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AC POWER MEASUREMENT SYSTEM OF UME

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Abstract: A high accuracy power measurement system, based on digital sampling techniques, has been developed and evaluated for the power frequencies at UME (National Metrology Institute of Turkey). The system is based on two sampling voltmeters and a phase-locking device. Using of a precision voltage transformer and a current transformer with a shunt resistor, and reducing the synchronizing errors results in an uncertainty of 20 ppm for active, reactive and apparent power measurements for power frequencies.

Keywords: digital sampling, phase-locking.

1. INTRODUCTION

The development of more accurate power related measuring devices for traceable calibrations of power and energy meters and the growth demand for lower uncertainties constrained to national metrology institutes to design new power measurement systems. To fulfill the requirements, several metrology institutes make use of digitally synthesized voltages and currents, of sampling-voltmeter measuring methods, and of computerized evaluation of the measurement data [1,2].

A digital sampling power measurement system has been designed and evaluated as a measuring standard for active, reactive and apparent power at power frequencies at UME. It is required for its high accuracy and flexible operation features. The operating principle is based on the use of two sampling voltmeters, computer controlled synchronization unit, and on computerized evaluation by means of discrete integration [3] and discrete Fourier transform (DFT).

The accuracy of the system is ensured by investigation of all probable error sources, and by testing its performance in a bilateral comparison.

2. THE POWER MEASUREMENT SYSTEM

The power measurement system consists of two digital sampling voltmeters, a precision voltage transformer, an electronically compensated current transformer with a temperature controlled AC shunt resistor, a computer controlled phase-locking device, and a PC with software (Fig. 1).

The voltage and current signals from a phantom power source are applied to the input terminals of voltage and current transformers. A regulated voltage from secondary terminals of the voltage transformer and a voltage obtained from the shunt resistor which is connected to the secondary terminals of the current transformer, are then applied to the DVMs. Each programmed DVMs samples the applied voltage signals with the help of trigger signals from phase-locking device.

The data from both DVMs is transferred to the PC via IEEE488, and analyzed by means of discrete integration. All available calculated results are displayed during the measurements.

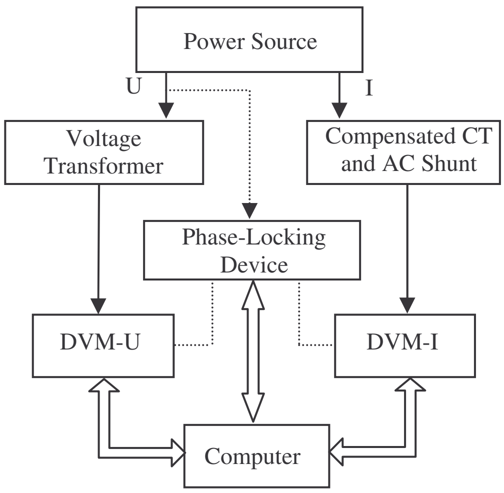

Figure 1. Block Diagram of The Power Measurement System

2.1. Voltage and Current Transformers

A home-made voltage transformer with four input ranges of 60V, 120V, 240V and 480V, and with a nominal output voltage of 6V for each nominal input ranges, is used for the regulation of input voltage signals to the nominal input voltage range (10V DC) of DVMs.

The voltage transformer has been carefully designed as a two-stage transformer with electrostatic-and-magnetic-shieldings. By using bootstrap method it is easily calibrated against traceable inductive voltage transformers.

A multi-ratio electronically compensated current transformer with an AC shunt resistor has been designed to convert the applied currents into the appropriate voltages. The current transformer has several input current ranges from 0.1A up to 10A, and a nominal secondary current of 0.01A. The secondary current of the transformer is burdened with a non-inductive 300Ω AC resistor to obtain a nominal voltage of 3V. The non-inductive shunt resistor is enclosed in a temperature controlled cabin to avoid the additional errors.

The current transformer is designed as a two-stage transformer by using magnetic cores with high permeability. Since, it is operated as a zero-flux current transformer, the ratio and phase errors could be decreased down to some ppm. The calibration of the current transformer is performed by comparing each ratio against home-made current comparators.

2.2. Phase-Locking Device

A home-made phase-locking circuit is used to phase-lock to the voltage to be measured through an attenuator. The trigger signal train obtained from the device is applied to the external trigger inputs of both sampling voltmeters. A home-made PC-controlled gate helps to the operator to send the trigger signal blocks periodically. The number of samples per period could be selected from 4 up to 1024 by a factor of 2^n.

After a long-term measurements and inspections, the best accuracy has been obtained below 256 samples per period for power frequencies. However, the resolution of the DMMs has been taken into account and 64 samples/period was decided as the best sampling and aperture time for the best accuracy.

With successive precautions, the phase deviation of the Phase-Locked Loop (PLL) could be kept in a very narrow band and eliminated. Any error arises from the design could be obtained by applying well-known frequency signals and analyzing the outputs of the device.

2.3. Sampling Voltmeters

The sampling process is achieved by two commercially available DVMs (Agilent 3458A Digital Multimeters). Several features of these devices, e.g. external triggering capability, high DC accuracy and memory options make them primitive to use in the system. Operating of sampling voltmeters in the range of 10V avoids the uncorrectable errors arise from the band-width difference of the internal ranges of voltmeters.

Switching and exchanging the input signals of the sampling voltmeters ensures the operator for any systematic errors in the set-up.

Since any deviation in the DCV measurement function of two DVMs directly effects the AC power measurements, some preliminary tests e.g. cross-check of DVMs, ratio and phase angle measurements to eliminate any offset and drift, are performed everyday.

2.4. Software

The power measurement system is completely controlled by computer with software. The software has been written under the Keithley Test Point program since it is easy to use for such laboratory applications. With the help of the software, DVMs are programmed with the calculated appropriate aperture times for the selected samples per period.

The calculation of the amplitudes of both signals and phase angle between them, and of total power is performed mainly by using discrete integration. To be ensured of distorted waveforms and to display the harmonic components however, DFT is also used on the software.

After all calculations, the results are sent to an MS Excel worksheet for the final evaluation of appropriate certification.

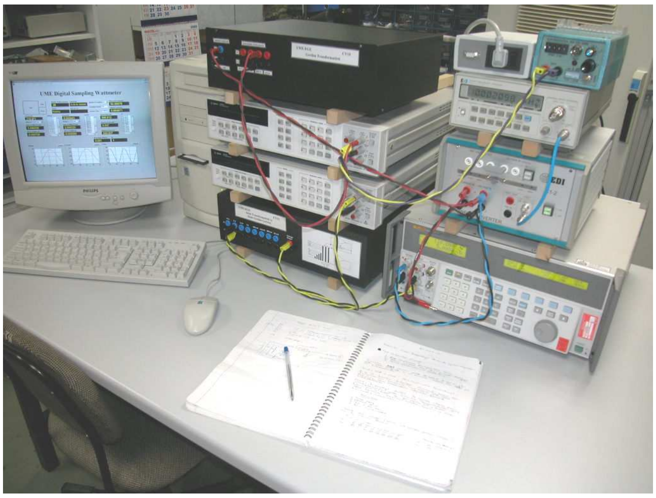

Figure 2. Power Measurement System

3. EVALUATION OF THE SYSTEM ACCURACY

An evaluation of the system accuracy has been made with respect to all probable error sources: voltage and current transformers, DVMs and Phase-locking device [4].

Ratio and phase angle errors of the voltage and current transformers were corrected in the software. The phase angle errors arise from the behavior of DVMs were checked by applying same voltages to both of them and calculating the phase angle difference.

The system was then transported to the power laboratory of PTB and two principally different power measuring systems were compared each other. Some measurements were performed for some different sinusoidal voltages and currents to correct the ratio errors and phase displacements of voltage and current transformers in the software.

A power converter (MTE C1-2) was used as a transfer standard. The comparison measurements were performed at 120V and 5A voltage and current values, respectively, and at 53Hz frequency.

The phase angles were 0°, ±30°, ±60° and ±90°. A high-stable power source was used to apply the values given above, so that the standard deviations of each measurement could be limited within few ppm. The difference between two systems is found below 10 ppm for any power factor.

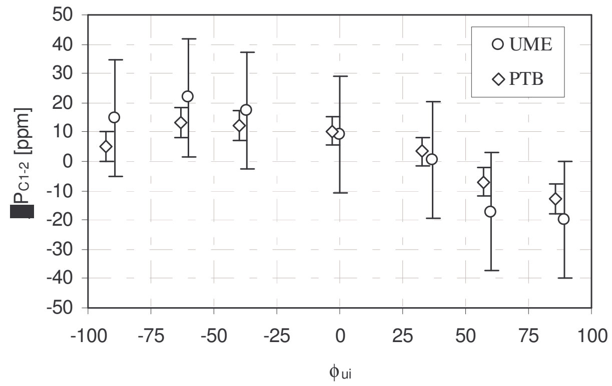

Figure 3. Comparison Results

4. CONCLUSION

A digital sampling wattmeter has been designed and evaluated for power frequency ranges. With commercially available sampling voltmeters, home-made voltage and current transformers, and with phase-locking circuits, a basic uncertainty of 20 ppm has been achieved for active, reactive and apparent power measurements.

5. FUTURE PLANS

The power measurement system will be modified for the direct calibrations of three-phase wattmeters by adding a voltage and a current transformer for each phase and by using PC-controlled switches to interchange the signals obtained from those transformers.

The power measurement system will also be modified for higher frequencies, and for traceable calibrations of power harmonics and flicker analyzers. For this purpose, a coaxial current shunt has already been designed, and it is planned to replace the voltage transformer by compensated voltage dividers.

Another modification on the system will be made for the measurements of voltage and current transformers. The ratio errors and phase displacements of instrument transformers could be measured with a good resolution after a successful study on the system.

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