Design of simulation platform for chassis engine driven generating system

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Abstract: With the development of equipment on-vehicles, the chassis engine driven generating technique is paid more and more attention in the mobile operation vehicles. Based on the analysis of engine driven power generating working principle, this paper designs a simulation platform for chassis engine driven generating system, mainly including the following four parts, such as engine chassis simulation mechanism, engine driven generator, electric energy transducer and testing and displaying system. With this platform, power generating experiments under different working conditions can be performed such as parking power generation, traveling power generation, section speed regulation power generation and load increase and decrease. The result of the experiment proves that the power output from this simulation platform can meet the demand for electric requirement from the equipment, and has good static and dynamic characteristics, which can provide certain reference value for the design of vehicle chassis engine driven generating system.

1. Introduction
In recent years, with the increasing degree of automation of weapons and equipment and the wide application of power electronic technology in new type of equipment, the demand for electricity for weapons and equipment is increasing greatly. The main battle tank is about 12~18kW; the missile launch vehicle is about 10~20kW; other military special vehicles are 5~15kW[1]. In addition, the traditional trailer power station is increasingly unable to adapt to the modern form of flexible maneuverability, which leads to the increasing demand of chassis engine driven generating technique from military vehicles such as large mobile combat vehicles[2-4]. This paper designs a simulation platform for chassis engine driven generating system which can simulate generation under different working conditions such as parking power generation, traveling power generation, section speed regulation power generation and load increase and decrease, aiming at providing theoretical guidance and engineering support for military vehicles with equipment.

2. Chassis Engine Driven Generating Principle
The chassis engine driven generating system takes vehicle chassis engine as the power source, working through mechanical drive or hydraulic drive to drive generator to work, then transforming the electric energy output by the generator into standardized format by power electronic converting
The system is a kind of "vehicle mobile power supply," which takes full use of the remaining space and excess power of chassis, improves the utilization rate of the engine, and has strong mobility that power can be generated both at parking and traveling conditions, which ensures the power supply demand of power consuming equipment. Thus it is widely applied in military application fields such as combat equipment, logistics support equipment and vehicle command.

3. The Design of Simulation Platform for Chassis Engine Driven Generating System

3.1. The Simulation Platform Diagram

The Simulation Platform mainly includes system cabinet, transducer, variable frequency motor, engine driven generator, rectification inversion device, test and display platform and testing mechanism etc. See Figure 1.

The frequency control motor performs its function by the transducer and carries out kinetic energy output control by using electrodeless control combination drive, which is used to simulate changing conditions of chassis engine rotating speed. The variable frequency motor drives engine driven generator to transform mechanical energy into electric energy by coupling. Then it connects the load cabinet by rectification inversion device which is used to solve problems such as generator output frequency and voltage instability caused by rotating speed great conversion of vehicle chassis engine. The final output voltage and frequency are stabilized within the required range of equipment by wide range input energy conversion mechanism. The torque sensor and parameter instrument is used to collect data. The test and display platform is used to test and display online for electricity parameters such as the output voltage, current, frequency of rotating speed and moment of variable frequency motor and rectification inversion device. The main function is shown in Figure 2.
3.2. The Composition of Simulation Platform

Set up simulation platform according to the diagram of chassis engine driven generating system. It includes one variable frequency motor, one engine driven generator, one system cabinet and one test and display platform, as shown in Figure 3. The test and display platform includes three parts. The one on the left is control buttons of engine driven generating system: scram switch, auto test switch, manual switch, motor loading, stop switch and inversion mechanism load and stop switch etc; the one in the middle section is upper computer software interface which can be used to choose generation experiment test under different working conditions, record all the experiment data in the process and generate data report as well as wave analysis; the one on the right is two parameter instruments 8962C2 which is used to test electric energy index directly sent out by the engine driven generator and by electric energy transducer. The indexes can show electrical parameters such as voltage, current, power factor, active power and frequency and have harmonic wave analysis. For being beautiful and compact, some electric components such as transducer, rectification inversion device and sensors are placed in the system cabinet. See Figure 4.

![Figure 3 Composition Diagram of Simulation Platform](image1)

![Figure 4 Layout of System Cabinet](image2)

In chassis engine driven generating simulation system, the transducer, which is the key to realize variable frequency and speed control of motor, controls variable frequency motor to simulate chassis engine rotating condition. Variable frequency motor uses asynchronous electromotor. The transducer adopts the rotation difference frequency control method, which is suitable for the control of wide rotation range. The process is as follows: first, the speed variation signal of actual rotating speed and the given one is obtained by speed sensor and control circuit. Then reference speed variation value is calculated by rotation difference controller. Add the reference speed variation value and the actual rotating value, then reference synchro-rotating value is obtained. With the valued obtained, the controller can calculate the frequency and voltage control signal of rectification inversion device. Rotating difference frequency control is a kind of speed closed loop standard control, which can achieve higher speed and precision and have good torque feature even when the load torque has changed greatly.

As the key to the whole system, the rectification inversion device rectifies and inverts the electric energy from the engine driven generator to realize the output voltage and frequency stability under wide range changing conditions of frequency electromotor rotating speed so as to meet the power consuming demand of load. The working principle is that the voltage output by the generator is filtered into DC first through three-phase uncontrollable rectification bridge and then the filtered capacitor. Through the BUCK circuit, it is stabilized. Through the inversion of three-phase controllable inverter, it outputs electric energy to the load. The three-phase inversion circuit uses double loop control method. The inner loop control carries out d-q transformation for collection load voltage signal and provides synchro-signal through phase-locked loop. In this way, d signal and q signal as well as their corresponding standard value are respectively obtained for comparison. The signal after comparison is
amplified by PI controller, then through d-q inversion, three-phase alternating signal is output. The outer loop control compares and amplifies the three-phase alternating signal output by d-q inverse transformation with load current signal and then output control signal for PWM and control the on and off of power tube.

4. The Experimental Verification of Simulation Platform

4.1. Electrical Parameter of Simulation System

In the chassis engine driven generating simulation system, the variable frequency motor adopts three-phase five-wire system 380VAC for power supply. The rated power is 37kW. The rated rotating speed is 3000rpm (the maximum one 6000rpm). The rated torque is 117.77N\,m. The range of transducer is 0-400Hz. The range of voltage is 0-380V. The range of power is 0-37 kW. The engine driven generator uses . The rated power is 22kW. The rated rotating speed is 3000rpm. The requirement for electrical parameter of electric energy output by the rectification inversion device is shown in Table 1.

| Electrical Parameter | Value             |
|----------------------|-------------------|
| output voltage       | 380VAC±1%         |
| output power         | 50Hz±0.5%         |
| power factor         | 0.8 (lag)         |
| total harmonic distortion (THD) | <5%       |

4.2. Simulation System Experiment Test

4.2.1. Parking Generating Experiment

The rotating speed of generator is regulated by transducer, then simulate the vehicle parking generating condition. The upper computer interface shows the real-time electrical parameters such as voltage, current, power, frequency and power factor before and after rectification inversion device. The rotating speed of engine driven generator in parking condition is 2000r/min. The running time is set as 200s. During the experiment, electrical parameter data of any time can be recorded and data report can be generated. Ten groups of recorded test data is shown in Table 2.

The parameter instrument of test and display platform can perform the task of output voltage and current harmonic analysis. From the bar pattern of parking generation, it can be seen that the voltage THD is 4.674%<5%, which can meet the index requirement.
4.2.2 Travelling Generating Experiment

The rotating speed of generator is regulated through transducer from 1500r/min→2300r/min→1800r/min, which simulates the vehicle’s travelling process of first acceleration and then deceleration. Table 3 shows the 15 groups of test data in travelling process.

Table 3 Travelling Generating Experiment Test Data

| Number | Front Section of Rectification Inversion | Rear Section of Rectification Inversion | Shaft Power |
|--------|-----------------------------------------|----------------------------------------|-------------|
|        | Voltage (V) | Current (A) | Power (kW) | Frequency (Hz) | Voltage (V) | Current (A) | Power (kW) | Frequency (Hz) | RS (r/min) | RT (N.m) | Output Power (kW) |
| 1      | 207.6 | 4.427 | 1.458 | 0.914 | 24.96 | 379.6 | 1.574 | 0.920 | 0.889 | 49.89 | 1498 | 22.94 | 3.599 |
| 2      | 207.5 | 4.426 | 1.457 | 0.916 | 24.98 | 379.4 | 1.574 | 0.920 | 0.889 | 49.96 | 1498 | 22.94 | 3.599 |
| 3      | 207.3 | 4.425 | 1.456 | 0.916 | 24.87 | 379.6 | 1.575 | 0.920 | 0.889 | 50.01 | 1499 | 22.93 | 3.599 |
| 4      | 207.4 | 4.437 | 1.461 | 0.916 | 25.01 | 379.7 | 1.574 | 0.920 | 0.889 | 50.00 | 1500 | 22.91 | 3.599 |
| 5      | 207.4 | 4.437 | 1.461 | 0.916 | 25.01 | 379.5 | 1.574 | 0.920 | 0.889 | 50.01 | 1498 | 22.87 | 3.587 |
| 6      | 318.0 | 3.307 | 1.643 | 0.902 | 38.42 | 382.1 | 1.585 | 0.933 | 0.889 | 49.95 | 2299 | 18.15 | 4.368 |
| 7      | 319.8 | 3.293 | 1.646 | 0.902 | 38.21 | 382.1 | 1.585 | 0.933 | 0.889 | 50.03 | 2303 | 18.13 | 4.371 |
| 8      | 319.0 | 3.295 | 1.642 | 0.902 | 38.19 | 382.0 | 1.584 | 0.932 | 0.889 | 50.00 | 2301 | 18.17 | 4.370 |
| 9      | 317.9 | 3.304 | 1.640 | 0.902 | 38.19 | 382.0 | 1.584 | 0.932 | 0.889 | 50.00 | 2295 | 18.06 | 4.340 |
| 10     | 318.7 | 3.289 | 1.637 | 0.902 | 38.19 | 382.1 | 1.585 | 0.932 | 0.889 | 50.00 | 2296 | 18.10 | 4.352 |
| 11     | 221.3 | 4.221 | 1.479 | 0.914 | 36.00 | 379.7 | 1.574 | 0.920 | 0.889 | 49.98 | 1801 | 20.41 | 3.849 |
| 12     | 221.3 | 4.221 | 1.479 | 0.914 | 36.00 | 379.8 | 1.574 | 0.920 | 0.889 | 50.00 | 1802 | 20.33 | 3.837 |
| 13     | 221.2 | 4.217 | 1.478 | 0.914 | 36.00 | 379.7 | 1.574 | 0.920 | 0.889 | 50.00 | 1803 | 20.33 | 3.839 |
| 14     | 221.0 | 4.210 | 1.472 | 0.914 | 36.00 | 379.7 | 1.574 | 0.920 | 0.889 | 50.00 | 1801 | 20.35 | 3.837 |
| 15     | 221.0 | 4.210 | 1.472 | 0.914 | 36.00 | 379.7 | 1.574 | 0.920 | 0.889 | 50.00 | 1799 | 20.46 | 3.855 |

It can be concluded from Table 3 that during traveling generation, after rectification inversion device, the minimum voltage is 379.4V AC, and the maximum one is 382.1V AC. The voltage volatility is -0.158%~0.553%, which can meet the requirement of electrical parameter property index of output voltage 380VAC±1%. The minimum value of output power is 49.89Hz, and the maximum value is 50.03 Hz. The power volatility is -0.22%~0.06%, which can meet the requirement for output power 50Hz±0.5%. According to the parameter instrument, the THD range during travelling is around 4.585%~4.736%, which can meet the index requirement for voltage THD.

4.2.3. Section Speed Regulation Generating Experiment

The rotating speed of generator is regulated through transducer. In this way, it can simulate the generating process when the vehicle accelerates evenly from one speed to another within a certain range. Take the rotating speed 1600r/min→2200r/min as an example, Table 4 shows 10 groups of test data during section speed regulation generating experiment.

Table 4 Section Speed Regulation Generating Experiment Test Data

| Number | Front Section of Rectification Inversion | Rear Section of Rectification Inversion | Shaft Power |
|--------|-----------------------------------------|----------------------------------------|-------------|
|        | Voltage (V) | Current (A) | Power (kW) | Frequency (Hz) | Voltage (V) | Current (A) | Power (kW) | Frequency (Hz) | RS (r/min) | RT (N.m) | Output Power (kW) |
| 1      | 221.3 | 4.221 | 1.479 | 0.914 | 26.61 | 379.6 | 1.574 | 0.920 | 0.889 | 49.93 | 1597 | 21.96 | 3.672 |
| 2      | 221.7 | 4.216 | 1.479 | 0.914 | 26.71 | 379.5 | 1.574 | 0.920 | 0.889 | 50.00 | 1600 | 21.90 | 3.669 |
| 3      | 221.5 | 4.217 | 1.478 | 0.914 | 26.71 | 379.4 | 1.574 | 0.920 | 0.889 | 50.00 | 1601 | 21.96 | 3.683 |
| 4      | 221.3 | 4.216 | 1.477 | 0.914 | 26.67 | 379.6 | 1.574 | 0.920 | 0.889 | 50.01 | 1602 | 21.96 | 3.684 |
| 5      | 220.4 | 4.229 | 1.475 | 0.914 | 26.79 | 379.5 | 1.574 | 0.920 | 0.889 | 49.92 | 1599 | 22.09 | 3.698 |
| 6      | 305.1 | 3.381 | 1.615 | 0.904 | 36.58 | 381.5 | 1.583 | 0.930 | 0.889 | 50.00 | 2190 | 18.59 | 4.281 |
| 7      | 305.1 | 3.381 | 1.615 | 0.904 | 36.58 | 381.5 | 1.583 | 0.929 | 0.889 | 50.00 | 2200 | 18.58 | 4.281 |
| 8      | 304.2 | 3.399 | 1.619 | 0.904 | 36.79 | 381.4 | 1.582 | 0.929 | 0.889 | 50.00 | 2200 | 18.58 | 4.281 |
It can be concluded from Table 4 that during section regulation generation process, after rectification inversion device, the minimum voltage is 379.4V AC, and the maximum one is 382.5V AC. The voltage volatility is -0.158%~0.395%.

The minimum value of output power is 49.92Hz, and the maximum value is 50.02 Hz. The power volatility is -0.16%~0.04%. According to the parameter instrument, the THD range is around 4.561%~4.623%. Therefore, during section regulation generation process, the electricity energy can meet the electrical parameter index requirement for output voltage, frequency and voltage THD.

4.2.4 Abrupt Load Increase and Decrease Experiment

It refers to the abrupt change of load at certain moment when the rotating speed of generator is constant and it simulates the generating process when the vehicle travels stably under the condition of abrupt load change. When the rotating speed is 2200r/min and it is operating stably under the load of 1kW+0.5kvar. The abrupt increase and decrease resistance load is 5kW+1kvar. The test data is shown in Table 5.

| Stability Time | Abrupt Load Increase | Abrupt Load Decrease |
|---------------|---------------------|---------------------|
| output power (V) | 380 | 376.8 | 382.6 |
| output frequency(Hz) | 50 | 49.8 | 50.18 |
| stability time(s) | \\ | 0.42 | 0.38 |

It can be seen from Table 5 that the voltage volatility during the abrupt load increase and decrease is respectively -0.842%~0.684% and the frequency volatility is -0.4%~0.36%. During the abrupt load increase and decrease, the output voltage and frequency can meet the index requirement.

Compare the output voltage and frequency volatility under four working conditions, that is parking generation, travelling generation, section speed regulation generation and abrupt load increase and decrease (See Table 6), it is obvious that the voltage and frequency volatility comes to the lowest in parking generation and it is highest in abrupt load increase and decrease; the voltage and frequency volatility in section speed regulation generation is smaller than that of in parking generation. From the experiment, it can be concluded that the electric energy is the most stable in parking. The section speed regulation generation in nature belongs to the scope of parking generation. Thus the output electric energy quality is lower than that from the parking. When the abrupt load increase and decrease changes dynamically, the output voltage frequency can still meet requirement of the system property index.

Table 5 Abrupt Load Increase and Decrease Experiment Test Data

| Electrical Parameter | Different Working Conditions | Parking Generation | Travelling Generation | Section Speed Regulation Generation | Abrupt Load Increase and Decrease |
|----------------------|-------------------------------|--------------------|----------------------|------------------------------------|----------------------------------|
| output voltage volatility | -0.026%~0.079% | -0.158%~0.553% | -0.158%~0.395% | -0.842%~0.684% |
| output frequency volatility | -0.1%~0.02% | -0.22%~0.06% | -0.16%~0.04% | -0.4%~0.36% |

5. Conclusion

With the development of equipment on-vehicles, the electricity consuming demand of various equipments in military weapons becomes greater and greater. With the advantage of rational construction, strong maneuverability and stable electric energy output, the chassis engine driven generating system has gained much more attention in military vehicles especially refitted ones. This paper explains the design of chassis engine driven generating system simulation platform which uses variable frequency motor to drive PMSM to simulate the generating process that the actual motor drives the generator and stabilize electric energy output through electric energy transducer. With this platform, four experiments such as parking generation, travelling generation, section speed regulation
generation and abrupt load increase and decrease can be carried out. The result of the experiments can meet the requirement of engine driven generating system electric energy technique index so as to provide reliable and stable power supply quality, which can lay an experimental foundation for the application of equipment in military weapons.

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