

Thyristor crowbar system for the high current power supplies of ASDEX upgrade

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Abstract

The ohmic heating system and the poloidal field coils of ASDEX upgrade are supplied by 15 thyristor converter units with an installed apparent power of 600 MVA. To protect the thyristor converters against dc overvoltage arising from abnormal operations and resulting damages caused by the large energy stored in the AUG magnet coils an overvoltage protection system was required. The paper describes the motivation for—and the design and testing of the thyristor crowbar system representing the thyristor converter overvoltage protection system. It will present the layout, analyse the results of measurements obtained during commissioning, compare them to the calculated (design) values and report on the first experience of operation on the AUG coils improving the safety of the equipment.

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1. Introduction

During the next few years, ASDEX upgrade (AUG) will strengthen its efforts concerning investigations of advanced Tokamak scenarios in connection with increased triangularity and divertor operation. This involves an extension of the pulse length as well as an increase of the currents in some vertical field coils, resulting in higher peak power and energy consumed

during a plasma pulse. Together with the rising age of the converters – the first converters were purchased in 1976 – the risk of malfunction and subsequent damages is growing. To protect the converters against dc overvoltages and to dump the energy stored in the magnets in such a case, a thyristor crowbar system (TCS) was designed, installed and commissioned.

2. Application

The abnormal operations that should cause the thyristor crowbar unit (TCU) of a converter to trig-

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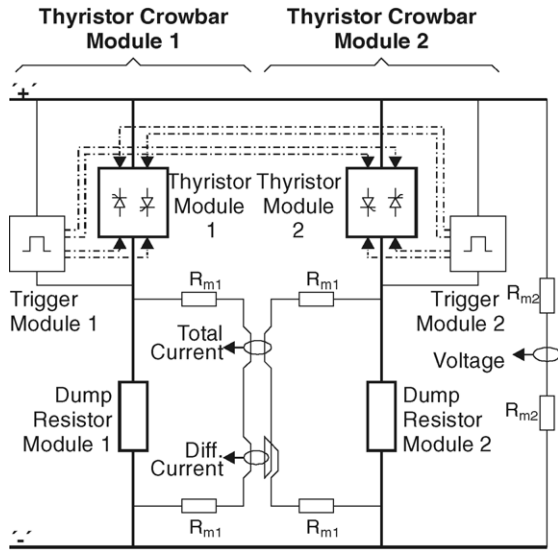


Fig. 1. TCU schematic diagram.

ger can be grouped into three classes: induced overvoltage—by the magnetic coupling of the AUG field coils; applied overvoltage—at series connection of thyristor converters; interruption of the load circuit—during a nominal current pulse.

3. Crowbar concept

The thyristor crowbar system consists of 15 thyristor crowbar units (TCU). The basic layout of the TCU is presented in Fig. 1. Each TCU is connected to the dc output terminals of one of the thyristor converters. The dc cable connections of $1 \times 300 \text{ mm}^2$ each are provided with a screen. The cable screens of both dc polarities are interconnected at both ends, thus allowing screen currents to circulate and hence achieving a low inductance of $5 \mu\text{H}$ per unit. In case of overvoltage the trigger circuit fires the thyristor modules, thereby

transferring the current from the converter to a resistor where the energy is dumped. The triggering voltage of each TCU is chosen to ensure adequate safety margins between the triggering voltage and the converter no-load voltage, respectively, the U_{drm} of the thyristor. The triggering circuit is suitable for a dc overvoltage of either polarity and the TCU is suitable to carry dc current of both polarities. The dc rated current of all units is 45 kA. The current rise-time is taken as 1 ms, while the worst-case decay time constant is 1.15 s. The design of the units is such that the capability for a total of 100 abnormally terminated pulses can be met during the lifetime of the TCU. The maximum cooling-off time is 30 min. The detection of an overcurrent in the TCU causes a trip of the thyristor converter (Action Level 2). The detection of an excessive overcurrent will also trip its HV circuit breaker (Action Level 3). The measurement of the converter dc voltage is realised by means of measurement resistors and a DCCT. For the crowbar total- and differential-current the same method is applied.

The TCS has to fulfil three main objectives: reliability—intervention in case of overvoltage but no tripping due to false alarms; modularity—independent operation of all units; flexibility—selection of triggering voltage taking account of the different dc system voltages. To increase reliability each TCU comprises two independent modules, parallel connected and with ‘cross-firing’ between each other. For modularity, each TCU includes its own instrumentation, protection and monitoring equipment to ensure all necessary interfaces with the AUG control system and the thyristor converter interlock system. To achieve maximum flexibility, the mechanical arrangement of all thyristor assemblies is about the same. If the converter configuration is changed the triggering voltage can easily be adapted by changing the overvoltage detection board and short-circuiting single dump resistor modules. An overview of the voltage ratings is given in Table 1.

Table 1
Voltage levels of TCU

Thyristor converter	Nominal voltage (V)	No-load voltage (V)	Thyristor U_{drm} (V)	Trigger voltage (V)	Dump resistor (m Ω)
1.1, 1.2	1500	1380	3200	2300	100
2.1, 2.2, 2.3	2400	2400/1200	$2 \times 2800/2800$	3600/1800	150/75
3.1, 3.2	500	500	1350	1060	50
4.1, 4.2, 5.1, 5.2	1500	1200	2800	1800	75
6.11, 6.12, 6.21, 6.22	1500	1600	4200	2300	100

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