PART III – Integer Model

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######### GAS MARKETING - PART 3 ####################
######### MATHS MODEL (INTEGER) ####################
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SETS

Cust	Customer 1 to 3
Days	Days: Day 1 … Day 30
Loc	Loc: City A … City G
FBC	FB Contract 1 to 6
Pipes	Pipe P1 … P9
****StockRanges**	

PARAMETERS

Demand{Cust, Days}	Customer Daily Demand.
CustomerLoc {Cust,Loc}	Customer Location
PreviousDay{d1 in Days,d2 in Days}	Parameter to represent days with previous days having stock. This parameter is 1 if d2 is the previous day to d1 param
FBDeliveryRange {FBC, Days}	Days that Flat Band Contract delivers gas.
FBMaxQuantity {FBC}	Maximum Daily delivery of Flat Band Contract.
FBPrice {FBC}	Price paid for Flat Band Contract.
DaysInContract {fb in FBC}	Number of days in a Flat Band Contract
SWCMaxTotalQuantity	Maximum Total MWh delivered by use of swing contract.
SWCTotalContractedCost	Cost for Total contracted MWh.
SWCDailyUseCost	Cost of daily use of swing contract.
PipeConn {Pipe, l1 in Loc, l2 in Loc}	Correspondence of Pipe connection (ex: P1 connects City A to City B).
PipeMaximumCapacity {Pipe}	Maximum Pipeline capacity.
PipeCapacityCost{Pipe}	Cost (in GBP/MWh) for contracted capacity.
PipeUseCost {Pipe}	Cost for volume use (in GBP/MWh).
StockWithdrawCapacityCost	Withdraw capacity cost.
StockInjectionCapacityCost	Injection capacity cost.

StockCapacityCost	Stock capacity cost.

****StockBWithdrawMaxRange{S_StockRanges}**

****StockBReducedWithdraw{S_StockRanges}**

****StockBInjectMinRange{S_StockRanges}**

****StockBReducedInject{S_StockRanges}**

****BigM := sum{ Days, Cust} P_Demand[c,d]**

****StockBCapacityCost**

VARIABLES

GasDeliveredToCustomer{Cust, Day} >= 0	Quantity of gas delivered to customer each day
ContractedFB {FBC} >= 0	Quantity of MWh negotiated for flat band contract
TotalContractedSWC >= 0	Total MWh contracted for Swing Contracts
DailyUseSWC {Days} >= 0	Quantity of MWh is being used on a daily
DailySWCCost >= 0	Daily cost due to use of Swing Contract
PipeContractedCapacity {Pipe} >= 0	Contracted capacity for Pipe during month
TransportGas {l1, l2, d } >=0	Quantity of gas transported from one city to another (represented by l1 to l2) in a day.
ContractedMaxStock >=0	Maximum contracted stock
MaxStockInject >=0	Maximum daily injection into stock
MaxStockWithdraw >=0	Maximum daily withdrawal from stock.
Stock{Days} >=0	Total gas stocked at the end of day ‘d’ at Location ‘City C’
BalanceSheet{Days}	If positive represents that the network has been injected with more gas than withdrawn, if negative represents there has been more withdrawals than injections
BalancingCapacity >=0	How much gas can be withdrawn or injected in excess each day

****StockB{ Days} >= 0**

****StockBMaxCapacity >= 0**

****StockBMaxWithdraw{S_Days,S_StockRanges} >= 0**

****StockBWithdrawRange{ Days,S_StockRanges} binary**

****StockBMaxInject{ Days,S_StockRanges} >= 0**

****StockBInjectRange{ Days, StockRanges} binary**

OBJECTIVE FUNCTION:

***** Minimize Total_Cost:**

$$\left[\sum_{fb\ in\ FBC} (ContractedFB[fb] * FBPrice[fb] * DaysInContract[fb]) \right]$$
$$+ \quad [TotalContractedSWC * SWCTotalContractedCost]$$
$$+ \quad [DailySWCCost]$$
$$+ \quad \left[\sum_{(p\ in\ Pipes)} PipeContractedCapacity[p] * PipeCapacityCost[p] \right]$$
$$+ \quad \left[\sum_{(l1,l2:PipeConn[p,l1,l2]=1)} TransportGas[l1,l2,d] \ * PipeUseCost[p] \right],$$
$$\forall\ p\ in\ Pipes, l1\ in\ Loc, l2\ in\ Loc, d\ in\ Days$$
$$+ \quad [\ ContractedMaxStock * StockCapacityCost]$$
$$+ \quad [MaxstockInject * StockInjectionCapacityCost]$$
$$+ \quad [MaxStockWithdraw * StockWithdrawCapacityCost]$$
$$+ \quad [StockBMaxCapacity * StockBCapacityCost]$$

CONSTRAINTS:

Gas delivery: guarantee's that the customer is delivered with the demand quantity

$$GasDeliveredToCustomer[c,d] \ = \ Demand[c,d], \ \forall\ c\ in\ Cust, d\ in\ Days$$

Maximum Pipe Capacity Contract

$$PipeContractedCapacity[p] \ \le \ PipeMaximumCapacity[p], \forall\ p\ in\ Pipes$$

Maximum Gas Transport Pipe:

$$\sum_{(l1,l2:PipeConn[l1,l2,p]=1)} TransportGas[l1,l2,d] \ \le \ PipeContractedCapacity[p], \forall\ p\ in\ Pipes, d\ in\ Days$$

Prohibit transport between cities without Pipe

$$TransportGas[l1,l2,d] \ = \ 0, \forall\ d\ in\ Days, \ l1 \text{ in Loc}, l2 \text{ in Loc}:$$
$$(p\ in\ (l1,l2) \notin (p\ and\ PipeConn[l1,l2,p] = 0)$$

Inflow and outflow Constraints

$$\left[\sum_{l2\ in\ Loc} 0.99 * TransportGas[l2,l1,d]\right] - \left[\sum_{l2\ in\ Loc} TransportGas[l1,l2,d]\right]$$

$$+ \left[\sum_{fb\ in\ FBC:\ l1='City\_A'\ and\ FBDeliveryRange[fb,d]=1} ContractedFB[fb]\right] + \left[\sum_{d2\ in\ Days:\ d=d2\ and\ l1='City\_A'} DailyUseSWC[d]\right]$$

$$+ \left[\sum_{d2\ in\ Days: l1='City\_C'\ and\ PreviousDay[d,d2]=1} Stock[d2]\right] + \left[\sum_{d2\ in\ Days: l1='City\_A'\ and\ PreviousDay[d,d2]=1} Balancesheet[d2]\right]$$

$$+ \left[\sum_{d2\ in\ Days: l1='City\_B'\ and\ PreviousDay[d,d2]=1} StockB[d2]\right]$$

$$=$$

$$\sum_{c\ in\ Cust:\ CustomerLoc[c,l1]=1} GasDeliveredToCustomer[c,d] + \left[\sum_{d2\ in\ Days:\ d=d2\ and\ l1='City\_C'} Stock[d2]\right]$$

$$+ \left[\sum_{d2\ in\ Days:\ d=d2\ and\ l1='City\_A'} Balancesheet[d2]\right] + \left[\sum_{d2\ in\ Days:\ d=d2\ and\ l1='City\_B'} StockB[d2]\right]$$

$$\forall\ d\ in\ Days, l1\ in\ Loc$$

Flat Band Contract maximum Quantity

$$ContractedFB[fb] \le FBMaxQuantity[fb], \forall\ fb\ in\ FBC$$

Swing Contract Maximum Daily Use

$$DailyUseSWC[d] \le \frac{TotalContractedSWC}{30}, \forall\ d\ in\ Days$$

Swing Contract Minimal Daily Use

$$DailyUseSWC[d] \ge (0.6) * \frac{TotalContractedSWC}{30}, \forall\ d\ in\ Days$$

Swing Contract Daily Cost

$$DailySWCCost \ge \left[\sum_{d\ in\ Days} DailyUseSWC[d]\right] * SWCDailyUseCost$$

Swing Contract Minimal Daily Cost

$$DailySWCCost \ge (0.8) * \frac{TotalContractedSWC}{30} * SWCDailyUseCost$$

Swing Contract Maximum Total Cost

$$TotalContractedSWC \le SWCMaxTotalQuantity$$

Limited Stock Capacity

$$Stock[d] \le ContractedMaxStock, \forall\ d\ in\ Days$$

Limited Stock Injection (minus Day 1)

$$\sum_{d2\ in\ Days:\ PreviousDay[d,d2]=1} Stock\ [d2] \le MaxStockInject, \forall\ d\ in\ Days$$

Limited Stock Withdraw (minus Day 1)

$$\sum_{d2\ in\ Days:\ PreviousDay[d,d2]=1} Stock[d2] - Stock[d] \le MaxStockWithdraw,\ \forall\ d\ in\ Days$$

Maximum daily withdrawal from stock

$$MaxStockWithdrawn \le \frac{ContractedMaxStock}{25}$$

Maximum Balance Capacity (if under 2000 MWh distribution capacity_

$$BalanceCapacity \le 0.1 * \left[\sum_{p\ in\ Pipes:\ p='P1'\ or\ p=''P6} PipeContractedCapacity[p] \right]$$

Maximum Balance Capacity (if over 2000 MWh distribution capacity)

$$BalanceCapacity \le (0.1 * 2000) + 0.05 * \left[\sum_{p\ in\ Pipes:\ p='P1'\ or\ p=''P6} PipeContractedCapacity[p] - 2000 \right]$$

Maximum Daily injection Balance

$$BalanceSheet[d] - \sum_{d2\ in\ Days:\ PreviousDay[d,d2]=1} BalanceSheet[d2] \le BalanceCapacity,\ \forall\ d\ in\ Days$$

Maximum Daily Withdraw Balance

$$\sum_{d2\ in\ Days:\ PreviousDay[d,d2]=1} BalanceSheet[d2] - BalanceSheet[d] \le BalanceCapacity,\ \forall\ d\ in\ Days$$

Maximum Overall Balanace:

$$BalanceSheet[d] \le 0 + \sum_{d2\ in\ Days:\ d=d2\ and\ d2<>30} (3 * BalanceCapacity) + 0,\ \forall\ d\ in\ Days$$

Minimum Overall Balanace:

$$BalanceSheet[d] \ge 0 - \sum_{d2\ in\ Days:\ d=d2\ and\ d2<>30} (3 * BalanceCapacity) + 0,\ \forall\ d\ in\ Days$$

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######### Constraints for STOCK at City B #################

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Maximum Stock Capacity @ City B

$$StockB[d] \le StockBMaxCapacity,\ \forall\ d\ in\ Days$$

Withdrawal Range Always On @ City B

$$StockBWithdrawRange[d,'A'] = 1,\ \forall\ d\ in\ Days$$

Injection Range Always On @ City B

$$StockBInjectRange[d,'A'] = 1,\ \forall\ d\ in\ Days$$

Limited Stock Withdraw (minus Day 1)

$$\sum_{d2\ in\ Days:\ PreviousDay[d,d2]=1} Stock[d2] - Stock[d] \le MaxStockWithdraw,\ \forall\ d\ in\ Days$$

Maximum daily withdrawal from stock

$$MaxStockWithdrawn \leq \frac{ContractedMaxStock}{25}$$

Maximum Stock Withdrawal @ City B

$$StockBMaxWithdraw[d,sr] \leq \left(\frac{StockBMaxCapacity * StockBReducedWithdraw[sr]}{15}\right)$$
$$+ BigM * (1 - StockBWithdrawRange[d,sr]) , \forall\ d\ in\ Days, sr\ in\ StockRanges$$

Days for Stock Withdrawal @ City B

$$StockBWithdrawRange[d,sr] * BigM \geq - \left[\sum_{d2\ in\ Days:\ PreviousDay[d,d2]=1} StockB[d2]\right]$$
$$+ StockBMaxCapacity * StockBWithdrawMaxRange[sr]$$
$$\forall\ d\ in\ Days, sr\ in\ StockRanges$$

Stock Withdrawal Limit @ City B

$$\sum_{d2\ in\ Days:\ PreviousDay[d,d2]=1} StockB[d2] - StockB[d] \leq StockBMaxWithdraw[d,sr]$$
$$, \forall\ d\ in\ Days, sr\ in\ StockRanges$$

Maximum Stock Injection @ City B

$$StockBInjectRange[d,sr] \leq \left(\frac{StockBMaxCapacity * StockBReducedInject[sr]}{8}\right)$$
$$+ BigM * (1 - StockBInjectRange[d,sr]) , \forall\ d\ in\ Days, sr\ in\ StockRanges$$

Days for Stock Injection @ City B

$$StockBInjectRange[d,sr] \geq \sum_{d2\ in\ Days:\ PreviousDay[d,d2]=1} StockB[d2]$$
$$- (StockBMaxCapacity * StockBInjectMinRange[sr] , \forall\ d\ in\ Days, sr\ in\ StockRanges$$

Stock Injection Limit @ City B

$$StockB[d] - \sum_{d2\ in\ Days:\ PreviousDay[d,d2]=1} StockB[d2] \leq StockBMaxInject[d,sr] ,$$
$$\forall\ d\ in\ Days, sr\ in\ StockRanges$$