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Theoretical and computational studies to estimate eddy current distribution in CS & VV for spherical tokamaks

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Abstract:
During the start-up phase the induction of eddy current is one of the main issues in vacuum vessel. Eddy current is very important for plasma equilibrium conditions and control of MHD. In this paper, we have successfully calculated eddy current in two different methods. Firstly, we have applied mathematical techniques to determined axisymmetric eddy current distribution by thin shell approximation. Secondly, we have used computationally techniques that depend on the numerical method. At the end, we have provided the sufficient way to keep minimum eddy current effects in metallic chamber. This is an indispensable innovative research for an emerging field of nuclear fusion reactor technology. The research will be extended to developed new models for other spherical tokamaks.

Introduction:
Estimations for the effect of electromagnetic force in the components, its effect on plasma equilibrium during the startup of nuclear reactor the disruption effect on plasma may effected by the induction of eddy currents that induced in the metallic components of magnetic fusion reactor. The effect of eddy current on tokamak plasma control of magneto hydrodynamic activity and its equilibrium is critical. Amount of handsome work has already been published contingent with eddy current issues by numerical techniques. These techniques have been used in different spherical tokamaks such as SUNIST [1], ETE [2] etc. many researchers have been investigated eddy current theoretically and then applied simulation in spherical tokamaks.

Research Methodology:
The constituted tasks are governed under two phases. In the first phase, we have completed the literature review that is directly related to eddy current problem in spherical tokamaks. Tap method, differential pick-up coil method, temperature distribution method, rogowski coil method, T-method and magnetic diagnostic response have been studied. We have chosen two methods, current vector potential method and differential pick-up coil method and developed new method by intense coupling techniques. This method has provided measurement of axisymmetric eddy currents distribution, linkage flux, mutual inductance and time constant in metallic chamber. In the second phase, Software techniques have been used such as ANSYS, MAXWELL etc. in addition, some developed code (VALEN, LRDRIT, STELLOPT, VMEC) have been studied.

Results:
In this section, the task is focused on eddy current calculation by theoretical investigation. Since, this is an emerging technology in the field of nuclear fusion reactor engineering therefore, we encompassed different mathematical approaches and developed a new models and method for calculating eddy current in spherical tokamak. We have used coupling techniques and then developed new method to determined axisymmetric eddy currents distribution by thin shell approximation. This method is the one in which supposition is made with two circuits, that can also help to finding out the linkage flux, mutual inductance, time constant and eddy current (I_{sol} & I_{vv}) as well.[3]

$$L_{sol}\frac{di_{sol}}{dt}+R_{sol}\cdot i_{sol}-M\frac{di_{vv}}{dt}=0 \qquad (1)$$

$$L_{vv}\frac{di_{vv}}{dt}+R_{vv}\cdot i_{vv}-M\frac{di_{sol}}{dt}=0 \qquad (2)$$

Required current flow in central solenoid

$$I_{sol}=\frac{1}{R_{sol}}\left\{1-e^{-\frac{t}{\tau_1}}\right\} \qquad (3)$$

Where,

$$\tau_1=\frac{2\left(L_{sol}L_{vv}-M^2\right)}{L_{vv}R_{sol}}$$

Required current flow in vacuum vessel

$$I_{vv}=\frac{M}{L_{sol}R_{vv}}\left(e^{\frac{-t}{\tau_1}}-e^{\frac{-t}{\tau_2}}\right) \qquad (4)$$

Where,

$$\tau_1=\frac{2\left(L_{sol}L_{vv}-M^2\right)}{L_{vv}R_{sol}}, \qquad \tau_2=\frac{\left(L_{sol}L_{vv}-M^2\right)}{R_{vv}L_{sol}}$$

References
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