The Integrated Modeling of Natural Gas and Power Flows

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Objectives: With the increasing development of natural gas fired generation units, the impacts of gas availability on power systems should be considered. We propose an integrated model to simulate the optimal power and gas flows simultaneously, which can be used for directing operations and planning of the national energy infrastructures.

Background

Natural gas and power systems are coupled national energy infrastructures (see the example in Fig.1). It is of importance to study the secure, economic and reliable operation of the two systems.

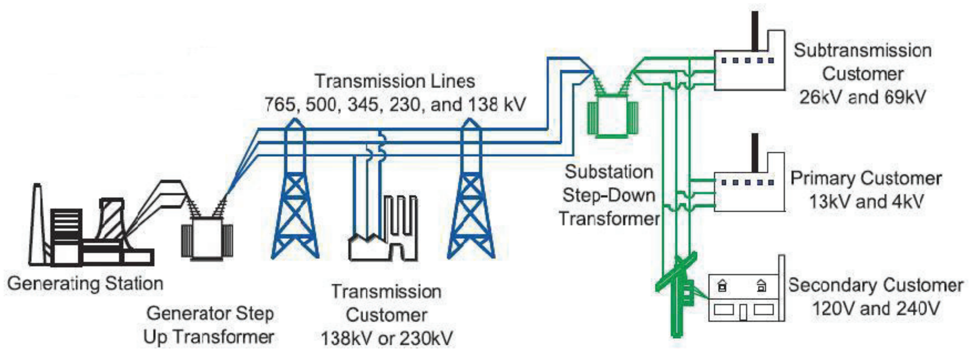
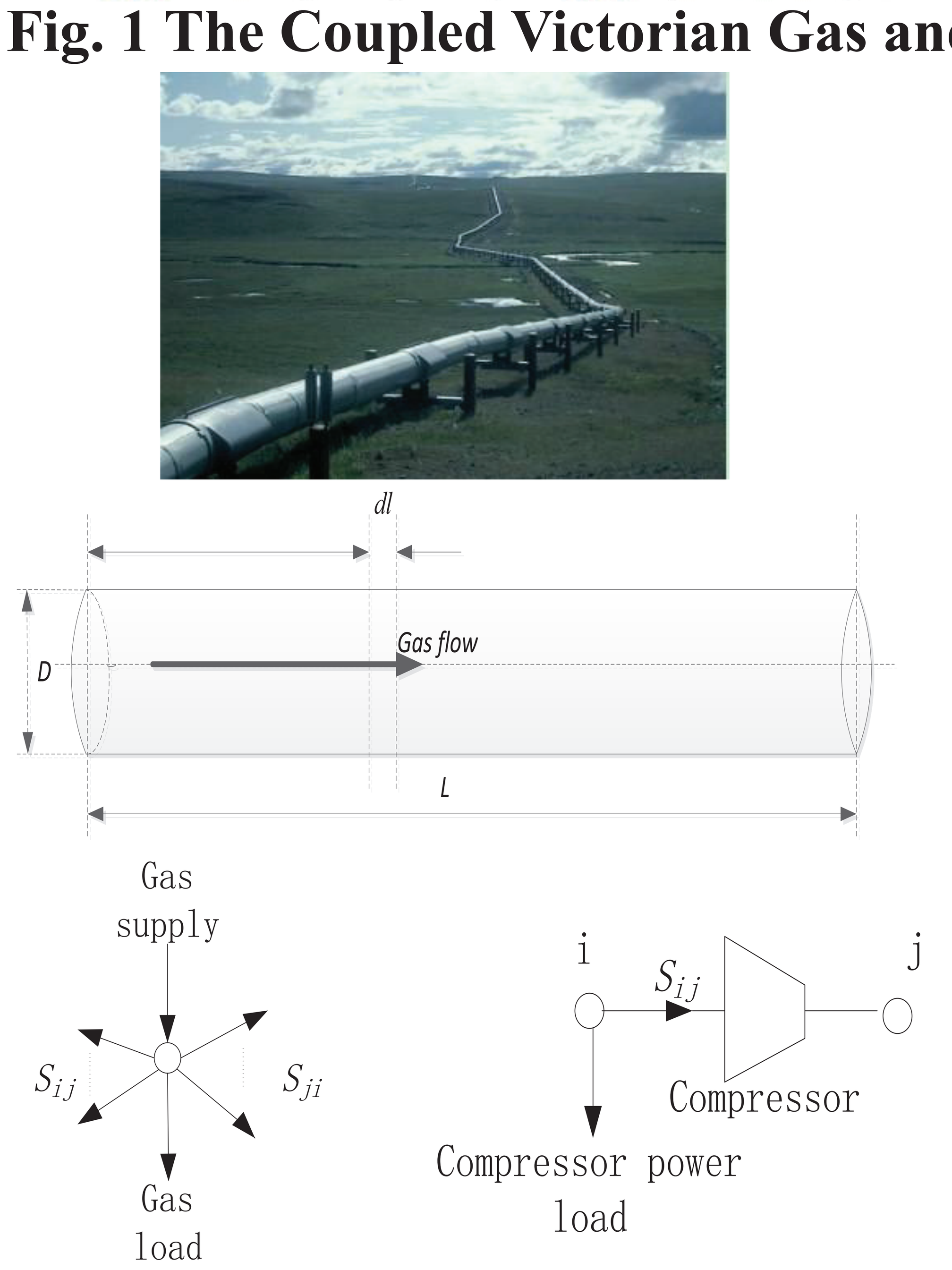


Fig. 1 The Coupled Victorian Gas and Power Systems, Australia.



$$S_{ij} = \mathrm{sgn}_{ij} K \frac{\Gamma_0}{\rho_0}\sqrt{\mathrm{sgn}_{ij}\frac{(\rho_i^2-\rho_j^2)D_{ij}^5}{F_{ij}GL_{ij}\Gamma Z}}$$

$$K=\sqrt{\frac{\pi^2 R_{air}}{64}} = 3.2387$$

$$\mathrm{sgn}_{ij} = \begin{cases} +1 & if\ \rho_i-\rho_j>0 \\ -1 & if\ \rho_i-\rho_j<0 \end{cases}$$

$$P_{Ci} = \frac{S_{Ci}\varphi}{\eta_i(\varphi-1)}\left[\left(\frac{\rho_i^{out}}{\rho_i^{in}}\right)^{\frac{\varphi-1}{\varphi}}-1\right]$$

Fig. 2 Gas Flow and Compressor Model.

$$C_{Ci}=a_{1i}P_{Ci}^2+a_{2i}P_{Ci}+a_{3i}$$

Optimal Flows

The optimal natural gas and power flows can be obtained by minimizing the total operation cost.

Minimize:

Cost of power generation, gas supply, and energy consumption of compressors.

Subject to:

1. Power balance and reserve constraints;
2. Individual generator constraints;
3. Gas contract and reserve constraints;
4. Power transmission constraints;
5. Gas transmission constraints
6. Technical constraints of compressors.

Case Study

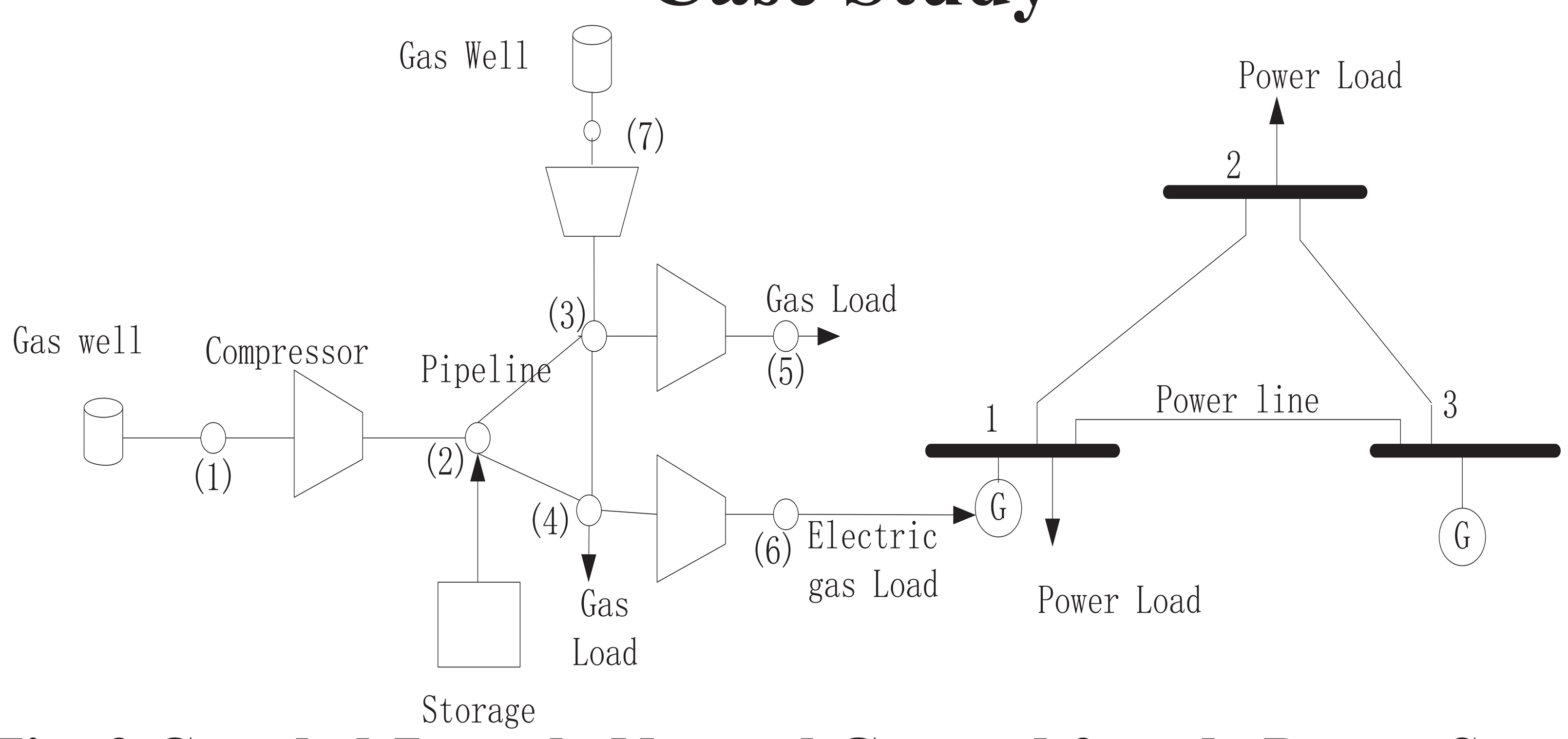


Fig. 3 Coupled 7 –node Natural Gas and 3-node Power Systems.

Table I Simulation Results

Gas system

From	To	Gas flow (GJ/hour)
(1)	(2)	0
(2)	(3)	-5.65
(2)	(4)	5.35
(3)	(4)	25.48
(3)	(5)	70.95
(4)	(6)	20.45
(7)	(3)	100.38

Gas system

Node	Pressure (kPa)	Compressor (kW)	Node	Pressure (kPa)	Compressor (kW)
(1)	11550	325	(5)	9874	-
(2)	9825	-	(6)	9755	-
(3)	10168	218	(7)	11550	365
(4)	9425	205			

Power system

From	To	Power flow P (MW)	Power flow Q (MVAr)	Loss P (MW)	Loss Q(MVAr)
1	2	5.89	0.54	0.11	0.08
2	3	-50.82	-4.98	1.02	4.32
3	1	-15.17	-0.13	0.14	0.25

Power system

Node	Voltage		Generation	
	Mag (p.u.)	Ang (deg)	P (MW)	Q (MVAr)
(1)	1.11	3.25	34.58	12.36
(2)	1.09	4.98	-	-
(3)	1.08	0.62	62.47	0.08