A HIGH-VOLTAGE REFERENCE TESTBED FOR THE EVALUATION OF HIGH-VOLTAGE DIVIDERS FOR PULSED APPLICATIONS

M. Cerqueira Bastos (CERN, Geneva Switzerland)
M. Hammarquist[1], A. Bergman (SP, Technical Research Institute of Sweden, Boras, Sweden)
[1]SP Technical Research Institute of Sweden, P.O. Box 857, SE-501 15 BORAS, Sweden

Abstract

The design, evaluation and commissioning of a high voltage reference testbed for pulsed applications to be used in the precision testing of high voltage dividers is described. The testbed is composed of a pulsed power supply, a reference divider based on compressed gas capacitor technology and an acquisition system which makes use of the fast measurement capabilities of the HP 3458 DVM. Results of the evaluation of the reference system are presented.

Introduction

In order to increase the luminosity of the protons beam injection into the LHC (Large Hadron Collider) at CERN, a new linear accelerator, Linac4, is being built to replace the old injector, Linac2. Operation is foreseen to start in 2014.

RF power requirements for the new accelerator translate into new high voltage measurement requirements at the level of the klystron power supplies: cathode and anode voltages will be pulsed at 110 kV and 55 kV respectively, with a repetition rate of 1.1 Hz. Voltage rise and fall times are in the range of 150 µs and 1.5 ms pulse width. The measurement of the flat top voltage must be done with uncertainty better than 0.5 %.

This poses a new measurement challenge since commercial high voltage dividers are not characterized in the time domain and indicated uncertainties at the given frequency ranges are usually not better than 1%. To overcome these difficulties, CERN is building a high voltage pulsed reference testbed, which includes a reference system supplied by SP Technical Research Institute of Sweden.

This paper describes the different elements of the reference testbed. Results of the evaluation of the reference system are presented.

Reference System Requirements

Anticipating future needs, the reference divider nominal voltage was specified to be 150kV. The system will to be used to characterise dividers with nominal voltages ranging from 60kV to 150kV so a very good linearity is essential.

Table 1. Reference system requirements

Flat top stability (max allowed flat top level variation)	0.1%
Repeatability (pulse to pulse, short term stability)	0.1%
1 year stability	0.1%
Flat top noise (>>kHz ripple)	0.1%
Linearity	better than 0.1%

The High Voltage Testbed

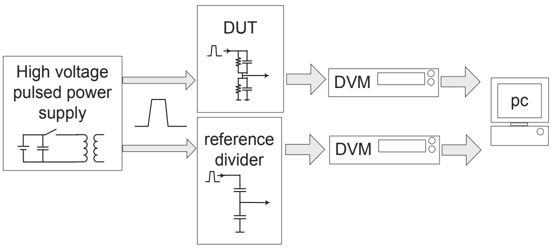

Figure 1. Block diagram of testbed

The error of the DUT can be calculated by comparison with the reference measurement. The reference divider uncertainty, the DVM uncertainty and the measurement process uncertainty must be taken in consideration.

The Power Supply

A high voltage pulsed power supply built at CERN generates the 110kV test pulses. The power supply is composed of a 250µF capacitor bank which is switched by a high voltage switch into a high voltage pulse transformer. An undershoot network circuit is included on the primary side to allow for demagnetisation of the transformer. Another important aspect is the inclusion of a 40 kΩ resistor on the secondary of the transformer for the damping of the capacitive load presented by the dividers and the high voltage cables. Although power supply accuracy requirements are relaxed because of the use of a reference measurement, it was decided to aim for a flat top stability of 0.25%.

The reference measuring system

The reference divider consists of a ~100 pF high voltage gas insulated compressed gas capacitor, a

~1.5 µF low voltage capacitor, an HP 3458 DVM and a computer with GPIB interface. Although the system is primarily characterized by capacitance measurements a test pulse with the characteristics described in the *Introduction* section and with amplitude 1 kV was used to verify its proper operation. This pulse was used as input signal to the high voltage arm. The output signal from the low voltage arm was measured using an HP 3458 making sampled DCV measurements at 50 kHz. These measurements have the following objectives: proving that the pulse response satisfies the requirements and verifying that the calculated ratio is equal to the measured ratio (within narrow uncertainty).

Measurements were performed only at low voltage (1 kV) since the system is assumed to be linear with voltage. This was confirmed by the first calibration of the compressed gas capacitor which included capacitance measurements over the entire voltage range of the capacitor using a 300 kV capacitor as reference. This ensures traceability over the whole voltage range. The voltage coefficient of the reference capacitor is less than 1 ppm from low voltage to 300 kV.

Verification of reference

Calibration

The scale factor of the divider was established from calibration data for the two capacitors and other contributing factors, such as cables and DVM input, to 15080.3 V/V ± 0.01%. An experimental scale factor of 15077.9, with a standard deviation of 0.006 %, was obtained by multiplying the measured output signal with the theoretical scale factor and comparing the result with the input signal. These two results agree favourably, with a deviation of 0.02 %. A typical output signal from the divider is seen below.

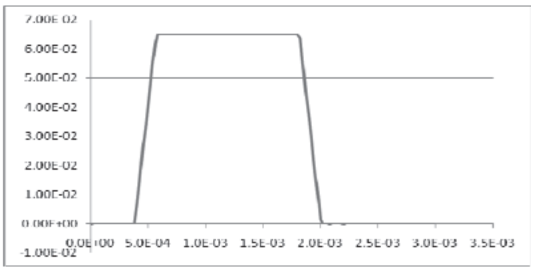

Figure 2. Example of output signal from the divider, in this case at 65 mV for a 977 V input. Rise time is 0.15 ms followed by a flat top with 1.2 ms duration**.**

Flat top stability, or variation in flat top level, is dominated by a droop, due to resistive loading (> 10 GΩ) in parallel with the low voltage capacitor Evaluation of flat top stability gives a droop from end to end of less than 0.02 % as shown in diagram below. The noise is on the same order of magnitude.

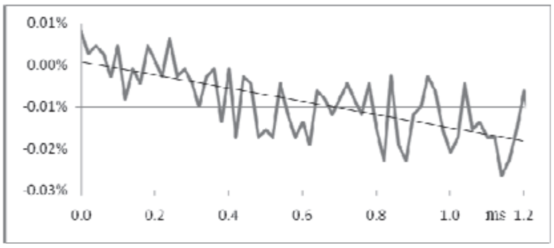

Figure 3. Evaluation of droop at flat top. Samples are shown for 1.2 ms of flat top. This is a zoom-in of a pulse with the same parameters as the one in Figure 1.

Short term stability of capacitance values is excellent, less than a few ppm. Practical measurements of pulses show very little variation, less than 4 µV or 0.006% standard deviation.

As for the **noise** on the signal measured, the standard deviation is less than 0.02 % and it is thus within specified limits.

The long term stability is governed by the stability of the capacitors. Experience from other equivalent systems shows a stability better than a few ppm per year.

Proximity effects: For safety reasons, the compressed gas capacitor will be permanently installed in a metallic cage. As a side effect, it will not experience any environmental changes causing proximity effects, hence these are estimated to be less than 10 ppm.

The linearity of the system is governed by the stability of the divider and the linearity of the DVM. The linearity error of the low voltage arm is less than 2 ppm and on the high voltage side linearity would typically be better than 10 ppm for similar capacitors. This effect will be measured as part of final testing. The DVM's contribution is negligible in comparison.

Conclusion

A high voltage reference testbed for the evaluation of high voltage dividers for pulsed applications is being built at CERN. A power supply has been built and is under test. A reference system has been developed, produced and evaluated by SP. The results show that the reference measuring system fulfils or exceeds the requirements posed for the application.