CHEMICAL ENGINEERING TRANSACTIONS

VOL. 62, 2017

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216

DOI: 10.3303/CET1762201

A Measuring Method about the Bus Insulation Resistance of Power Battery Pack

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For the shortcomings of insulation resistance detection method about battery pack, a novel detection method is introduced. This method can effectively realize the real-time measurement for the insulation resistance of the positive and negative bus, relative to the ground. In the dynamic conditions, improved the positive and negative bus insulation resistance measurement accuracy, more suitable for applications in integrated battery pack monitoring unit, it has a simple circuit, low power consumption, low cost hardware.

1. Introduction

In electric vehicles, because the working voltage of power battery is higher (generally in the 300 v to 600 v), when the battery power bus cable insulation aged or affected by damp environment factors, which can lead to high voltage circuit and the insulation performance is degraded, resulting in leakage current between the positive and negative bus and the environment, which is the threat to personal safety and vehicle safety (Lei et al., 2010). Therefore, accurate real-time monitoring of battery power bus insulation resistance and safety are of great significance to ensure that vehicles and personnel (Huang et al., 2005).

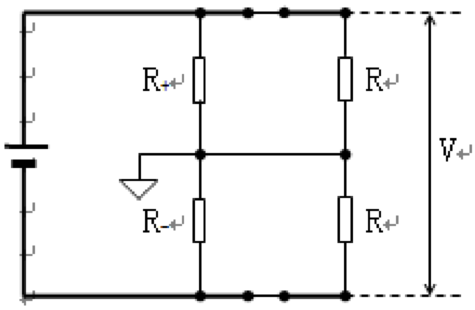
Currently, the measuring methods of battery bus insulation resistance include auxiliary power method, current sensing method, the positive and negative bus on the Environment and the partial pressure of the asymmetric method and bridge method (Wang, 2011). Due to the asymmetric bridge measurement is relatively simple, currently received more applications. The basic principle is to connect the parallel connection between the positive bus-to-ground insulation resistance Rp and the negative bus-to-ground insulation resistance Rn, respectively, and the two known positive and negative bus parallel resistors R + and R-,By measuring the positive and negative bus-to-ground voltages Vp, Vn and the battery voltage V, according to the loop equation, Since this method is done by switching R + and R- times to complete sampling and measurement of Vp, Vn, and V ,therefore, in sampling measurement, when the battery voltage V is steady state value, the measurement error approach mainly from the dividing resistor, an operational amplifier A1, A2 and an error of the ADC. However, when the battery is in a dynamic state of working conditions, due to the drastic changes in the battery voltage V,Vp, Vn and V sampling measurement time is not synchronized, the measured value Rn and Rp will produce large errors (Zhou et al., 2013).

This article provides a battery powered bus insulation resistance measurement apparatus and method which can reduce the measurement error bus insulation resistance in dynamic conditions (Cheng et al., 2012; Luo et al., 2013; Wu, 2015; Zhang and Wen, 2013).

2. Bus insulation resistance measurement method

Measurement of power batteries bus insulation resistance, comprising: these shown in Figure 2, 3, 4.

Please cite this article as: Hongyu Zhao, Cheng Liu, Chunyan Xu, 2017, A measuring method about the bus insulation resistance of power battery pack, Chemical Engineering Transactions, 62, 1201-1206 DOI:10.3303/CET1762201



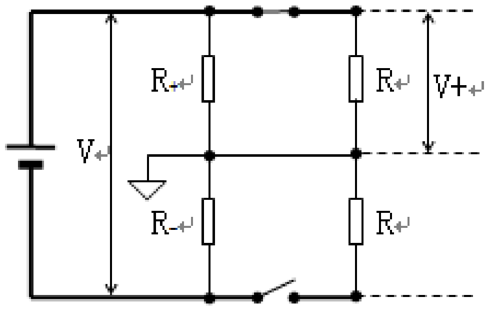


Figure 1: Measuring the total voltage *Figure 2: Measuring V+*

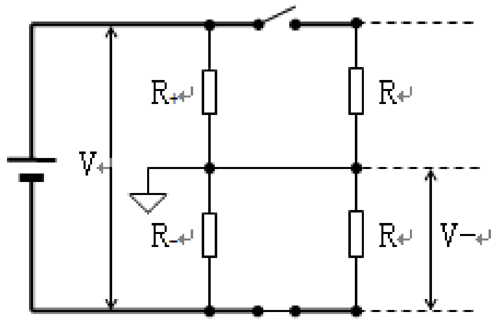


Figure 3: Measuring V-

2.1 Bus insulation resistance calculation method

$$\frac{R_+\|R}{R_-}=\frac{V_+}{V-V_+}=K_+ \quad (1)$$

$$R_-=\frac{R_+R}{K_+(R_++R)} \quad (2)$$

$$\frac{R_-\|R}{R_+}=\frac{V_-}{V-V_-}=K_- \quad (3)$$

$$R_+=\frac{R_-R}{K_-(R_-+R)} \quad (4)$$

Take equation (2) into equation (3)

$$R_+=\frac{(1-K_+K_-)R}{K_-(1+K_+)} \quad (5)$$

Take equation (4) into equation (1)

$$R_-=\frac{(1-K_+K_-)R}{k_+-(1+K_-)} \quad (6)$$

2.2 Improvement bus insulation resistance calculation method

Above is calculated on the assumption that V is constant deduced conclusions. The practical application of V is within a certain range, and if unable to V, V +, V- strictly simultaneous measurement, when the change rate V is larger, since the measurement process will not synchronize V +, V- of deviation from the measured value of V sampling time of the actual value of the insulation resistance caused by a calculation error (Wang et al., 2012).

To do this, use the following measurement and compensation:

1. △T cycle, sequentially V, V +, V-, V sampling, measurement values were obtained V0s, V_{+s}, V_{-s}, V3s;
2. V increment calculation of △V = V3s-V0s;

Calculate the percentage of increment per unit time V coefficient K△V = △V/V0s / (3△ T)

3. The V in the sampling period (0.0-3 △T) can be approximated by a linear change, and V +, V- and V has a linear relationship, that is, V +, V- and V have the same K△V. Thus, in the sampling period, with K△V at the same time point to V +, V- and V were estimated.

4. Click the estimated time in 3 ∆T / 2, the computing V +, V-, V in 3 ∆T / 2 time estimates V_{+ES}, V_{-ES}, V_{ES},
$V_{ES} = V_{0s} + K_{\Delta V}\,(3\Delta T/2)$
$V_{+ES} = V_{+ES} + K_{\Delta V}\,(3\Delta T/2-\Delta T)$
$V_{-ES} = V_{-ES} - K_{\Delta V}\,(3\Delta T/2-\Delta T)$
5. The V_{ES}, V_{ES}, V_{ES} as (1), (2), (5), (6) where V, V+, V- calculated
S1: the following order cycle sampling: First, the battery voltage is sampled; then on the positive bus voltage is sampled on the ground; and then the battery voltage is sampled; and negative-ground voltage sampling;
S2: Calculation positive bus to ground voltage sampling value, twice the measured battery voltage difference as a first increment coefficient, calculated in negative ground voltage value, twice the measured battery voltage difference as a gain in the second, and respectively positive bus and negative bus voltage to ground-to-ground voltage estimates at the time of sampling the battery voltage based on the first and second incremental increase coefficient;
S3: According to the sampled battery voltage and the battery voltage sampling time is positive, negative ground voltage estimation value obtained in the sampling time positive bus and negative bus insulation resistance.

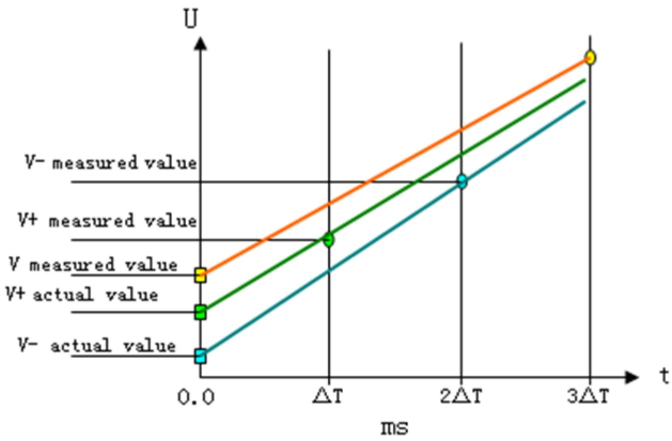


Figure 4: The actual value and the measured value of the voltage

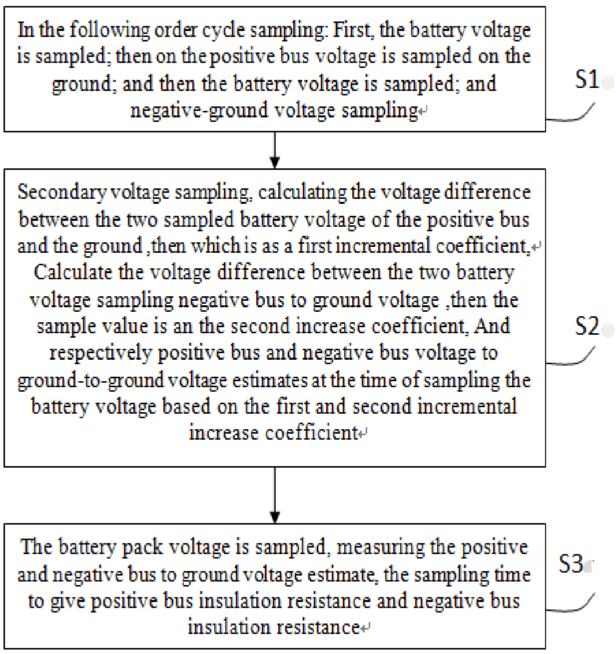


Figure 5: Voltage sampling process of traditional methods

Loop sampling process in particular:
S11: initialization of the loop sampling counter i = 0;
S12: positive bus and negative bus communication, measuring the battery voltage V (4i * Δt), where Δt is the sampling period;
S13: positive bus communication, disconnect the negative bus, measuring positive bus to ground voltage Vp ((4i + 1) * Δt);
S14: communicating positive bus and negative bus, measure battery voltage V ((4i + 2) * Δt);
S15: negative bus communication, disconnect the positive bus, measure negative ground voltage Vn ((4i + 3) * Δt);
S16: loop sampling counter i = i + 1, go to step S12.
Voltage sampling process is shown in Figure6.

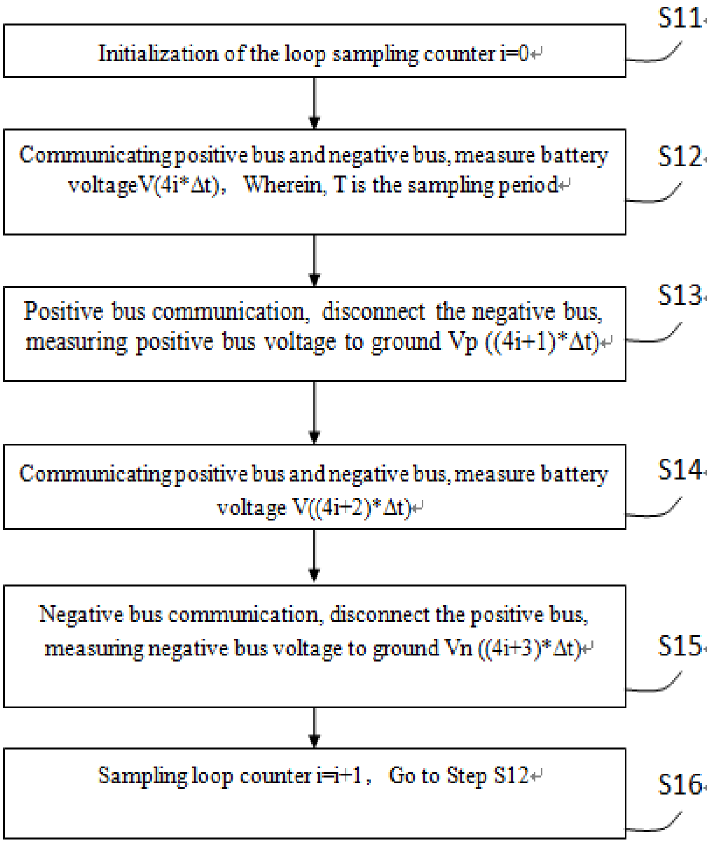


Figure 6: Voltage sampling process

In practice sampling period Δt = 10ms or 20ms.
Since the insulation performance degradation is a slow process, the insulation resistance Rp positive bus and negative bus insulation resistance Rn in a sampling cycle time can be approximated as a constant by the formula (1), (2) and (3) can be seen, when incremental coefficient R + = R-, = N, the positive bus to ground voltage Vp in 4NΔt- (4N + 2) Δt sampling time has a first gain in battery voltage V of the same kp (N), which is
$k_p(N) = \Delta V_p / V_p = [V((4N + 2)\Delta t) - V(4N\Delta t)] / V(4N\Delta t)$
Similarly, negative ground voltage Vn at (4N + 2) Δt- (4N + 4) having an inner Δt sampling time and battery voltage of the second gain in the same incremental coefficient kn (N), that is,
$k_n(N) = \Delta V_n / V_n = [V((4N + 4)\Delta t) - V((4N + 2)\Delta t)] / V((4N + 2)\Delta t)$
Accordingly, by the positive bus to ground voltage Vp at (4N + 1) * Δt time and negative bus to ground voltage Vn at (4N + 3) * Δt time measurement Vp ((4N + 1) * Δt) and Vn ((4N + 3) * Δt) calculate the estimated value of the bus to the positive and negative voltages Vp and Vn in the (4N + 2) Δt time:
$V_p((4N + 2) * \Delta t) = V_p((4N + 1) * \Delta t) [1 + k_p(N) / 2]$
$V_n((4N + 2) * \Delta t) = V_n((4N + 3) * \Delta t) [1 - k_n(N) / 2]$

The battery pack voltage (4N + 2) * Δt time measurement values V ((4N + 2) * Δt) and known R +, R-, the use of (1) - (5), we can calculate the positive negative insulation resistance Rp and Rn at (4N + 2) * measured value Δt time.
When the next sampling cycle, that is, i = N + 1, the positive and negative moments in 4NΔt ground voltage Vp and Vn can be calculated
kp (N) = ΔVp / Vp = [V ((4N + 2) Δt) - V (4NΔt)] / V (4NΔt)
Vp ((4N + 2) * Δt) = Vp ((4N + 1) * Δt) [1-kp (N) / 2]
Vn ((4 (N-1) +2) * Δt) = Vn ((4 (N-1) +3) * Δt) [1 + kn (N-1) / 2]
The battery pack voltage measurements V in 4NΔt time (4NΔt) and known R +, R-, the use of (1) - (5), we can calculate the positive and negative insulation resistance Rp and Rn measurements in 4NΔt time,as shown in picture 7.

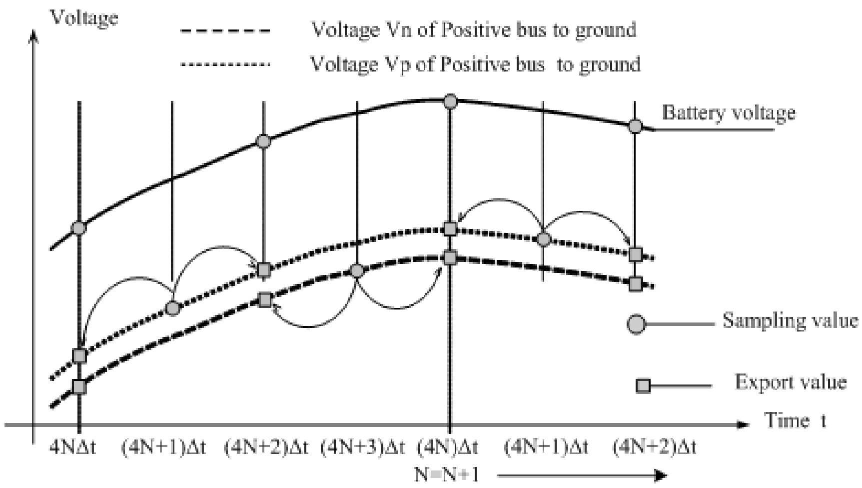


Figure 7: The positive and negative bus voltage to ground to the schematic diagram of estimate measurement

3. Measurement Embodiment

This measure can effectively achieve the insulation resistance of the positive, negative battery voltage and the bus in real time measurement, improve the dynamic conditions of positive and negative bus to ground insulation resistance measurement accuracy, with a simple circuit, low power consumption, low cost hardware, it is more suitable for integration in the power battery monitoring unit (Guo et al., 2011).
When used, the basic principle of asymmetric bridge method, measuring means circuit has three inputs, i.e. positive bus input terminal, a negative input bus bar and vehicle ground through a first resistor R1 and the second resistor R2, the third resistor R3 and the fourth resistor R4 as a voltage divider resistors constituting the first and second voltage divider circuits 5, 6, Measuring device provide positive Vp, negative bus voltage to ground. vn and V battery voltage measurement signal for high impedance differential operational amplifier A1 in-phase side and reverse side.
In this embodiment R1 = R3, R2 = R4, kf = R1 / R2 = R3 / R4 ratio of the partial pressure. After the signal the operational amplifier A1 is amplified to ADC input AD conversion of the microprocessor CPU via isolation amplifier A2 ADC. Measurements:
(1) When the first gate switch J + and the second gate switch J - conducting at the same time, Battery voltage V via the first to fourth resistor R1, R2, R3 and R4, bleeder circuit amplifier A1 provide partial pressure signal V/kf of battery voltage operational V, realized measurement of battery voltage V.
(2) When the first gate switch J + and the second gate switch J - turned off at the same time, voltage Vp of positive bus opposite ground is divide after the resistors R1 and R2, which provide with the partial pressure signal Vp/kf for amplifier A1 to achieve measurement of the positive bus to ground voltage Vp (Ding, 2016). Because the amplifier A1 input has G the level of input impedance, Thus, R1 + R2 can be regarded as parallel resistance R between the positive bus and ground, used to calculate the insulation resistance Rp of positive bus and insulation resistance Rn of negative bus (Li et al., 2015).
When the second gate switch J- turned on, the first gate switch J + turn-off, the voltage Vn of the negative bus opposite ground is divide after the resistors R3 and R4,which provide with the partial pressure signal Vn/kf for amplifier A1 to achieve measurement of the negative bus to ground voltage Vn.Because the input of amplifier

A1 has G ohms the level of input impedance, Thus, R3 + R4 can be regarded as parallel resistance R- between the positive bus and ground, Used to calculate the insulation resistance Rp of positive bus and insulation resistance Rn of negative bus. To give positive and negative bus insulation resistance value via the specific formulas (1) to (5).

4. Conclusion

This design reduces the measurement error of the positive bus insulation resistance Rp and the negative bus insulation resistance Rn , duing to the non-synchronization measurement of the battery voltage V for the positive bus-to-ground voltage Vp and the negative bus-to-ground voltage Vn in the rapid change of the battery voltage, improved the measurement accuracy of the insulation resistance of the bus to ground, reduced the complexity of the measurement circuit, making the measurement circuit more simple and reliable. To achieve an integrated measurement of bus insulation resistance and battery voltage.

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