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FTP/P1-26: The Influence on System Design of the Application of Neutral Beam Injection to a Demonstration Fusion Power Plant

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Steady state fusion power plants require significant non-inductive current drive possibly provided by neutral beam injection (NBI); in addition, NBI can be used for q-profile control for plasma stability. Economic considerations impose limitations on the necessary current drive and electrical efficiencies of the NBI system, with a figure of merit defined by the product of these quantities being greater than 0.25Am-2W-1.
The impact of the plasma density profile on non-inductive current drive is assessed using the PENCIL code and the results expressed in terms of a spatial map of current drive efficiency. The effect of beam shinethrough on the far first wall is used to determine limiting tangency radius and elevation for beam injection and thus define an average current drive efficiency. This is used in conjunction with the figure of merit to define the lower limit of electrical efficiency, for a given plasma profile, that will provide an economic power plant.
A NBI system code has been developed to allow the electrical efficiency of a combination of different technologies to be calculated. Gas, plasma and photon neutralizers and energy recovery systems can be considered along with the effect of beam divergence, background gas density and DC electrical efficiency. The code is used to investigate system sensitivities and to identify strategy for reducing technical risk. The primary determinant of electrical efficiency is neutralization efficiency, followed by beam stripping and transmission losses. Despite the gas neutralizer being limited to 58% neutralization efficiency, it is shown that the figure of merit can be achieved by a combination of energy recovery and reduced stripping. For the photoneutralizer system, where the neutralization efficiency can be varied up to 95%, the range of options is greater. Adding energy recovery to the system reduces the sensitivity of electrical efficiency to the neutralization, offering reduced risk and hence improved reliability options. However, the range of options available depends on the current drive obtainable for a particular plasma density profile, thus the plasma itself influences the choice of NBI technology.

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