Equation 2 above that C1 should be greater than 27.4Ah. Considering the technical level and cost of existing lithium iron phosphate batteries, power batteries with a single capacity of 30 Ah should be selected.

3. Experimental Test Scheme

In order to study the electric transmission system under stable load condition, the relationship between engine output power, motor output power and motor speed, as well as the stability, reliability and control accuracy of the motor under load. In this paper, taking the stable load of 50N·m as an example, the output speed of the motor is 500R /min, 1500R /min and 3000R /min respectively. The data acquisition instrument is used to measure the process of the motor from sudden load to stable load under 50N·m load. Engine output torque, speed, motor output speed and torque, and DC bus voltage, current.

Before the sudden load test, an initial load should be given to the motor to prevent the phenomenon of "running away" when the motor runs at high speed without load. In the test process by recording the motor output torque, power, DC bus voltage, engine output torque speed and power data. Finally, when doing experimental research and analysis, all the collected data parameters are summarized into the Matlab interface, and the collected information is classified and sorted out by Matlab software.

The matching relation of engine and motor speed and DC bus voltage determined in this paper are shown in Table 3.

Table 3. Initial parameters of engine, generator and DC bus

output speed(r/min)	1200	1600	1800
Motor output speed	500	1500	3000
Dc bus voltage (V)	450	520	550

4. Stable Load Test

According to the test data in FIG. 1, when the output speed of the motor is running at a low speed of 500r/min, the output torque of the motor will respond quickly to the given 50N·m surge loading in the test. When the motor speed is 1500r/min, the torque response time increases, and the actual steady-state measured motor torque average value decreases slightly when the motor speed reaches the steady state. When the motor is 3000r/min, the output torque response of the motor reaches a stable state after about 1000ms. It can be seen that with the continuous increase of the output speed of the motor, the pulsation of the output torque response of the motor becomes larger and larger. If the motor speed continues to increase, that is, when the motor runs at a high speed above the fundamental frequency, the torque response of the motor will drift. In serious cases, the bus voltage will rise sharply, and the transmission system will enter the protection state. It can also be seen from the figure that when the motor is 3000R /min, overshoot also occurs, and the motor's response regulation time is significantly longer and there is oscillation. Although it tends to be stable after a period of time, it has seriously affected the stability and reliability of the electric drive system in operation. It shows that the precision and reliability of torque response of electric drive system motor will decrease obviously when it runs above the fundamental frequency.

It can be seen from FIG. 2 that under the premise of stable load, the output power of the motor increases with the increase of the motor output speed.

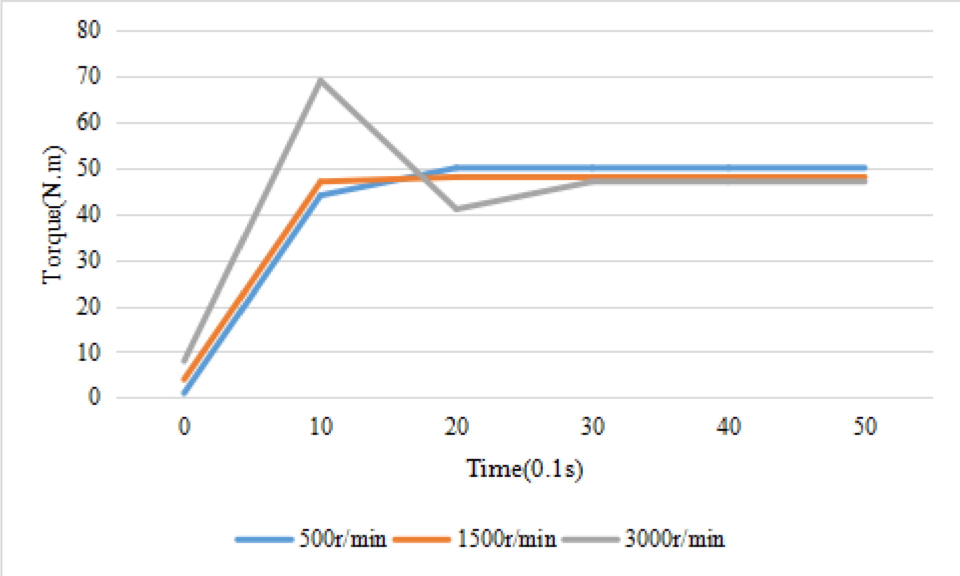

Figure 1. Load the torque response of the 50N· M motor

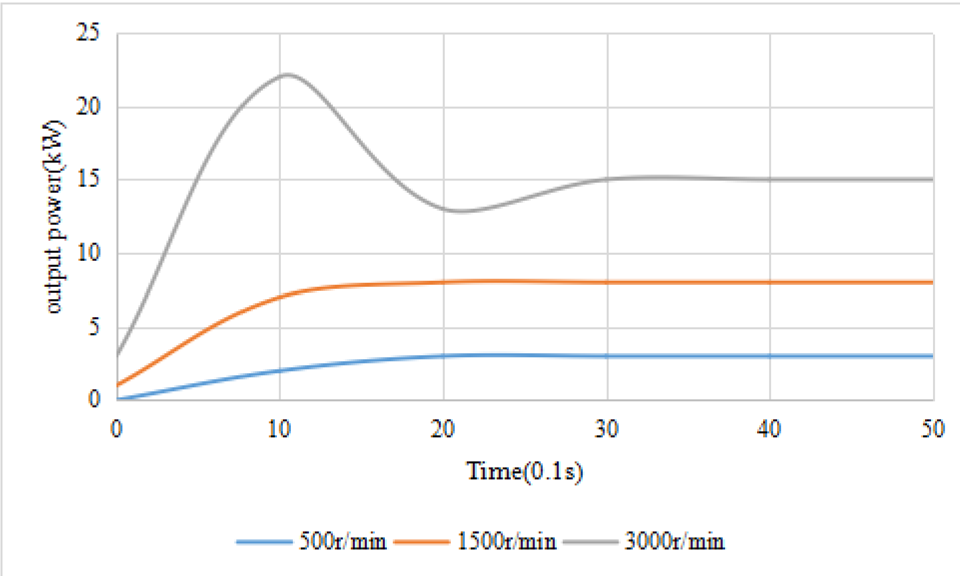

Figure 2. Motor output power response curve

5. Conclusion

In this paper, through the study of the structure design of engineering machinery electric drive, and the test bench of the electricity transmission as the research object, through the ac electric dynamometer load simulation, under the action of the electric drive system in load mutation in response to the research and analysis, through the electric drive system main components the response to the analysis of the electric drive system operation reliability and stability and test precision. It provides important basic theory and research method for electric transmission technology applied to the field of construction machinery. Due to the wide range of electric transmission technology, it is necessary to consider more complex working conditions when it is applied to the field of construction machinery. The following aspects need to be continued to improve. Due to the limitation of test time and conditions, when the electric transmission system mutation load test is done in this paper, the test cycle is long, which leads to the large heat of some components of the electric transmission system, such as dynamometer, motor and engine, resulting in a certain deviation of the test data.

Funding

This article is not supported by any foundation.

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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