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The DC-link of the inverter system BUSSARD for ASDEX Upgrade in vessel saddle coils

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HIGHLIGHTS

- Use of a current-mode thyristor rectifier as DC-link supply is possible.
- Feed-forward operation is preferred to closed loop operation.
- The output inductance of the DC-link supply has been optimized.
- Safety functions, like arc protection, are implemented.
- Linearization of the control system is shown.

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ABSTRACT

For the nuclear fusion experiment ASDEX Upgrade (AUG) an inverter system to individually feed the 16 in-vessel saddle coils was built. After an operating phase with four inverters that supplied groups of up to 4 coils connected in series, now the full system is working. The common DC-link is fed by an existing current-mode thyristor rectifier.

The idea was to use the thyristor rectifier in voltage control mode. Therefore the control system and the power stack had to be adjusted. This publication describes the modifications made to the thyristor rectifier in order to feed a DC-link and stabilize its voltage under all load conditions. Also the integrated safety systems are shown.

1. Introduction

A set of 16 in vessel saddle coils (dubbed "B-Coils") has been installed into ASDEX Upgrade (AUG). The experimental aim of these coils is to mitigate different kinds of plasma instabilities by the help of small perturbation fields [1].

Initially, these coils have been operated at low bandwidth or direct current (DC) only. In order to use the B-coils up to their specified bandwidth of DC . . . 500 Hz with alternating currents (AC) of arbitrary waveforms and up to 1.3 kA peak, a new inverter system "BUSSARD" (German abbr. for "Bayerischer Umrichter, schnell schaltend für AUGs rasche Drehfelder) with 16 individual power inverters was built. After an initial operating phase with 4 inverters, now the full system is working [1–3]. The inverter system has a common DC-link which is fed by 2 thyristor rectifiers operated in voltage-control mode.

2. DC-link supply

2.1. Group 0–current-mode thyristor rectifier

The current-mode thyristor rectifier Group 0 is a 15 years old system, which was mainly used for the supply of test bench coils. It consists of two independent 2-quadrant thyristor rectifiers (modules 0.1 and 0.2). Each module can provide a current of up to 4 kA at a voltage of 340 V or 600 V (star- or delta-circuit configuration) for 10 s.

Each module is controlled individually. The control system is realized with the digital Logidyn-D2-system, offered by Alstom. It is set up by means of a graphical programming software, called Logicad. Some software parts (like the current control), which require a short cycle time, are implemented in machine language and can

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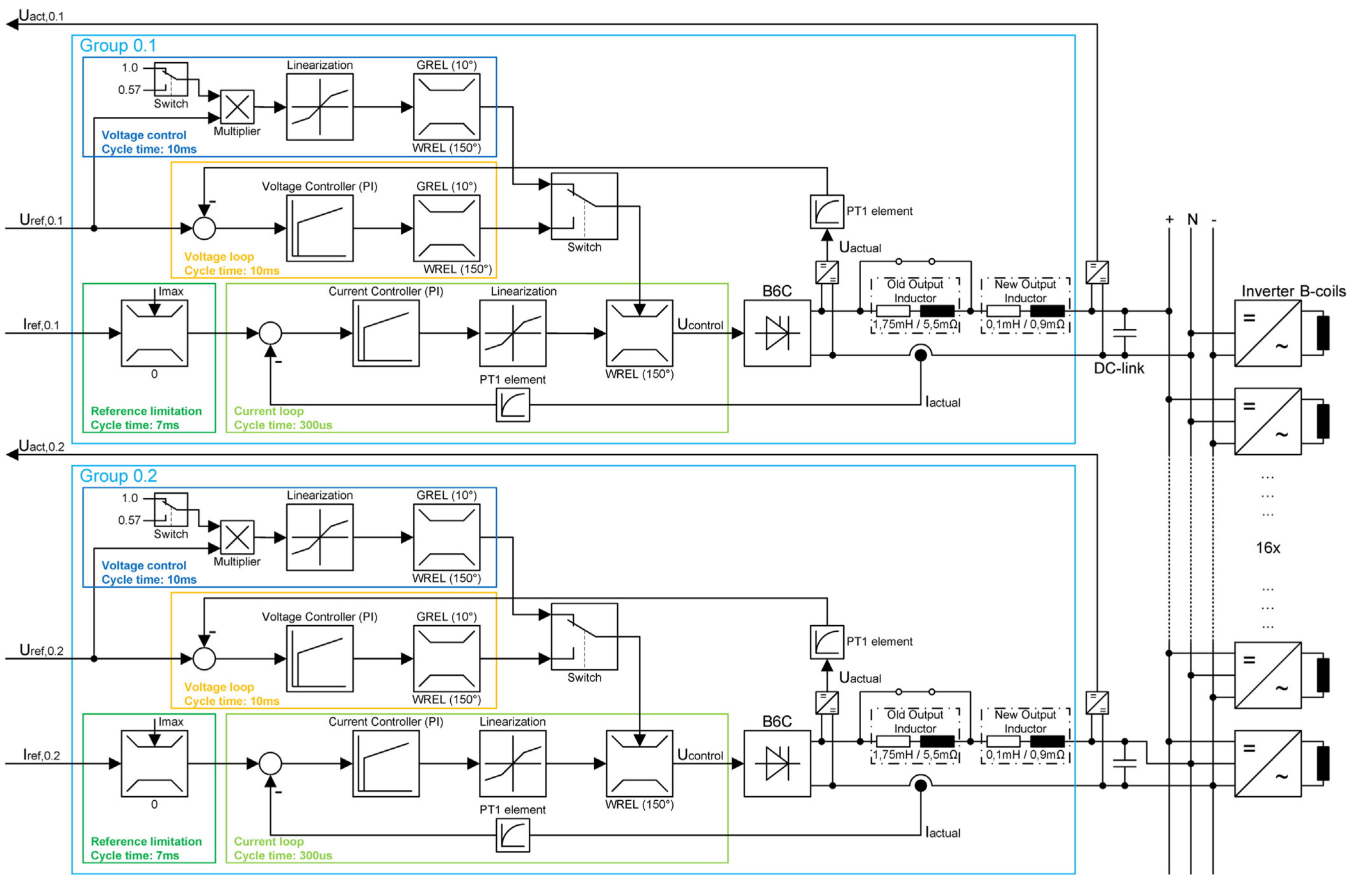

Fig. 1. Control schematic of Group 0.

only be modified by the supplier with a special compiler. Unfortunately, support of this system has ceased and so only limited modifications can be performed.

For the supply of test bench coils the thyristor rectifier is operated in current control mode, only. For the application as a supply for the DC-link of BUSSARD voltage control mode is required.

Therefore the control concept of the thyristor rectifier had to be adjusted for the new application, while current-mode coil power supply still needs to be possible for other test benches. With these boundary conditions, the new control concept has been designed and tested.

2.2. Optimized output inductance

For the new application the output inductance of the thyristor rectifier had to be adjusted. The existing output inductors had a value of 1.75 mH, which was much too high. However, there is a possibility to short-circuit them by disconnectors (Fig. 1). So it is possible to keep the old chokes for other applications and only short-circuit them for operation of BUSSARD.

For BUSSARD operation new output chokes were integrated into the output of the thyristor rectifier (Fig. 2). Their task is to limit the capacitive charge current. On the other hand every serial inductance costs dynamic (*di/dt*) and reduces voltage stability. Therefore, the inductance has to be chosen carefully.

Simulations showed that a value of 0.1 mH seems to be a good compromise. Also the resistance of the inductors should be as small as possible to limit voltage losses.

In the operation phase it shows only small voltage drops and overshooting. The resonance frequency of output inductance and DC link capacity that is about 63 Hz is not excited by the switching

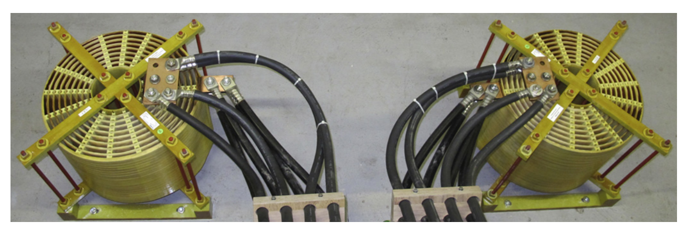

Fig. 2. New output inductors (air-core coils, 2 × 100 μH, 1500 A @ continuous operation, 525 × 525 × 510 mm (LxWxH)).

frequency of the inverters. This means that the inverters are sufficiently decoupled from each other and the DC link for all relevant operation scenarios [3].

2.3. Open-loop voltage control

Many tests with a closed-loop control were done, but showed problems by mutual interference with the internal control-loops of the inverters at low voltage (see also [3]). Another problem of closed-loop control is that Group 0 is a 2-quadrant converter (pos. and neg. voltage, but only pos. current). For a capacitive load only the operating quadrant involving positive current and positive voltage is usable because a negative voltage is always related to a negative current. In order to this only control errors in one direction can be compensated.

The "voltage loop" shown in Fig. 1 was already integrated in the control system by the supplier and is only used as a voltage limitation for the current-mode control. Thus the implementation is not perfect and has no linearization, because of the low needs for the use as a limitation. For the new application it is not suitable

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