AN IMPROVED ISO-FLUX METHOD AND VERTICAL DISPLACEMENT EVENTS PREDICTOR


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ABSTRACT

• To resolve concerns for heat/electromagnetic loads from vertical displacement events (VDEs), we developed an equilibrium controller, which can predict and control VDEs to an arbitrary direction and allows us to cope with either upward or downward unmitigated VDEs. Here we improve the prediction rate by parametrizing a power supplies voltage saturation rate with a newly developed adaptive voltage allocation (AVA) scheme.

• Furthermore, the AVA scheme also broadens accessible elongation by 0.3 in the presence of power supplies voltage saturation due to hybrid plasma current and shape/position control and unknown plasmas disturbances.

• In preparation for coming JT-60SA integrated commissioning, the VDE predictor and the AVA scheme are implemented in our equilibrium controller, and its performance is demonstrated by using “MECS” (Fig. 1).

BACKGROUND

Fusion output $\propto$ Plasma pressure $\propto I_p \times 1 + \kappa^2$ when fixing machine unique parameters, e.g., toroidal field, machine size, etc. [Troyon 84, ITER PB 1 (OVo)]

• For fusion output, hybrid control of $I_p$ and $VDE$ is required

• Device conditions of DEMO and JT-60SA (during the integrated commissioning, Fig. 1) for VDE control are highly disparate from present day tokamaks and even from ITER, such as the absence of in-vessel coils, a large gap between plasmas and vacuum vessels, and eddy currents flowing in the breeding blanket (DEMO)

$\nu$ W (gap/ $R_{major\ radius} = 0.12$ (ITER), $\sim 0.18$ (DEMO), 0.2 (JT-60SA comm.))

• Disruption prevention including VDEs has been extensively explored [e.g., Strait 19], but it may still be easy to mitigate all disruptions perfectly, which requires forecasting disruptions before delay time of actuators

NEWLY DEVELOPED CONTROL SCHEME

Adaptive Voltage Allocation (AVA) scheme [submitted to NF]

AVA scheme achieves hybrid control of the $P/S$ and the $I_p$ under power supply voltage limits

Position/shape & $I_p$ control

ISO-FLUX control : diff. btw. LCSF and control points (P/S) and its offset ($I_p$)

PID control

Automatic gain control

Control & Circuit equation

VDE Prediction scheme

• VDE control to an arbitrary direction could halve the concerns to protect the device from either upward or downward VDEs: one divertor side of MGI/SP is sufficient?

• VDE Predictor: a support vector machine (SVM) classifier with three parameters: vertical velocity ($v_{ZAVA}$), decay index (n-index), newly introduced gain ($G_{AVA}$)

• SVM is trained by 17 simulation with 7 upward VDEs and 378/460747 trained/test data

CONCLUSION

• An advanced ISO-FLUX control scheme as well as VDE control scheme is developed and implemented in the JT-60SA equilibrium controller

• An accessible $\kappa_x$ is broadened by 0.35 in the presence of the moderate $I_p$ mini-collapse (30 ~ 70 kA in JT-60SA)

• New logic guides the VDE to an arbitrary direction and could halve the concerns to protect the device from either up/downward VDEs

$G_{AVA}$ improves false alarm rates for the VDE detection

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