Study of real-time n_e profile evolution and control

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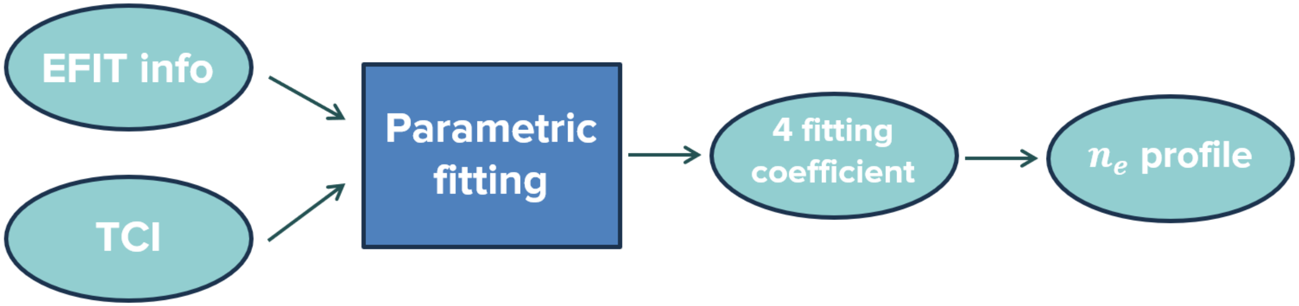
Plasma Control

Objectives

- Conducting system identification of n_e with respect to RMP, GAS, Pellet, and SMBI
- Developing pedestal-top n_e controller using multiple actuators
- Developing two-point n_e controller one at core another at edge
- Studying profile evolution with respect to different actuators

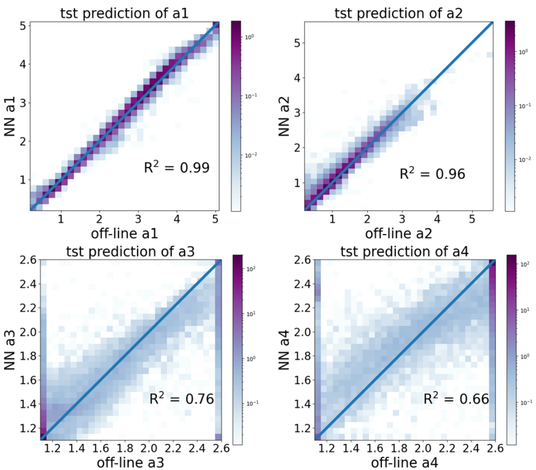
Reconstructing n_e profile

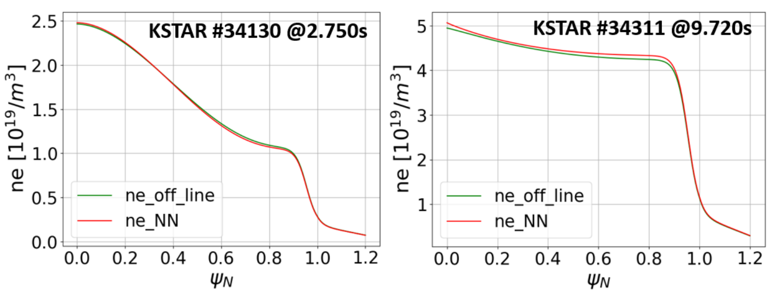


- n_e profile was reconstructed by using five channels of two-colored interferometer (TCI).

Neural Network acceleration

1. Training: 2022 KSTAR [93,812 ($\sim 10^5$)]
2. Val: Half 2023 KSTAR [33,591 ($\sim 10^5$)]
3. Test: Half 2023 KSTAR [33,591 ($\sim 10^5$)]





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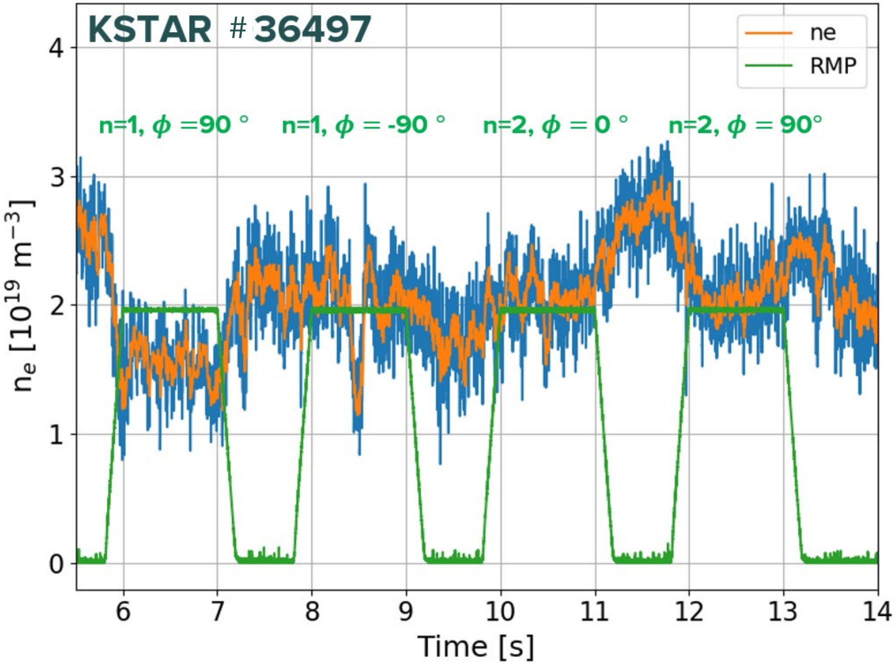
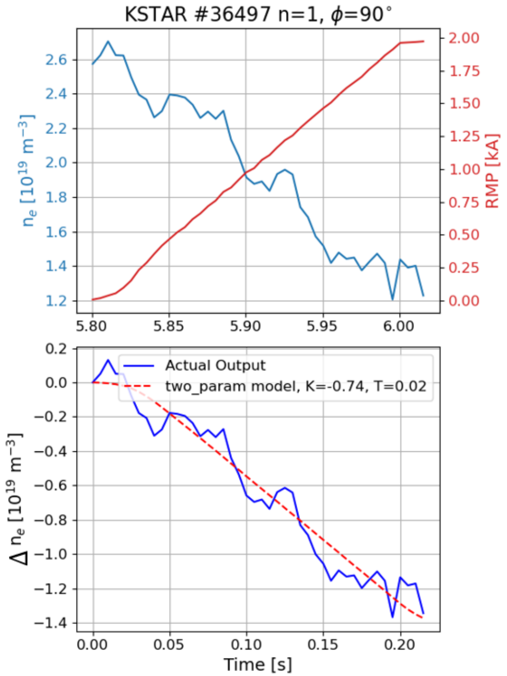
System identification w.r.t. RMP





- By analyzing the plasma density response w.r.t. RMP (as well as Gas), we designed PI controller.

Minseok Kim

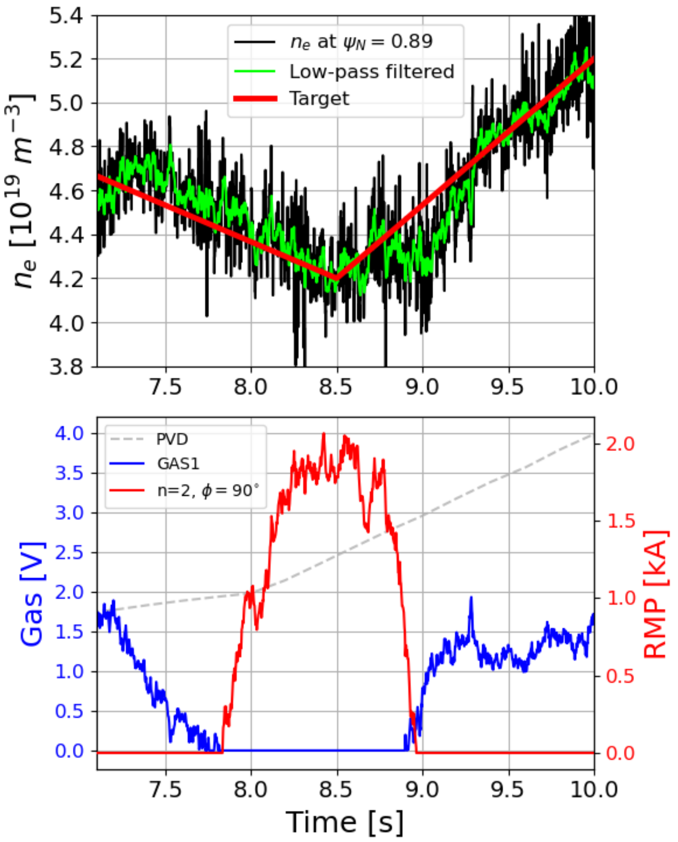
Fri, Jan 03rd, 2025, Afternoon (4H)

Plasma Control

Controlling pedestal -top n_e using Gas1 and RMP

Fri, Feb 14th, 2025, Piggyback on Sang -Hee Hahn's exp

KSTAR #37650



- The controller could successfully follow the density target by using both actuators.
- When we run out of the Gas, RMP can be applied to further decrease the density.
- Even if the system identification was conducted for n=1, $\phi = 90°$ RMP and PVD, the controller was functional for different actuator set.

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Plasma Control

Conclusion

- Conducting system identification of n_e with respect to RMP, GAS, Pellet, and SMBI

→ For RMP and Gas are done, and pellet and SMBI can also be done from other's experimental data.

- Developing pedestal -top n_e controller using multiple actuators

→ Done

- Developing two -point n_e controller one at core another at edge

→ Can be proposed for the coming campaign

- Studying profile evolution with respect to different actuators

→ Can be conducted for the coming paper

Successful!

Appendix

(a)

$$\text{Edge model: } a_1\left[\gamma + \frac{1-\gamma}{2}\left(1 - \frac{\tanh(\frac{\psi-\psi_m}{\Delta/2})}{\tanh(1)}\right)\right]$$

ψ : Normalized poloidal flux function

ψ_m : Position of the middle of pedestal $(\psi_m = 1 - \Delta/2)$

Δ : Pedestal width

a_1 : Plasma density at the pedestal top

γ : The ratio of electron density between pedestal top and LCFS

(b)

$$\text{Core model: } a_2\left|1 - \left(\frac{\psi}{\psi_t}\right)^{a_3}\right|^{a_4}$$

ψ_t : Position of the pedestal top $(\psi_t = 1 - \Delta)$

a_2 : The difference of the plasma density between axis and pedestal top

a_3 : Fitting coefficient in the core region

a_4 : Fitting coefficient in the core region

(c) Scrape off layer multiplier: $4 - 3\psi$

$$s(\psi) = \begin{cases} 1 & (1 \geq \psi \geq 0) \\ 4 - 3\psi & (\psi > 1) \end{cases}$$

(d)

$$n_{e0}(\psi) = \begin{cases} \text{Edge model} & (\psi \geq \psi_t) \\ \text{Edge model + Core model} & (\psi < \psi_t) \end{cases}$$

$$n_e(\psi) = n_{e0} \times s$$