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Development of an Intelligent Energy Management Device for Vehicles

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Abstract. In this paper, we propose a novel intelligent energy management device for vehicles. Our main objective is to develop and fabricate an intelligent, low-energy-loss, voltage-regulator device for use in vehicle recharging circuits. After the core technology is developed, resulting applications and products can be promoted in the vehicle industry. In addition, the proposed device has the potential to be promoted to international markets. The vertical integration of R&D allies can help reduce production cost, while making the quality of the resulting products equivalent to those of domestic and international major companies. As a result, the competitive capability of Taiwan products will increase.

Keywords: Intelligent Device, Energy Saving, Voltage Regulator

1. Introduction

Vehicle voltage regulators maintain output voltage under a certain value, so that components do not overheated, and electric energy loss is reduced. Electric energy loss occurs when the power generator charges the battery. The main characteristic is that fuel consumption is reduced. In vehicles, the battery supplies the main power. Power from the power generator is used to charge the battery (12 V) through the voltage regulator [1]. The output of the voltage regulator is controlled, so that the battery is charged at approximately 14±0.5 V. Problems occur at high speeds, when the voltage of the power generator under no-load conditions is very large. In our study, we used an IC with high-input impedance (a MOSFET), to overcome the problem of regulating high-voltage power, occurring at high-speed, under no-load conditions. Specifically, when the voltage of the battery is below 13.5 V, the voltage-detecting crystal circuit controls the conductivity of the charging crystal, and allows the battery to charge. However, when the charging voltage of the battery reaches 14±0.5 V the battery is fully charged. Then, the voltage-detecting crystal circuit stops the conductivity of the charging crystal, and as a result, the battery stop charging [2].

When the power generator charges the battery through a voltage regulator, the output voltage of the voltage regulator must be maintained at 14±0.5 V. When the battery is detected to be fully charged, an SCR is used to create a short circuit and discharge power from the power generator. Transformation of a large current causes power draining, and it affects the horsepower, torque and fuel consumption of the car engine [3].

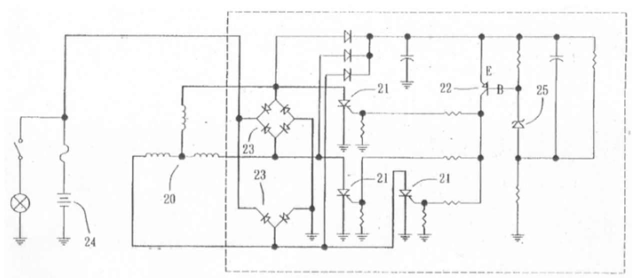

Fig.1 Traditional three-phase generator charging system

2. Intelligent Energy Management Device

The main component used in the power generator to extract the waveform when the voltage impulse is below 30 V, is a high-voltage MOSFET (250 V). To obtain the value for the stabilized voltage, we used a common voltage-stabilizing circuit with Zener diodes and an electric crystal. This voltage is connected to the G-pole of the SCR, and is used by the SCR to control the charging of the battery (BT 151, BSP254, Tof2-30×50 mm). The main goal is to use the power generated by the power generator to charge the battery though the rectification voltage-stabilizer circuit. When the battery is detected to be fully charged, the power generator is isolated, and the battery stops charging. To save energy by minimizing unnecessary power consumption, the power generator is maintained in a no-load mode. When the battery is full, the isolated power generator becomes an open circuit and stops charging the battery. Because no external load is present, there is no power consumption [4].

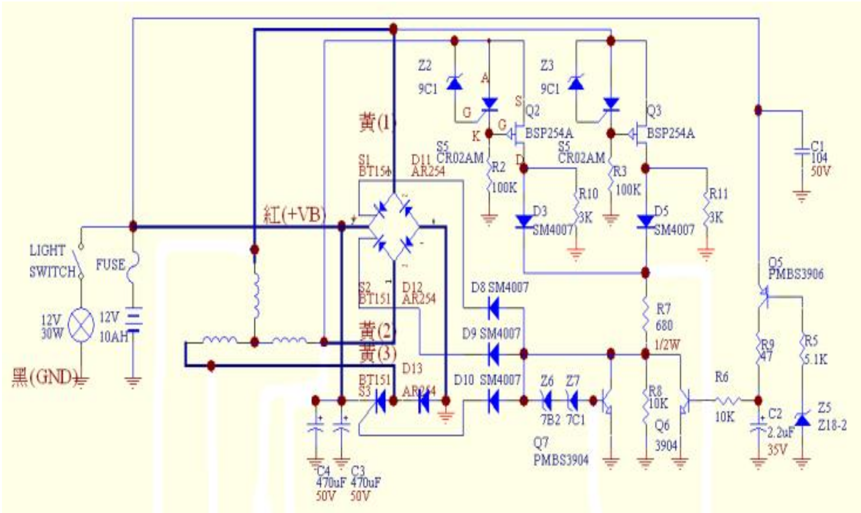

Fig. 2 Circuit of charging device

2.1. Design and planning of a environmentally-friendly and energy-saving charging system

When the power generator charges the battery through the voltage regulator, the output voltage of the voltage regulator must be maintained at 14±0.5 V. When the battery is detected to be fully charged, the SCR is used to create a short circuit to discharge power from the power generator. Large currents generate heat, which in turn causes an increase in the temperature of the power generator and rectifier voltage regulator. Conventional battery-charging systems use the power generator to charge the battery through the voltage stabilizer. When the battery is full at 14±0.5 V, the excess power is discharged to the ground through a short circuit. Figure 2 illustrates the operation principle.

1. We proposed an intelligent low-power consumption, vehicle-charging system that uses a high-impedance electric component (MOSFET), to control the voltage power of the power generator, under zero-load conditions at high speeds. Voltage impulses below 30 V are extracted. An SCR is used to control the ON/OFF operation of the proposed system.
2. When the battery voltage is below 13.5 V, a voltage-detecting crystal circuit controls the conductivity of the charging crystal, and the battery starts charging. When the charging voltage of the battery reaches 14±0.5 V, the battery is fully charged. Then, the voltage-detecting crystal circuit stops the conductivity of the charging crystal, and charging is terminated.

2.2. Design and Verification of the Voltage Regulator back-end Circuit

The specifications used to design our proposed power generator, are based on specifications of a common power generator, which includes: 4 magnets, an 8-pole flywheel, and an 18-pole stator. The circuit design of the charging system is shown in Figure 1. To characterize the performance of the circuit of the charging system, we performed the following tests: 1) Three-phase stator wave; 2) Charging wave (battery); 3) Charging time; 4) Terminating voltage of the battery. The results of these tests are presented in appendix A1-1. According to these results, when the battery starts charging, the battery voltage is 11.5 V, and the charging current is 1.75 A. After 2 hours of charging, the battery voltage is 12.36 V, and the charging current is 100 mA. These values indicate that the battery is almost fully charged. The terminating voltage for the battery is approximately 15.3 V. The output voltage is 14±0.5 V, which is within the design requirement.

At the beginning of charging, the voltage of the battery is 11.5 V, and the charging current is 1.75 A. After 2 hours of charging, the charging voltage of the battery is 12.36 V, and the charging current is 100 mA. These values indicate that the battery is almost fully charged. The terminating voltage of the battery is approximately 15.3 V. To overcome the high-voltage power problem for the power generator under high-speeds at no-load conditions, we used an IC with high-input impedance (MOSFET). Voltage waves below 30 V are extracted, indicating that voltages above 30 V are not conducted, and the SCR is designed to be open circuit. In other words, when the voltage of the battery is below 13.5 V, the voltage-detecting crystal circuit controls the conductivity of the charging crystal, and allows the battery to charge. The battery is fully charged when the charging voltage of the battery reaches 14±0.5 V. When the battery is fully charged, the voltage-detecting crystal circuit stops the conductivity of the charging crystal, and stops charging the battery. Test were performed to determine the values of the charging current of the battery, and the voltage control value of a fully charged battery. To test the temperature of the magnetic electric motor and the voltage stabilizer, we used a three-phase double-wire system. The tests included placing the magnetic electric motor in a 110 °C environment, while running at 8000 rpm for 30 minutes. Under a 100 W load, the voltage of the battery was 9 V. In Table 1, we list all the charging currents for different light bulb loads. In Table 2, we list the charging currents for different light bulb loads, while applying a battery voltage of 11 V. The values for voltage control are tested for the battery charging current, as well as the voltage when the battery is fully loaded. We used a three-phase double-wire system to test the temperature of the magnetic electric motor and the voltage stabilizer. When the battery is fully loaded, the voltage is maintained at 14.18 V (0.1 A). The three-phase double-wire system with a magnetic electric motor by Huaci (T = 110 °C), and a voltage stabilizer by E-Yang (T = 23.5 °C) was operated for 30 minutes at 8000 rpm. The three-phase double wire system has the impedance of 1.37 Ω. The three-phase double-wire system has an impedance of 1.10 Ω (the voltage stabilizer by E-Yang has the temperature of T = 74.3 °C). Based on the abovementioned test results, we conclude that the requirements of our proposed system are satisfied.

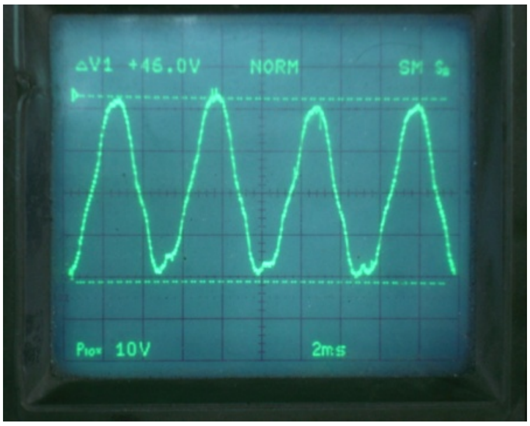

Fig. 3 Coil AC voltage wave

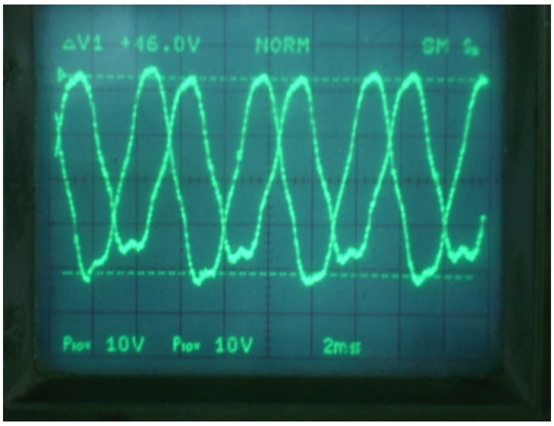

Fig. 4 AC voltage wave (phase difference 120°)

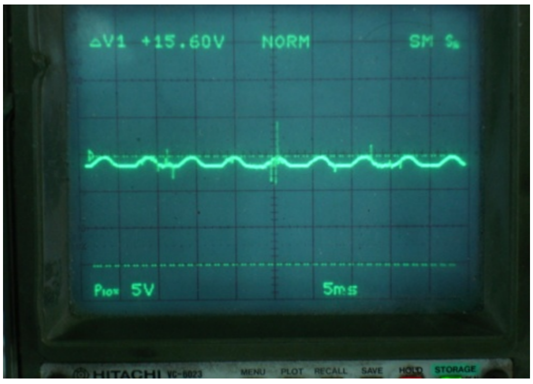

Fig. 5 Charging current 1.5 A, DC voltage of battery 13.9 V

Tests were performed with a fully loaded battery (approximately 12.9 V). The minimum output of the voltage stabilizer was 1200 rpm, the output voltage was 13.3 V, and the output current was 0.1~0.28 A. At the maximum revolution of 8000 rpm, the output voltage was 14.12 V, and the output current was 2.12 A. Based on these results, we note that without a battery, the electric components are undamaged, and the engine operates normally. In addition, the full-battery detector is not installed. (a. output voltage is within 14±0.5 V, b. endurance tests were performed for 200 hours)

Tab. 1 Charing current for bulbs with load. Battery voltage is set to 9 V.

Bulb Load	Low Rev	Mid Rev	High Rev
0W	12.52V/3.63A (1522rpm)	12.17V/1.76A (3835rpm)	12.21V/1.86A (7980rpm)
45W	12.36V/5.40A (1360rpm)	12.0V/4.45A (3761rpm)	11.93V/4.46A (7980rpm)
60W	11.89V/5.59A (1345rpm)	11.57V/5.04A (3790rpm)	11.35V/4.98A (7980rpm)
80W	11.09V/5.60A (1295rpm)	10.85V/5.13A (3780rpm)	10.94V/4.86A (7980rpm)
100W	11.4V/5.61A (1342rpm)	11.21V/4.94A (3780rpm)	11.23V/4.80A (7920rpm)

Tab. 2 Charing current for bulbs with load. Battery voltage is set to 11 V.

Bulb load	Low Rev	Mid Rev	High Rev
0W	12.67V/5.42A (1495rpm)	12.2V/2.15A (3858rpm)	12.22V/1.86A (7980rpm)
45W	12.07V/5.41A (1414rpm)	11.94V/4.11A (3797rpm)	11.70V/2.30A (7980rpm)
60W	11.81V/5.51A (1421rpm)	11.64V/4.59A (3797rpm)	11.54V/4.50A (7980rpm)
80W	11.73V/5.52A (1422rpm)	11.52V/4.71A (3797rpm)	11.52V/4.50A (7980rpm)
100W	11.80V/5.70A (1463rpm)	11.55V/4.71A (3750rpm)	11.50V/4.62A (7980rpm)

3. Conclusion

The main goal of this work was to improve traditional voltage regulators used in vehicles, which recharge the battery continuously, even when it is fully loaded. This over-charging results in a constant loss of energy. To overcome this drawback, a novel regulator was proposed, which intelligently opens the recharging circuits to avoid over-charging. The proposed system unloads the power generator, which drastically reduces energy loss, and in turn saves energy, and decrease the temperature of the generator. The developed device will make the following contributions:

1. Technological:
   (1) reduce energy loss, save energy, improve efficiency of electrical power systems.
   (2) the applied targets can be initially chosen to be motorcycles, replace traditional regulator devices, improve power system energy efficiency and exhaust pollution of internal combustion engines.
2. Results
   (1) energy savings increased by 20%
   (2) product value increased by 30%
   (3) product yield rate increase more than 20%

4. Acknowledgements

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