

Preliminary design of the ITER AC/DC converters supplied by the Korean Domestic Agency

J.S. Oh^{a,*}, J. Choi^a, J.H. Suh^a, H. Liu^b, K. Hwang^b, I. Chung^b, S. Lee^b, J. Kang^b, H. Park^b, W. Jung^b, S. Jo^b, H. Gweon^b, Y. Lee^b, W. Lee^b, J.B. Kim^c, S.H. Han^c, G.D. Hong^c, J.S. Lee^c, B.W. Lee^c, C.H. Yeo^c, H.G. Kim^d, E. Seo^d, P. Reynaud^e, J. Goff^e, H. Tan^e, J. Tao^e

^a ITER Korea, National Fusion Research Institute, Daejeon 305-806, Republic of Korea

^b Dawonsys Corp., Siheung 429-450, Republic of Korea

^c Hyosung Corp., 450, Gongdeok-Dong, Seoul 121-720, Republic of Korea

^d Mobii Corp., 16-3, Yoonhwa Bldg, Yangjae-dong, Seoul 137-888, Republic of Korea

^e ITER Organization, Route de Vinon sur Verdon, 13115 Saint Paul Lez Durance, France

HIGHLIGHTS

- ▶ A self-supporting aluminium structure and symmetrical thyristor assembly are devised to assure a strong and reliable ITER converter.
- ▶ Converters are designed to be installable in a compact space with three times higher power density than normal industrial installations.
- ▶ Heating of the building structure due to high magnetic field by converters are identified and certain solutions are addressed in the building design.
- ▶ A cooperative fast control scheme is adopted to compensate fast reactive power change of up to the level of 900 Mvar.

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ABSTRACT

The preliminary design for ITER AC/DC converters under the responsibility of the Korean Domestic Agency is performed on the basis of the engineering experience of previous R&D for a full-scale 6-pulse CS (Central Solenoid) converter unit. This paper describes key features of the preliminary design for the respective sub-systems; integrated self-supporting aluminium structure and symmetrical thyristor assembly for strong and reliable converters, optimised impedance of the converter transformer to limit short circuit current, coaxial-type AC bus bars to shield high magnetic field around wall penetrations, compact components to fit into given building space. The insulation and the minimisation of electrical loops of concrete rebar below the converter installations are essential to prevent floor heating. Required output voltage or current of converters is provided by a conventional controller. A master controller is designed to collect predicted reactive powers from each converter and deliver processed data to the reactive power compensation (RPC) system to improve the regulation speed of the RPC controller with fast feed-forward compensation under fast reactive power transients.

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1. Introduction

The ITER AC/DC converters provide on-load voltage up to 1.05 kV and current up to 68 kA to the superconducting magnets, i.e. toroidal field (TF), central solenoid (CS), poloidal field (PF), and correction coils (CC). CC top and bottom coils are powered by CCU and CCL converters, and CC side coil is powered by CCS converter. The stabilisation of plasma vertical displacement is performed by the VS (vertical stabilisation) converters. The detail specifications of ITER AC/DC converters are shown in Table 1 [1].

TF converter is 12-pulse, 2-quadrant and uses constant margin angle control to limit maximum firing angle in inversion mode. The output voltage of TF converter in normal operation is kept lower than 160 V to limit reactive power; however, it must be increased to 650 V to discharge TF current within 30 min under abnormal conditions. TF coil current is bypassed by a continuous-duty bypass switch while changing the output voltage with the operation of an off-circuit tap changer (OCTC). All other converters are 12-pulse, 4-quadrant (4Q) converters and implement sequential control to reduce the reactive power demand. The solid state bypass switches for CS, VS and CC converters have bipolar pulsed capability, current being finally transferred to a mechanical protective make switch (PMS).

* Corresponding author. Tel.: +82 42 879 5740.

E-mail address: jsoh@nfri.re.kr (J.S. Oh).

Table 1
Specifications of ITER AC/DC converters.

Converter type (no. of units)	Input voltage (kVrms)	Output on load voltage (V)	Output current (kA)
TF (1)	66	±160/650	+68
CS (12)	66	±1,050	±45
PF (16)	66	±1,050	±55
VS (6)	66	±1,050	±22.5
CCU/CCL (6)	22	±65	±10
CCS (3)	22	±325	±10

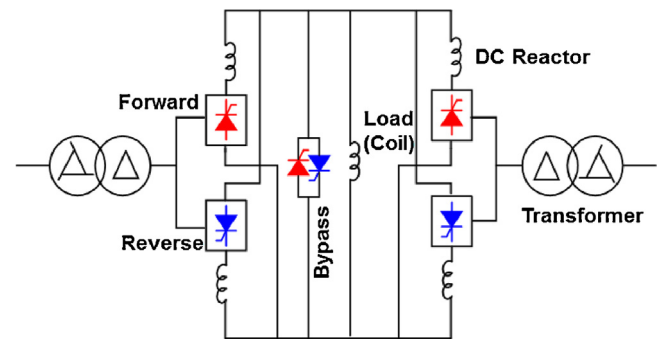


Fig. 1. Schematic of a 12-pulse, 4-quadrant converter.

The converters have fault suppression capability (FSC) under worst-case conditions as follows: (1) thyristors are sized to retain their capability of blocking reverse voltage after DC terminal fault; (2) all thyristors are connected to the AC source through fuses that shall only blow in the case of a single thyristor fault.

ITER AC/DC converters are supplied by China and Korean Domestic Agencies. The Korean Domestic Agency (KO-DA) is responsible for TF, CS, CC, and VS converters. The engineering basis is established by full-scale Korean R&D of 6-pulse CS converter unit [2,3] and previous experiences [4,5], where the current sharing among paralleled thyristors is proven to be within the level of 120%, FSC and soundness against electromagnetic stress are verified. This paper shows various aspects of design details of the converter units, converter transformers, building layout, and interlock and control system.

2. Converter unit

Fig. 1 shows a schematic of a 12-pulse, 4-quadrant converter for CS, VS, CCS and CCU/L. TF has only forward converters because

it is 2-quadrant. The two transformers supply 30° phase-shifted voltages by extended delta primaries to form a 12-pulse converter. An unacceptable current imbalance rises between the two 6-pulse converters if the output voltage variation is not limited. Therefore, the same phases are applied to the VS converter for fast voltage response, while 12-pulse operation is provided by two in series connection with 30° phase-shifted voltages. There are 4 kinds of thyristor with different voltage rating, the converter is designed in 2 groups by current rating for convenience of maintenance; CS type for TF, CS, VS converter, CC type for CCU/L and CCS.

The structure of a 6-pulse 4Q converter unit is arranged as shown in Fig. 2. Two bridges are integrated by placing on the three common rails (1–3) aligned to the AC bushings of a converter transformer. DC outputs (4–7) of each thyristor group are combined to form output terminals on the top side. This design provides an integrated self-supporting structure with high mechanical strength against electromagnetic force due to high fault current. Adequate distance between two bridges is maintained to assure easy access for maintenance. However, this structure is susceptible to horizontal forces on the insulators from seismic vibration. Ceramic insulators being very strong in compression are not suitable for high shear stress. In addition, low water absorption is a basic requirement for electrical insulators. Polyoxymethylene (acetal polymer – POM-C) is the material selected to meet both requirements for all support insulators [6].

Many factors must be considered in the structure design of thyristor assembly; mechanical stability with even surface contact over the lifecycle, efficient water cooling, and good current balance among paralleled thyristors. Thyristors are clamped onto the DC bus bar with fuses mounted on the AC bus bar. Symmetrical assembly on both sides secures even surface contacts under cyclic heating resulting from the pulsed operational nature of the ITER machine, see Fig. 3.

To make even temperature profile of components, a cooling circuit is applied to two sides of a thyristor and a fuse. The converter

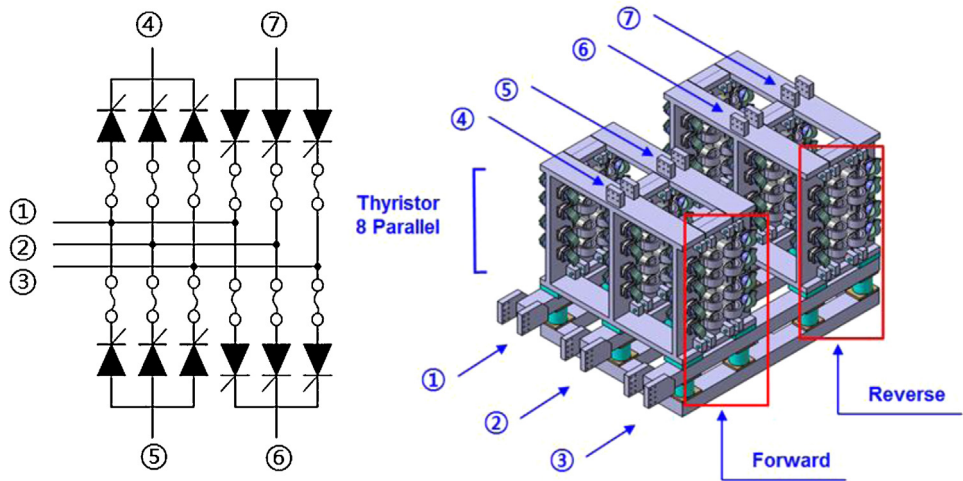


Fig. 2. Structural design of 6-pulse 4Q converter unit.

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