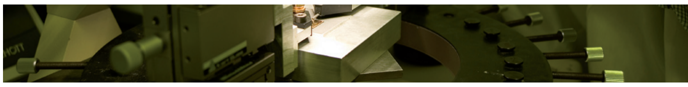
E.ON Energy Research Center





E.ON Energy Research Center Series

Versatile Low-Power DC Supply for Medium-Voltage Testing

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RWTH AACHEN UNIVERSITY

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2 Executive Summary

The acquisition of a 250-kW medium-voltage power supply, which is part of the infrastructure of the new PGS test facility at E.ON ERC, is accomplished. Due to the delayed approval of the 3.8 Mio € "Large Equipment Support" for E.ON ERC, a low-power medium-voltage dc supply had to be designed and acquired within this project.

This medium-voltage power supply will be used to test the 5-MW dc-dc converter built under E.ON ERC gGmbH project "High-Power DC-DC Converter" (gGmbH project no. 1). Furthermore, the supply will serve to provide variable medium-voltage to PGS test benches. This will allow a higher versatility in thermal and efficiency characterization of devices and components.

Since the low power level of the supply is non-standard with regard to the provided dc voltage levels, the supply is custom-built. The electrical and thermal system design was done by PGS, while component acquisition and assembly into a cabinet was carried out by contractors. Thus, the activities within the completed project were limited to system specification, supplier identification, bid preparation, acquisition and commissioning of the supply.

3 Introduction

3.1 Goals of the project

The goal of the project was the acquisition of a 250-kW medium-voltage power supply with a variable dc voltage output up to 4.6 kV.

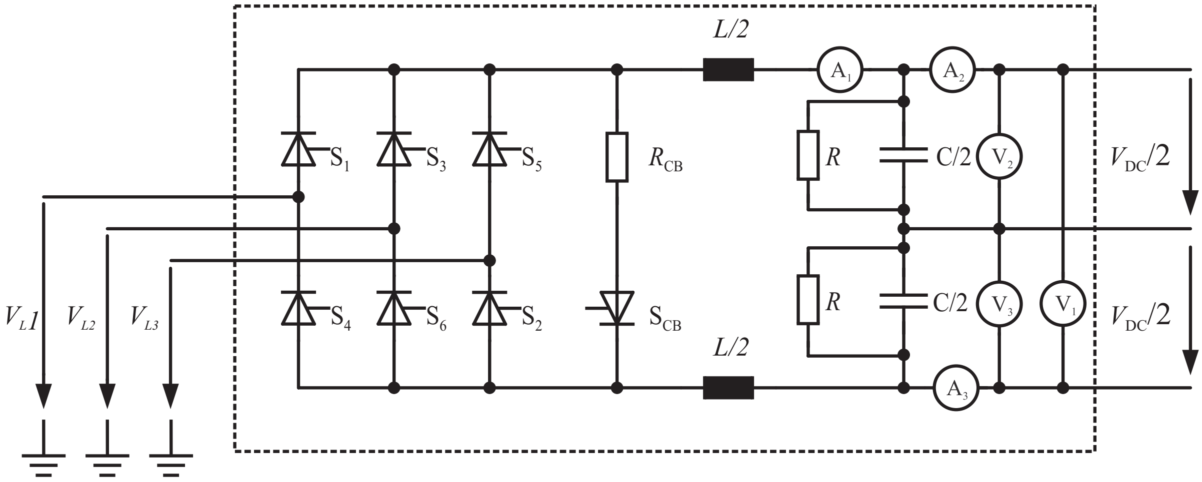


Fig. 1: Schematic of 250-kW medium-voltage supply

3.2 State of the art

A 3.3-kV grid transformer and a medium-voltage breaker on the secondary is already part of the approved test facility infrastructure. Since the target power level of the supply is low with regard to the provided voltages, no standard power supply is available on the market that would not be overrated in terms of power and cost for the targeted purpose. Therefore, the supply had to be custom-built with main components shown in Figure 1, including main parts (rectifier, dc capacitors) and, most important, auxiliary components for safety, control and connection.

3.3 Positioning within E.ON ERC strategy

This project was accomplished to keep testing procedures of the ongoing PGS project “High-Power DC-DC Converter” (funded by E.ON ERC gGmbH, project no. 1) on schedule.

Additional later use of the dc power supply has been considered. For example, it will be possible to test semiconductor devices and converter components under permanent operation, which allows a characterization of losses and thermal behavior.

4 Results

4.1 Specification

The variable dc-voltage supply is specified to provide an output voltage between 0.5 kV and 4.6 kV and an output current between 55 A and 70 A as illustrated in Fig. 2. The input voltage is 3.3 kV with a variation of +/- 10 %. Depending on the rectifiers' operating point a power between 35 kW and 250 kW can be supplied to test benches.

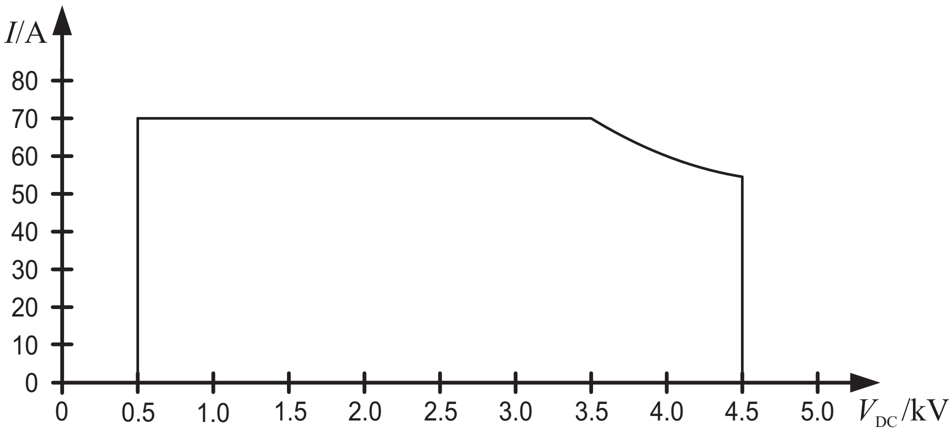


Fig. 2: Output voltage- and current- range

The total dc-link capacitance had to be 2.1 mF. Additionally, the capacitor bank had to be equipped with resistors for discharging these devices within 10 s. The charging time of the capacitors does not exceed 60 s during soft-start of the rectifier. Furthermore, the dc-link capacitors have to be protected against overvoltage with a crowbar circuit. The maximum voltage of the capacitors is 3.3 kV. For filtering the current, the inductors in Fig. 1have an inductance of 2 mH each.

The distortion of the rectifier's input current must be within the system operator's specifications. Following prescriptive limits must not be exceeded:

Number of Harmonic	Max. RMS value in A
3	24
5	60
7	39
11	20
13	16
17	8
19	6
>19	4

The rectifier is equipped with a control panel to set the output voltage and to check the actual state of the device. Furthermore, warning lamps for indicating energized capacitors, maximum output current and overheating are installed. Remote control of the rectifier via MODBUS allows the integration into the PGS test bench control system.

4.2 Measurements

After commissioning the rectifier, measurements were taken to check the output voltage specifications. Soft start of the rectifier, discharging time of the capacitors and the output voltage ripple were in the focus. The rectifier, which is placed in the PGS test hall, is shown in Fig. 3.

Fig. 3: Delivered low-power medium-voltage dc supply

4.2.1 Soft start

In Fig. 4 the soft start of the rectifier is illustrated. The yellow curve shows the voltage measured across a resistive divider; hence it is only one third of the real value. The final output voltage of 4.6 kV is reached after 16 s and thus fulfills the specifications. The blue curve shows the current through the resistive load.

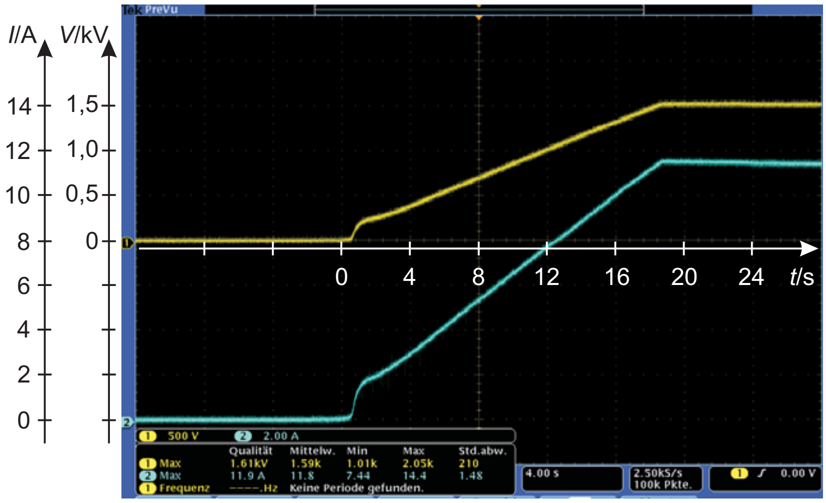


Fig. 4: Soft start of the rectifier

4.2.2 Discharging time of the capacitors

The discharging time of the capacitors is specified to be lower than 10 s. The yellow curve in Fig. 5 shows the voltage measured across the resistive divider after turning off the rectifier at maximum output voltage. The discharge time of the capacitors is about 3 s. The blue curve shows the corresponding current.

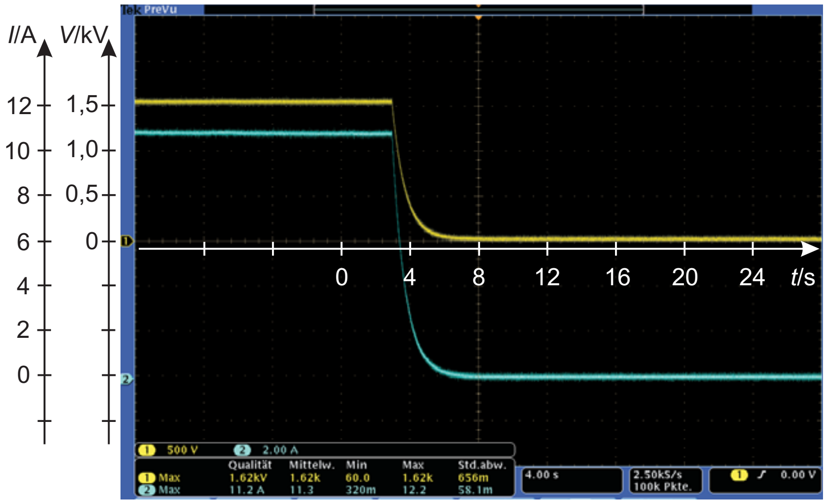


Fig. 5: Discharging of the capacitors

4.2.3 Voltage ripple

The voltage ripple is measured at the rectifier's output terminals at different voltage settings. The dc-ground terminal is connected to protective earth.

At 500 V the voltage ripple at the rectifier's output (Fig. 6) has a peak-to-peak value of 2 V, corresponding to 0.4 %. This ripple decreases to 0.35 % with an increase of the output voltage to 700 V (Fig. 7). Operating the rectifier with its maximum output voltage of 4.6 kV, the voltage ripple is only 0.22 % (Fig. 8).

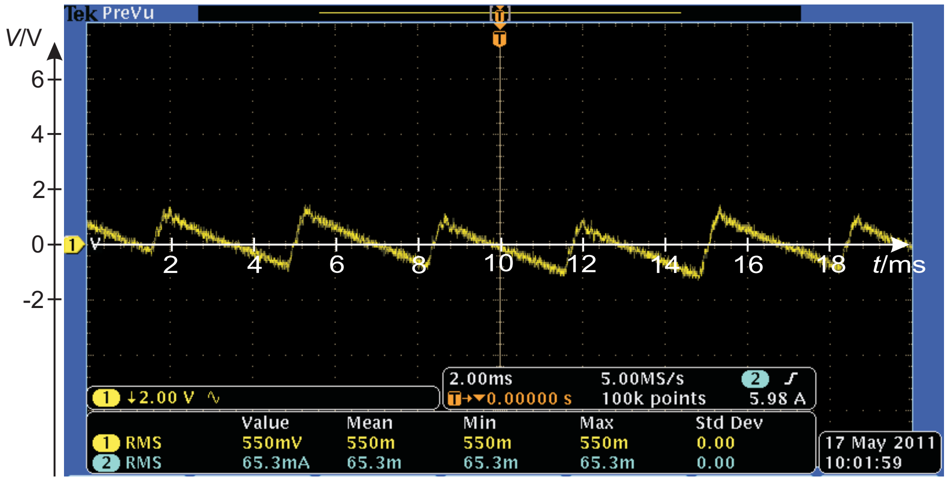


Fig. 6: Voltage ripple at 500 V

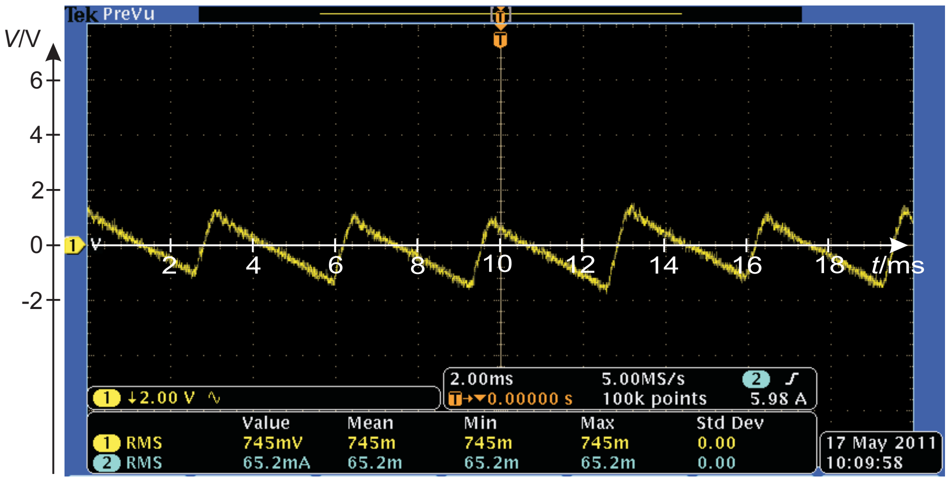


Fig. 7: Voltage ripple at 700 V

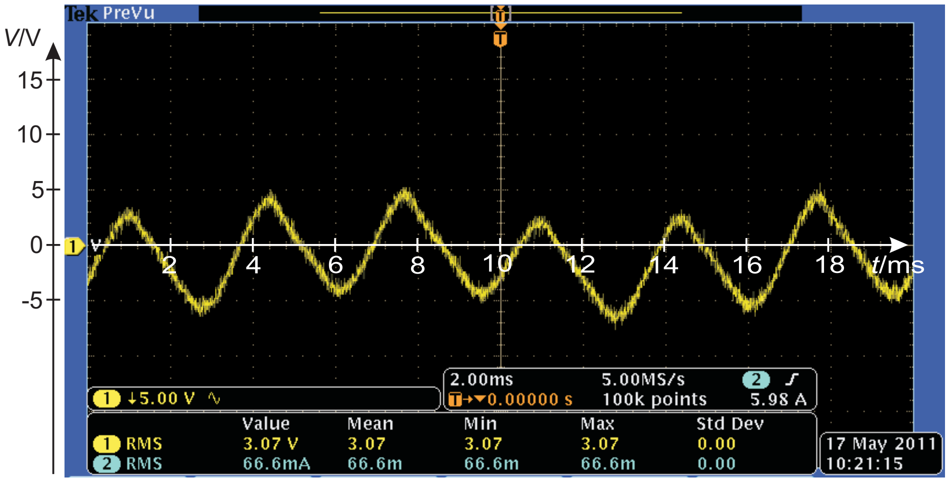


Fig. 8: Voltage ripple at 4.6 kV

5 Conclusions

A low-power medium-voltage dc supply was specified by PGS and delivered by a contractor. The rectifier operates within its specifications. This is proven by measurements, which confirm previously gained simulation results.

6 Future Work

This medium-voltage power supply will be used to test the 5-MW dc-dc converter built under E.ON ERC gGmbH project “High-Power DC-DC Converter” (gGmbH project no. 1).

7 Attachments

7.1 List of figures

7.2 Publications

n/a

7.3 Short CV of scientists involved in the project

Dipl.-Ing. Marco Stieneker has studied electrical power engineering at RWTH Aachen University and NTNU Trondheim, Norway. After his diploma thesis conducted at the Institute for Power Generation and Storage Systems (PGS, E.ON ERC), he started as a research associate at the same institute in 07/2010.

Dipl.-Ing. Florian Mura received his diploma in electrical engineering and communication technology of RWTH Aachen University in 12/2006. Since 03/2007 he is a research associate at the Institute for Power Electronics and Electrical Drives, later Institute for Power Generation and Storage Systems (PGS, E.ON ERC), RWTH Aachen University.

Prof. Rik W. De Doncker received his Ph.D. degree in electrical engineering from the Katholieke Universiteit Leuven, Belgium in 1986. In 1987, he was appointed a Visiting Associate Professor at the University of Wisconsin, Madison, where he lectured and conducted research on field-oriented controllers for high-performance induction motor drives. In 1988, he was a General Electric Company Fellow in the microelectronic center, IMEC, Leuven, Belgium. In December 1988, he joined the General Electric Company Corporate Research and Development Center, Schenectady, NY, where he led research on drives and high-power soft-switching converters, ranging from 100 kW to 4 MW, for aerospace, industrial, and traction applications. In 1994, he joined Silicon Power Corporation (formerly GE-SPCO) as Vice President, Technology. He worked on high-power converter systems and MTO devices and was responsible for the development and production of a 15 kV medium-voltage transfer switch. Since October 1996, he has been a professor at RWTH Aachen University, Aachen, Germany, where he leads the Institute for Power Electronics and Electrical Drives. He has published over 170 technical papers and is holder of 25 patents, with several pending. Currently, Prof. De Doncker is member of the Board of the German engineering Society VDE-ETG. He is an IEEE Fellow and is former president of the IEEE Power Electronics Society (PELS). He is member of the EPE Executive Council. He was a founding Chairman of the German IEEE IAS-PELS Joint Chapter. Prof. De Doncker is recipient of the IAS Outstanding Achievements Award and the IEEE Power Engineering Custom Power Award

(2008). In 2009, he led a VDE/ETG Task Force on Electric Vehicles. In 2010, he became member of the German National Platform for Electromobility.

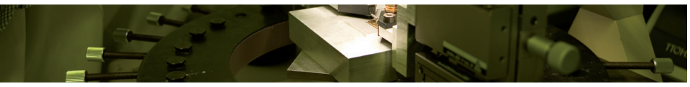
7.4 Project Timeline

The end of project was behind schedule, since the contractor was delayed with delivering the low-power medium-voltage dc supply.

Versatile Low-Power DC Supply for Medium-Voltage Testing																
	2010												2011			
Task 1: Dimensioning, Supplier Identification, Public Bid Preparation																
	■	■														
Task 2: Acquisition process																
			■	■	■	■										
Task 3: Commissioning																
							■	■	■	■	■	■	■			

7.5 Activities within the Scope of the Project

n/a



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