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Implementation of Integrated Generation Unit Simulation Platform With Power Electronic Load and Engine Simulator

Jing Guo[1,2,3], Tao Fan[2,3,4] ,Xuhui Wen[1,2,4]

[1]*University of Chinese Academy of Sciences，Beijing，P.R. China*

[2]*Institute of Electrical Engineering of Chinese Academy of Sciences, Beijing, P.R. China*

[3]*Key Laboratory of Power Electronics and Electric Drive, Institute of Electrical Engineering, Chinese Academy of Sciences*

[4]*Collaborative Innovation Center of Electric Vehicles in Beijing*

Summary

According to the characteristics of SHEV, power electronic load and engine simulator are introduced in order to improve the quality and efficiency for IGU (Integrated Generation Unit) performance testing. The basic organization and simulation principle of the IGU system are presented firstly, then the simulation model is put up using MATLAB and the generation algorithm and operating condition are verified. A method to solve the engine stall problem is presented. Finally, the effectiveness was validated through the experiment.

Keywords: series HEV, simulation, generator, converter, torque

1 Introduction

IGU (Integrated Generation Unit) which contains six-phase PMSG (Permanent Magnet Synchronous Generator) and rectifier is used in SHEV (Series Hybrid Electrical Vehicle) with six legs. It can convert the mechanical power provided by the engine into more than 120 kilowatts of military-grade DC power for external operations. The SHEV which is used to carry supplies in the harsh mountains come in two forms, one as a normal wheeled vehicle and the other as a six-legged robot when it encounters mountainous region.

As the only power source (no battery), the reliability of IGU is crucial in the six-legged crawl mode. Before the whole vehicle debugging, the simulation system built in this paper can realize the comprehensive assessment of IGU system. Due to the limited volume and weight requirements, the maximum torque provided by the engine just met the demand. At a low speed, when the power required by the load is large, the engine will shut down due to insufficient torque provided. In addition, the power of the electric equipments used in the six-legged joint are varied and complex, and the ordinary resistive load cannot meet the assessment of real power demand. So, the structure of the IGU simulation platform cotains engine simulator and Powe Electronic load (PEL) is shown in figure 1.

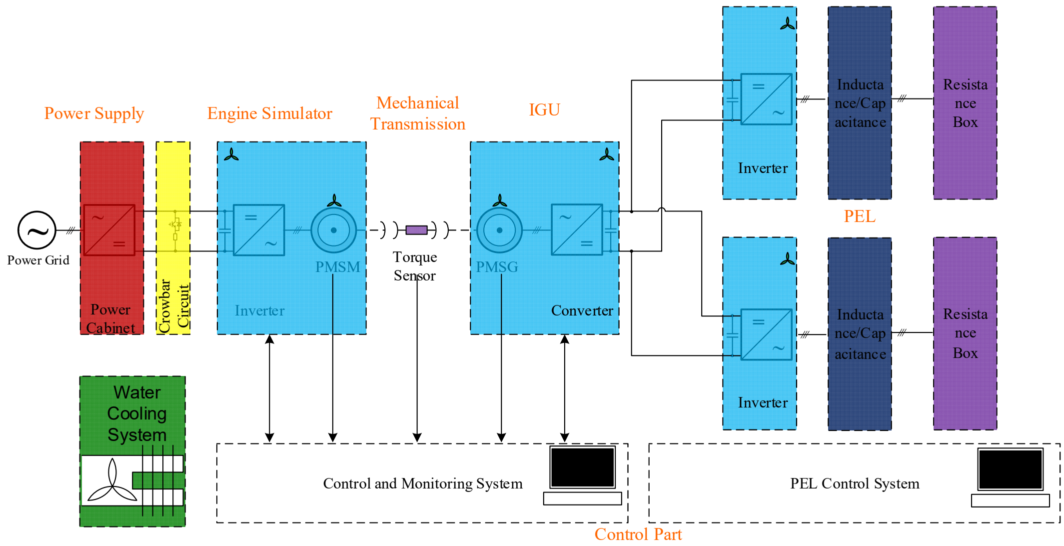


Figure 1: Structure of Integrated Generation Unit simulation platform

2 IGU

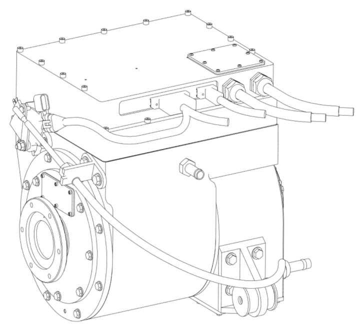


Figure2: Structure of Integrated Generation Unit

Because the generator is located between the engine and the gearbox, installation space is extremely limited. And the light weight of the vehicle is very high, so the overall structure scheme of motor and controller structure integration is adopted, as shown in figure 2. It can be seen that this integrated power generation unit design can highly share the structural parts of the motor and the controller as well as the ac power cables connecting them, so as to reduce the total weight of the equipment and improve the power density at the system level. In addition, the adoption of integrated power generation units brings two other technical advantages. The first is higher electromagnetic compatibility. The ac cable between the motor and the controller is an important emi propagation path. The longer the cable is, the more obvious the antenna effect will be, and the greater the emi harm will be. With the integrated design, the ac cable becomes the internal cable of the equipment, the cable length is extremely short, and the antenna effect is significantly reduced. At the same time, the whole cable is sealed inside the metal shell of the equipment to minimize the external propagation of electromagnetic interference on the ac cable. The second advantage is to improve the efficiency of equipment installation. Compared with the separated generator and controller, the integrated generation unit saves the ac cable, weak current wiring harness and cooling pipeline between the motor and controller. Only the dc wiring terminal of the high voltage bus and the nozzle interface of the cooling system of the whole vehicle are retained. This structure can realize integrated lifting, one-time installation and disassembly of the entire power generation unit.

2.1 Engine Simulator

The power limitation and speed regulation of the engine have a significant impact on the power generation system, so the engine model must be built in the IGU simulation platform. The dynamic characteristics of the engine body are ignored, and the influence of engine parameters such as the inertial constant is converted to the engine shaft. In this way, it can be considered that the diesel engine is a linear plus a delay link. The general structure of the linear small deviation dynamic model near a working point is shown in figure 3.

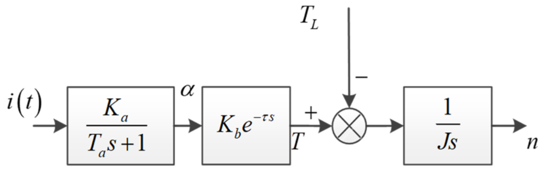


Figure3: The linear small deviation dynamic model of engine

The target system is applied to the SHEV in which the engine speed is controlled by a governor and remains essentially unchanged. The engine and its speed control system is a typical application of multi-system and multi-level complex system, and is difficult to use a suitable model to express the structure and describe the relationship between system input and output. At present, most of the diesel engine models based on D'Alembert's principle are established or adopted in the field of engine speed control. According to the above characteristics of diesel engine and its speed control system, the simulation device is divided into digital and physical part. The engine is simulated by a permanent magnet synchronous motor (PMSM), and its speed is controlled by an inverter. The engine closed-loop algorithm is used to control the PMSM in order to simulate the characteristics of the diesel engine, as shown in figure 4.

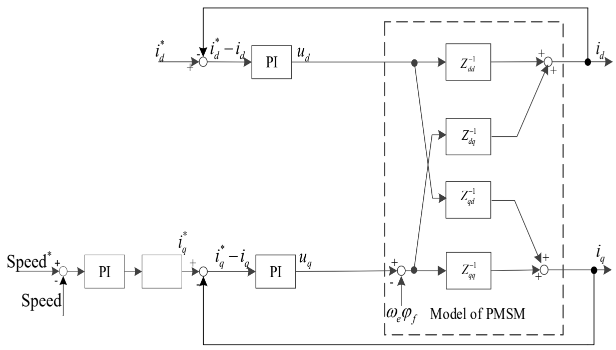


Figure 4 : The model of engine closed-loop algorithm

By adjusting the PI parameters of the speed loop, the characteristics of slow dynamic response of the engine were simulated. According to figure 5, the maximum current value of the speed loop was generated by matlab. The maximum current value of the current loop was given according to the current speed table, so as to simulate the characteristics of the engine with limited output torque.

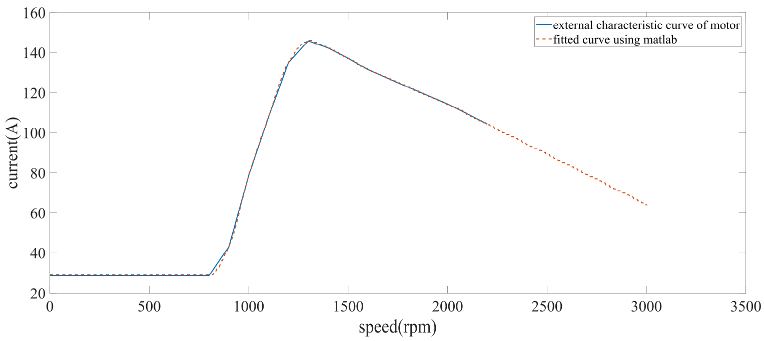


Figure 5 : The torque and speed curve of the engine

2.2 PEL

PEL, as a device for assessing the performance indicators of power equipment, is more flexible in control than traditional testing methods. Therefore, it is widely used in ex-factory experiments of ac stabilized voltage power supply, variable frequency power supply and dc power supply[2] [3].

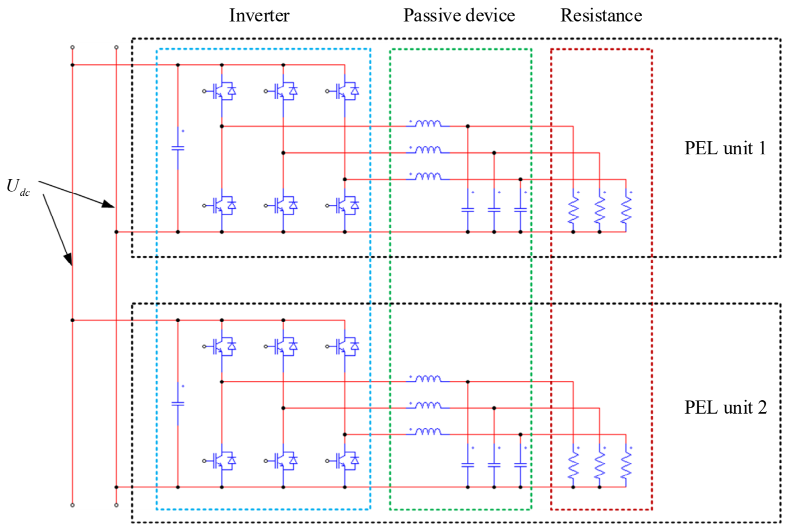


Figure 6: Structure of PEL

As shown in figure 6, the PEL consists of two units in order to simulate the left and right legs respectively. Each unit is composed of three parts: switching device, passive device and energy consumption part. The switching device is realized by conventional three-phase half-bridge topological inverter, and the IGU rectifier can act as the function. The passive device is designed as a separate device with three identical inductance and capacitance branches, which are connected by common ground. The energy consumption part is realized by the resistance cabinet. The bridge arm of the inverter, the external inductance capacitance and resistance acts as a single-leg of the vehicle, and the inverter is controlled in three independent buck modes. In order to make the control simple, the system sets a fixed value of the load resistance during operation, using the current sensor of the inverter as the feedback control quantity, and adopts the closed-loop current control strategy to simulate the load power demand of the single-leg movement.

2.3 Proposed method

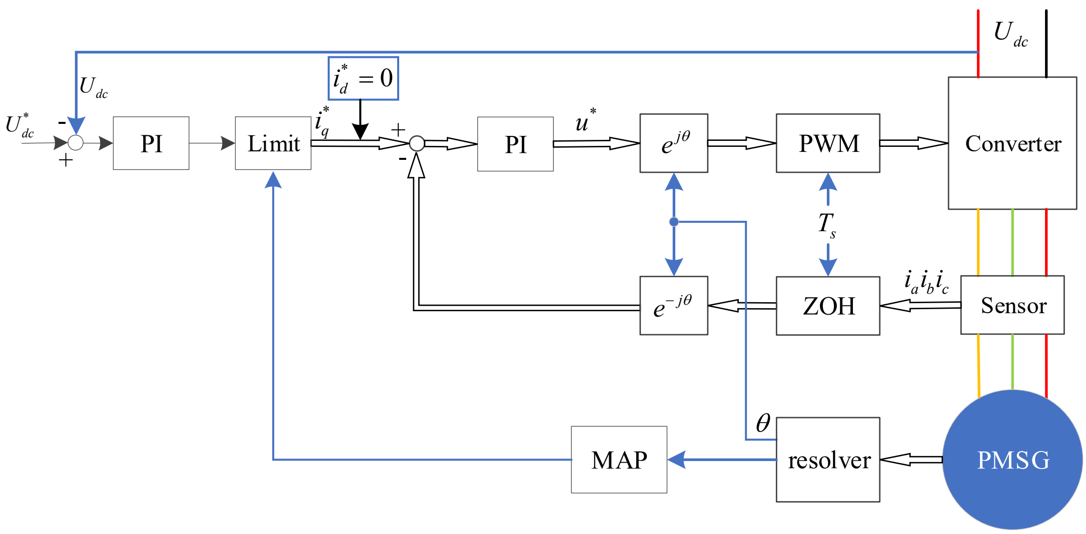


Figure 7: Structure of proposed method

The maximum torque limitation algorithm is adopted to solve the engine stall problem caused by the mismatch between the engine power and the required power in the speed acceleration process. According to the characteristics of the engine torque, the limit value of the voltage loop output current instruction of the generator controller is dynamically adjusted. However, because of the output power of the generator is limited, the bus voltage will decrease with the increase of the load demand power, and the bus voltage cannot be maintained.

3 MATLAB Simulation

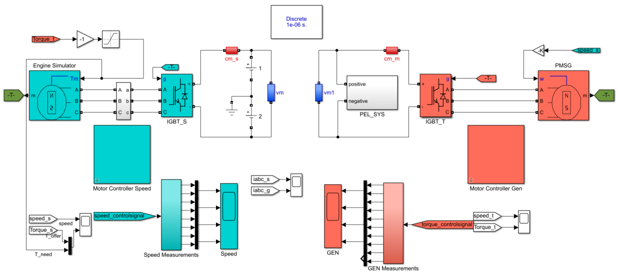


Figure 8: MATLAB Simulink model

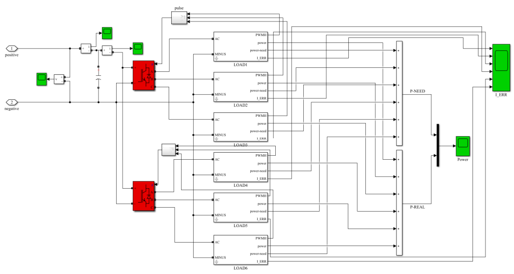
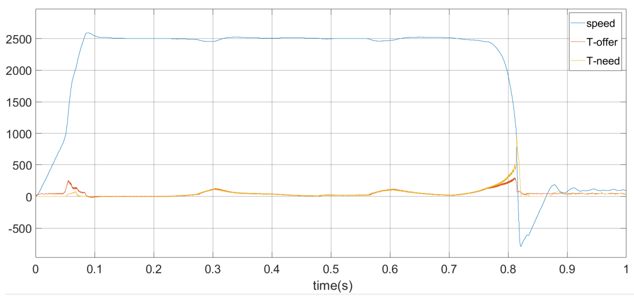
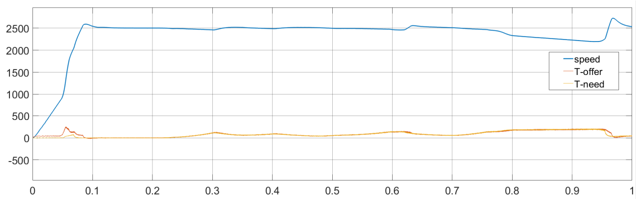


Figure 9: PEL model

As shown in figure 8 and figure 9, the IGU testing platform Simulink simulation model is built, including an engine simulator to simulate the engine characteristics, IGU using voltage loop control, and the PEL to simulate the vehicle's six legs. The simulation waveform is shown in figure 10-13. Figure 13 shows the tracking situation of the six buck current instruction and current feedback value. Time-varying load changes are simulated by the PEL. Figure 11 shows the total power P-NEED of the load simulation demand and the actual power P-REAL provided. When the simulation time approaches 0.8s, the demand power of the load simulator increases continuously to 60kW, while the output power of the simulation engine cannot meet the demand at this time. As can be seen from figure 11, the torque t-offer provided by the engine is continuously less than the demand torque t-need, which causes the engine to hold, and the generation voltage U_{dc} also drops to 0.

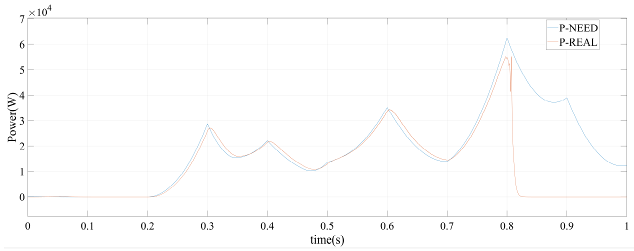


(a) without torque limite algorithm

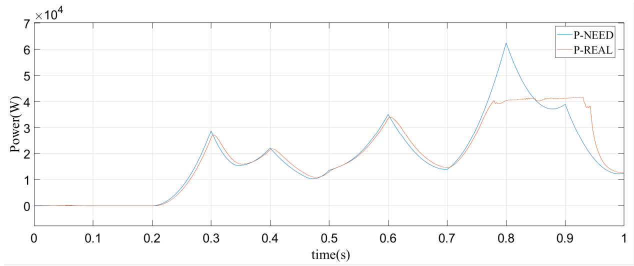


(b) with proposed method

Figure 10: Engine stall simulation

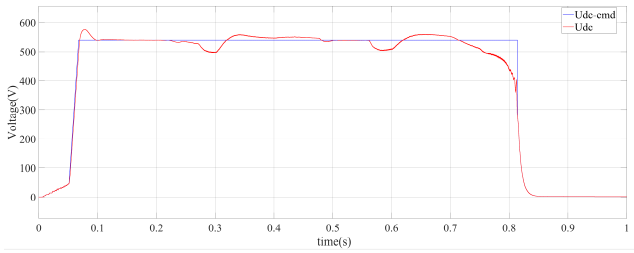


(a) without torque limite algorithm

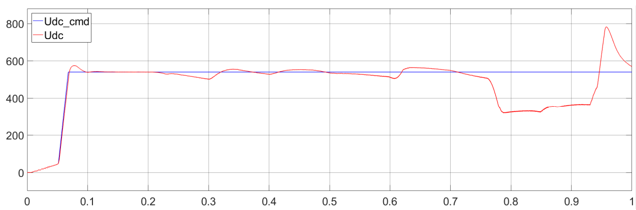


(b) with proposed method

Figure 11: Power of PEL need and real power of engine supply

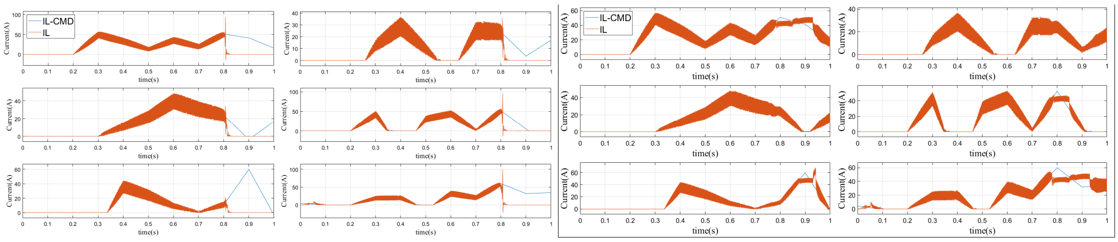


(a) without torque limite algorithm



(b) with proposed method

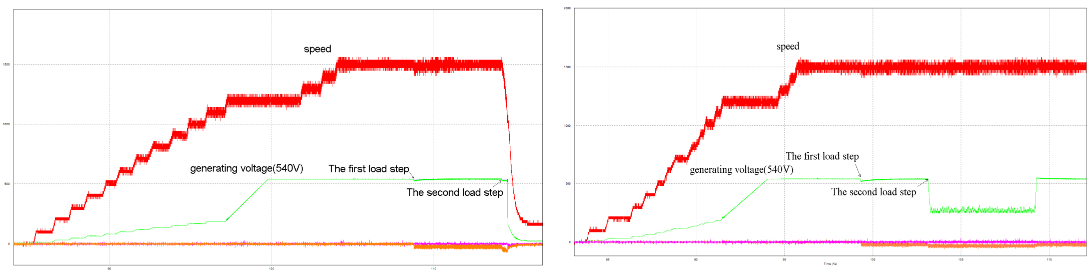
Figure 12: The voltage supplied by IGU



(a) without torque limite algorithm (b) with proposed method

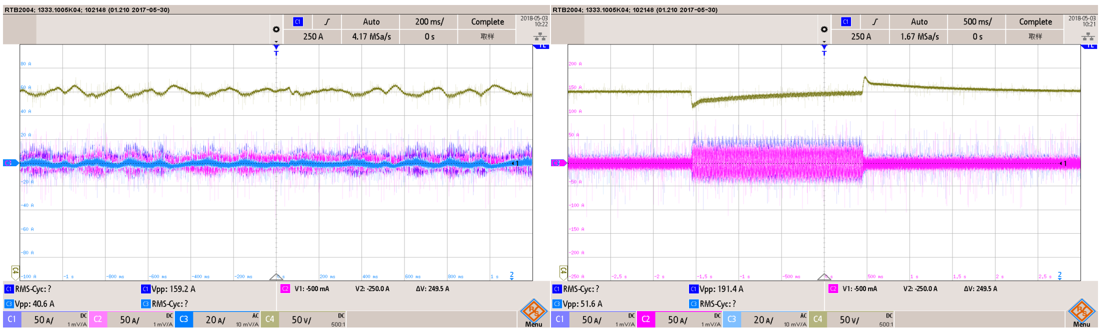
Figure 13: Power command and actual values of six legs

4 Experiment



(a) without torque limite algorithm (b) with proposed method

Figure 14: Engine stall testing waveform



(a) random load (b) pulse load

Figure 15: PEL waveform

As shown in figure 14.(a), when the torque provided by the engine fails to meet the load requirements, the engine is suppressed. Using the proposed torque limit algorithm, the engine does not hold back in the same operating condition, but the generation voltage drops, shown in figure 14.(b). Figure 15 shows the response waveform of the generation voltage when the PEL simulates random load and pulse load.

5 Conclusion

Experiments show that the system can reflect the engine characteristics and load characteristics and meet the Requirements.

Acknowledgments

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Authors

Jing Guo received the B.S. degree in electrical engineering in 2008 from Beijing Jiaotong University, Beijing, China , and the M.S. degree in power electronics and electrical drives from North China University of Technology, Beijing, China, in 2012. He is currently working toward Ph.D. degree in power electronics and electrical drives at the University of Chinese Academy of Sciences， Beijing，China.

His current research interests include advanced control of permanent magnet synchronous motor drives and position sensor-less control of ac motors.