TUGAS AKHIR

Analisis Optimal Power Flow dengan Mempertimbangkan Emisi Menggunakan Metode Multi-Objective Particle Swarm Optimization

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Dosen Pembimbing :

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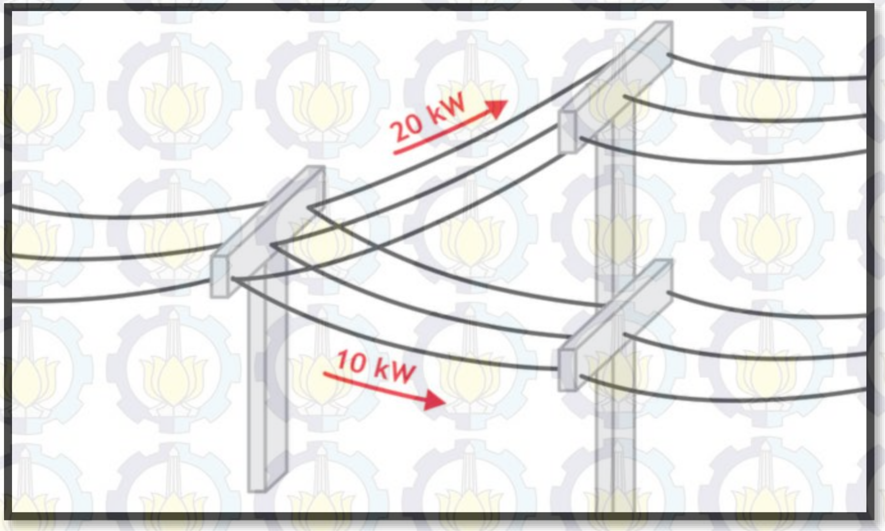
Latar Belakang

Sumber Energi Listrik Berasal dari Sumber Energi Terbarukan dan Tak Terbarukan

Latar Belakang

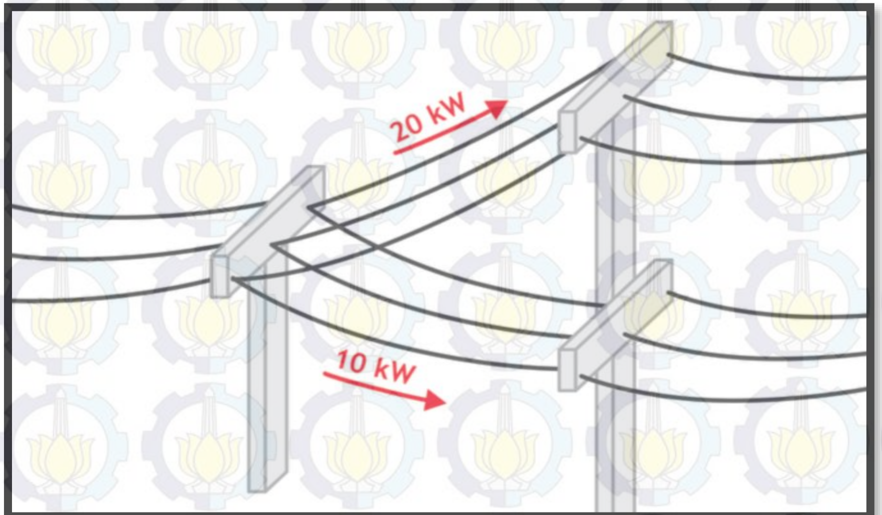


Optimal Power Flow untuk Meminimalkan Biaya Pembangkitan

Latar Belakang

Faktanya…..
Pembangkit Saat Ini Masih Didominasi Pembangkit Fosil

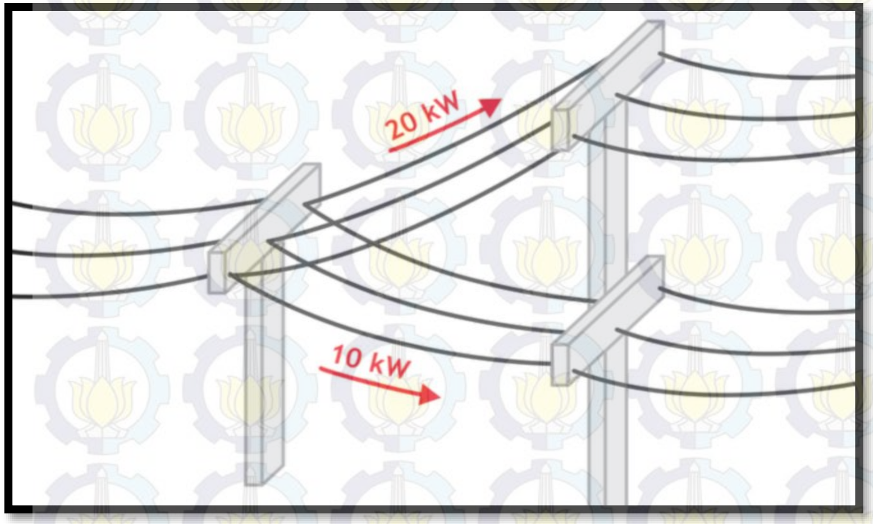
Latar Belakang



Optimal Power Flow

- Meminimalkan Biaya Pembangkitan
- Mempertimbangkan Emisi

Penelitian Sebelumnya



Optimal Power Flow

Menggunakan Metode *Deterministic* dan *Undeterministic*

Single Objective

Permasalahan

Melakukan Perhitungan Optimal Power Flow dengan Dua Fungsi Tujuan yaitu Biaya Pembangkitan dan Emisi

Melakukan Perhitungan Optimal Power Flow Mempertimbangkan Emisi dengan Menjaga Batasan-Batasan dalam Optimal Power Flow

Tujuan Penelitian

Melakukan Perhitungan **Optimal Power Flow** dengan **Mempertimbangkan Emisi** Menggunakan Metode **Multi-Objective Particle Swarm Optimization**

Metode Penelitian

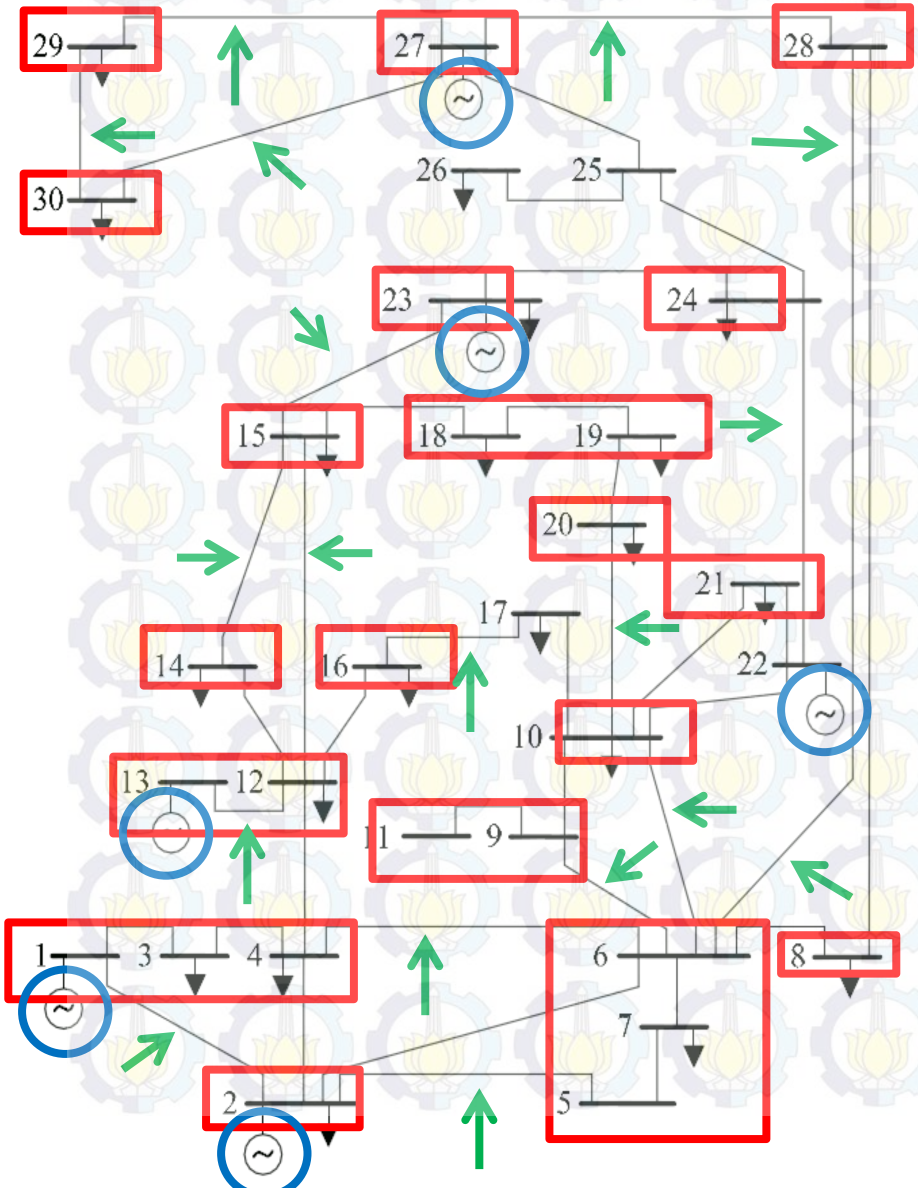
1. Sistem IEEE 30 Bus

1. *Optimal Power Flow*

1. *Multi-Objective Optimization*

2. Algoritma *Particle Swarm Optimization*

Sistem IEEE 30 Bus



30 bus

6 pembangkit

41 saluran transmisi

Sistem IEEE 30 Bus

Table 1. Fuel Cost Function dan Batasan Kemampuan Pembangkitan

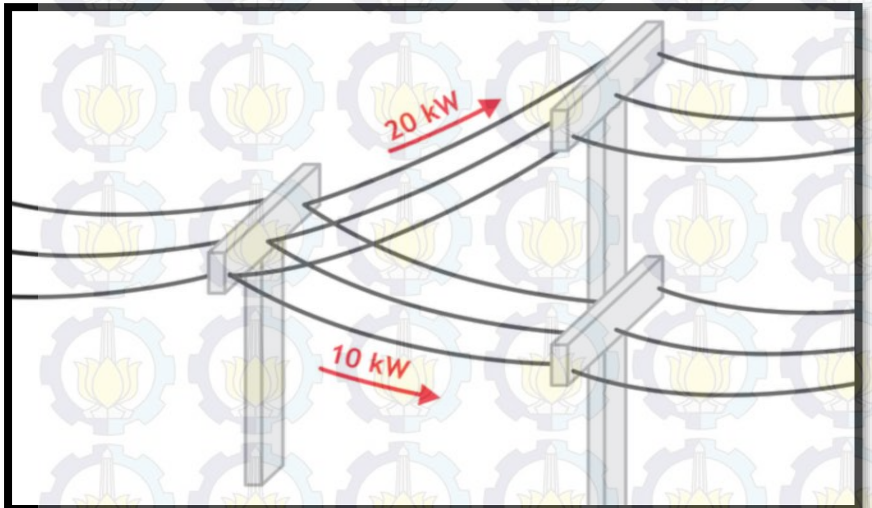
Unit i	a	b	c	Pmin (MW)	Pmax (MW)
1	0.00375	2.00	0	50	200
2	0.01750	1.75	0	20	80
3	0.06250	1.00	0	15	50
4	0.00830	3.25	0	10	35
5	0.02500	3.00	0	10	30
6	0.02500	3.00	0	12	40

Table 2. Emission Function

Unit i	d	e	f
1	0.006323	-0.381280	80.901900
2	0.006480	-0.790270	28.824900
3	0.003174	-1.360610	324.177500
4	0.006732	-2.399280	610.253500
5	0.003174	-1.360610	324.177500
6	0.006181	-0.390770	50.380800

Load Total = 283.4 MW

Optimal Power Flow



Objective Function :

$$F = \sum_{i=1}^{Ng} (a_i P_{gi}^2 + b_i P_{gi} + c_i) \quad \$/h$$

$$E = \sum_{i=1}^{Ng} (d_i P_{gi}^2 + e_i P_{gi} + f_i) \quad kg/h$$

Optimal Power Flow

-Equality Constraint

$$\sum_{i=1}^{Ng} P_{gi} = P_D + P_L$$

-Inequality Constraint

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max}$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}$$

-Voltage Constraint

$$V_{bi}^{min} \leq V_{bi} \leq V_{bi}^{max}$$

-Line Capacity Constraint

$$S_{li} \leq S_{li}^{max}$$

Multi-Objective Optimization

Penyelesaian Permasalahan Optimasi dengan Fungsi Tujuan yang Lebih dari Satu Secara Simultan

$$M = w \sum_{i=1}^{Ng} F(P_{gi}) + (1 - w)\, P_F \sum_{i=1}^{Ng} E(P_{gi})$$

$$F = \sum_{i=1}^{Ng} (a_i P_{gi}^2 + b_i P_{gi} + c_i) \quad \$/h$$

$$E = \sum_{i=1}^{Ng} (d_i P_{gi}^2 + e_i P_{gi} + f_i) \quad kg/h$$

Particle Swarm Optimization

Particle Swarm Optimization

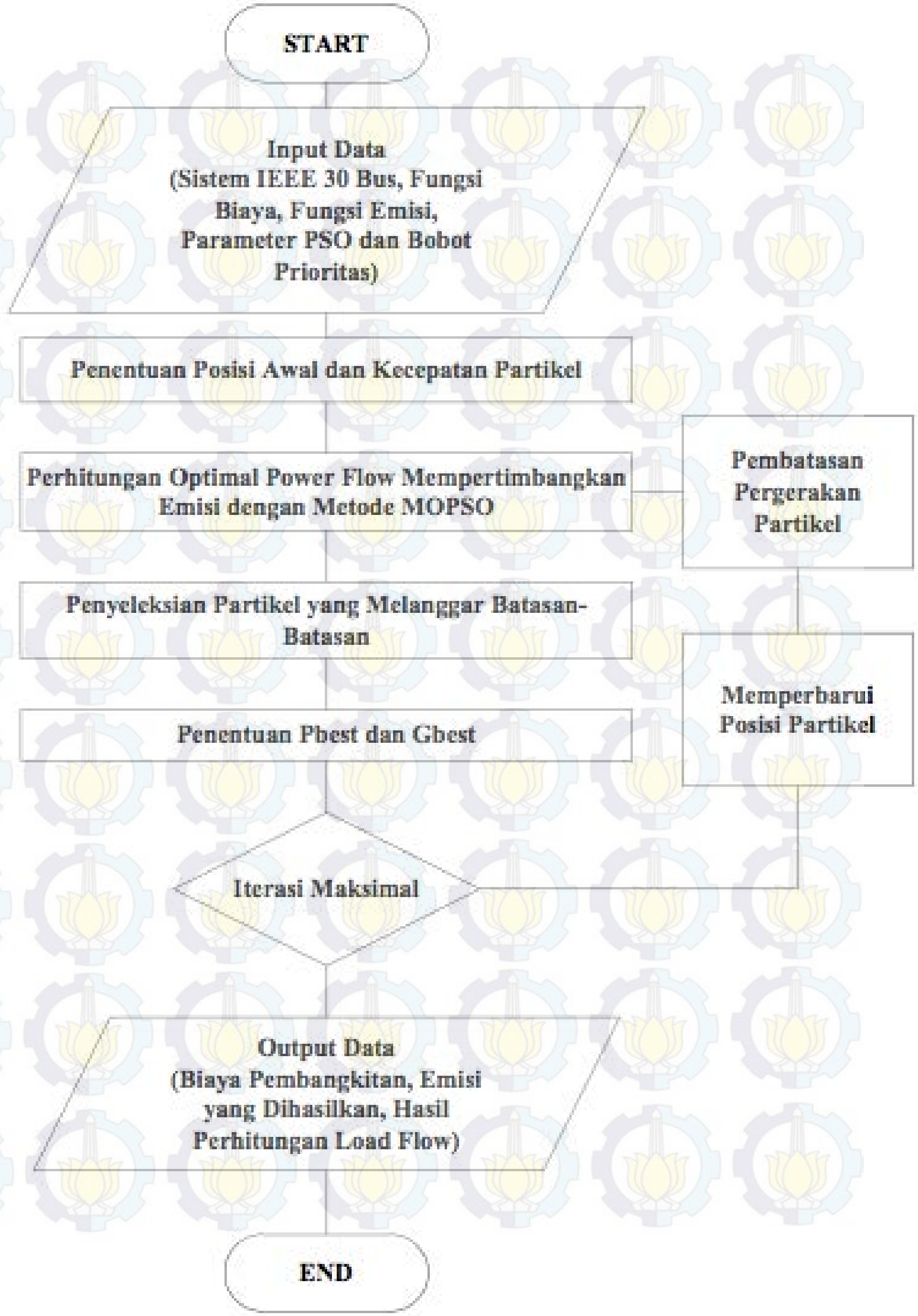
Persamaan Matematis Algoritma PSO :

$$V_{ir+1} = w * V_{ir} + c1.rand * (P_{best_{ir}} - X_{ir}) + c2.rand * (G_{best_{ir}} - X_{ir})$$

$$X_{ir+1} = X_{ir} + V_{ir+1}$$

$$w_{It} = w_{max} - \frac{(w_{max} - w_{min}) * It}{It_{maks}}$$

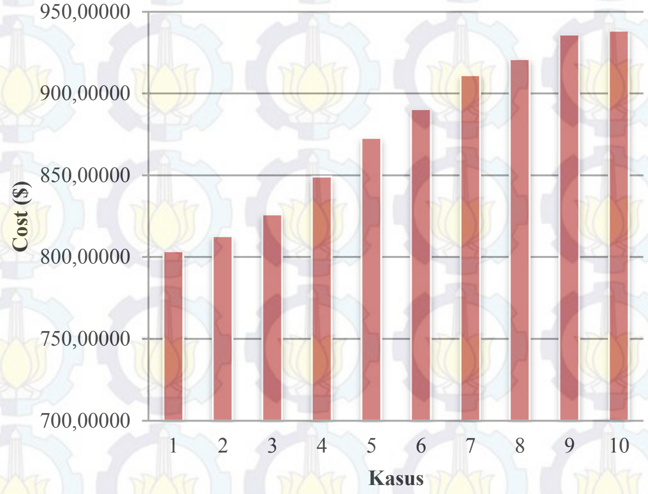
Flowchart Program

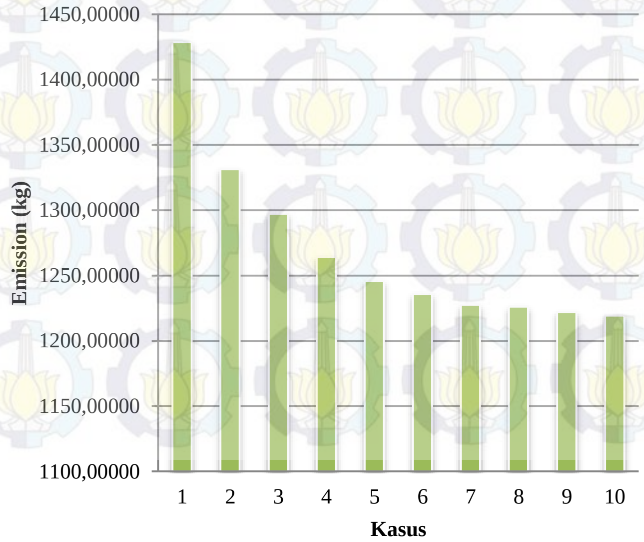


Hasil Metode MOPSO

Tabel Hasil Simulasi

Kasus	Weight 1 (Harga)	Weight 2 (Emisi)	Harga ($)	Emisi (Kg)
1	1	0	803.60000	1428.57000
2	0.9	0.1	812.75000	1331.36000
3	0.8	0.2	826.15000	1297.10000
4	0.7	0.3	849.29000	1264.06000
5	0.6	0.4	872.79000	1245.77000
6	0.5	0.5	890.59000	1235.67000
7	0.4	0.6	911.33000	1227.48000
8	0.3	0.7	921.07000	1226.15000
9	0.2	0.8	936.13000	1221.94000
10	0.1	0.9	938.41000	1219.24000





Hasil Simulasi Kasus 3

Bobot Biaya Pembangkitan
w1 = 0.8

Bobot Emisi
w2 = 0.2

Tabel Hasil Simulasi

	Kasus 6 (w1 = 0.8 , w2 = 0.2)
Harga ($)	826.15000
Emisi (kg)	1297.10000
Rugi-Rugi (MW)	6.49000
P1 (MW)	125.00115
P2 (MW)	57.99912
P3 (MW)	25.32070
P4 (MW)	34.98316
P5 (MW)	27.87492
P6 (MW)	18.71222
Ptotal (MW)	289.89127

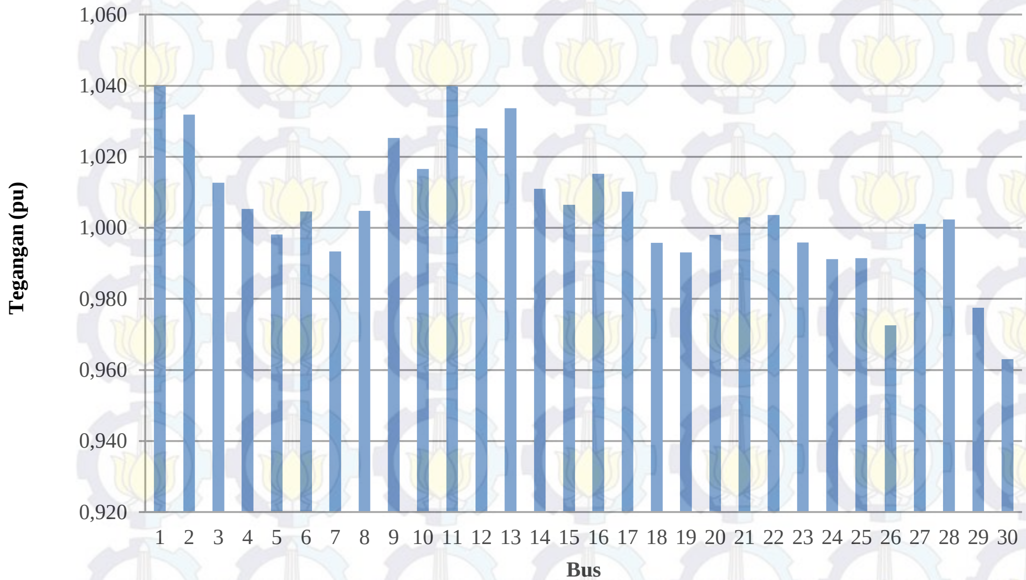
$$\sum_{i=1}^{Ng} P_{gi} = P_D + P_L$$

$= 283.4 + 6.49$

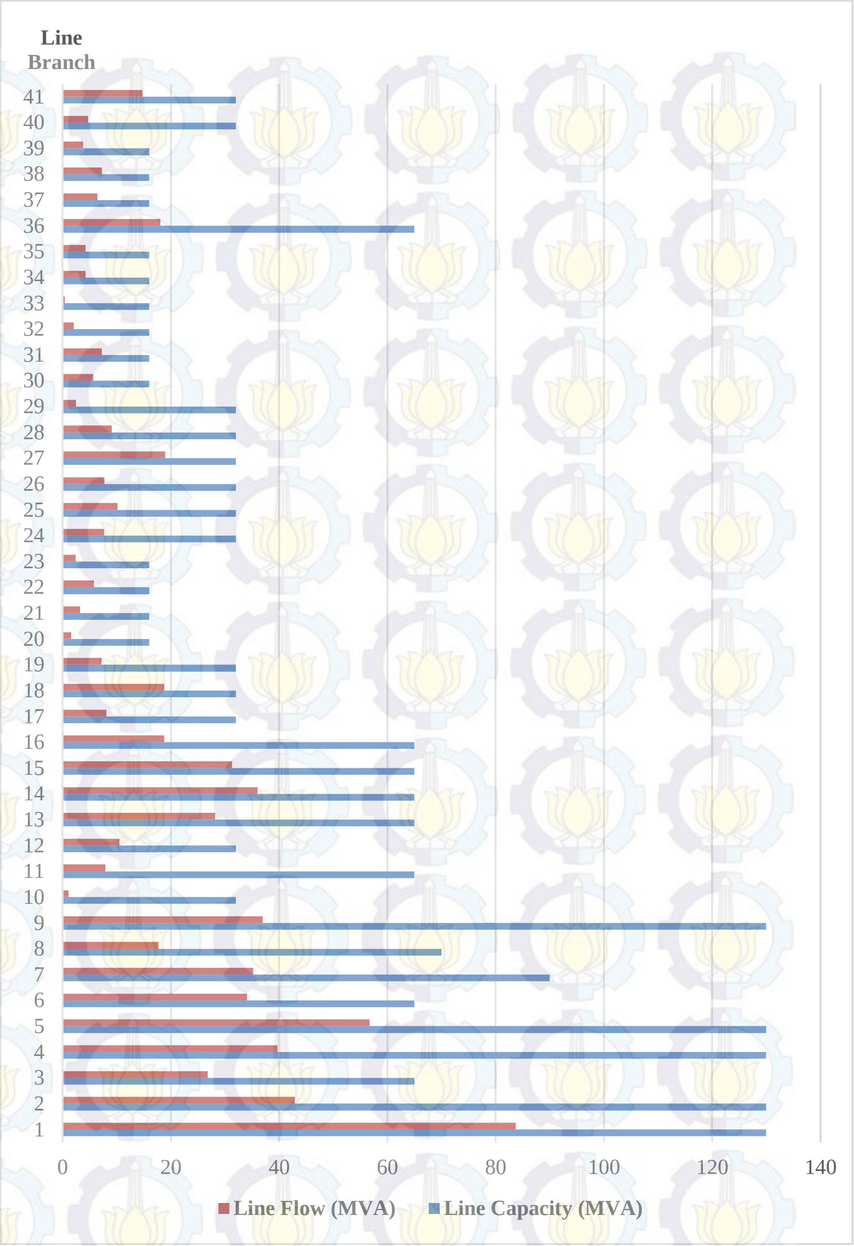
$= 289.89$ MW

Unit i	a	b	c	Pmin (MW)	Pmax (MW)
1	0.00375	2.00	0	50	200
2	0.01750	1.75	0	20	80
3	0.06250	1.00	0	15	50
4	0.00830	3.25	0	10	35
5	0.02500	3.00	0	10	30
6	0.02500	3.00	0	12	40

Hasil Simulasi Kasus 3



Profil Tegangan Di Setiap Bus



Perbandingan Line Flow dan Line Capacity

Hasil Simulasi Kasus 6

Tabel Hasil Simulasi

	Kasus 6 (w1 = 0.5 , w2 = 0.5)
Harga ($)	890.59000
Emisi (kg)	1235.67000
Rugi-Rugi (MW)	4.36000
P1 (MW)	87.43544
P2 (MW)	65.17022
P3 (MW)	44.75072
P4 (MW)	34.98398
P5 (MW)	29.94141
P6 (MW)	25.48058
Ptotal (MW)	287.76236

Bobot Biaya Pembangkitan
w1 = 0.5

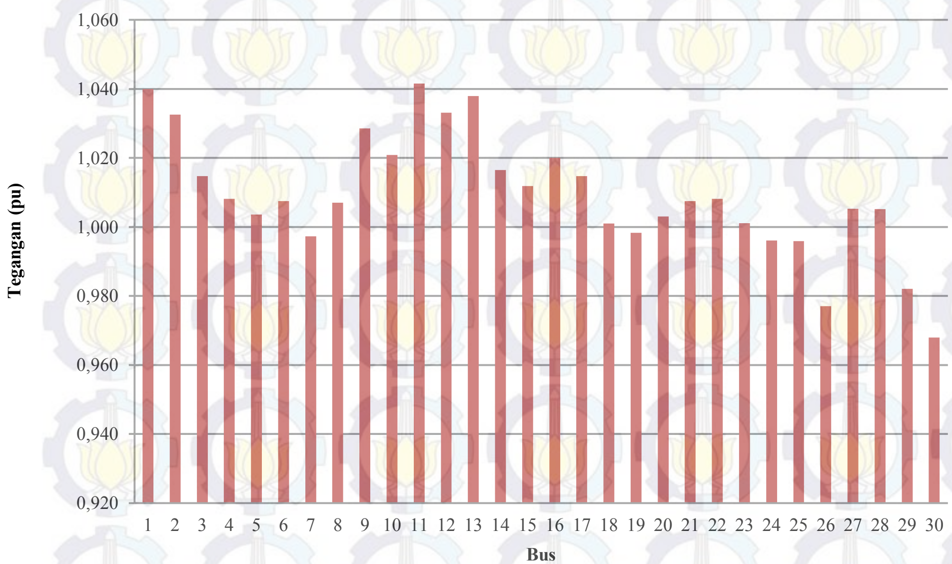
Bobot Emisi
w2 = 0.5

$$\sum_{i=1}^{Ng} P_{gi} = P_D + P_L$$

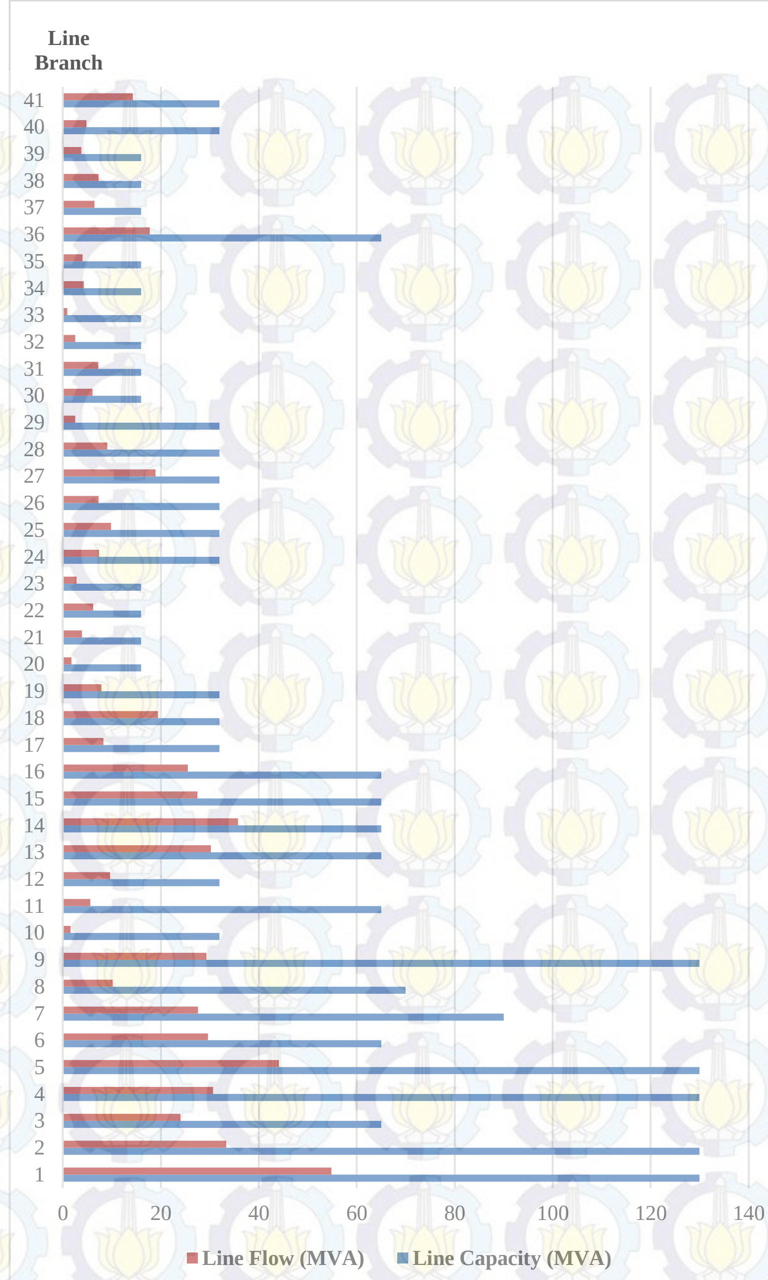
= 283.4 + 4.36
= 287.76 MW

Unit i	a	b	c	Pmin (MW)	Pmax (MW)
1	0.00375	2.00	0	50	200
2	0.01750	1.75	0	20	80
3	0.06250	1.00	0	15	50
4	0.00830	3.25	0	10	35
5	0.02500	3.00	0	10	30
6	0.02500	3.00	0	12	40

Hasil Simulasi Kasus 6



Profil Tegangan Di Setiap Bus



Perbandingan Line Flow dan Line Capacity

Hasil Simulasi Kasus 9

Bobot Biaya Pembangkitan
w1 = 0.2

Bobot Emisi
w2 = 0.8

Tabel Hasil Simulasi

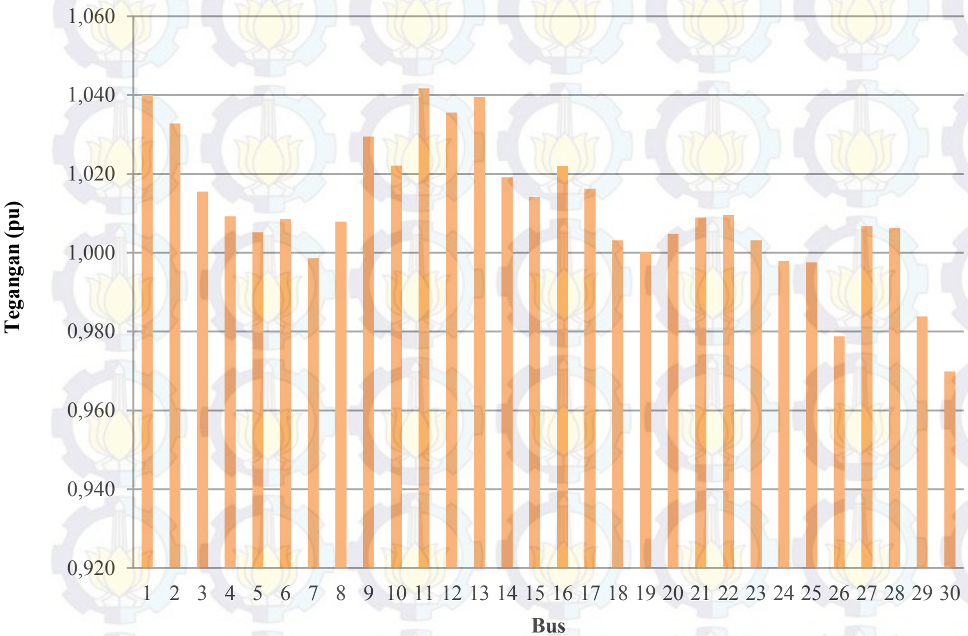
	Kasus 6 (w1 = 0.5 , w2 = 0.5)
Harga ($)	936.13000
Emisi (kg)	1221.94000
Rugi-Rugi (MW)	3.80000
P1 (MW)	65.44134
P2 (MW)	78.81047
P3 (MW)	48.69304
P4 (MW)	34.88572
P5 (MW)	28.72916
P6 (MW)	30.63966
Ptotal (MW)	287.19939

$$\sum_{i=1}^{Ng} P_{gi} = P_D + P_L$$

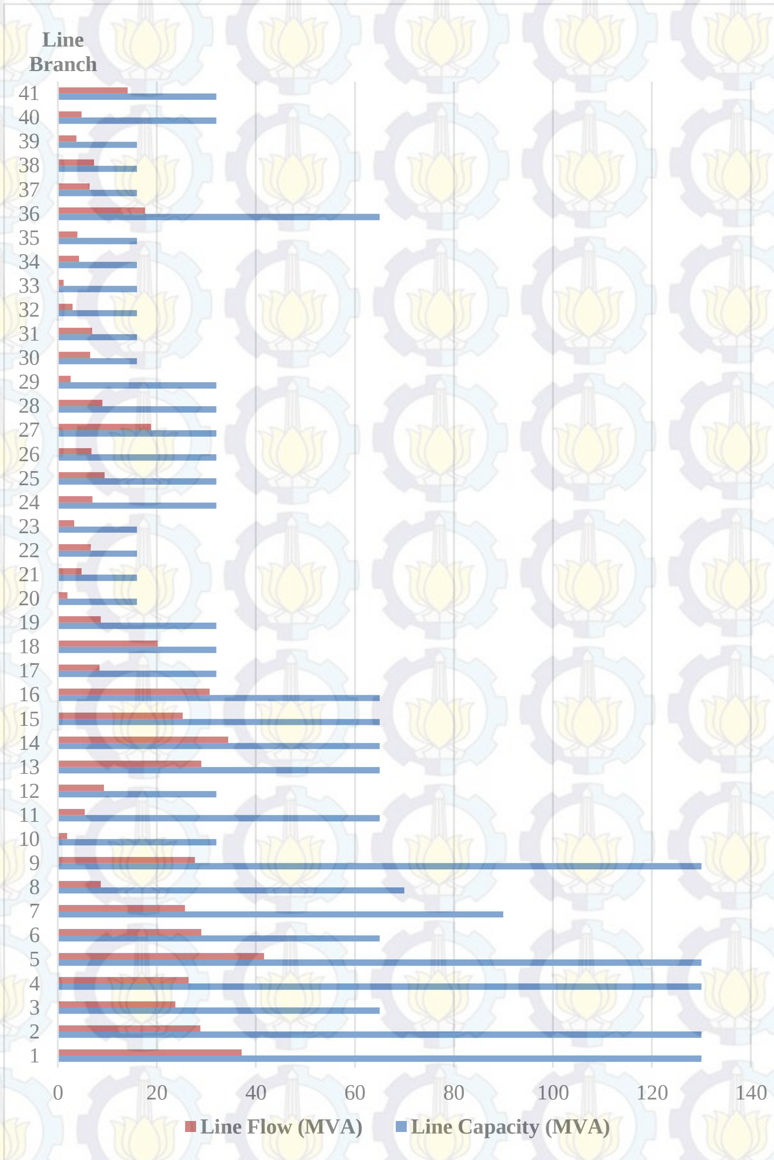
= 283.4 + 3.8
= 287.2 MW

Unit i	a	b	c	Pmin (MW)	Pmax (MW)
1	0.00375	2.00	0	50	200
2	0.01750	1.75	0	20	80
3	0.06250	1.00	0	15	50
4	0.00830	3.25	0	10	35
5	0.02500	3.00	0	10	30
6	0.02500	3.00	0	12	40

Hasil Simulasi Kasus 9



Profil Tegangan Di Setiap Bus



Perbandingan Line Flow dan Line Capacity

Kesimpulan

1. Metode Multi-Objective Particle Swarm Optimization (MOPSO) mampu melakukan perhitungan Optimal Power Flow (OPF) dengan mempertimbangkan emisi dengan menjaga batasan-batasan, seperti batasan inequality contstraint, equality constraint, tegangan dan kapasitas saluran.
2. Semakin besar nilai bobot yang diberikan untuk biaya pembangkitan maka biaya pembangkitannya semakin murah dan sebaliknya, semakin kecil bobot yang diberikan maka biaya pembangkitannya semakin mahal.
3. Semakin besar nilai bobot yang diberikan untuk emisi maka emisi yang dihasilkan semakin kecil dan sebaliknya, semakin kecil bobot yang diberikan maka emisi yang dihasilkan semakin besar.

Daftar Pustaka

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TERIMA KASIH

LAMPIRAN

Perbandingan Metode

	OPF (PSO)	ED + Load Flow (Iterasi Lambda)	OPF (Iterasi Lambda)
Harga ($)	803.60000	807.55000	803.62855
Emisi (kg)	1428.57000	1500.99929	1428.99835
Rugi-Rugi (MW)	9.85000	11.76930	10.01390
P1 (MW)	176.96439	197.03700	177.11600
P2 (MW)	48.17876	46.87200	48.50200
P3 (MW)	21.52579	19.12400	20.85400
P4 (MW)	21.94086	10.00000	22.26200
P5 (MW)	12.58447	10.00000	12.55700
P6 (MW)	12.05552	12.00000	12.00000
Ptotal (MW)	293.24978	295.03300	293.29100

Perhitungan Penalty Factor

Langkah 1 : Menghitung nilai Fmax dan Emax setiap unit pembangkit.

Langkah 2 : Membagi nilai Fmax dan Emax setiap unit pembangkit dengan nilai Pmax setiap unit.

Langkah 3 : Membagi nilai Fmax setiap unit pembangkit dengan Emax setiap unit pembangkit sehingga didapatkan nilai h setiap unit pembangkit.

Langkah 4 : Urutkan nilai h tiap unit dari nilai terkecil ke terbesar.

Langkah 5 : Jumlahkan nilai Pmax tiap unit mulai dari h terkecil hingga Σ Pimax $\geq$ Pd (Pd = 283.4 MW)

P4 = 35 MW
P4 + P5 = 65 MW
P4 + P5 + P3 = 115 MW
P4 + P5 + P3 + P1 = 315 MW (stop)

Maka dipilih h = 2.13537584 untuk beban 283.4 MW.

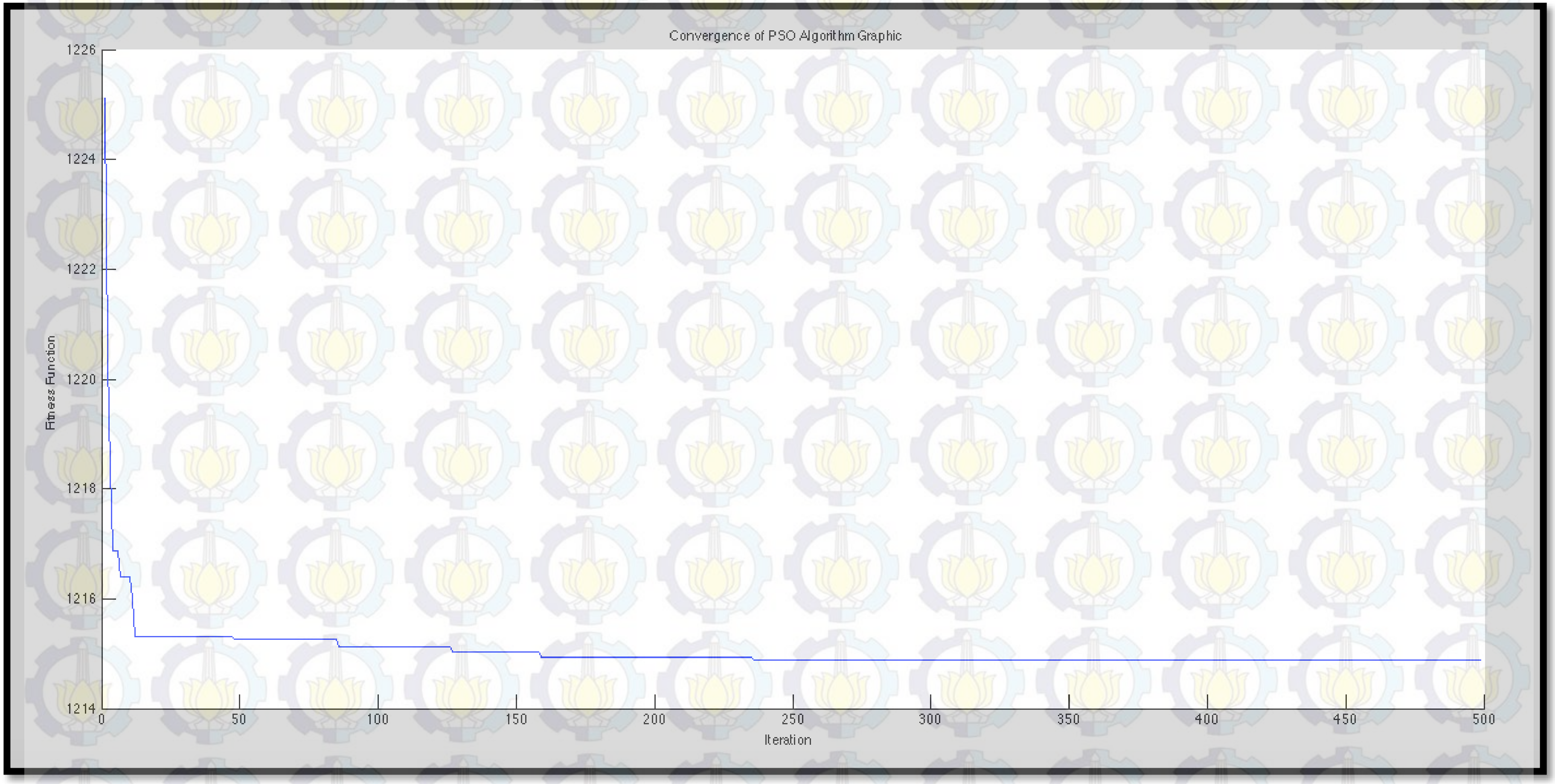
Perhitungan Penalty Factor

Unit	**hi**	Pmax MW)	Σ Pimax ≥ Pd
P4	0.23182715	35	35
P5	0.393060062	30	65
P3	0.781007414	50	36
P1	2.13537584	200	236
P6	3.584261508	40	37
P2	35.6168643	80	117

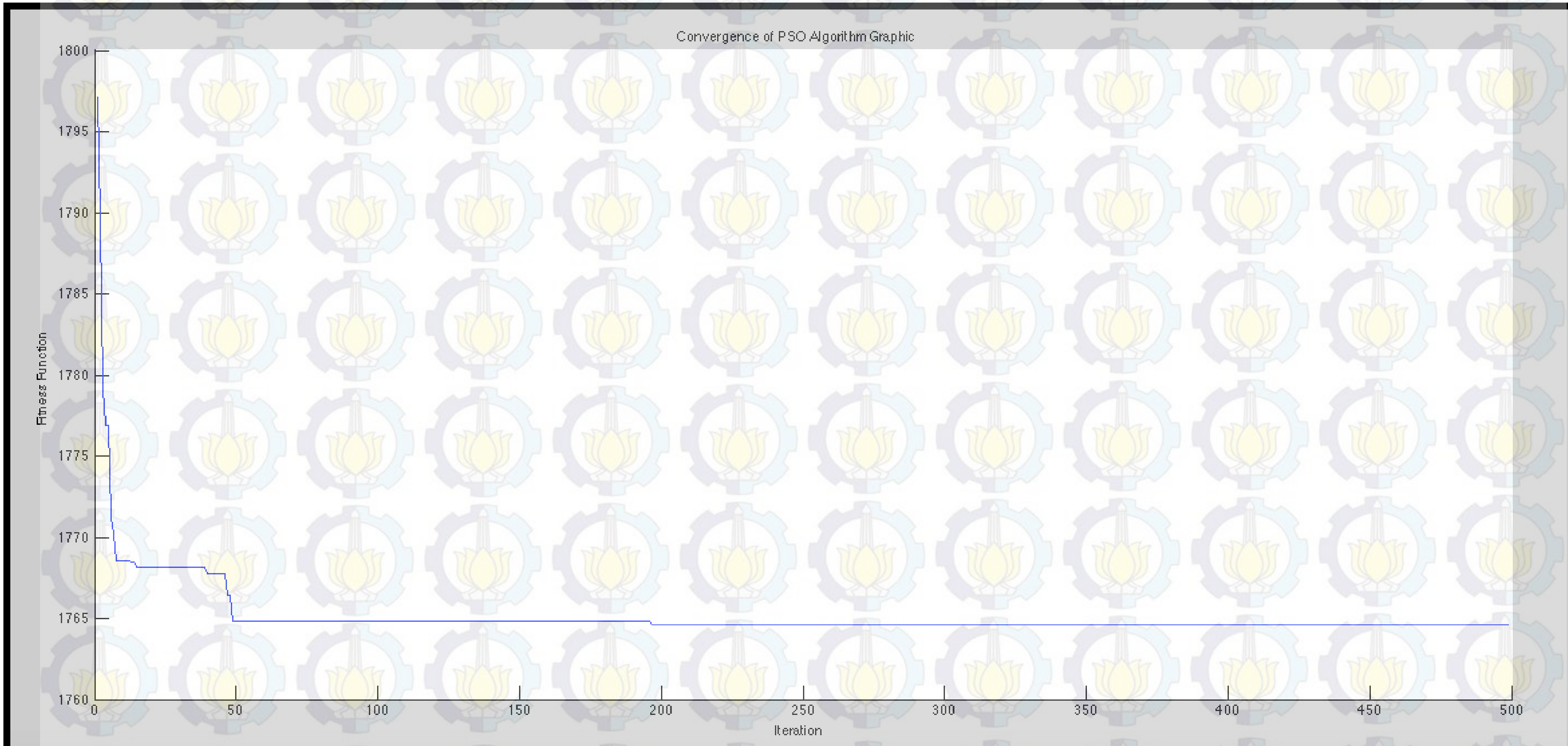
Parameter PSO

-Jumlah *swarm*	: 30
-Jumlah variabel	: 6
-Iterasi maksimal	: 500
-*Social constant*	: 0.5
-*Cognitive constant*	: 0.01

Kurva Konvergensi Kasus 3

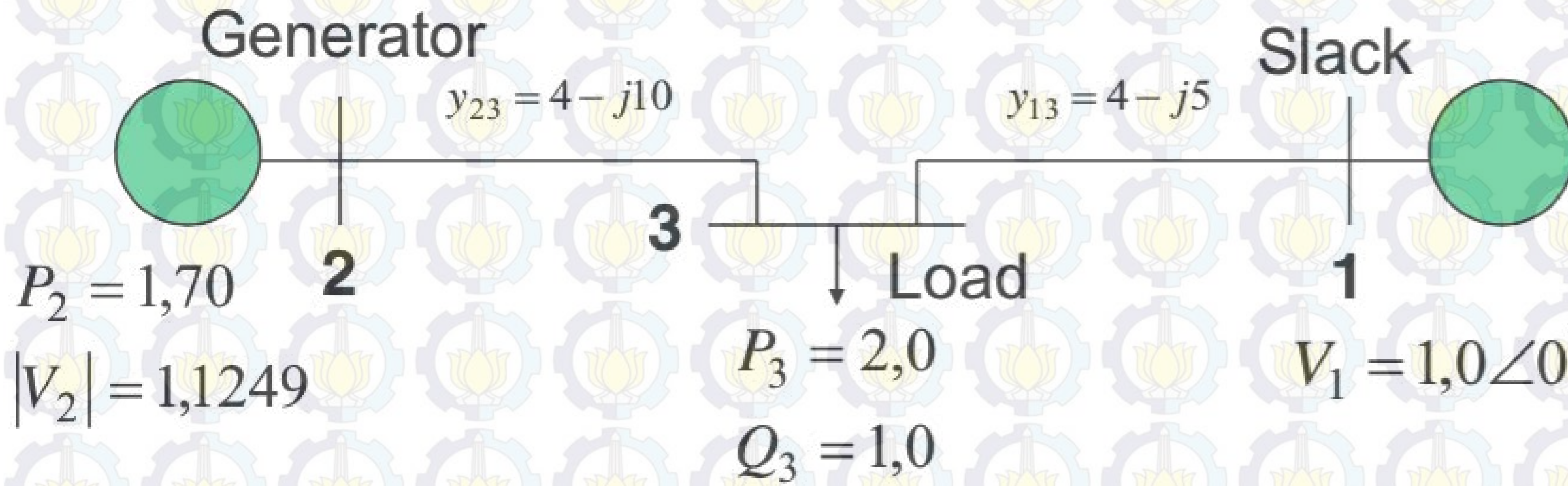


Kurva Konvergensi Kasus 6



Kurva Konvergensi Kasus 9

PF dengan NR



Generator
$y_{23} = 4 - j10$
$y_{13} = 4 - j5$
Slack
3
2
Load
1
$P_2 = 1{,}70$
$|V_2| = 1{,}1249$
$P_3 = 2{,}0$
$Q_3 = 1{,}0$
$V_1 = 1{,}0\angle 0^0$

PF dengan NR

1. Tentukan Matriks Y Bus

$$Y_{bus} = \begin{bmatrix} 4 - j5 & 0 + j0 & -4 + j5 \\ 0 + j0 & 4 - j10 & -4 + j10 \\ -4 + j5 & -4 + j10 & 8 - j15 \end{bmatrix}$$

PF dengan NR

2. Tentukan Matriks Jacobian (Rumus)

$$\begin{bmatrix} H & N \\ J & L \end{bmatrix} \begin{bmatrix} \Delta\theta \\ \dfrac{\Delta|V|}{|V|} \end{bmatrix} = \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix}$$

JACOBIAN

$$H_{ij} = \frac{\partial P_i}{\partial \theta_j} \qquad N_{ij} = \frac{\partial P_i}{\partial |V_j|}|V_j|$$

$$J_{ij} = \frac{\partial Q_i}{\partial \theta_j} \qquad L_{ij} = \frac{\partial Q_i}{\partial |V_j|}|V_j|$$

PF dengan NR

2. Tentukan Matriks Jacobian

$$\begin{bmatrix}
\frac{\partial P_1}{\partial \theta_1} & \frac{\partial P_1}{\partial |V_1|} & \frac{\partial P_1}{\partial \theta_2} & \frac{\partial P_1}{\partial |V_2|} & \frac{\partial P_1}{\partial \theta_3} & \frac{\partial P_1}{\partial |V_3|} \\
\frac{\partial Q_1}{\partial \theta_1} & \frac{\partial Q_1}{\partial |V_1|} & \frac{\partial Q_1}{\partial \theta_2} & \frac{\partial Q_1}{\partial |V_2|} & \frac{\partial Q_1}{\partial \theta_3} & \frac{\partial Q_1}{\partial |V_3|} \\
\frac{\partial P_2}{\partial \theta_1} & \frac{\partial P_2}{\partial |V_1|} & \frac{\partial P_2}{\partial \theta_2} & \frac{\partial P_2}{\partial |V_2|} & \frac{\partial P_2}{\partial \theta_3} & \frac{\partial P_2}{\partial |V_3|} \\
\frac{\partial Q_2}{\partial \theta_1} & \frac{\partial Q_2}{\partial |V_1|} & \frac{\partial Q_2}{\partial \theta_2} & \frac{\partial Q_2}{\partial |V_2|} & \frac{\partial Q_2}{\partial \theta_3} & \frac{\partial Q_2}{\partial |V_3|} \\
\frac{\partial P_3}{\partial \theta_1} & \frac{\partial P_3}{\partial |V_1|} & \frac{\partial P_3}{\partial \theta_2} & \frac{\partial P_3}{\partial |V_2|} & \frac{\partial P_3}{\partial \theta_3} & \frac{\partial P_3}{\partial |V_3|} \\
\frac{\partial Q_3}{\partial \theta_1} & \frac{\partial Q_3}{\partial |V_1|} & \frac{\partial Q_3}{\partial \theta_2} & \frac{\partial Q_3}{\partial |V_2|} & \frac{\partial Q_3}{\partial \theta_3} & \frac{\partial Q_3}{\partial |V_3|}
\end{bmatrix}
\begin{bmatrix}
\Delta \theta_1 \\ \Delta |V_1| \\ \Delta \theta_2 \\ \Delta |V_2| \\ \Delta \theta_3 \\ \Delta |V_3|
\end{bmatrix}
=
\begin{bmatrix}
\Delta P_1 \\ \Delta Q_1 \\ \Delta P_2 \\ \Delta Q_2 \\ \Delta P_3 \\ \Delta Q_3
\end{bmatrix}$$

PF dengan NR

2. Tentukan Matriks Jacobian (Penyederhanaan)

$$\begin{bmatrix} \frac{\partial P_2}{\partial \theta_2} & \frac{\partial P_2}{\partial \theta_3} & \frac{\partial P_2}{\partial |V_3|} \\ \frac{\partial P_3}{\partial \theta_2} & \frac{\partial P_3}{\partial \theta_3} & \frac{\partial P_3}{\partial |V_3|} \\ \frac{\partial Q_3}{\partial \theta_2} & \frac{\partial Q_3}{\partial \theta_3} & \frac{\partial Q_3}{\partial |V_3|} \end{bmatrix} \begin{bmatrix} \Delta\theta_2 \\ \Delta\theta_3 \\ \Delta|V_3| \end{bmatrix} = \begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \Delta\theta_3 \end{bmatrix}$$

JACOBIAN

Matrix

$$\begin{bmatrix} \frac{\partial P_2}{\partial \theta_2} & \frac{\partial P_2}{\partial \theta_3} & |V_3|\frac{\partial P_2}{\partial |V_3|} \\ \frac{\partial P_3}{\partial \theta_2} & \frac{\partial P_3}{\partial \theta_3} & |V_3|\frac{\partial P_3}{\partial |V_3|} \\ \frac{\partial Q_3}{\partial \theta_2} & \frac{\partial Q_3}{\partial \theta_3} & |V_3|\frac{\partial Q_3}{\partial |V_3|} \end{bmatrix} \begin{bmatrix} \Delta\theta_2 \\ \Delta\theta_3 \\ \frac{\Delta|V_3|}{|V_3|} \end{bmatrix} = \begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \Delta Q_3 \end{bmatrix}$$