

Compact Power Supplies for Tokamak Heating

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ABSTRACT

As extension of power transformers, efficient large-scale contactless power transfer between stationary and reference frames is a problem of world-wide importance, to such applications as electric vehicles, materials handling and plasma heating for fusion science. Tokamak is the common developed fusion device where heating is recognized as one of its key technologies for its future reactor roadmap. Snubber is often used as protection device in NBI system for Tokamak heating [1-3]. The present NBI generally use 50/60 Hz High Voltage (HV) Insulation Transformers to configure its dc power supply to offer the bias current to the snubber, which could use the full flux swing of the core from the negative saturation point to the positive one of its BH major loop. The snubber weight could then be decreased to its half by using the bias power supply. But this 50/60Hz HV insulation transformer is much heavier than High Frequency (HF) High Voltage (HV) Insulation system. The paper gives the requirement, design and test of this Compact Power Systems based on HF HV Zero Current Switching (ZCS) technologies for Experimental Advanced Superconducting Tokamak (EAST) NBI snubber as well as its potential for its compact HVDC power supply. Its new control strategy is also implemented with one macro pulse composed by the digital defined continuous micro pulses. Some experimental evaluations have been done to verify the analysis results, which have been extended to over 100s and could be used for detail engineering design of power supplies for EAST based on IGBT.

Index Terms - Compact power supplies (PS), core snubber, experimental advanced superconducting Tokamak (EAST), international thermonuclear experimental reactor (ITER), inductively coupled power transfer (IPT), high voltage (HV) insulation transformers, high frequency (HF), neutral beam (NB), microwave, pulse mode, IGBT, zero current switching (ZCS)

1 INTRODUCTION

THE Experimental Advanced Superconducting Tokamak (EAST) is being upgraded with 4 MW microwave (4.6 GHz/10-1000 s) and 4 MW neutral beam (NB, 50-80 keV/10-100 s) heating systems as a part of the ongoing EAST Enhancement Programme. This is one of the largest upgrades of the EAST machine carried out within the EAST framework, two positive ion neutral injectors will be implemented in the near future as illustrated in Figure 1. In order to get the solid test foundation of the complex engineering system for about 100 s long pulse or even 3600 s, just as the requirement of ITER [1-4], one test platform is being constructed, which includes the HV snubber as well as its bias power supply. This system will be inserted between the ion source and 80 kV HV Pulse Step Modulator (PSM) power supply [5-6], as a means for protecting the expensive ion source while sparking in

operation. Due to the narrow space around the EAST machine, one compact power supply is developed based on high frequency HV insulation transformer implemented with IPT, i.e. inductively coupled power transfer technology. IPT can be used for bi-directional contactless power transfer between one frame and another reference one, and has the merits of being clean, spark free, environmentally benign and low maintenance. It is a solution to the power transfer problem, which has been investigated using coaxial transformers at the University of Wisconsin-Madison, USA [7] and a coupled coil arrangement at Auckland University, New Zealand [8]. This paper describes a new system structure for plasma heating, which gives the requirement, design and test of this bias Power Systems implemented with power electronics based on IPT, where its theories are essentially the same as that of the transformers although IPT deals with the motion case with varied coupling factor. Its control strategy is also described. Some experimental evaluations have been done to verify the analysis results, which could be used for detail engineering design for plasma heating.

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