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Development of a Portable Power Measurement System for Electric Sanitation Vehicle

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Abstract—In general, the chassis dynamometer is a commonly used device for vehicle power measurement. But it has a high price and cannot obtain the real-time power for the electric sanitation vehicle (ESV) when the auxiliary equipments are operating. Aiming to the problem, a portable power measurement system has been developed based on the virtual instrument for the ESV. The portable power measurement system can be installed on the ESV and acquire the real-time power under the various working condition by measuring current and voltage of the load device. Data acquisition, data processing and waveform display are achieved by virtual instrument programming. The system has been tested on an ESV, and a method of motor efficiency measurement for the ESV is presented. Furthermore, the system can provide much convenience for performance measurement and saves production cost for manufacturers.

Keywords—Electric sanitation vehicle; Power measurement system; virtual instrument; motor efficiency

I. Introduction

The Electric vehicle (EV) has prevailed over the world when energy dilemma and ecologic crisis come. Carbon dioxide is a greenhouse gas and the main emissions of the internal combustion engine vehicle (ICEV). The EV emits no pollutants and has higher engine efficiency compared with the ICEV. Therefore, many countries have striven to develop EVs [1, 2].

The haze is getting heavier and heavier with the growth of economic. At the same time, the municipal solid waste becomes more and more with the growth of urban population. Thus, the Green City has become a development direction of numerous cities, and municipal vehicles, especially low-speed municipal vehicles, are increasingly applied in city sanitation, public transportation, and other municipal management fields. These vehicles are being converted to the electric drive vehicles with the government support [3, 4]. Hence, many enterprises have massively produced the municipal electric vehicle such as the electric sanitation vehicle (ESV) [5-7]. The dynamic performance is a fundamental parameter for the ESV. Conventional test equipments, like the chassis dynamometer with a high price, would increase the test cost and it cannot measure all working conditions of the ESV, which has some auxiliary equipments with special functions. Thus, it is indispensable to design a convenient, efficient and sensitive device for power measurement of the ESV. As the EV has a higher electrification degree than the ICEV, the real-time power can be acquired by measuring current and voltage of the load device [8].

A portable power measurement system is presented based on the LabVIEW platform for the ESV in this paper. The system uses a NI Data Acquisition (DAQ) Card with the LabVIEW to achieve power data acquisition. And the feasibility of the measurement system is verified by testing on an ESV.

II. The structure of the electric sanitation vehicle

The ESV with the feature of high flexibility, high efficiency and low-carbon, is very suitable for city sanitation. As shown in Fig. 1, the ESV, which is the test object for the portable power measurement system, includes two parts: the vehicle body and the auxiliary equipments.

Fig. 1. *The picture of electric sanitation vehicle*

The vehicle body is comprised of a driving cab and a chassis. A 72V battery pack, a 5.5kW DC motor, a differential and the drive shaft constitute the powertrain of the ESV. All electricity demands, which include the demands of vehicle travel and auxiliary equipments operating, are supplied by the battery pack.

The auxiliary equipment is a garbage trunk with a hydraulic lifter which can help sanitation workers to lift the dustbin for dumping garbage into the garbage trunk, a hydraulic scraper which can compact the garbage and a hydraulic jacking system which can jack up the garbage trunk to dump the garbage out.

There are 2 DC motors in the ESV: a drive motor and a hydraulic system motor. The basic parameters of the motor are given in Table Ⅰ.

TABLE I. THE BASIC PARAMETERS OF THE MOTORS

Items	***Drive motor***	***Hydraulic system motor***
Rated voltage(V)	72	72
Rated current(A)	89	24
Rated power(kW)	5.5	1.5
Rated speed(RPM)	2500	3500

III. THE DEVELOPMENT OF THE MEASUREMENT SYSTEM

Power is an important performance parameter which can reflect battery performance, acceleration performance and matching degree of the auxiliary equipment. In general, power measurement of the vehicle is done by the chassis dynamometer which has a high price. As the EV is a high integration electrical system, this paper offers a modern alternative, to the traditional power measurement system, a portable system which can be installed on the vehicle and measure power in different working conditions.

As shown in Fig. 2, there is a DC/DC converter between the battery and the motor. The system is installed between the battery and the DC/DC converter in parallel. If the ESV uses an AC motor as the power source, this system should be installed between the battery and the inverter. Most of ESVs have a clear connection between the battery and the motor, so it is easy to install the system.

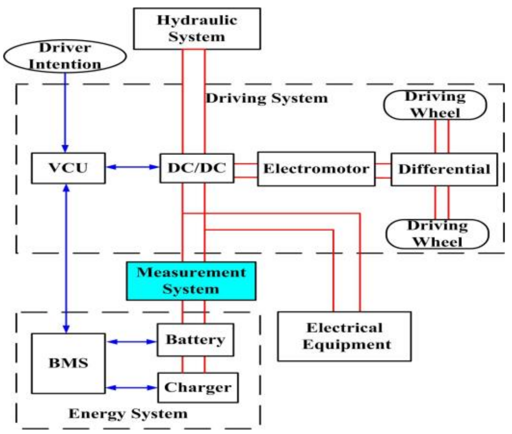


Fig. 2. *The connection location of the measurement system*

A. The Hardware of the Measurement System

The hardware of the measurement system is shown in Fig. 3 and it includes a DAQ card, a voltage divider, a current sensor and a laptop with the LabVIEW software.

The NI USB 6002 is used for data acquisition, and it has 8 analog voltage inputs which support 4 differential signals and 8 single-ended signals. The DAQ card is connected to the laptop by a USB cable and it supports ±10V voltage input and has feature of high sampling rate, high resolution and high anti-interference ability [9, 10]. The voltage signals, which are output by the current sensor and the voltage divider, are sent to the DAQ card which is connected to the LabVIEW in the laptop.

The voltage divider consists of 2 tandem resistances and it is connected with the battery and the DC/DC converter in parallel. The values of R_1 and R_2 are 10 KΩ and 500Ω respectively. The R_2 measured by the DAQ card, can maintain the voltage never greater than 10V [11]. The equation of U_0 is given as:

$$U_0 = U_2 \frac{R_1+R_2}{R_2} \quad (1)$$

where U_2 is the voltage of R_2.

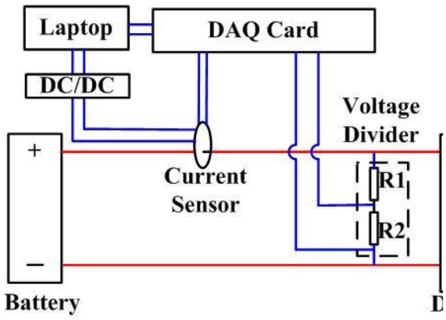


Fig. 3. *The structure of the measurement system*

The current of the circuit is measured by a closed loop hall current sensor. The current sensor provides output of 50mA under the ±12V power supply. The DC/DC module, which is connected to the laptop for the power supply of the current sensor, can convert the voltage of 5V from the laptop to ±12V. The connection of the current sensor is presented in Fig. 4.

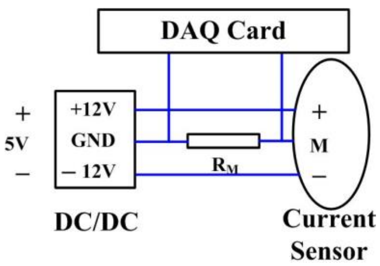


Fig. 4. *The connection of the current sensor*

The current output by sensor and the current of wire measured by sensor can be obtained by measuring the voltage of the resistance R_M. The resistance value of R_M is 125Ω. If the wire has current and passes through the loop of the current sensor, there would be a voltage signal sent to the DAQ card. The conversion rate K_N of current sensor is 1:2000 and the relevant equation for calculating the current of wire is given as:

$$I_0 = \frac{U_M}{R_M} K_M \quad (2)$$

where U_M is the voltage of R_M, and I_0 is the current of wire measured by sensor.

B. The Software of the Measurement System

The NI LabVIEW, which is installed on the laptop, can support the DAQ card to implement various types of measurement. It provides graphical programming language instead of conventional text code and can achieve data acquisition, data processing and waveform display. To reflect the function of procedure intuitively, the LabVIEW uses the concept of data stream to program.

Given below is the introduction of the power measurement procedure. To begin with, the DAQ card is set to collect a set of 2×100 voltage data per circulation and the data are changed to 2 dynamic data in the procedure of the DAQ part. Fig. 5 shows the procedure diagram of the DAQ part. The mode of data acquisition uses the differential signal which has been widely used in high-speed digital circuits and has the feature of high anti-interference. In the procedure, samples, sample rate and test time can be predefined. For making the procedure to be concise, the DAQ part is packed as a subprogram of the measurement system procedure.

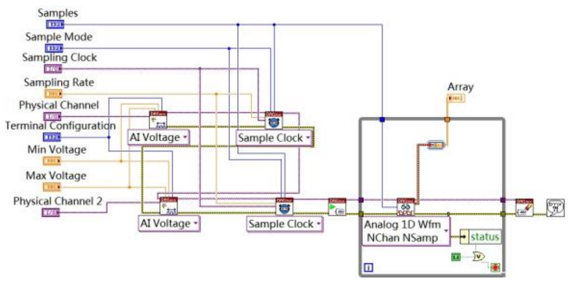


Fig. 5. *The procedure diagram of the DAQ part*

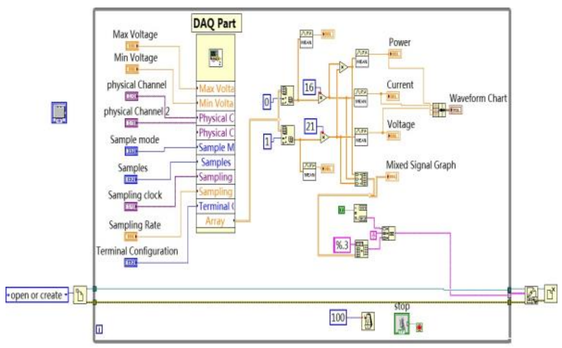


Fig. 6. *The procedure diagram of the measurement part*

Then as shown in Fig. 6, the data output by DAQ part are converted to a dynamic two-dimension array which includes 2×100 elements and the array is subsequently divided into 2 one-dimensional arrays. Next, each one-dimensional array respectively becomes the final value of current and voltage by calculating according to equation (1) and equation (2). The power can be calculated according to equation (3).

$$P = UI \quad (3)$$

where P is the power that battery offered, U is the motor voltage and I is the motor current.

The power, current and voltage are presented in the form of curves at the waveform graph of the front panel and their mean is also shown at the front panel, as shown in Fig. 7.

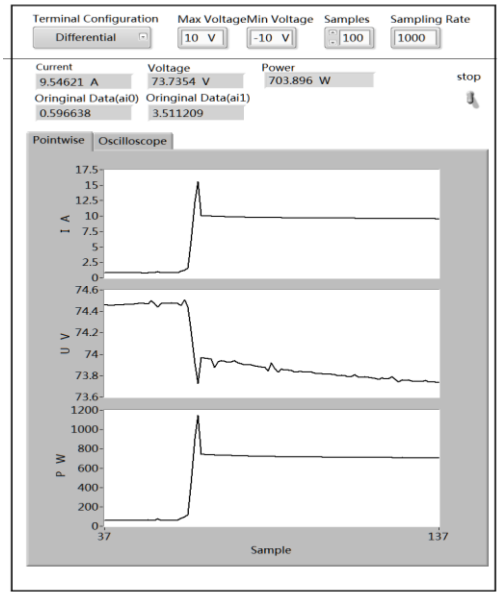


Fig. 7. *The front panel of the measurement procedure*

In the end, the measurement data of power, current and voltage are saved as a file output by the procedure. The LabVIEW provides multifarious file I/O functions and the final file can be opened as a textfile or an Excel worksheet. Therefore, it is very convenience to use other software, such as Matlab, to analyze the data further.

IV. Experiment and Analysis

A. The Experimentation on the Electric Sanitation Vehicle

The system is installed on an ESV to obtain power of various work operating modes which include no-load travel, full-load travel, hydraulic scraper operating, hydraulic lifter operating of up and down, hydraulic jack operating of up and down.

According to Fig. 3, the measurement system is installed between the battery and the DC/DC voltage convertor before the experimentation.

1) The Power measurement in the vehicle travel mode

The vehicle travel mode of the ESV includes full-load and no-load. At the beginning of the measurement, the procedure of the LabVIEW is running and the accelerator is kept to be the largest state. Then, the measurement is ended when the speed is steady.

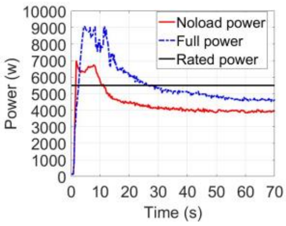
The test selects the maximum speed as the steady speed because the maximum speed of the ESV is only 30km/h and is much lower than that of the other vehicle on the road. Also, it is the common work speed.

2) The Power measurement in the hydraulic system operating mode

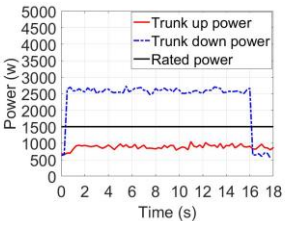
The power of the hydraulic system is provided by a BLDC motor. Similarly, the match degree of the hydraulic equipments can be known through measuring the power of the motor. The measurement procedure is run to record real-time power and the lifter is moving from initial position to rise to extreme position by operating the control panel. Then the lifter moves to the initial position by operating and the measuring is ended finally. For scraper and jack are done by the same operation.

B. Data Analysis

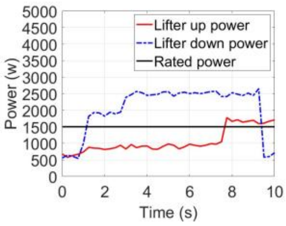
The result of power measurement has been output from the laptop by testing each operating mode respectively. Measurement procedure can output a set of data of power, current and voltage and by the Matlab processing, the results are obtained and are presented in Fig. 8 and Fig. 9.



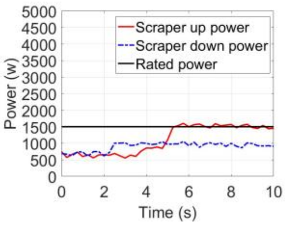
(a) Vehicle traveling



(b) hydraulic trunk operating

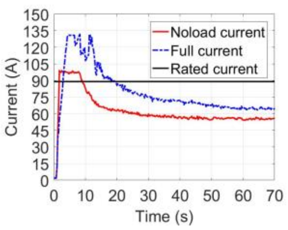


(c) Hydraulic lifter operating

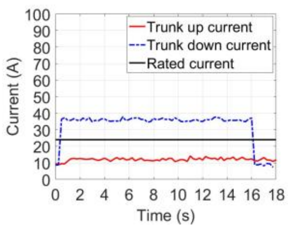


(d) Hydraulic scraper operating

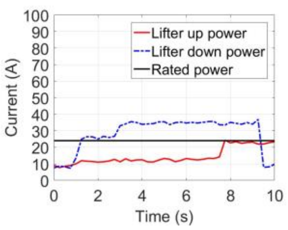
Fig. 8. *The real-time power in various modes*



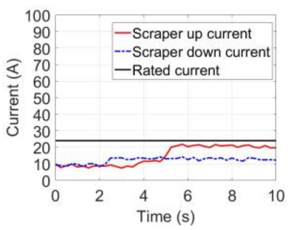
(a) Vehicle traveling



(b) Hydraulic trunk operating



(c) Hydraulic lifter operating



(d) Hydraulic scraper operating

Fig. 9. *The real-time current in various modes*

From the results, the peak power and the peak current reach about 9kW and 130A respectively and the average power of full and no-load are about 4.5kW and 4kW respectively in the vehicle travel mode. The electric sanitation vehicle is driven by a 5.5kW DC motor with the rated current of 89A. However the motor can satisfy the power demand of the vehicle travel at maximum stable speed. But the ESV is used for collecting garbage from many garbage bins and it needs frequent acceleration. So it is possible that the motor becomes overheated and the maximum current should be limited at lower value.

In the hydraulic system operating mode, the maximum power of lifter operating is about 2.5kW. The maximum power of scraper operating is about 1.5kW. The maximum power of jack operating is 2.6kW. The rated power and the rated current of the hydraulic system DC motor are 1.5kW and 24A. It is observed that the power and current of lifter operating and jack operating exceed the rated value for most of the time. The operation of hydraulic lifter up or down is a frequent working mode and there is a hidden danger of overheating which may shorten the life of motor [12].Therefore, the motor is not very suitable for the hydraulic system. So a higher power motor should be chosen for the work safety.

C. The Motor Efficiency of the Electric Sanitation Vehicle

The input power and the output power of the motor is important parameter for dynamic performance matching. But it is not easy to measure the motor efficiency for the ESV in the condition of no disassembly. For the ESV, the driving power P_t that battery provides drives wheels via motor, retarder, differential, transmission shaft. There are some power losses including battery discharge loss, motor energy loss and transmission loss. The power P_t can be expressed as:

$$P_t = P_b n_b n_e n_T = P_E n_e n_T \quad (4)$$

where P_b is the power provided the battery, n_b the battery efficiency, n_e is motor efficiency and n_T is transmission efficiency. The n_T can be seen as a constant because there is no gearbox in the ESV.

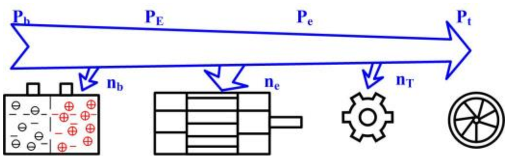


Fig.10. *The power transmission process*

The power transmission process is shown in Fig. 10. The measurement result is the power P_E of both sides of the motor in this test. Obviously, it would be easy to obtain the efficiency η_e of the motor if the driving power P_t is known. And the drive power P_t can be measured by the chassis dynamometer. So the curve of motor efficiency can be obtained by using the power measurement system and the chassis dynamometer to measure the input power P_E of the motor and driving power P_t in the condition of no disassembly. The motor efficiency n_e can be calculated by follow equation.

$$n_e = \frac{p_t}{n_T p_E} \quad (5)$$

V. CONCLUSION

The following conclusions are drawn from the study:

a. A portable power measurement system based on the LabVIEW platform has been developed for the ESV. According to the experiment on the ESV, the portable power measurement system can expediently measure the power under different working condition.

b. A method to measure the motor efficiency of ESV by using the power measurement system with the chassis dynamometer is introduced. It facilitates the test of the motor match degree of the ESV in actual situation.

c. The system is beneficial to the ESV dynamic performance and auxiliary equipment matching. Meanwhile it saves a lot costs for small-scale electric vehicle manufacturers to test the performance of the new product.

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REFERENCES

[1] Du Jiu-yu, Ouyang Ming-gao, Chen Jing-fu."Prospects for Chinese electric vehicle technologies in 2016–2020: Ambition and rationality," J. Energy, 120 (2017): 584-596

[2] Hannan M A, Hoque M M, Mohamed A, A Ayob. "Review of energy storage systems for electric vehicle applications: Issues and challenges," J. Renewable and Sustainable Energy Reviews, 69 (2017): 771-789

[3] Cheng M, Tong M. "Development status and trend of electric vehicles in China," J. Chinese Journal of Electrical Engineering, 3(2017): 1-13

[4] Shao Lu, Zhou Zhi-guang, Han E, Yan Guofeng. "New energy road sweeper scenario design and simulation," 2014 IEEE Conference and Expo Transportation Elect, 2014: 1-4.

[5] Zhao D, Wang R. "Research on Parameters Matching of Electric Sanitation Vehicle Powertrain," 2013 International Conference on Mechanical and Au, 2013: 95-97.

[6] Xiong G, Xi J, Zhai Y, et al. "Development of pneumatically automatic mechanical transmission for a pure electric garbage truck," 2010 IEEE International Conference on Industrial T, 2010: 1108-1112.

[7] Wu X-h, Wang Z-f, Zhang C-n, Chen Z y. "Research on a Control Strategy for an Electric Sanitation Vehicle," 2010 Asia-Pacific Power and Energy Engineering Con, 2010: 1-5.

[8] Zhou Bo-wen, Littler T, Meegahapola L, Zhang hua guang. "Power system steady-state analysis with large-scale electric vehicle integration," J. Energy, 115, Part 1 (2016): 289-302

[9] Sekhar N C, Reddy T S, Bhavani G. "Implementation of low-cost MEMS based temperature measurement and control system using Lab VIEW and microcontroller," 2014 International Conference on Power, Control an, 2014: 1-4.

[10] Jamaluddin A, Sihombing L, Supriyanto A, M Nizam. "Design real time Battery Monitoring System using LabVIEW Interface for Arduino (LIFA)," 2013 Joint International Conference on Rural Infor, 2013: 1-4.

[11] Chompoo-inwai C, Mungkornassawakul J. "A Smart Recording Power Analyzer Prototype Using LabVIEW and Low-Cost Data Acquisition (DAQ) in Being a Smart Renewable Monitoring System," IEEE Green Technologies Conference (GreenTech, 2013: 49-56.

[12] Driesen J, Belmans R M, Hameyer K. "Finite-element modeling of thermal contact resistances and insulation layers in electrical machines," J. IEEE Transactions on Industry Applications, 37(2001): 15-20