Buffering the demand shocks

Integrated gas electric optimisation considering gas storage

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1 Introduction

In addition to the existing significant oil & gas areas in North Africa (Algeria, Egypt Tunisia and Libya), a number of considerable gas discoveries in recent years in Mozambique, Tanzania, Namibia, Ghana and Nigeria has resulted in a noticeable increased interest in gas developments in Africa. Demand areas for this gas includes Gas-to-Liquids (GTL), Liquefied Natural Gas (LNG), fertilizers, Gas-to-Power (GTP) and industrial heat processes. Supplementing this, there is a known lack of investment in power generation capacity resulting in noticeable energy constraints in most African countries.

With this in mind, there is a clear requirement for an integrated view of the interactions between the gas and electricity industry to assess existing demand-supply balances short-term, to optimise the operation of existing infrastructure in the medium-term and for long term planning purposes to assess the optimal expansion of infrastructure for both gas and electricity industries.

The focus of this article is the analysis of a representative gas-electric system in the short term and medium-term using a dataset developed in the *PLEXOS Integrated Energy Model®* ("PLEXOS").

2 The integrated gas-electric model

A generic integrated gas-electric model has been developed assuming the layout shown in Figure 1.

As can be seen in the summary given in Table 1, the gas and electric systems have been linked via the gas offtake at *GasNode2.* Gas pipelines transmit the gas generated at the gas field to gas nodes. The gas generators in the electrical system are in fact dual fuelled (using either gas from the *Gas System* or the *Diesel* fuel provided). Gas demand is modelled with some degree of variability but is relatively constant for *Industrial* and *GTL* demands while *Residential* demand in winter is assumed to spike. There is also a degree of variability in electrical demand which gradually moves towards a peak in winter from the minimums in summer (an even split of 50% of total load between the two nodes is assumed). A base-load coal fired generator is included at *ENode2* with a transmission line between the two electrical nodes.

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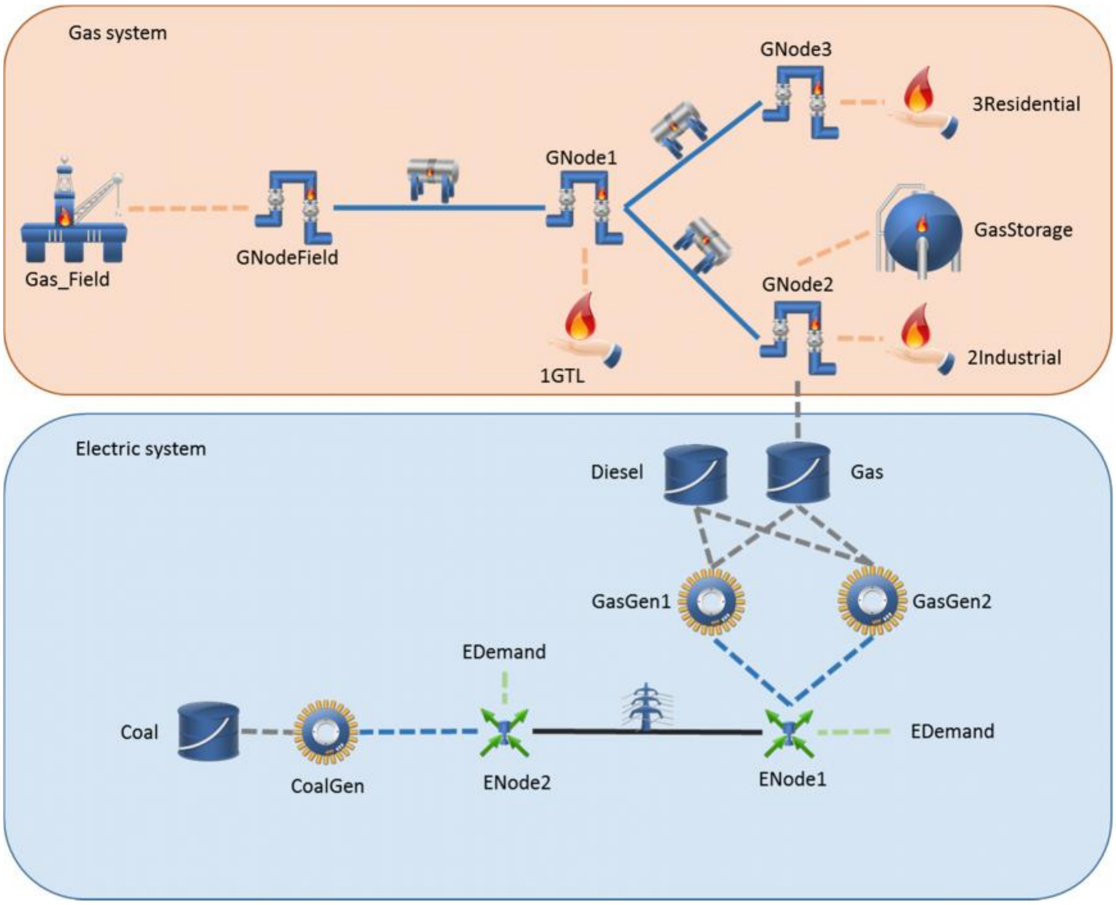

Figure 1: Layout of generic gas-electric model

Table 1: Summary of properties of generic gas-electric dataset

	Item	Value	Unit
	Electrical system		
Demand	Maximum demand	1 000 ± 2% variability	MW
	Annual energy	3835.50	GWh
Generation	CoalGen (Max Capacity)	600	MW
	GasGen1 (Max Capacity)	300	MW
	GasGen2 (Max Capacity)	250	MW
Fuels	Coal (price)	1.5	USD/GJ
	Gas (price)	6.5	USD/GJ
	Diesel (price)	20	USD/GJ
Transmission	Line (Max Capacity)	180	MW
Nodes	ENode1 (participation)	0.50	#
	ENode2 (participation)	0.50	#
	Gas System		
Demand	1GTL	72 ± 2% variability	TJ/day
	2Industrial	72 ± 2% variability	TJ/ day
	3Residential	72-108 ± 2% variability	TJ/ day
Storage	GasStorage (Max Volume)	2000	TJ
	GasStorage (Initial Volume)	1500	TJ
Pipeline	GNode1-GNode2 (max flow)	6.00	TJ/hr

3 Selected results

As can be seen in Figure 2, the *GNode1-GNode2* gas pipeline flow reaches the limit defined as a combined result of the *Industrial* gas demand and the gas offtake for the gas generators in the electrical system. A result of the gas pipeline constraint is that the dual fuel gas generators need to switch to diesel fuel as a result of the scarcity of gas supply to *GNode2*. This results in an increase in the average price of electricity of ~46% over the year (from USD 31.59 /MWh to USD 46.11 /MWh).

A gas storage facility at *GNode2* is included in the model in an attempt to cushion the spiking gas demand requirements during the winter period (*Residential*) combined with peak electrical power demand requirements at the same time. As can be seen in Figure 3, even though the gas pipeline max constraint is reached during high demand periods for gas, there is no requirement for the gas generators to switch to diesel fuel as they can use the gas storage capacity (see Figure 4). Worth noting in Figure 4 is the recycling nature of the storage that ensures the storage volume at the end of the year is restored to the volume at the beginning of the year.

Another interesting result is in the electrical system where an out of merit order generation dispatch is noted as a result of the limited ENode1-ENode2 transmission line capacity for a small part of the year assessed (see Figure 5).

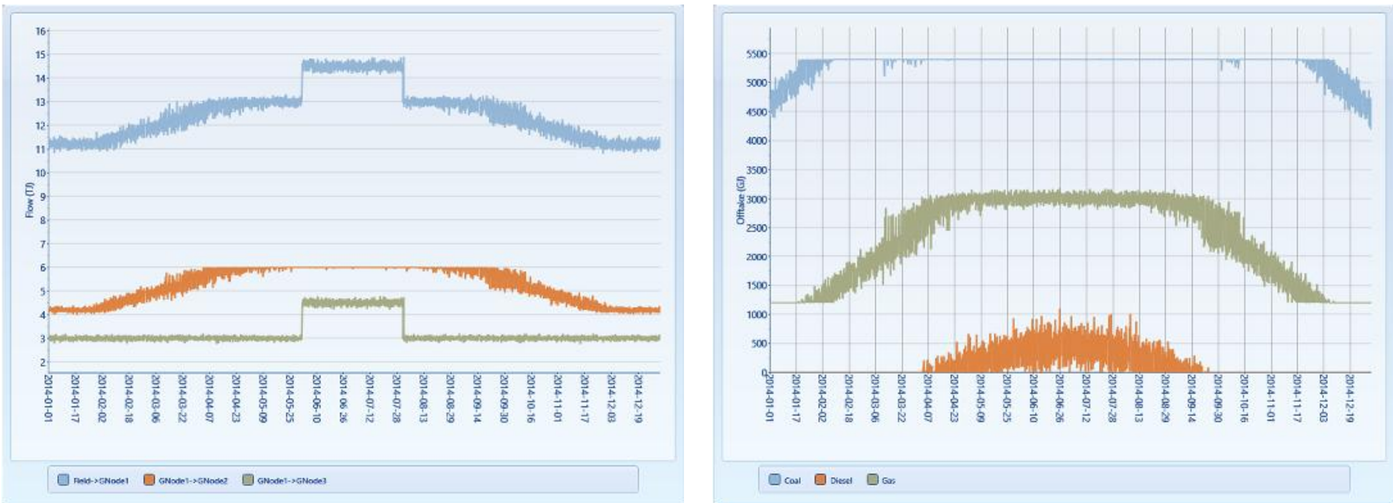

Figure 2: Gas pipeline flows and fuel offtake (assuming no gas storage)

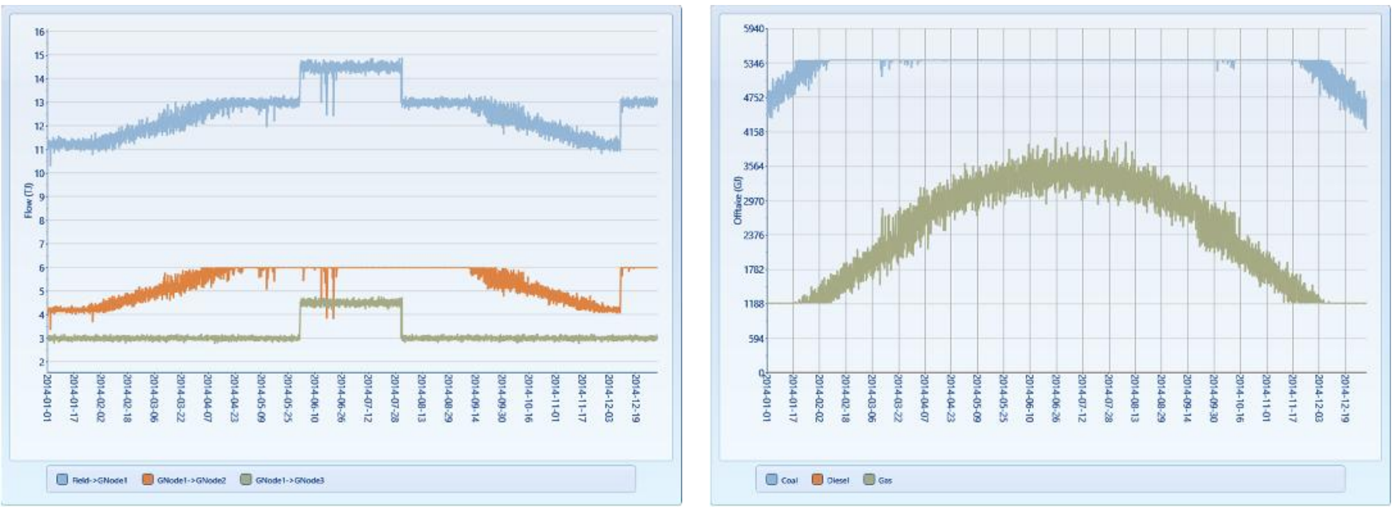

Figure 3: Gas pipeline flows and fuel offtake (with gas storage)

Figure 4: Gas storage volume (ensuring recycling of volume by year end)

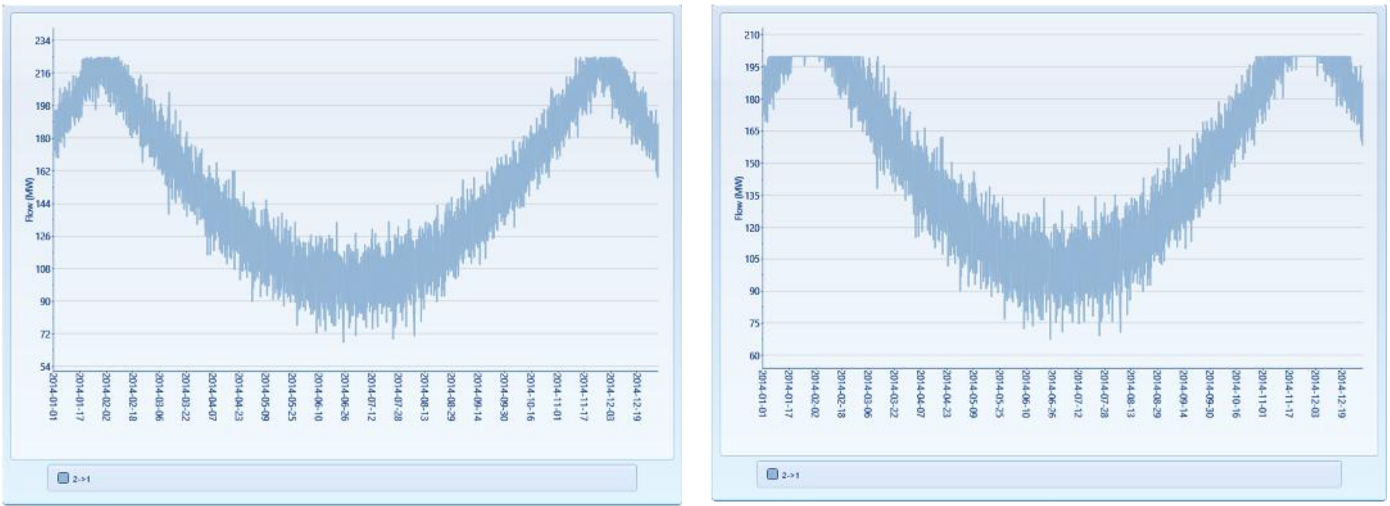

Figure 5: Transmission interconnector power-flows (unconstrained vs constrained)

4 Conclusions

An integrated view of the interactions between gas and electricity systems has been given using a generic model developed in PLEXOS. The gas system model included a gas-field, gas pipelines, gas demands and gas storage while the electrical system included generators, electrical demands, a transmission line and fuels. The interconnection between the two systems was made via a gas fuel offtake to the generators in the electrical system. Results presented revealed the power of an integrated view of gas and electrical systems. Namely, the required increased use of diesel fuel as a result of a gas pipeline maximum capacity constraint. The introduction of gas storage was shown to benefit the system by providing a buffering effect to gas pipeline constraints during times of high gas demands (increased winter residential gas demand and coincident electrical peak demand). The effects of transmission constraints in the electrical system were also shown to result in an out of merit order dispatch to meet load requirements.