# DEVELOPMENT, TESTING, AND COMMISSIONING OF 300 KVA T-NPC INVERTER FOR 300 KV, 2A HIGH VOLTAGE DC POWER SUPPLY FOR NEUTRAL BEAM ACCELERATOR SYSTEM

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## 1. Introduction:

The Neutral Beam Injector (NBI) system plays a crucial role in plasma heating for fusion experiments. A stable and reliable High Voltage DC (HVDC) power supply is essential for the efficient operation of the accelerator grid in the NBI system. To meet this requirement, a 300 kVA Three-Level T-Type Neutral Point Clamped (T-NPC) inverter has been developed as a critical component of a 300 kV, 2A HVDC power supply. The T-NPC topology has been chosen due to its superior efficiency, reduced switching losses, and enhanced voltage handling capability.

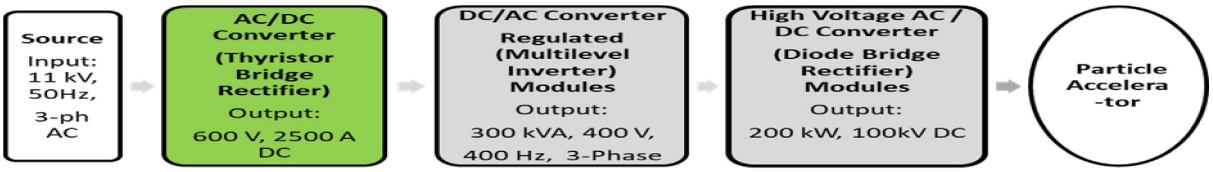


*Figure 1 Bird' eye view of High Voltage Power Supply*

The 300 kVA T-NPC inverter has been designed to operate at high frequency, ensuring minimized harmonics, fast turn off during break down conditions, and efficient power conversion. The design incorporates Space Vector Modulation (SVM) to optimize the utilization of the DC link voltage while reducing harmonic distortion. The inverter topology is selected to improve reliability and efficiency in high-power applications, making it suitable for fusion-related high-voltage power supplies.

Key design considerations include:

- Selection of appropriate power semiconductor devices to handle high voltage and current stresses.
- Implementation of closed-loop control to regulate the output waveform.
- Optimization of switching strategies to reduce Total Harmonic Distortion (THD).
- Integration of thermal management techniques to ensure stable operation under high power loads.

Comprehensive testing was carried out to validate the inverter's performance under different operating conditions. The testing process included:

- Accelerator Breakdown Tests: Evaluating the inverter's ability to withstand transient over voltages and rapid load changes typical in accelerator operations.
- Full Power Heat Run Tests: Ensuring thermal stability and efficiency at the rated power of 300 kVA.
- Integrated Testing with Rectifier-Inverter System: Verifying coordination between rectifier and inverter stages to maintain a stable High Voltage DC output.
- Total Harmonic Distortion (THD) Measurement: Ensuring compliance with stringent harmonic standards for accelerator applications.

The results demonstrated that the inverter operates efficiently, maintaining low THD and high power conversion efficiency under various loading conditions.

2. Test Results:

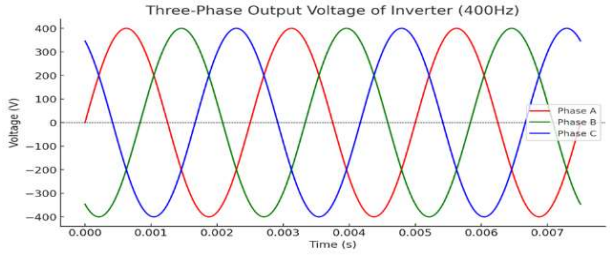


*Figure 2 Output Voltage waveform of the Inverter*

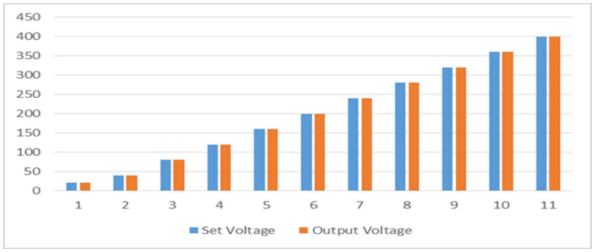


*Figure 3 No load Accuracy test results*

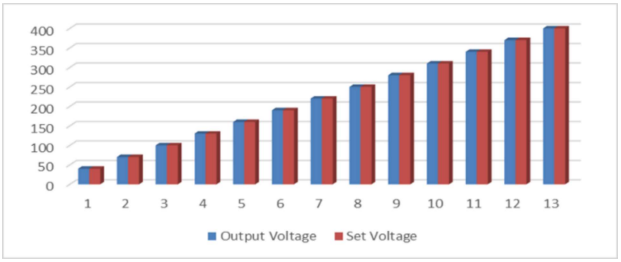


*Figure 4 Accuracy test results at rated load*

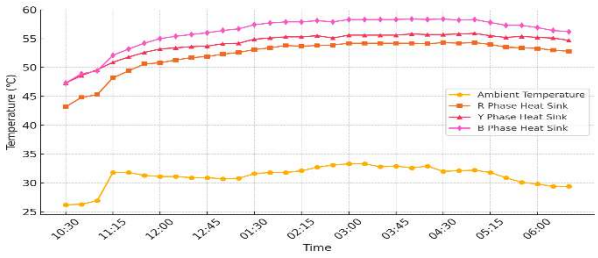


*Figure 5 8 hour Heat Run test results*

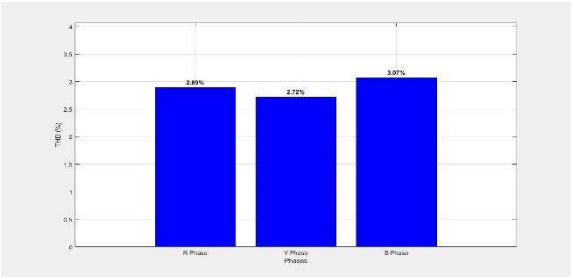

*Figure 6 Voltage THD at 400V*


*Figure 7 Developed Inverter System*

The development of the 300 kVA T-NPC inverter represents a significant milestone in high-voltage power electronics for fusion applications. The successful testing and commissioning validate its capability to deliver stable, high-efficiency power conversion for the Neutral Beam Accelerator System. As the primary subsystem of the HVPS, this inverter addresses critical requirements.

3. References:


[1]. M. Zhang et al., "Modeling and Analysis of Inverter-Type High Voltage Power Supply for NBI Accelerator Grid," in IEEE Transactions on Plasma Science, vol. 44, no. 9, pp. 1716-1721, Sept. 2016, doi: 10.1109/TPS.2016.2590432.

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[3]. A. Chakraborty, S. Kumar, A. Mankani, A. S, P. D. Christian and U. K. Baruah, "Commissioning and Initial Operational Experience of 2 MVA AC/DC Power Converter at IPR for Neutral Beam Injector Applications," in IEEE Transactions on Plasma Science, vol. 52, no. 5, pp. 1832-1841, May 2024, doi: 10.1109/TPS.2024.3401743.