Load Frequency Control of Single Area Power Systems having Multi-Source Power Generation

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Objective

- To study the load frequency control (LFC) performance of a single area power system having multi-source power generating units.

Power System Model

- A single area power system with hydro, thermal and gas power generation sources is considered for the study.
- Load Frequency Control is applied only to thermal and gas power generating units
- Hydro is allowed to operate at its scheduled generation level with only speed governor control.

Load Frequency Control

- A proportional-integral (PI) load frequency control is applied to thermal and gas power generating units.
  - Common LFC for both thermal and gas power generating units.
  - Individual LFC for thermal and gas power generating units.

- The LFC performance for above two schemes is studied with following performance indices.
  - ISE, ITAE and (ISE+ITAE)

Mathematical Modeling

- Under normal operating conditions there is no mismatch between generation and load. The total generation is given by,

$$P_G = P_{Gth} + P_{Ghy} + P_{Gg} \qquad (1)$$

Where

Area thermal power generation, $P_{Gth} = K_{th} P_G$

Area hydro power generation, $P_{Ghy} = K_{hy} P_G$

Area gas power generation, $P_{Gg} = K_g P_G$

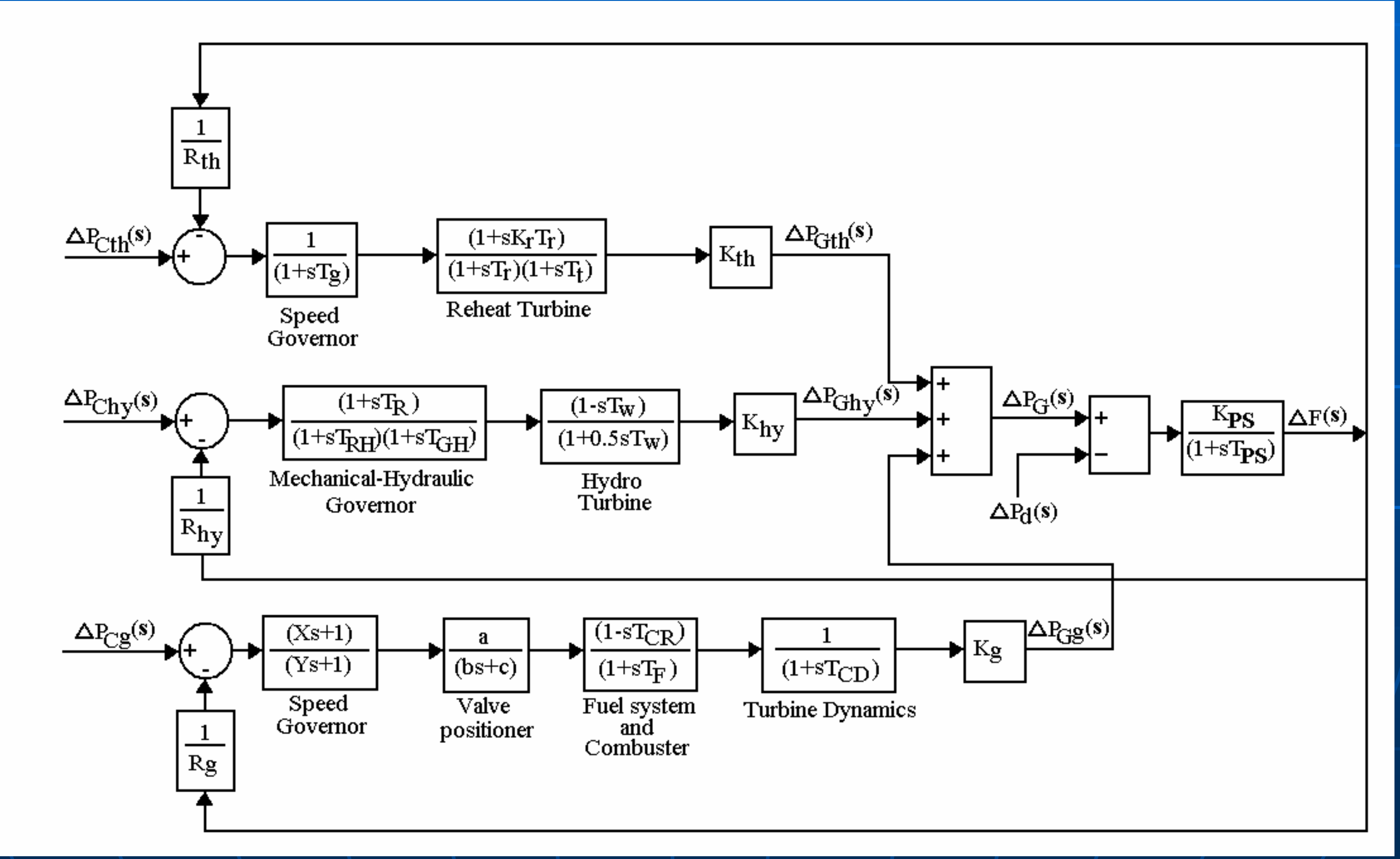
$$K_{th} + K_{hy} + K_g = 1.0 \qquad (2)$$

K_{th} K_{hy} and K_g represent the share of the power generation by thermal, hydro and gas sources to the total area power generation respectively.

- For small perturbation equation (1) can be written as

$$\Delta P_G = \Delta P_{Gth} + \Delta P_{Ghy} + \Delta P_{Gg} \qquad (3)$$

Transfer function block diagram of a Power system having hydro, thermal and gas power generations.



Simulation Studies

- Single area power system is simulated for 1% step load disturbances for the following cases

  - For different nominal loading conditions by adjusting thermal power generation

  - For different nominal loading conditions by adjusting gas power generation

Parameter Optimization

- Common Load Frequency Controller
  - $\Delta P_C = K_P\,\Delta f + K_I \int \Delta f\, dt$

- Individual Load Frequency Controller
  - $\Delta P_{Cth} = K_{Pth}\,\Delta f + K_{Ith} \int \Delta f\, dt$
  - $\Delta P_{Cg} = K_{Pg}\,\Delta f + K_{Ig} \int \Delta f\, dt$

- Performance Indices
  - $\eta_{ISE} = \int (\Delta f)^2\, dt$
  - $\eta_{ITAE} = \int t|\Delta f|\, dt$
  - $\eta_{ISE+ITAE} = \int \{(\Delta f)^2 + t|\Delta f|\}\, dt$

Genetic Algorithm

- Genetic Algorithm is used to optimize the PI controller gains for both schemes.

• Initial Population Size	-	20
• Fitness Function	-	$1/(1+\eta_{ISE})$, $1/(1+\eta_{ITAE})$, $1/(1+(\eta_{ISE}+\eta_{ITAE}))$
• Elitism	-	2
• Selection	-	Roulette wheel
• Crossover Probability	-	0.8
• Cross Over Function	-	Multi-point
• Mutation Probability	-	0.03
• No. of Generations	-	400

Optimal PI controller gains for variation in thermal power generation

Optimal Gains using ISE, ITAE and ISE+ITAE

Operating load (MW)	Thermal (MW)	Hydro (MW)	Gas (MW)	Common controller gains		Individual controller gains			
				K_P	K_I	K_{Pth}	K_{Ith}	K_{Pg}	K_{Ig}
1750	1000	500	250	3.7966	0.3969	7.4588	1.1005	0.0256	2.703
1500	750	500	250	2.9986	0.447	8.6235	1.1569	0.0569	1.5578
1250	500	500	250	2.3214	0.4782	10.5059	1.5708	0.02585	0.9309
1000	250	500	250	1.5771	0.2207	17.7725	2.0706	0.0412	1.074

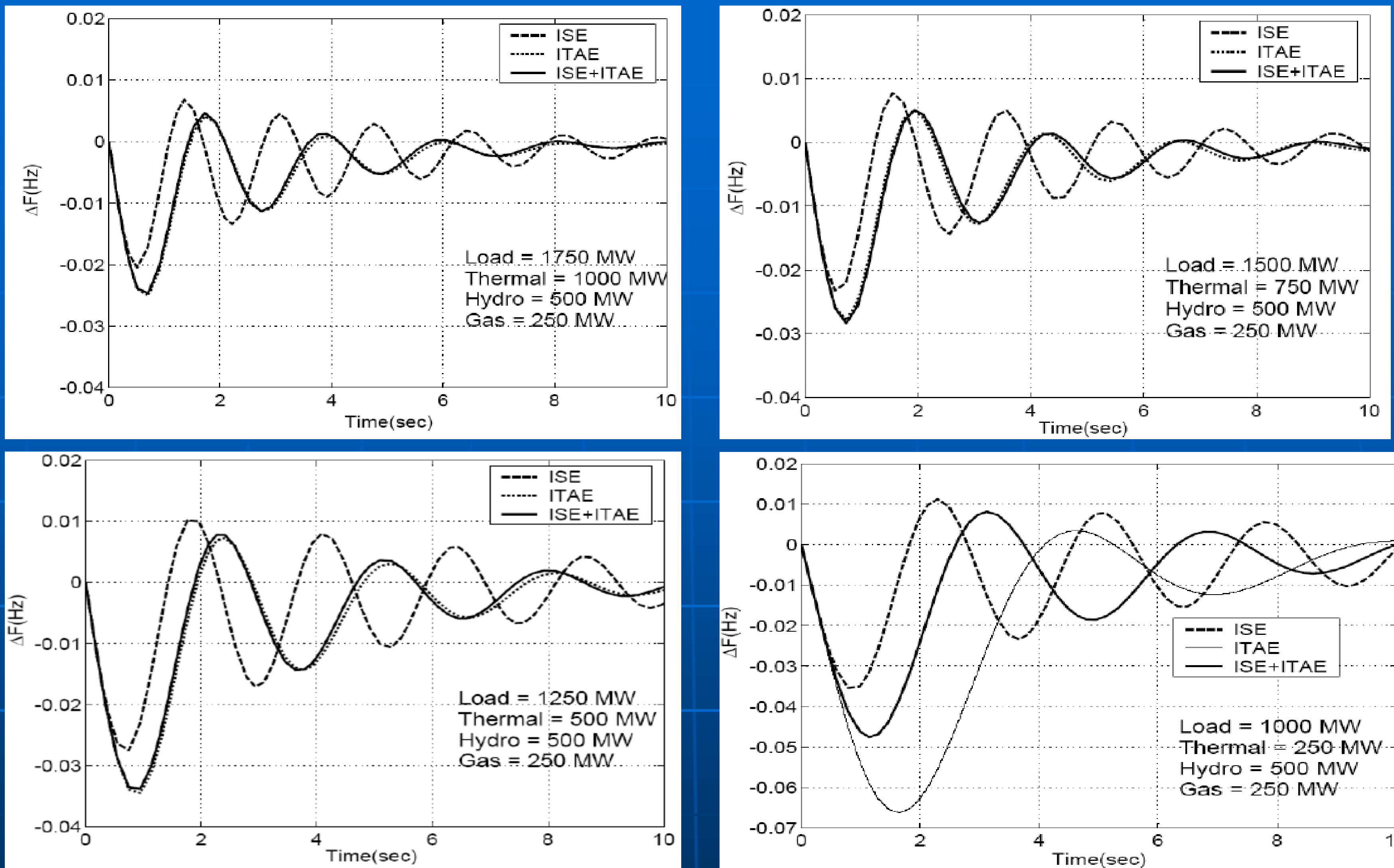
Operating load (MW)	Thermal (MW)	Hydro (MW)	Gas (MW)	Common controller gains		Individual controller gains			
				K_P	K_I	K_{Pth}	K_{Ith}	K_{Pg}	K_{Ig}
1750	1000	500	250	2.2555	0.35	6.9353	0.7745	0.0078	1.6332
1500	750	500	250	1.9659	0.3161	7.8196	0.8659	0.0078	1.5552
1250	500	500	250	1.2926	0.3031	8.9216	1.0196	0.0078	1.4693
1000	250	500	250	0.1106	0.1071	12.9176	1.5226	0.0035	0.9480

Operating load (MW)	Thermal (MW)	Hydro (MW)	Gas (MW)	Common controller gains		Individual controller gains			
				K_P	K_I	K_{Pth}	K_{Ith}	K_{Pg}	K_{Ig}
1750	1000	500	250	2.3157	0.3827	6.7882	0.7549	0.001	1.8127
1500	750	500	250	1.8907	0.3284	7.8894	0.8851	0.0471	0.9612
1250	500	500	250	1.3481	0.2468	9.5412	1.0494	0.0157	0.9449
1000	250	500	250	0.6644	0.1847	13.3804	1.4565	0.0157	0.6878

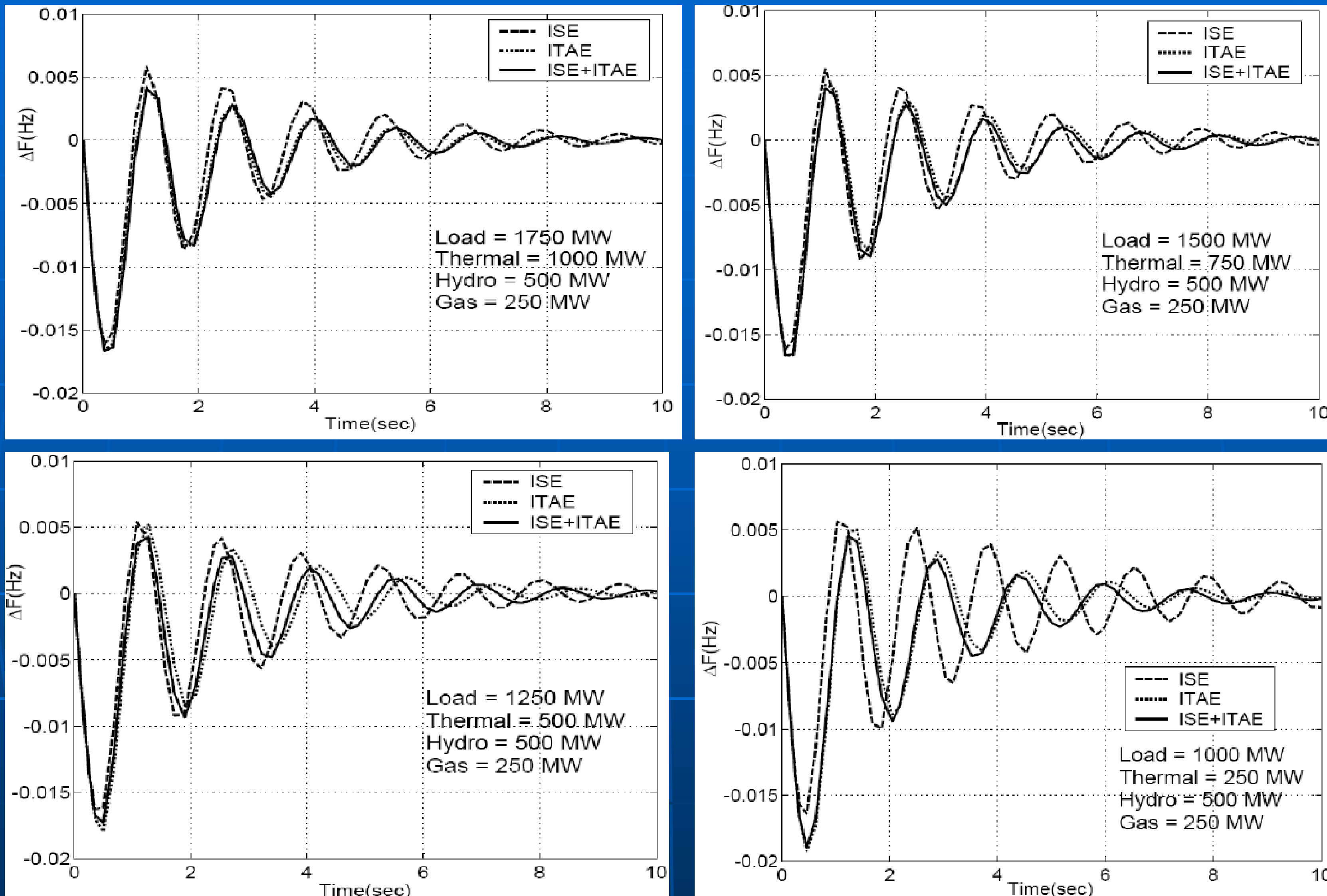
Variation Optimal LFC gains with decrease in thermal power generation

- The common controller gain value, K_P, considerably decreases as the operating load of the system decreases. The optimum value of K_I found using ITAE or ISE +ITAE also follows the similar trend.

- The optimum value of the individual controller gains K_{Pth} and K_{Ith} increase with decrease in the operating load.



Transient response of frequency deviation for 1% step load disturbance at nominal loading conditions and with common controller gains by varying scheduled thermal generation.



Transient response of frequency deviation for 1% step load disturbance at different nominal loading conditions and with individual controller gains by varying scheduled thermal generation.

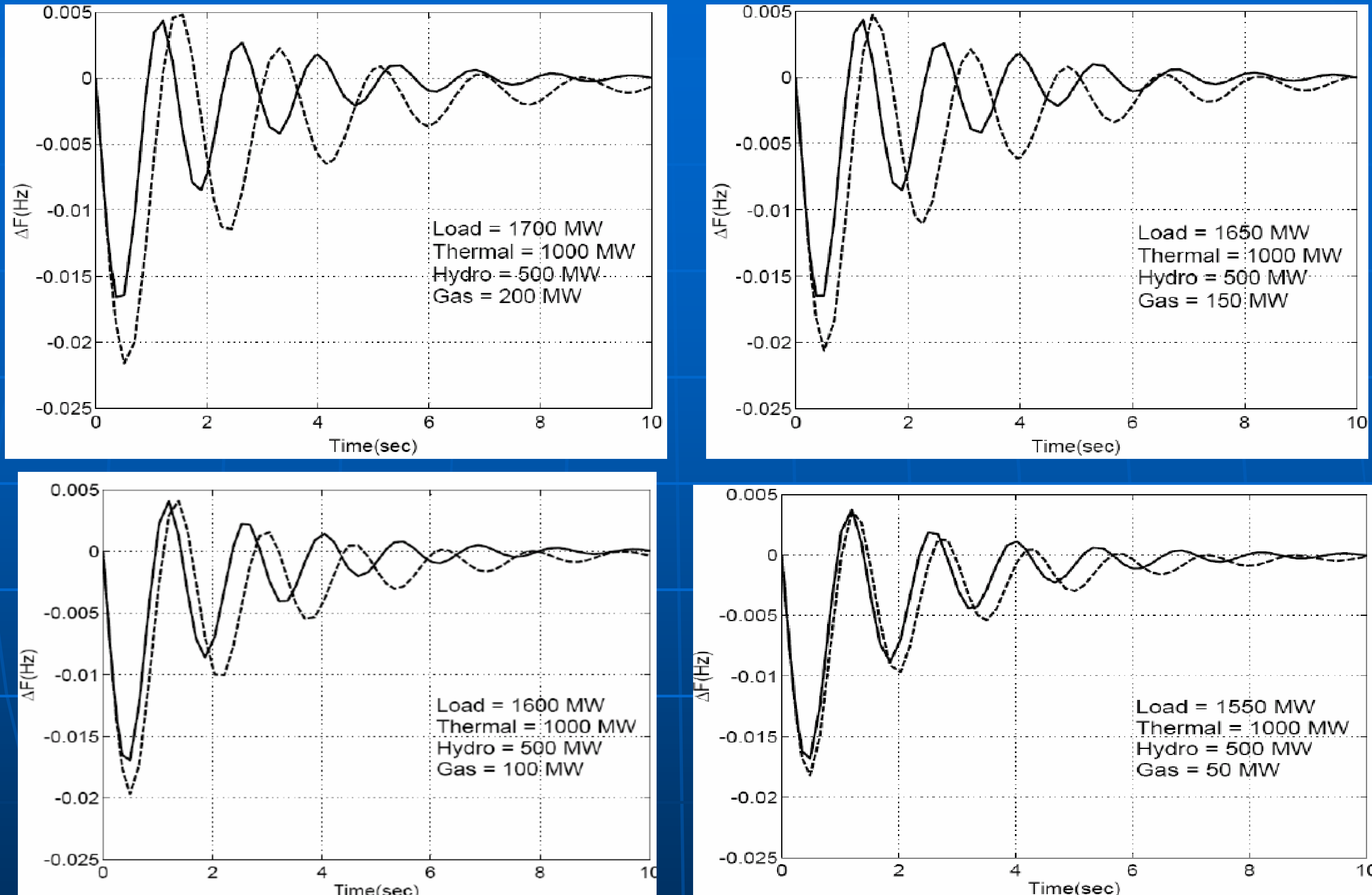
Observations

- It is observed that ISE is more effective in reducing the first peak of the transient response and ITAE is more suitable in reducing long duration transients.
- The combination (ISE+ITAE) of both is giving better transient response with less oscillatory.
- Individual LFC provides better response that common LFC.
- Performance of the system deteriorates as thermal power generation decreases.

Optimal PI Controller gains for variation in gas power generation

Optimal gains using (ISE+ITAE)

Operating load (MW)	Thermal (MW)	Hydro (MW)	Gas (MW)	Common controller gains		Individual controller gains			
				K_P	K_I	K_{Pth}	K_{Ith}	K_{Pg}	K_{Ig}
1750	1000	500	250	2.3157	0.3827	6.7882	0.7549	0.001	1.8127
1700	1000	500	200	3.31412	0.4328	6.6193	0.7526	0.0314	2.0824
1650	1000	500	150	3.7765	0.4953	6.5137	0.7353	0.0016	2.6753
1600	1000	500	100	4.2471	0.5553	6.1176	0.7141	0.0024	3.2
1550	1000	500	50	5.0745	0.6294	6.0843	0.6826	0.0129	4.4196



Transient response of frequency deviation for 1% step load disturbance at different nominal loading conditions and with common and individual controller gains by varying scheduled gas power generation.(------- common, _______ individual)

Observations

- The optimum values of K_P and K_I increase whereas K_{Pth} and K_{Ith} decrease and K_{Ig} increase with decrease in gas power generation to match the decrease in operating load.
- Individual LFC provides better response that common LFC.
- Performance of the system improves as gas power generation decreases.

Conclusions

- For optimal LFC performance of an area having multiple sources of power generation, the LFC parameters are required to be adjusted optimally for different nominal loading/generation conditions.
- Optimal controller parameters obtained using (ISE+ITAE) provide better transient performance
- Individual LFC for different types of power generating units provides better performance than common LFC.
- Performance of the system deteriorates as thermal power generation decreases.
- Performance of the system improves as gas power generation decreases.

Questions

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