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Automatic Measurement for Internal Resistance of Battery in Uninterruptible Power Source

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Abstract- **This paper considers the approach to the measurement of internal resistance of the battery in the uninterruptible power sources (UPSs [1]). Advantages of the approach are the measurements in power supplies without switching-off the battery, simplicity in realization of algorithm.**

The basic expressions of the theory used in the method about internal resistance of the storage battery are considered.

The function chart of construction of an analog part of the scheme, and also algorithm of action of the scheme of logic of decision-making are considered.

Construction of the tracing generator of load, the important part in realization of the method is stated. The use of the analog machine for processing of the results of measurements and a differential method of measurement with the purpose of increase the accuracy of the method is offered.

Key words- **UPS, internal resistance of battery, measuring algorithm, tracing load generator, analog machine, decision logic, differential measuring.**

I. INTRODUCTION

The condition of the reserve battery is important for UPSs. Most of UPSs have only tools of measurement and the control for a voltage and a current of the battery, and also the program to notice the preliminary processing results of measurement. It does not allow to define refusals for battery UPS, or allows to predict not precisely. The condition of the battery will be precisely certain through an estimation of the variation of the internal resistance of the battery.

Internal resistance is the characteristic of the battery as a source of power supply, it is caused by a condition of chemical and physical elements of a design of the battery, and defines ability of the battery to transfer in loading energy of a direct current ("Fig.1").

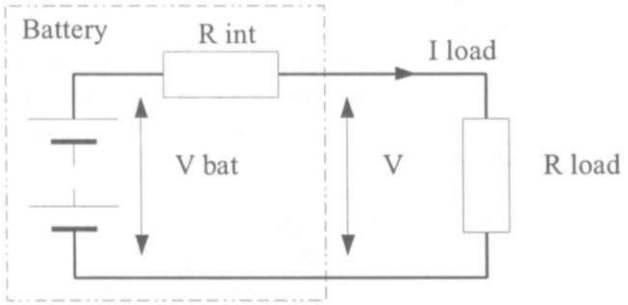

Fig. 1 Internal resistance of battery

The internal resistance of battery depends on the conditions of physical and chemical components of battery.

The internal resistance of battery is defined as:

$$R_{int} = \frac{\partial U}{\partial I}, \quad (1)$$

where - ∂U-increment of a voltage of the battery caused by increment of the current of the battery ∂I .

If the current through the load is constant, defined R_{int} is not suitable to practical use. Measurement R_{int} is based on the use of superposition of constant and variable currents of load.

First, it demands for a method of computing capability that is used for processing results of measurement in the computer or in the digital signal processor to process [2]. Second, if the current of loading is not constant then influence of harmonics in the load current on the accuracy of the method is possible. Third, this method, for realization in simple devices is not optimum and has high cost.

At realization should resolve problems connected with:

- the excitation in a current in load of a variable component;
- the measurement of a variable component in a current in load;
- the measurement of a variable component in a voltage on the battery;
- the calculation of the relationship between small level.

The simplification of definition R_{int} has given a method which is known as ΔV method. The given method is not considered as a method with high accuracy in comparison with considered earlier, but has one conclusive advantage, namely: it is simple in realization. Simplicity of realization allows to develop the given method and to use for the automatic control of a condition of the battery.

The internal resistance of battery calculated ΔV via method:

$$V_{bat} = I * (R_{int} + R_{load}) = I * R_{int} + V$$

If $V_1 = I_1 * R_{load\ 1}$ and $V_2 = I_2 * R_{load\ 2}$, then:

$$I_1 * R_{int} + V_1 = I_2 * R_{int} + V_2,$$

and

$$R_{int} = \frac{V_2 - V_1}{I_1 - I_2} = \frac{\Delta V}{I_1 - I_2}. \quad (2)$$

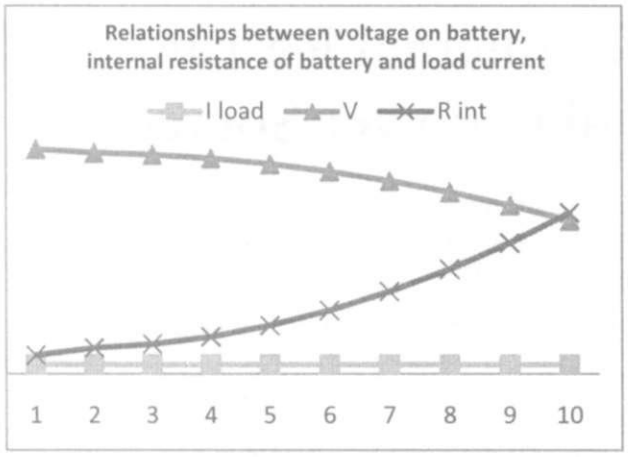

Fig. 2 relationships between voltage on battery, internal resistance of battery and load current

II. PROBLEMATIC OF MEASUREMENT OF INTERNAL RESISTANCE

Reliable measurement of the important parameter of the battery, such as internal resistance, can be probably made, when the battery is disconnected. When the battery is switched off the uninterruptedness of a UPS does not exist.

In most cases it is possible to consider the condition of UPS for faulty when the battery has been switched off for the preventive maintenance. This preventive maintenance is not a cheap process if it is completed by a certified expert - the necessary inquiry of the expert services is made for optimization of this process, if the occasion has been presented. An occasion for inquiry of the expert can be result of action of self-diagnostics UPS. Such approach in preventive maintenance has a number of difficulties.

Enough uses of the devices for the long-term action in remote arrangement exist and are widespread. The system of automatics distributed on territory can have some remote devices. The presence UPS in such system of automatic needs of preventive works under the schedule.

Realization of preventive works on the system distributed in space under the schedule, will demand presence in the staff of employees of the expert on UPS, thus it will not be used with the big feedback.

The need for the work under the schedule can be caused by absence data on a condition of the battery because designers do not know the accessible and practical approach for this purpose.

The condition of the battery can be checked up by one on ext ways:

- the electronic tester of the battery with an opportunity of measurement of internal resistance (the high price, multipurpose, stationary);
- the verifier of the battery consisting of the voltmeter and loadings (it is simple, internal resistance does not measure, suitable for one or two types of the battery).

The ΔV method is comprehensible to measurement of internal resistance and test of the battery during measurement. This method allows to develop the inexpensive measuring device for measurement of internal resistance and can be used for creation of the additional equipment for automatic measurement of internal resistance.

The condition of the battery is important for the starter's batteries also. ΔV the method can be suggested to be used in the car, for the automatic test of the battery. The indicator of type "the Green eye" is present not in all batteries. Such indicator is accessible, only if the battery is visible. The starter's battery works with very high stream during the moment of start of the engine. It is the preferable moment for reception of the information on a condition of the battery.

III. ALGORITHM OF MEASURING

Below an investigated case when the battery is loaded by a current with the changing in time is presented.

Simplification of expression (2) by substitution in expression (3) operations of division into operation of multiplication allows to receive a graceful method of measurement of internal resistance at multiple 10 values of factor. Realization of the analog machine on expression (3) allows to make calculations in electric sizes, that simply enough and precisely.

$$\Delta I[A] = (1/C_m[1/A])$$
$$R_{int}[\Omega] = \Delta V[V] * C_m[1/A] \quad (3)$$

In other words it means, in algorithm the estimation of reaction of the battery on increase in a current of loading of multiple $1/C_m$ amperes is used.

For example:

$$\Delta I \ni [1mA, 10mA, 100\,mA,\ \ 1000mA,\ \ 10A]$$

That is during measurement the suitable multiply coefficient C_m is set, the necessary difference of a current is established and increment of voltage ΔV is measured.

It is necessary to develop for realization of algorithm:

- the tracing generator of loading (fig. 3);
- the logic of decision-making (fig. 5).

The function chart of the tracing generator of loading is represented in fig.3.

Let's consider action TGL in more detail. The action of the generator consists in the maintenance of an invariance of a total current of loading of the battery in a time interval necessary for carrying out of the measurements. The signal of a feedback for the management's circuit of the tracing generator of loading is the total signal from gauges of current CS1 and CS2. The influence on an operating input of the generator is defined by size and a sign on a signal of a error. A signal of a error - a difference between sizes of signals - exemplary, synthesized by decision-making logic, and total. The power operated element works in an active mode, in other words changes the internal resistance changing shunting

action in a total load circuit of the battery, depending on size and a sign on a signal of an error.

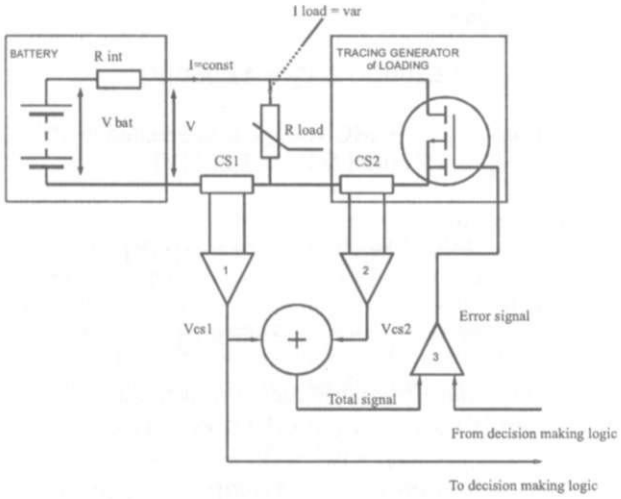

Fig. 3 Tracing generator of loading 1,2 –differential's amplifiers; 3- amplifier of error.

As an explanation of the action of the generator in fig. 4 forms, voltage and current of the battery in the time are presented.

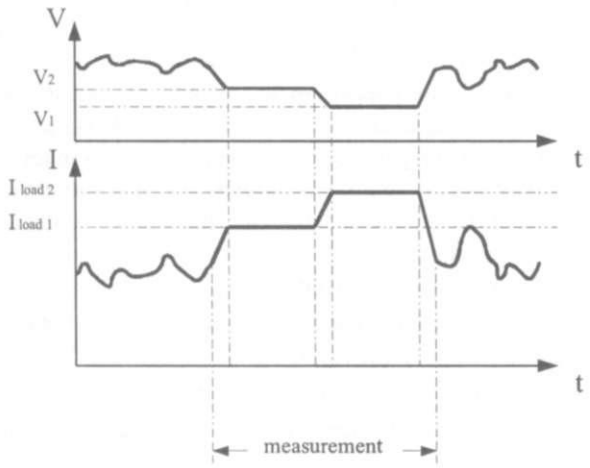

Fig. 4 Internal resistance measuring

As the forms of signals during the time interval of the measurement show the values of current and voltage are stabilized by action of the tracing generator of loading.

The advantage from the work of the offered algorithm is the occurrence of the analog machine of processing when the result is solved directly after the measurement. It essentially simplifies the further processing result.

The decision-making logic (DML, fig. 5) synthesizes exemplary value for TGL, makes the measurement for the values of current and voltage, makes the processing for the measurement, and reproduces the signals for the interfaced circuits. The algorithm of the DML - is shown in fig. 6.

Fig. 5 Decision-making logic

The DML carries out problem of the organization of the correct functioning for UPS and the maintenance of the process of the reception for the necessary information.

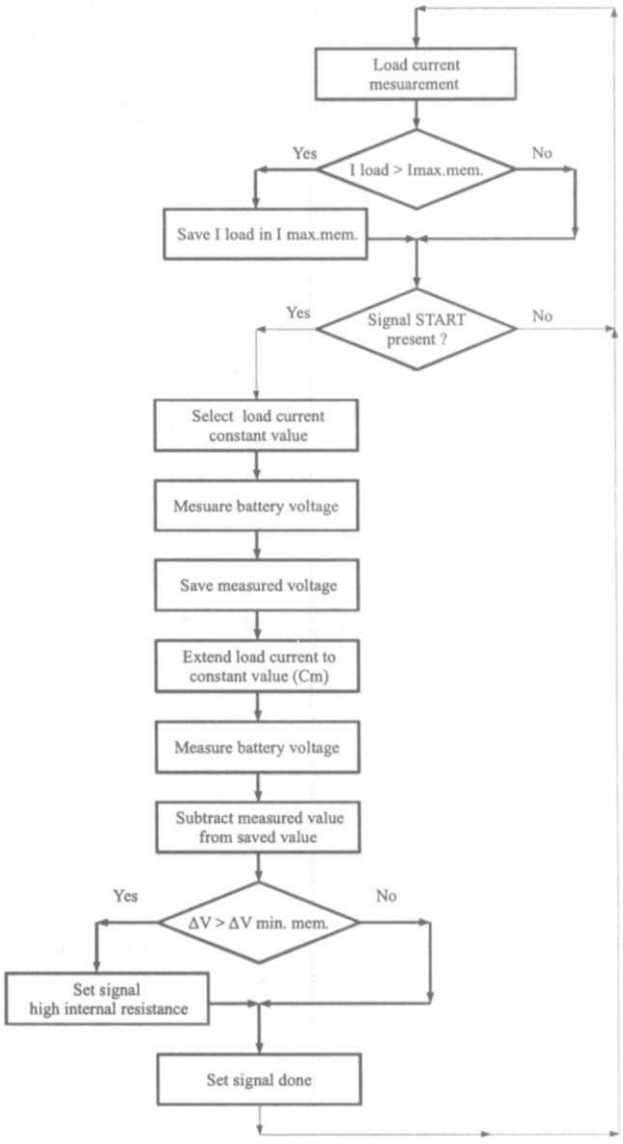

Fig. 6 Decision logic processing algorithm

For this purpose the supporting source for the battery, all over again, is disconnected, that is the battery feeds the load. After time necessary for the approach of the established

condition, DML reproduces a signal start and synthesizes the first exemplary signal for the control's circuit for TGL, makes the measurement and storing of value V1.

The second exemplary signal, according to the chosen coefficient of the multiplication, synthesized DML, allows to measure value V2. Value of internal resistance is defined as a difference between V1 and V2 multiplied on the coefficient of multiplication. In this way, the operation of multiplication is not made. The answer from DML is numerical value of the calculated difference and value of the coefficient of the multiplication.

Example:

$$V_{ref\,1}\,;C_m = 1.0\frac{1}{A} \qquad I_{load\,1} = 6.00A\ \&\ V_1 = 12.20V$$

$$V_{ref\,2}\,;C_m = 1.0\frac{1}{A} \qquad I_{load\,2} = 7.00A\ \&\ V_2 = 12.05V$$

$$R_{int} = (V_1 - V_2) * C_m =$$

$$= (12.20V - 12.05V) * 1.0\frac{1}{A} = 0.15\frac{V}{A}$$

Then DML reproduces a signal of execution of actions "Done" on measurements and the supporting source for the battery again connects. The process occurs for the time duration of some seconds In overall aim DML is based on 8-bit's microcontrollers (MC). It is enough opportunities of MC for realization of a method.

For the increasing of accuracy of the method, measurement of voltage with higher resolution is necessary.

The resolution of the voltage measurement will be better, if differential measurement of voltage ((4), fig. 7) is used:

$$V_{dif} = (V - I_0 \cdot R_0) - (V_0 - I_0 \cdot R_0) \qquad (4)$$

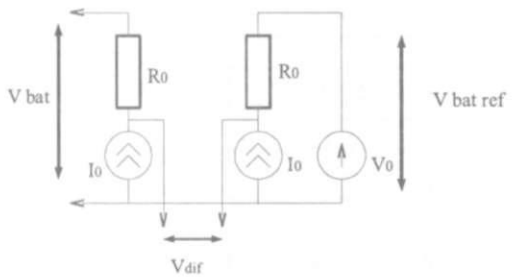

Fig. 7 Differential measurement of voltage

Compare both of a method of measurement of a voltage, to a condition, that the signal is prepared for processing for 8-bit's MC.

Conditions: 8-bit's MC; 10-bit's ADC; 1024- resolution of MC of ADC; MC power voltage 3,3 V -5,0 V, ADC reference voltage 5,120 V, ADC resolution 5 mV.

1.1 Measured:

$$V_1 = 12.200[V]\ \&\ V_2 = 12.050[V]$$

1.2. For processing in MC voltage is attenuated to 10:

$$V_1^{'} = 1.220[V]\ \&\ V_2^{'} = 1.205[V]$$

1.3. Voltage from ADC:

$$V_1^{'} = 244 \cdot 5\ [mV]\ \ V_2^{'} = 241 \cdot 5[mV]$$

1.4. Result:

$$\Delta V^{'} = V_1^{'} - V_2^{'} = 3 \cdot 5[mV]$$

1.5. Voltage value from differential measurement:

$$V_0 = 12.000[V]\ \&\ V_1 = 12.200[V]\ \&\ V_2 = 12.050[V],$$

$$\Delta V_{dif}^{'} = (V_2 - V_0) - (V_1 - V_0) =$$

$$= (12.200[V] - 12.000[V]) - (12.050[V] - 12.000[V]) =$$

$$= 200[mV] - 50[mV] = 150[mV]$$

1.6. Result:

$$\Delta V^{'} = 30 \cdot 5[mV]$$

The system without the use of a divider allows making the resolution 10 times higher.

IV. CONCLUSION

The method of the measurement of internal resistance entered by this article, is universal for both use - detection of a condition of the battery in UPSs and in simple portable tools of measurement. The approach allows, to do automatic measurement of internal resistance for the battery without infringement of continuity UPS.

This approach has inconveniences, type:

- Efficiency of the use depends on capacity of the battery and a voltage of the battery;
- Works TGL change capacity of the battery;
- Demands to provide necessity of the management to UPS.

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Karevs V., Mezitis M., Automatic measurement for internal resistance of battery in uninterruptible power source

The condition of the reserve's battery is important for UPS. Most part UPS has only tools of measurement for a voltage of the battery and a current, also the program of the notice for preliminary processing results of measurement. It does not do a prediction of reserve's for battery UPS, or does not precisely. The condition of the battery will be precisely certain through the measurement of internal resistance of the battery. Internal resistance of the battery depends on a condition of basic elements of the battery (chemical and physical). Basic elements are on the dependence on processes of ageing, on irreversible electrochemical processes, on stresses during service and from conditions of service. During direct diagnosing the battery is separated from UPS. In many aim, the condition of UPS is defective, when the battery switched-off for preventive maintenance. It is preventive process - not cheap process if it is done by the certified expert. The entered approach assumes automatic measurement for internal resistance of the battery and guarantees necessary accuracy. The loadings considered the watching generator for loading and logic of decision-making are hardware of the approach. During the action of the generator there is a stabilization of a current of load from the battery. Work of the generator copes decision-making logic. The approach - is simple for understanding and is guided by 8-bit microcontrollers. Analog calculation replaces arithmetic division in the program of the microcontroller. The approach is useful in the automatic system distributed on territory with a large number of the remote devices, in portable tools of measurement. To the batteries with high capacity (power) we shall apply with parallel inclusion of generators of loading.

Karevs V., Miezītis M., Automātiska akumulatoru baterijas iekšējas pretestības mērīšana nepārtrauktās barošanas avotā

Iekšējā pretestība vienmozīmīgi definē rezerves barošanas avota akumulatoru baterijas stāvokli, kas nosaka nepārtrauktās barošanas avota drošumu. Lielākajai daļai nepārtrauktās barošanas avotu praksē ir pieņemta periodiska akumulatoru baterijas nomaiņa. Industriālie nepārtrauktās barošanas avoti satur speciālas sprieguma un strāvas mērīšanas shēmas, kas nodrošināta akumulatoru baterijas uzturēšanas nosacījumus un veic tās stāvokļa kontroli. Tādējādi tiek netieši identificēts akumulatoru baterijas stāvoklis. Akumulatoru baterijas iekšējo pretestību nosaka konstrukcijas pamatelementu (elektroķīmisko un elektromehānisko sastāvdaļu) stāvoklis. Pamatelementus ietekmē novecošanās procesi, neatgriezeniski elektroķīmiskie procesi, pārslodzes ekspluatācijas laikā, kā arī ekspluatācijas apstākļi. Tiešai iekšējās pretestības diagnosticēšanai nepieciešama akumulatoru baterijas atslēgšanas no nepārtrauktās barošanas avota, kas nozīmē, ka netiek nodrošināta barošanas nepārtrauktība. Turklāt, korektu diagnosticēšanu var veikt tikai kvalificēti speciālisti ar speciālām testēšanas iekārtām. Piedāvātā metode ļauj mērīt rezerves akumulatoru bateriju iekšējo pretestību ar pietiekamu precizitāti, lai spriestu par akumulatoru baterijas stāvokli. Metode tiek realizēta, izmantojot slodzes ģeneratoru, kas nodrošina konstantu baterijas slodzes jaudu, un speciālu atbildes pieņemšanas loģiku. Metodes realizācija ir vienkārša, un ir piemērota realizācijai uz 8-bitu mikrokontrolleru bāzes. Izveidotā īpašā analogā skaitļošanas mašīna izslēdz dalīšanas operāciju no mikrokontrollera programmas, tādēļ metodes realizācijai pietiek ar 8-bitu mikrokontrolleru skaitļošanas jaudu. Metodi ir iespējams pielietot automātiskās sistēmās ar sadalītu objektu izvietojumu, kā arī pārnēsājamās mērīšanas ierīcēs. Lielas jaudas akumulatoru bateriju iekšējās pretestības mērīšana ar piedāvāto metodi ir iespējama, izmantojot slodzes ģeneratoru paralēlā slēgumā.

Карев В.В., Мезитис М.М., Автоматическое измерение внутреннего сопротивления аккумуляторной батареи в источнике бесперебойного питания

Внутреннее сопротивление однозначно определяет состояние аккумуляторной батареи (АКБ), как резервного источника питания. Состояние резервной АКБ определяет надёжность ИБП. Большинство ИБП предполагают периодичность замены АКБ. Индустриальные ИБП содержат схемы измерения напряжения и тока для обеспечения работы схем заряда/разряда АКБ и контроля состояния АКБ. По результатам обработки измерении существует возможность косвенно определить состояние АКБ. Внутреннее сопротивление АКБ определяется состоянием основных элементов конструкции (химические и механические). На основные элементы наибольшее влияние оказывают процессы старения в АКБ, необратимые электрохимические процессы, стрессы в процессе эксплуатации и условия эксплуатации. Прямая диагностика АКБ предполагает исключение АКБ из ИБП, т.е. бесперебойное питание не поддерживается. При этом коректно диагностику могут проводить квалифицированные специалисты при наличии соответствующих тестирующих приборов. Метод позволяет измерять внутреннее сопротивление резервной АКБ ИБП автоматически. Метод реализует использование следящего генератора нагрузки, действие которого приводит к неизменности мощности отдаваемой АКБ, и специальной логики принятия решения. Алгоритм измерения прост в реализации, является ориентированным на 8-битные микроконтроллеры. Видоизменнная аналоговая вычислительная машина исключает в программе микроконтоллера операцию деления. Вычислительных мощностей 8-битных микроконтроллера достаточно для реализации метода. Метод является доступным для реализации в системах автоматики с удалённым расположение объектов, в переносных измерительных приборах. При измерении внутреннего сопротивления АКБ большой ёмкости возможно использование паралельнного включения нескольких следящих генераторов.