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The Establishment of DC Power Meter Calibration System at China Electric Power Research Institute

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Abstract –**The establishment of a DC power meter calibration system using a DC current comparator and a synchronous sampling technique at China Electric Power Research Institute (CEPRI) is described. Measurements can be made at DC voltages ranging from 10mV to 1000V, and DC currents from 10mA to 500A. The system features a synchronous voltage/current sampling system and a multi-ratio DC current comparator. The uncertainty of the DC power meter calibration system is estimated to be not more than 120 µW/W. Furthermore, a comparison of DC power meter calibration systems between CEPRI and National Institute of Metrology China (NIMC) is discussed and presented.**

Index Terms —**DC power, calibration system, DC current comparator, synchronous sampling.**

I. Introduction

The recent evolution of power systems and industrial equipments toward larger flexibility requirement is progressively leading to increasing demands for DC power measurements [1]-[2]. The calibration of DC power meters is easier than that of AC power meters since in DC power measurements there are no phase differences between the voltage and current signals. However, in some industrial applications accurate DC power measurements could be difficult. For example, accurate measurements of high current DC power of electric vehicle charging and electrolytic plating of aluminum sheets. Digital measurement techniques could improve the accuracy of the measurements. However, it would require the high DC current to be scaled down to an appropriate level to allow digital measurements techniques to be used. This in turn would require a proper sampling technique of the voltage and scaled down current, including the proper synchronization between the voltage and current sampling systems.

A DC power calibration system with high accuracy using DC current comparator and synchronous sampling technology is described in this paper. The uncertainty of the established DC power meter calibration system has been estimated and comparison of calibration results between the established system and that at NIMC has been made. Both systems uncertainties and comparison results will be presented in the conference.

II. System Description

The DC power meter calibration system is shown in Figure 1. It consists of a DC voltage source and a DC current source to provide the operating voltage and current to the meter-under-test (UUT). The counter counts the output pulses of UUT, which are recorde by the control computer. Meanwhile, the DC voltage is sampled by the voltage sampler, and the DC current is supplied to input connectors of the DC current comparator. The output current from this comparator is connected to a sampling resistor R and its voltage drop across it is sampled by the current sampler . The voltage and current samplers operate synchronously, and their sampling results are recorded by the control computer with a DC power calibration system software that is programmed to calculate the reference DC power supplied to calibrate the UUT. All of the components are driven by the IEEE-488 bus.

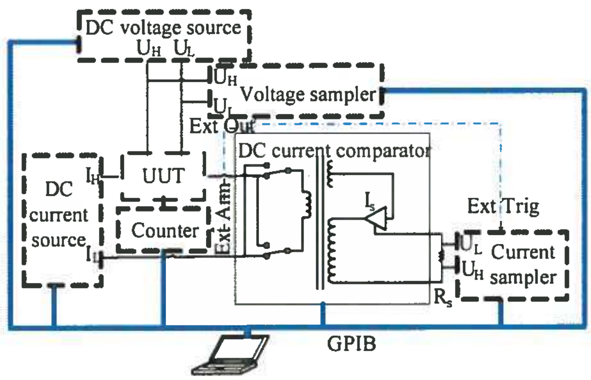


Fig. 1. The DC power meter calibration system

Two main important components of the DC power meter calibration system are the DC current comparator to scale down the high DC operating current and the synchronous digital sampling technology to sample simultaneously the operating voltage and and current signals.

The DC current comparator whose functional diagram is shown in Fig.2 is based on the magnetic modulation principle [3].

The voltage drop across the sampling resistor R is a measure of the output current I_{out} of the secondary winding. If $I_{out}N_s \neq I_{in}N_p$,. the detector will provide an unbalanced ampere-turn feedback signal to modify I_{out} to minimize the unbalance ampere-turn signal. When the unbalance ampere-turn signal is minimized, including its zero offset, the ampere-turn balance equation $I_{out}N_s=I_{in}N_p$ holds within an uncertainty depending on the overall feedback gain. As a result, the output current can be expressed as in (1):

$$I_{out} = I_{in}\frac{N_p}{N_s} \tag{1}$$

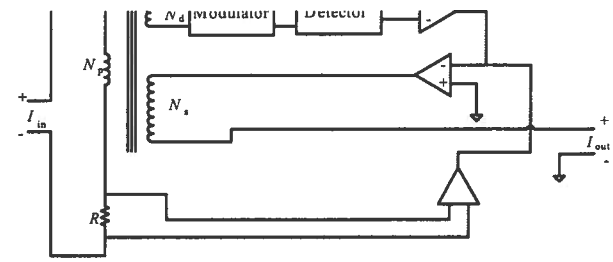


Fig. 2. Functional diagram of the DC current comparator

The proper synchronization is quite important in the DC power meter calibration system. The voltage and current sampling systems, including the counter, should start and operate simultaneously.. The proper synchronization process is further explained.

The active power consumed from t_1 to t_2 can be expressed as

$$E = \int_{t_1}^{t_2} u(t)i(t)dt \tag{2}$$

where u is the DC voltage, i the DC current.

If initial time is 0 and sample interval is T_s, the discretization of the equation (2) can be given as

$$E = \lim_{m->\infty}\sum_{n=0}^{m} u(n)i(n)T_s \tag{3}$$

The desynchronization is described as

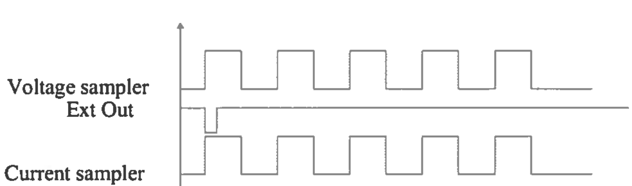
$$\begin{aligned} &u(t_1+n\Delta t)i(t_1+n\Delta t)\Delta t \\ &\neq u(t_1+n\Delta t)i\left(\left(t_1+\varepsilon_1\right)+n\left(\Delta t+\varepsilon_2\right)\right)\Delta t \end{aligned} \tag{4}$$

where ε_1 is time difference between initial time of the voltage and the current sampling systems, ε_2 is the difference between the sampling interval of the voltage and the current sampling systems.

Equation (4) is valid if the DC voltage and the DC current is stable and constant. However, in practice both the DC voltage and the DC current are not stable/constant, which may lead to a large errors in calibration results if desynchronization exists.

A synchronous-sampling technique is used to minimize the desynchronization problem. Two high accuracy sampling systems are used to sample synchronously the voltage and current signals at appropriate intervals, and triggered simultaneously, including the counter, to allow them to start synchronously, as shown in Fig.3.

Fig.3. Timing diagrams of synchronization.



III. PERFORMANCE

The uncertainty of the DC power meter calibration system is determined primarily by the performance characteristics of its main components, which are the DC current comparator with its ratio errors and the feedback gain which determines the residual unbalanced and zero-offset ampere-turns, the current-to-voltage shunt resistor at the secondary output current of the DC current, and the synchronization of the voltage/current sampling systems.

The errors of these main components would be known from their corresponding performance evaluations. These known errors are taken into account through software by applying corrections. The remaining uncertainties, consequently, are only due to the calibration uncertainties from their corresponding performance evaluations..

Furthermore, the performance of the DC power meter calibration system is confirmed by a comparison with a DC system of the National Institute of Metrology China (NIMC). A known commercial DC power meter is used as the transfer standard for the comparisons, which have been done at the following operating points of 200V/10A， 380V/10A， 220V/100A and 380V/100A. The performance evaluations of the CEPRI DC power meter calibration system and comparison results between the CEPRI and NIMC systems will be discussed and presented.

IV. CONCLUSION

An overview of the development of a DC power meter calibration system at CEPRI with an uncertainty of not more than 120 µW/W is described. Also, its system performance characteristics and comparison results with a DC calibration system of NIMC will be discussed and presented.

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