

# Pengaturan Tekanan Boiler Berbasis *Hybrid Fuzzy PID*

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# POKOK BAHASAN

-Pendahuluan

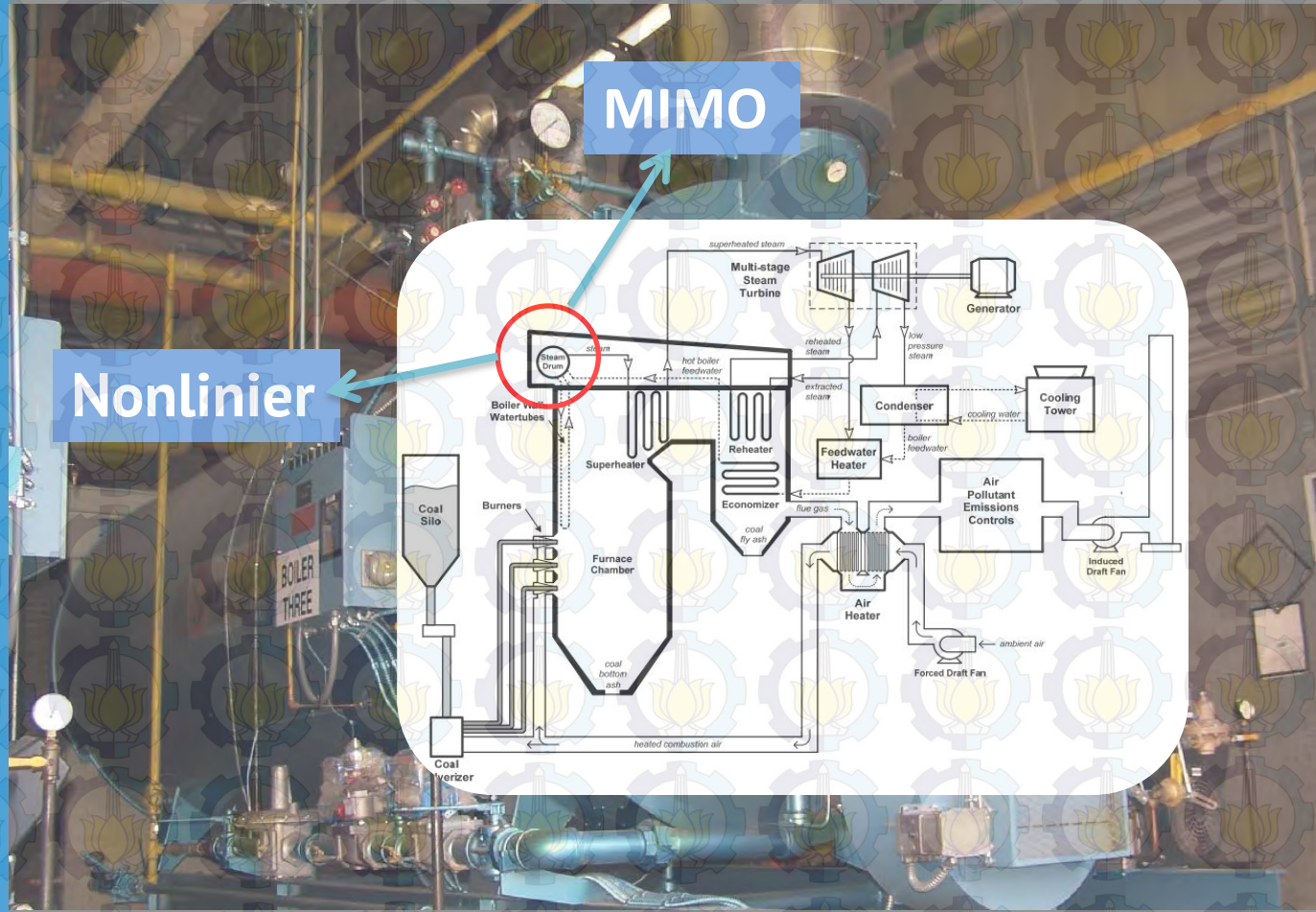
-Perancangan

-Hasil Pengujian

-Kesimpulan

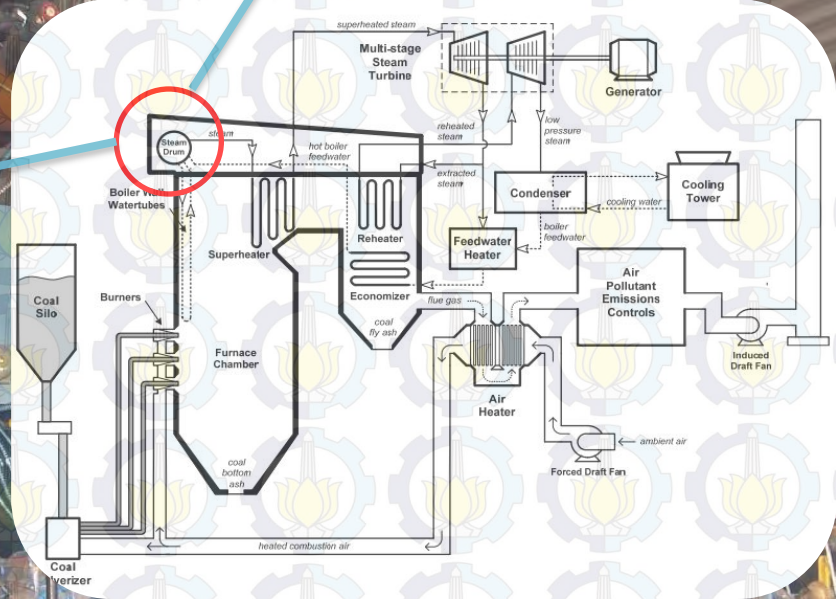
Pendahuluan

Latar Belakang



MIMO

Nonlinier





# Pendahuluan

Latar Belakang

## Permasalahan

- Merancang suatu metode *decoupling* untuk menghilangkan pengaruh interaksi *input-output*
- Merancang kontroler tekanan drum pada *boiler-turbine* agar tekanan mampu mengikuti sinyal referensi yang diberikan

# Pendahuluan

## Latar Belakang

## Permasalahan

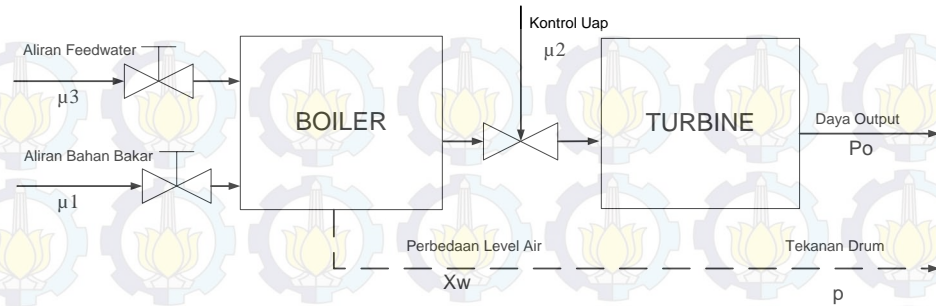
- Merancang suatu metode decoupling untuk menghilangkan pengaruh interaksi input-output
- Merancang kontroler tekanan drum pada boiler-turbine agar tekanan mampu mengikuti sinyal referensi yang diberikan

## Tujuan

- Merancang decoupling dengan metode *inverted decoupling* untuk menghilangkan interaksi *input-output*, sehingga masing-masing input hanya mempengaruhi satu output.
- Merancang *Hybrid Fuzzy PID* untuk mengatur tekanan pada boiler-turbine agar mampu mengikuti sinyal referensi yang diberikan



## Diagram Boiler-Turbine



### Elemen Vektor State Boiler-Turbine

- $x_1$  : tekanan drum (kg/cm<sup>2</sup>)
- $x_2$  : daya output (MW),
- $x_3$  : masa enis fluida (kg/cm<sup>3</sup>)

### Persamaan state Boiler-Turbine:

$$\dot{x}_1 = -0.0018u_2x_1^{9/8} + 0.9u_1 - 0.15u_3$$

$$\dot{x}_2 = (0.073u_2 - 0.016)x_1^{9/8} - 0.1x_2$$

$$\dot{x}_3 = (141u_3 - (1.1u_2 - 0.19)x_1) / 85$$

$$y_1 = x_1$$

$$y_2 = x_2$$

$$y_3 = 0.05(0.23073x_3 + 100\alpha_{cs} + q_e / 9 - 67.975)$$

Dengan

$$\alpha_{cs} = \frac{(1 - 0.001538x_3)(0.8x_1 - 25.6)}{x_3(1.0394 - 0.0012304x_1)}$$

$$q_e = (0.854u_2 - 0.147)x_1 + 45.59u_1 - 2.514u_3 - 2.096$$

## Transfer function boiler-turbine

$$G(s) = C(sI - A)^{-1}B + D$$

$$G_{11} = \frac{0,9}{s + 0,0026}$$

$$G_{12} = \frac{-0,4787}{s + 0,0026}$$

$$G_{13} = \frac{-0,15}{s + 0,0026}$$

$$G_{21} = \frac{0,06615}{s^2 + 0,1026s + 0,00026}$$

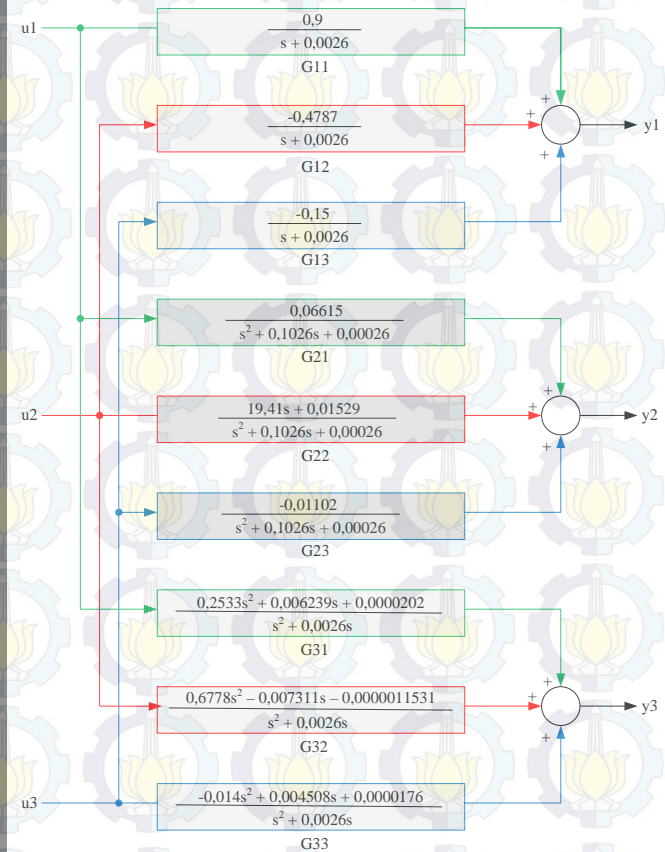
$$G_{22} = \frac{19,41s + 0,01529}{s^2 + 0,1026s + 0,00026}$$

$$G_{23} = \frac{-0,01102}{s^2 + 0,1026s + 0,00026}$$

$$G_{31} = \frac{0,2533s^2 + 0,006239s - 0,0000202}{s^2 + 0,0026}$$

$$G_{32} = \frac{0,6778s^2 - 0,007311s - 0,0000011531}{s^2 + 0,0026}$$

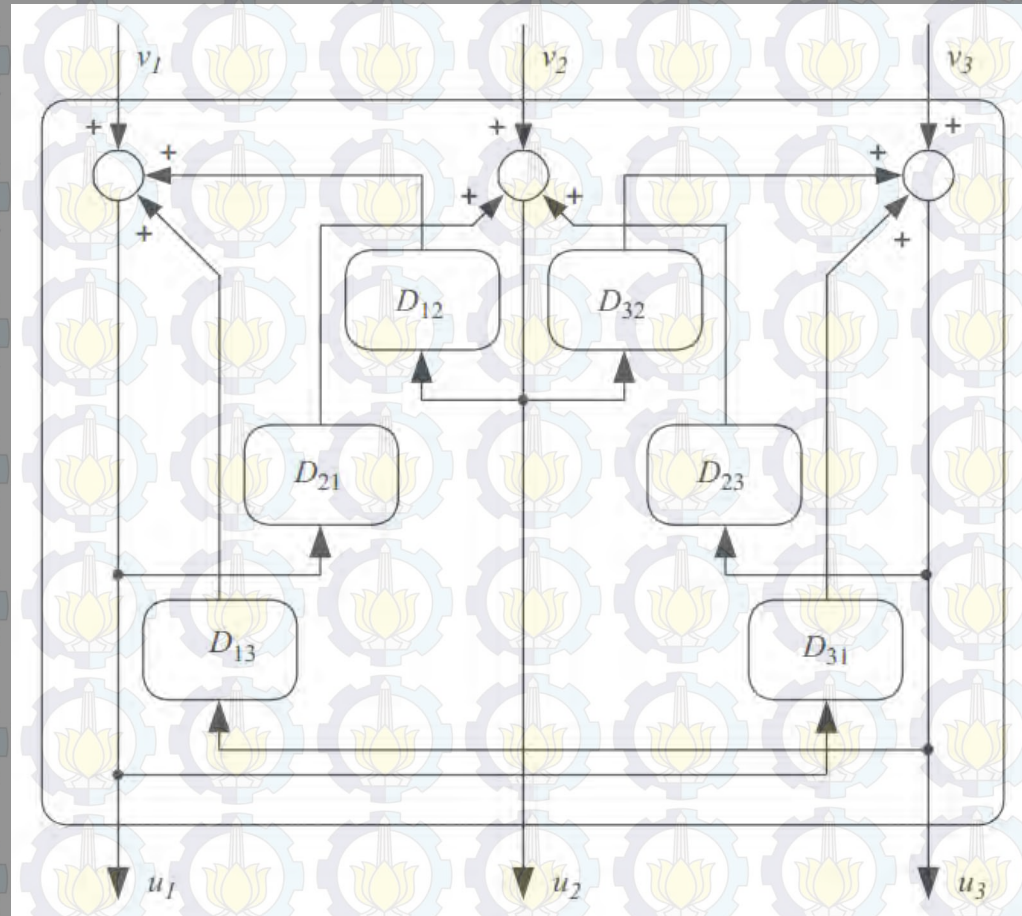
$$G_{33} = \frac{-0,014s^2 + 0,004508s + 0,0000176}{s^2 + 0,0026}$$





# Perancangan

## Model Plant Decoupling



Desain Inverted dcoupling



## Perancangan

desain *inverted decoupling*

### Model Plant Decoupling

$$d_{12} = \frac{-g_{12}}{g_{11}} = \frac{0,4787}{0,9}$$

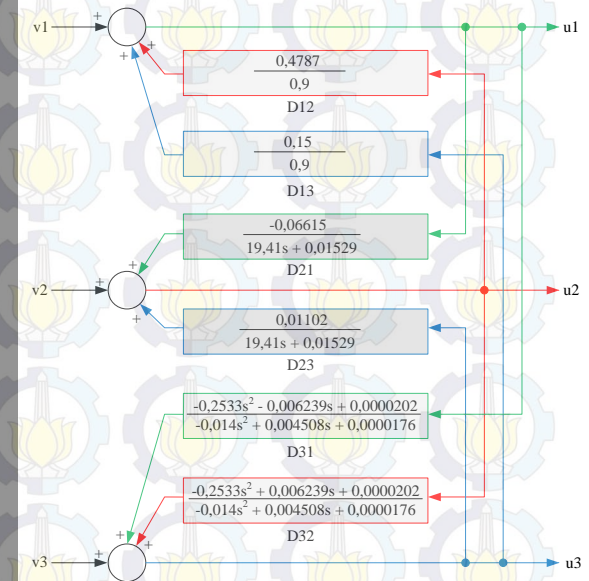
$$d_{13} = \frac{-g_{13}}{g_{11}} = \frac{0,15}{0,9}$$

$$d_{21} = \frac{-g_{21}}{g_{22}} = \frac{-0,066157}{19,41s + 0,01529}$$

$$d_{23} = \frac{-g_{32}}{g_{22}} = \frac{0,01102}{19,41s + 0,01529}$$

$$d_{31} = \frac{-g_{31}}{g_{33}} = \frac{-0,2533s^2 - 0,006239s + 0,00002022}{-0,014s^2 + 0,004508s + 0,00001769}$$

$$d_{32} = \frac{-g_{32}}{g_{33}} = \frac{-0,6778s^2 + 0,007311s + 0,0000011531}{-0,014s^2 + 0,004508s + 0,00001769}$$

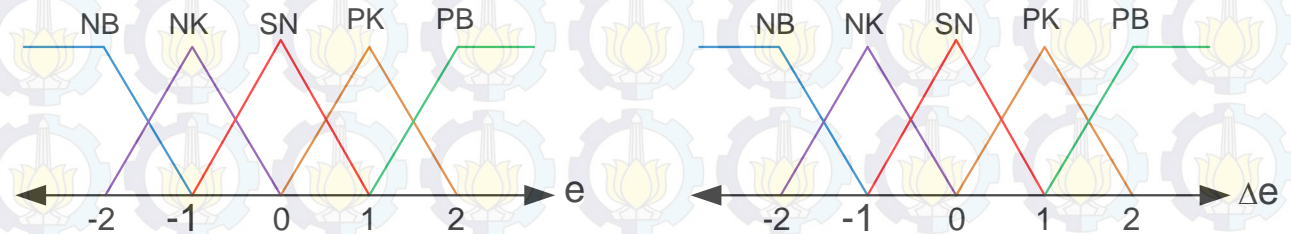


-- Fuzifikasi --

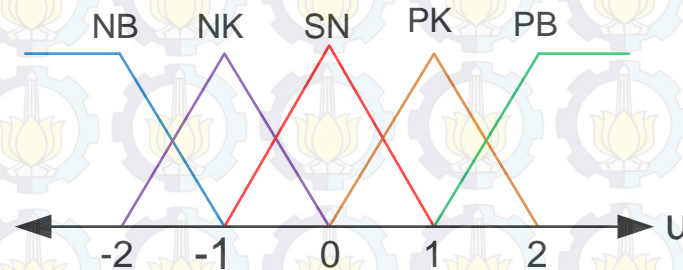
# Perancangan

Model Sistem  
Decoupling  
Kontroler

## 2 Masukan (error dan perubahan error)



## 1 keluaran (sinyal kontrol /tekanan)





## Rule Base

$\Delta e \backslash e$	NB	NK	SN	PK	PB
NB	NB	NB	NK	NK	SN
NK	NB	NK	NK	SN	PK
SN	NK	NK	SN	PK	PK
PK	NK	SN	PK	PK	PB
PB	SN	PK	PK	PB	PB

Deskripsi linguistik dari fungsi keanggotaan *input* dan *output* adalah Negatif Besar (NB), Negatif Kecil (NK), Sekitar Nol (SN), Positif Kecil (PK) dan Positif Besar (PB) sehingga didapatkan 25 buah kaidah yang berbentuk seperti berikut:

- IF  $x_1$  is  $A_1^k$  AND  $x_2$  is  $A_2^k$  then  $y^k$  is  $B^k$   
dimana  $x$  adalah *input* dan  $y$  adalah *output*

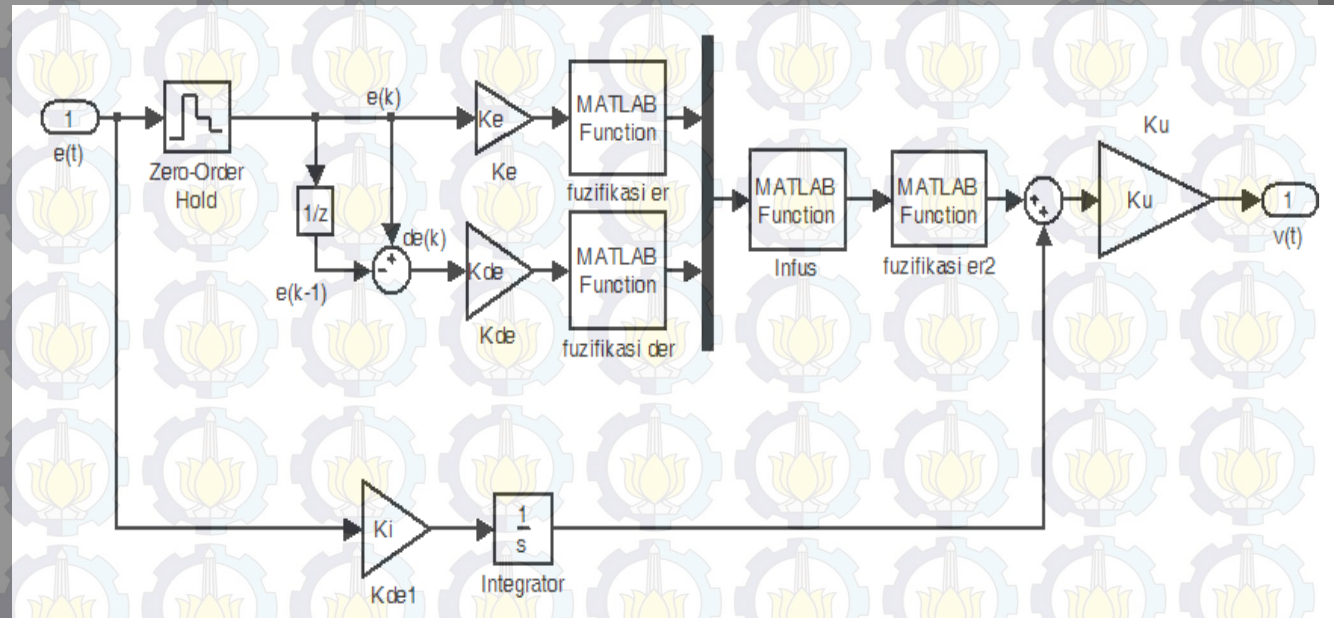
## Inferensi

$$uf(k) = \max(uf(k)), \min(e(j)), \Delta_e(i)$$

## Defuzifikasi

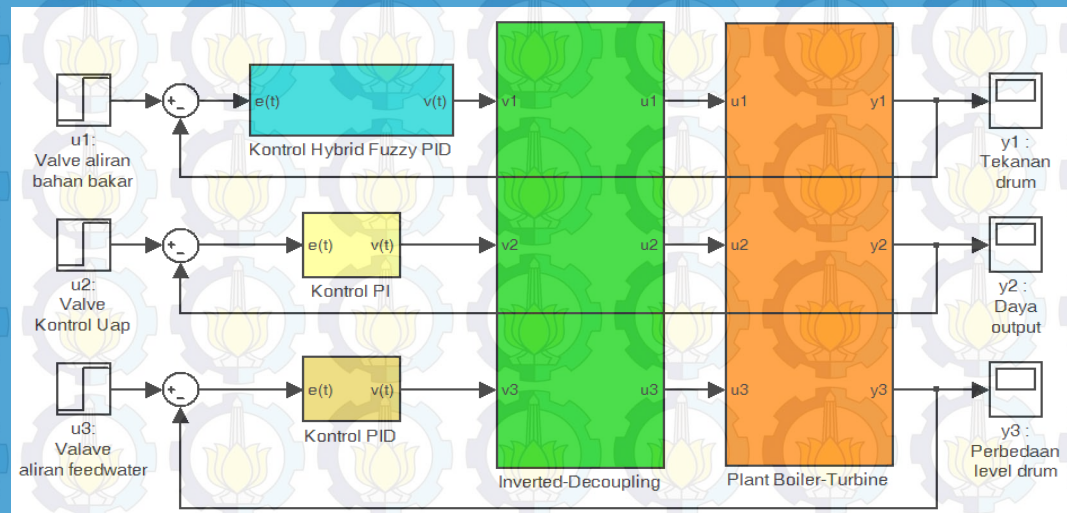
$$y_i = \frac{\sum_n \max(\mu_i^n) \cdot y_n}{\sum_n \max(\mu_i^n)}$$

Skema Kontroler *Hybrid Fuzzy PID*



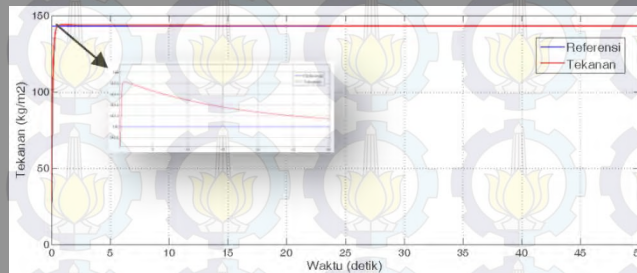


Simulink *Boiler-Turbine Plant* secara keseluruhan



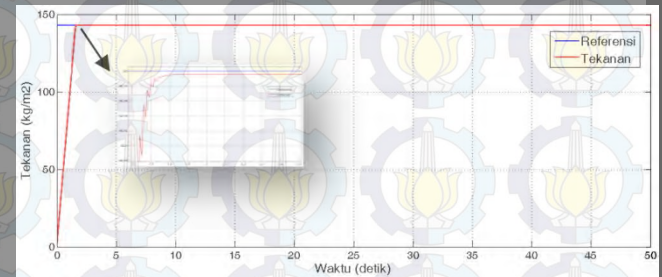
## Respon Tekanan Kondisi Tanpa Beban

### Respon tekanan dengan PID



Waktu *Steady State* = 10,83 detik  
*Rise Time* = 0,47 detik  
Tekanan *Boiler-Turbine* = 143,16 kg/cm<sup>2</sup>  
*Ess* = 0,07%  
*Overshoot* = 0,58 %

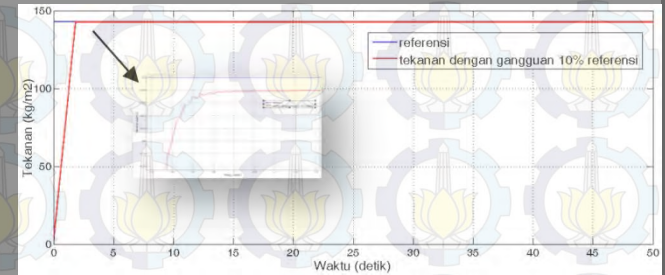
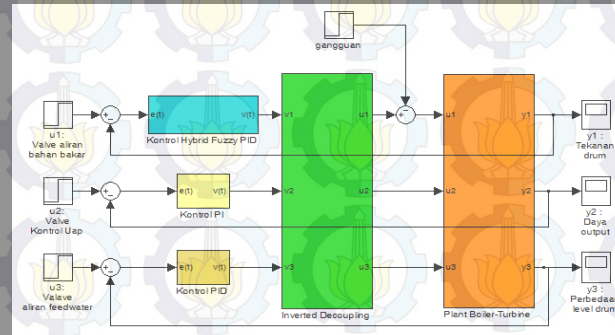
### Respon tekanan dengan Hybrid Fuzzy PID



Waktu *Steady State* = 1,8detik  
*Rise Time* = 1,62 detik  
Tekanan *Boiler-Turbine* = 142,99 kg/cm<sup>2</sup>  
*Ess* = 0,003%  
*Overshoot* = 0



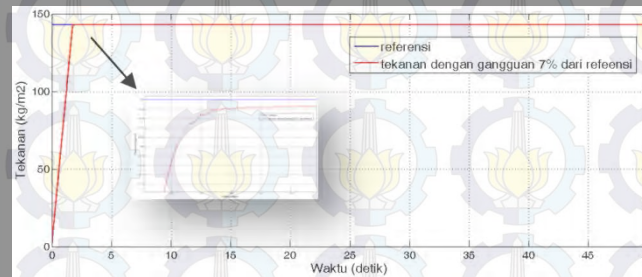
# TUGAS AKHIR – TE 141599



## Gangguan

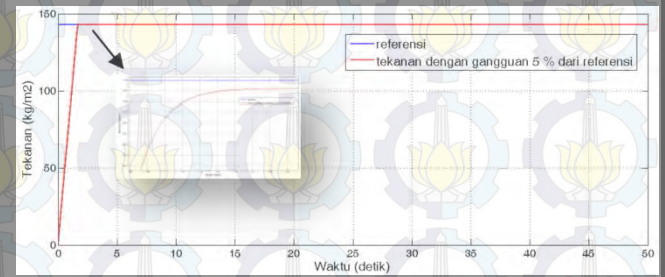
### Gangguan 10%

*Waktu Steady State* = 2,1 detik  
*Rise Time* = 1,89 detik  
 Tekanan *Boiler-Turbine* = 142,79 kg/cm<sup>2</sup>  
*Ess* = 0,15%



### Gangguan 7%

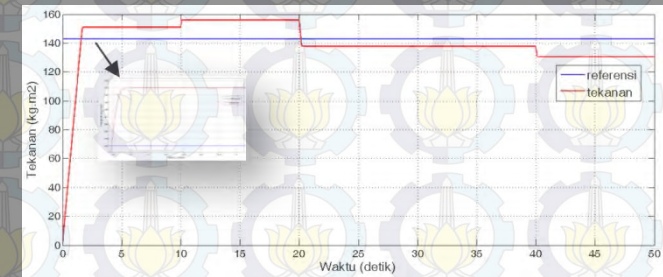
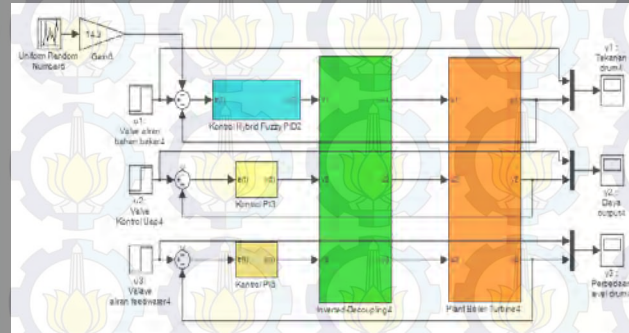
*Waktu Steady State* = 1,96 detik  
*Rise Time* = 1,76 detik  
 Tekanan *Boiler-Turbine* = 142,85 kg/cm<sup>2</sup>  
*Ess* = 0,103%



### Gangguan 5%

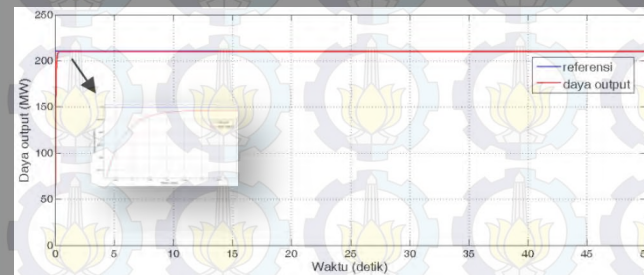
*Waktu Steady State* = 1,81 detik  
*Rise Time* = 1,70 detik  
 Tekanan *Boiler-Turbine* = 142,92 kg/cm<sup>2</sup>  
*Ess* = 0,055%

## Decoupling

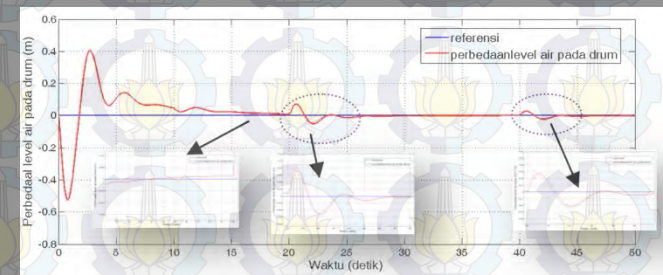


### Tekanan

### Respon Tekanan



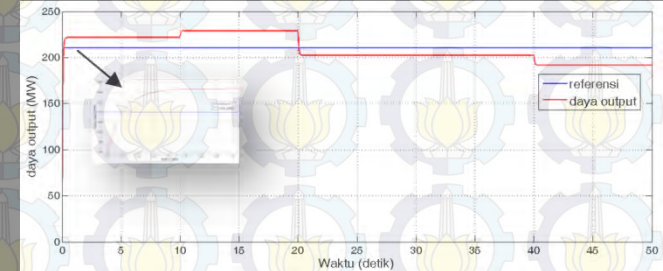
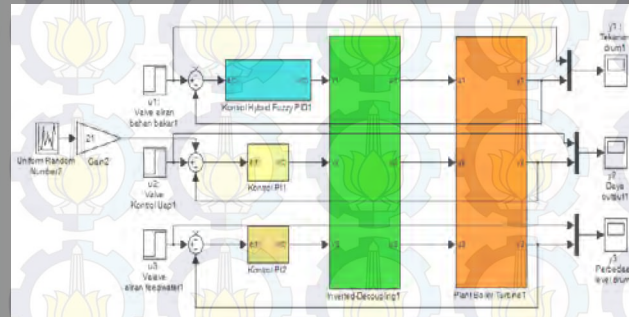
### Respon Daya Output



### Respon Perbedaan Level Air

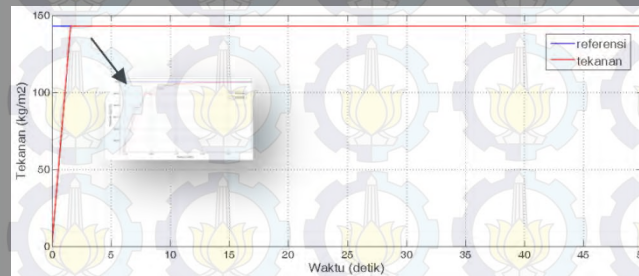


## Decoupling

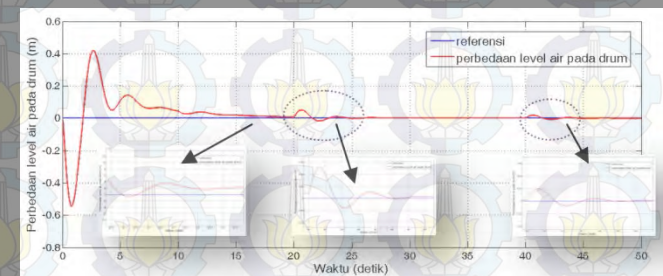


Daya Output

Respon Daya Output

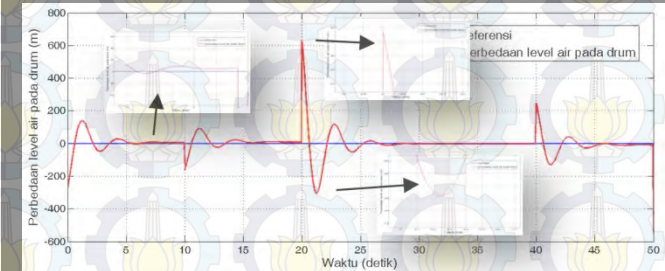
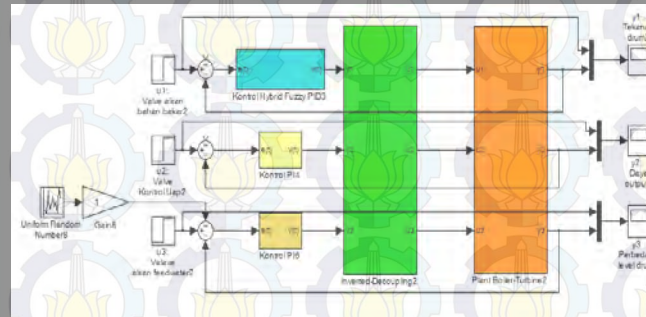


Respon tekanan



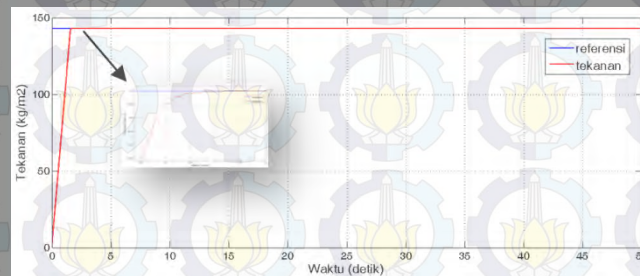
Respon Perbedaan Level Air

## Decoupling

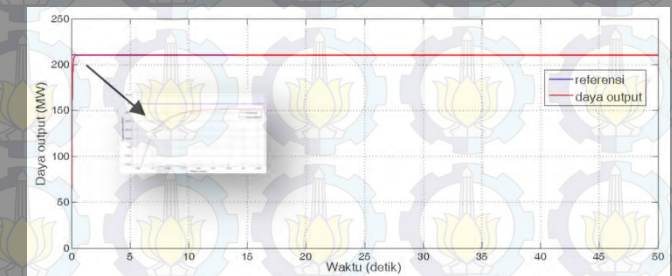


Perbedaan Level Air

Respon Perbedaan Level Air



Respon Tekanan



Respon Daya Output



- a. Proses *decoupling* dengan metode *inverted decoupling* dapat menghilangkan sifat saling mempengaruhi antar *input-ouput* pada konfigurasi *plant* MIMO.
- b. Pengendalian tekanan pada *boiler-turbine plant* dengan menggunakan kontroler *Hybrid Fuzzy PID* mampu mengikuti sinyal referensi yang diberikan, dengan beberapa pengujian:
  - Pada kondisi tanpa beban diperoleh *settling time* sebesar 1,80 detik dengan eror *steady state* 0,003%
  - Pada kondisi pengujian dengan diberikan gangguan seperti gangguan 7%, *rise time* diperoleh sebesar 1,76 detik dan *settling time* diperoleh sebesar 1,96 detik. Semakin besar nilai gangguan yang diberikan nilai *settling time* juga semakin lama. Akan tetapi harus diperhatikan batasan kemampuan *boiler-turbine* menerima gangguan untuk tekanan *drum*, di mana kemampuan tekanan *drum* pada *boiler-turbine* menerima gangguan untuk variabel tekanan mempunyai batasan sebesar 10%.



An aerial photograph of a large industrial complex, possibly a refinery or chemical plant. The facility features several large white cylindrical storage tanks, a network of pipes and walkways, and several multi-story industrial buildings with flat roofs. A prominent blue banner with the Indonesian text "Terima Kasih" (Thank you) is overlaid in the center of the image. The background is a light, hazy sky.

Terima Kasih



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