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PHOTOVOLTAIC DC-DC CONVERTER TEST SYSTEM

This paper describes LabVIEW based integrated measurement system to determine key parameters of DC-DC converters working in low-voltage photovoltaic (PV) systems. DC-DC converter should demonstrate high efficiency of energy conversion as well as sufficient voltage gain to yield as much energy from PV panel as it is possible. Efficiency and voltage gain can be measured across the number of parameters such as input voltage, output load, frequency and duty cycle of converter driving signals. The LabVIEW application works with both Hioki 8855 data recorder which carries out power measurements and a microcontroller Digital Driver who drives a converter tested. Measurement system allows to automate time consuming measurements as well as experimentally verify DC-DC converter design assumptions. The laboratory test results of selected DC-DC converter prototype as well as sources of error has been discussed in this paper.

1. INTRODUCTION

With rapidly increasing number of photovoltaic (PV) systems there is a need to develop efficient PV converters which can reduce overall power conversion losses thus introduce the savings during overall lifetime of the system. PV DC-DC converters [1] are widely used in PV systems which require high voltage gain to adjust low level voltage provided by parallel connected PV panels as well as other renewable energy sources to the sufficient level which is further DC to AC converted to match electrical grid standard. The major issue in PV converter designing is to obtain highest power efficiency possible within wide input power range. High voltage gain is required to deliver DC bus voltage at certain level i.e. around 400 V_{DC} or more. Moreover PV converter designers cope with different contradictory constraints such as low cost, long term reliability, safety and protection issues and power quality [2]. To qualify the performance of PV DC-DC converter the test system has been developed. This paper presents DC-DC PV converter test system where a designer can practically verify theoretical converter design assumptions and evaluate the performance of a converter tested.

2. PV DC-DC CONVERTER TEST SYSTEM DESCRIPTION

The measurement system (Fig. 1) consists of Hioki 8855 Data Recorder [3], LabVIEW based application run on a PC and the Digital Driver.

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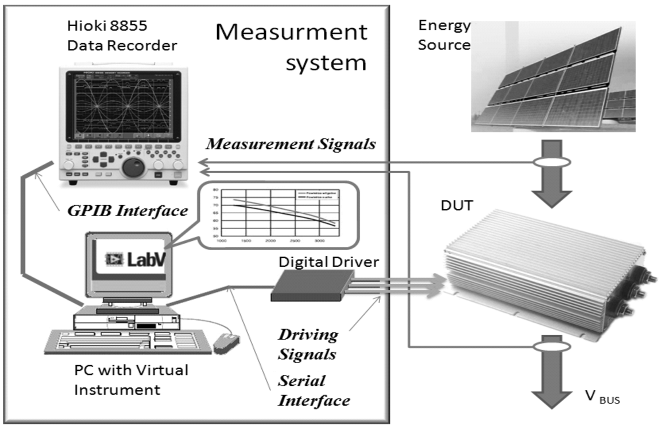

Fig. 1. Simplified PV DC-DC converter test system diagram

LabVIEW application i.e. Virtual Instrument (VI) (Fig. 2) is responsible of:

- Data Recorder configuration and measurement data transfer,
- Data gathering, analysis, presentation and save,
- Digital Driver configuration,
- Measurement automation according to pre-defined test sequence.

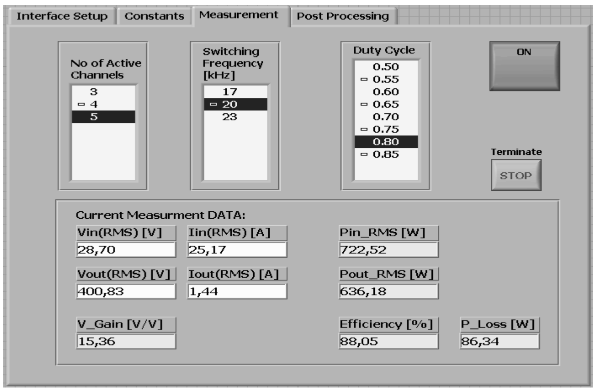

Fig. 2. LabVIEW application's measurement section

Digital Driver parses the commands transmitted out of the VI through RS-232 interface and provide driving waveforms for converter's transistors. It generates the waveforms of required frequency and duty cycle thus setting converter under test in particular mode of operation.

Data Recorder is equipped in a number of independent separated channels. It allows to measure input and output voltages of transformer based converters [1].

RMS values of input and output currents and voltages records $I_{i(RMS)}$, $I_{o(RMS)}$, $V_{i(RMS)}$, $V_{o(RMS)}$ respectively are calculated by Data Recorder and transferred to the VI.

Fig. 2 shows the screenshot of the VI during the test. The test is carried out according to the sequence pre-defined in this section. The program flow of the VI will be demonstrated on the example of interleaved step-up DC-DC converter test where the number of working phases can be configured (No of Active Channels). The converter's performance is tested across the number of switching frequencies (f_s) and duty cycles (D). For each combination of abovementioned parameters the record of input and output power, currents and voltages as well as converter efficiency and voltage gain is shown and saved to the text file. The data collected during the test can then be easily presented in the form of tables or charts. The test is carried out according to the sequence depicted in Fig. 3.

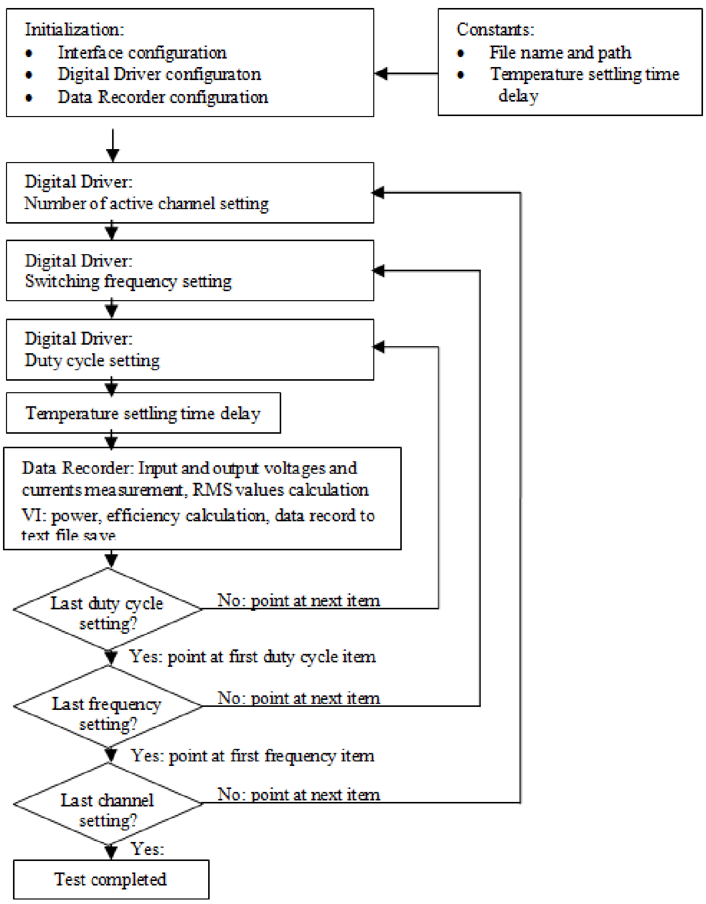

Fig. 3. Interleaved step-up DC-DC converter test sequence

Parameters of a DC-DC converter that can be measured in the test system are:

- Input and output power (P_i and P_o):

$$P_i = V_{i(RMS)} I_{i(RMS)} \tag{1}$$

$$P_0 = V_{0(RMS)} I_{0(RMS)} \tag{2}$$

- Total power loss of entire converter (P_{LOSS}):

$$P_{LOSS} = P_i - P_0 \tag{3}$$

- Efficiency (η), European efficiency for different load conditions (η_{EU}) [3]:

$$\eta = \frac{P_0}{P_i} 100\% \tag{4}$$

$$\eta_{EU} = 0{,}03\eta_{5\%} + 0{,}06\eta_{10\%} + 0{,}13\eta_{20\%} + 0{,}1\eta_{30\%} + 0{,}18\eta_{50\%} + 0{,}2\eta_{100\%} \tag{5}$$

- Voltage gain (B):

$$B = \frac{V_0}{V_i} \tag{6}$$

3. INTERLEAVED STEP-UP DC-DC CONVERTER TEST RESULTS EXAMPLE

The converter tested is depicted on Fig. 4a. It comprises up to 5 identical sections which are driven interchangeably (Fig 4b). Microcontroller based Digital Driver to work with that converter supports interleaved driving mode generating up to 5 phase shifted PWM waveforms of adjustable frequency and duty cycle.

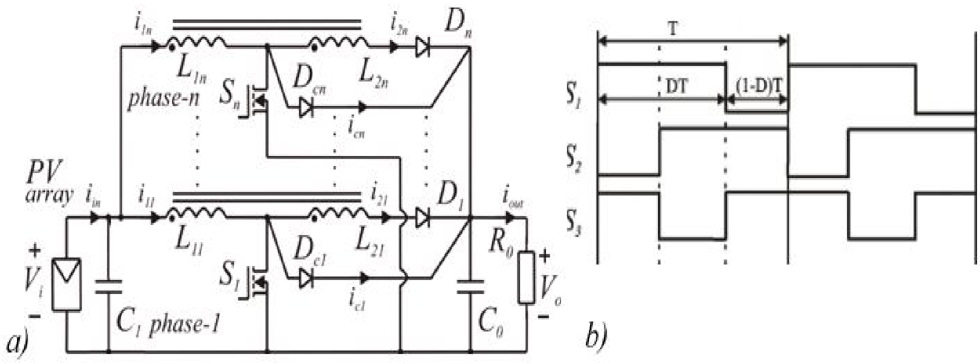

Fig. 4. a) Interleaved step-up DC-DC converter, b) driving signals of n = 3-phase converter

For fixed load and fixed input voltage level it is possible to show the charts with the efficiency and voltage gain vs. duty cycle or output current which characterize the performance of PV DC-DC converter tested.

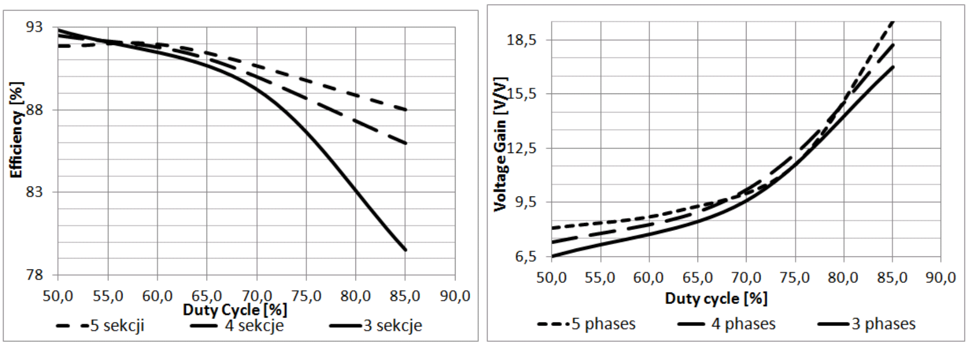

Fig. 5. a) Efficiency vs. duty cycle, b) voltage gain vs. duty cycle – both at fixed load

4. THE DISCUSSION ON SOURCES OF ERRORS

In order to eliminate temperature dependent errors all the measurements have to be carried out in settled conditions. The ambient temperature in the lab should not change noticeably during the measurement. Configurable temperature settle time delay before each measurement was introduced to the measurement sequence. Alternatively more advanced test system can trigger each measurement checking the power switches temperature rise or fall rate until it reaches acceptable value.

The other source of error is the offset drift of current probe which should be degaussed before each measurement. In total error budget the uncertainties of Hioki 8855 Data Recorder acquisition channels and probes should be considered [5].

To improve the accuracy of the measurement averaging technique is introduced. Maximum length of data records available should be set in the Data Recorder along with high sampling frequency to cover as much switching periods as it is possible. RMS values calculated of large number of samples decrease the mean value error. The results of several consecutive measurements can be averaged furthermore.

5. CONCLUSION

The PC based test system has been developed to automate time consuming measurements. The other benefit of such approach is to avoid human based source of error assuring repeatable measurement conditions. The data gathered during the measurement can be (remotely) monitored on the PC computer screen and stored to the text file afterwards. The software developed for the system is highly generic and can be accommodated to particular topology of converter to be tested as well as different test plans. However further development of the system is still required to enhance its functionality.

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