International Journal of Sciences:
Basic and Applied Research
(IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Design and Implementation of Inferential (IQ) Model to Predict i-C4 Percentage and to Save Fuel Gas Consumption in Gas Train De-Propaniser Tower

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Abstract

The main goal of this paper is to present the effect of using reflux to feed ratio as an independent variable in designing a Model-Base Inferential IQ to predict the i-C4 percentage in the top of a DE-Propaniser tower. The addition of this variable is a modification of an existing inferential IQ model with a design, which only uses the De-Propaniser tower top temperature and pressure as independent variables, and has resulted in significant improvements in the prediction of i-C4 percentage, operation and economics of the tower operation.

Keywords: Model-Base Inferential IQ; i-C4 percentage; De-Propaniser; Linest Correlation; DMC uptime; Control Variable (CV); DMCplus; Gain; Inferential Predictive Control.

1. Introduction

Model-base [1] inferential (IQ) is a technology used where critical measurements have limited measurement problems [3] or slow to reflect process changes. In such cases, we use inferential predictive control [8] property calculation to overcome measurement limitations and to improve the performance of control and monitoring applications.

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Inferential property calculations are an important part of any advanced control project. While the technology is often applied to predicting product qualities from more easily measurable operating conditions, it is applied to almost any variable that costly to measure directly or difficult to maintain its field analyzer.

2. Existing Inferential

The existing inferential model was developed in 2008. It was designed to predict the percentage of i-C4 in top of Gas Train De-Propaniser tower based only on changes in temperature and pressure at the top of the tower. The DMC model configuration was used to develop the existing IQ model.

2.1. Reasons for Replacing the Existing Inferential

It was noted that the accuracy of the existing inferential model was not qualified and was causing a lot of oscillation. The field analyzer is very slow to calculate the percentage of i-C4, requiring more than one hour to reflect its value based on the previous process changes.

Figure 1 shows the slow behavior of the field analyzer vs DE-Propaniser tower top temperature changes. The tower top temperature (TI0235_2) data shown in “Orange”.

The field analyzer (AR2202B) data shown in “Red”.

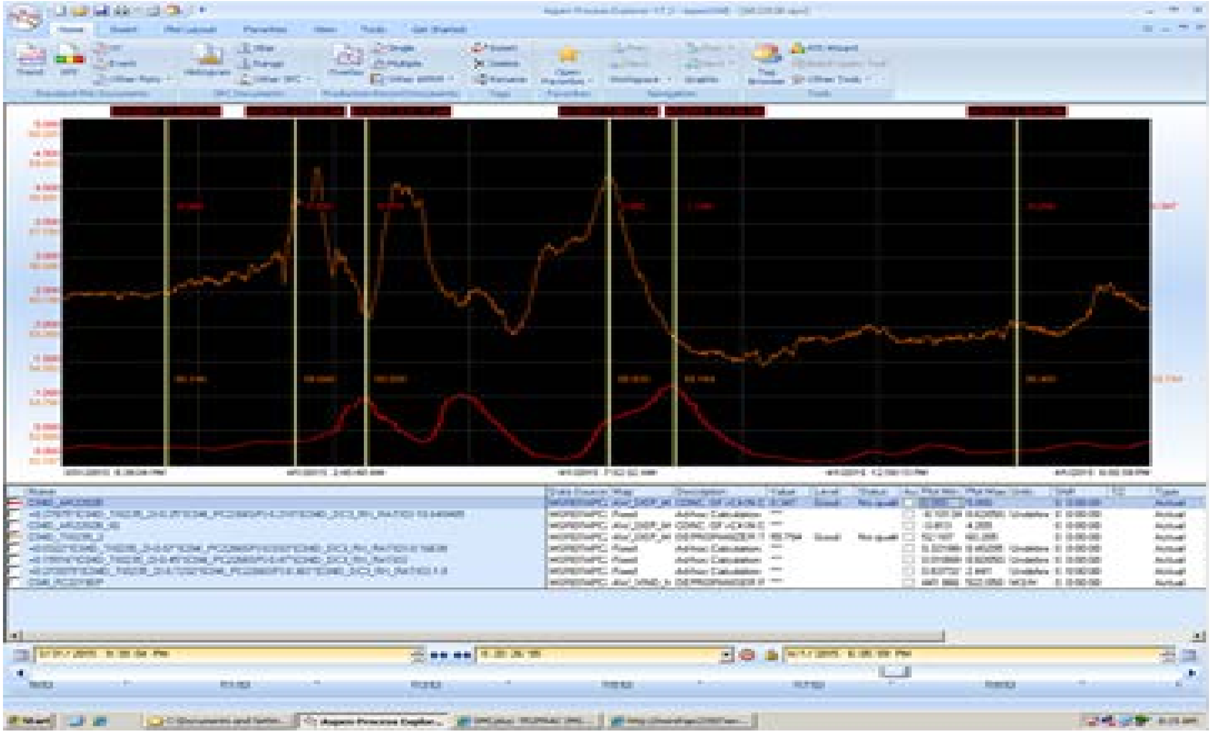


Figure 1: Field Analyzer (AR2202B) vs DE-Propaniser Tower Top Temperature (TI10235_2) changes.

Note: The hairline in the chart shows the delay of the field analyzer in reflecting the tower top temperature changes.

Figure 2 shows the behavior of the existing inferential (AR2202B_IQ) vs DE-Propaniser tower top temperature (TI0235_2) changes.

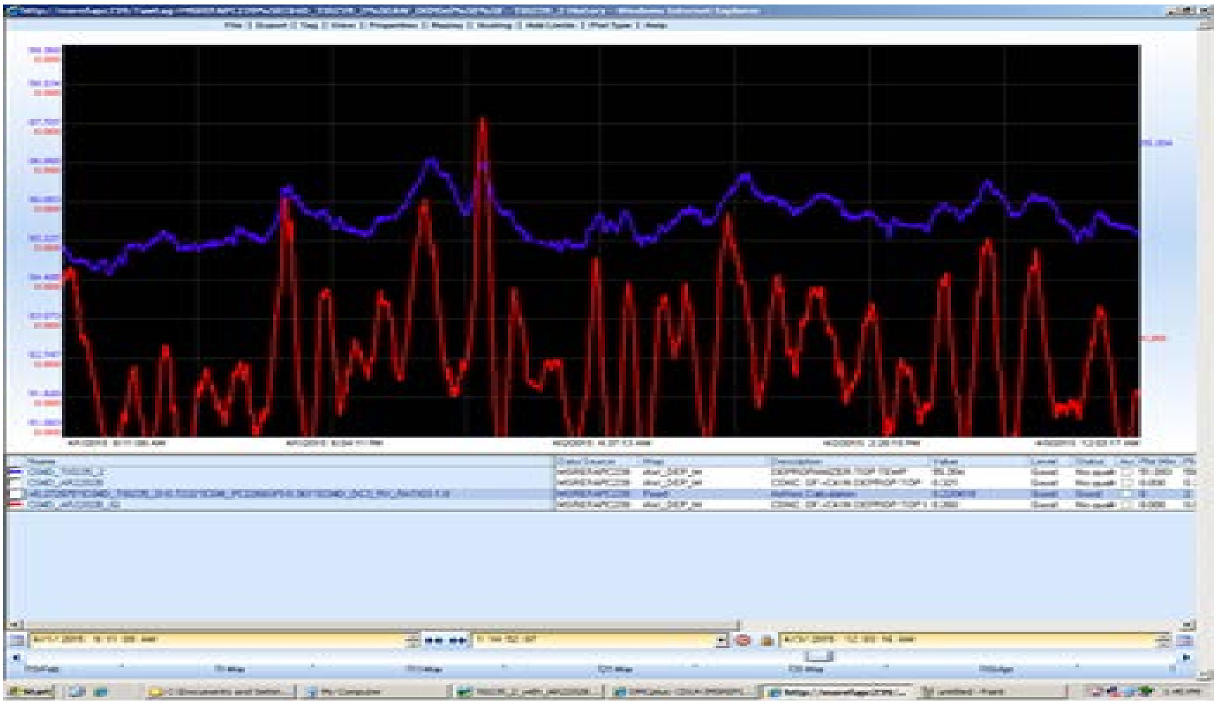


Figure 2: Existing IQ (AR2202B_IQ) vs DE-Propaniser tower top temperature (TI0235_2) changes.

- TI0235_2 (DEC3 tower top temperature) shown in “Blue”.
- AR2202B_IQ (Existing Inferential) shown in “Red”.

3. Proposed Inferential

Proposed new Model-Base Inferential IQ [1] is an application of advanced predictive control [7] constructed using IQ development tool, which is part of Aspen Tech Manufacturing Suite [4], designed to include the reflux-to-feed ratio [6] as a new independent variable in addition to the DE-Propaniser tower top temperature and pressure. The derivation of the Gains used in “LINEST” algebraic equation [2] is from the new DMC model.

Proposed Inferential predictive control [8] will allow for on-spot prediction of i-C4 percentage based on any changes in the DE-Propaniser tower’s process condition. The DMCplus main controller will use the IQ model prediction value as Control Variable (CV) to improve the operation of the DE-Propaniser tower, the C3 and C4 product quality and fuel gas consumption.

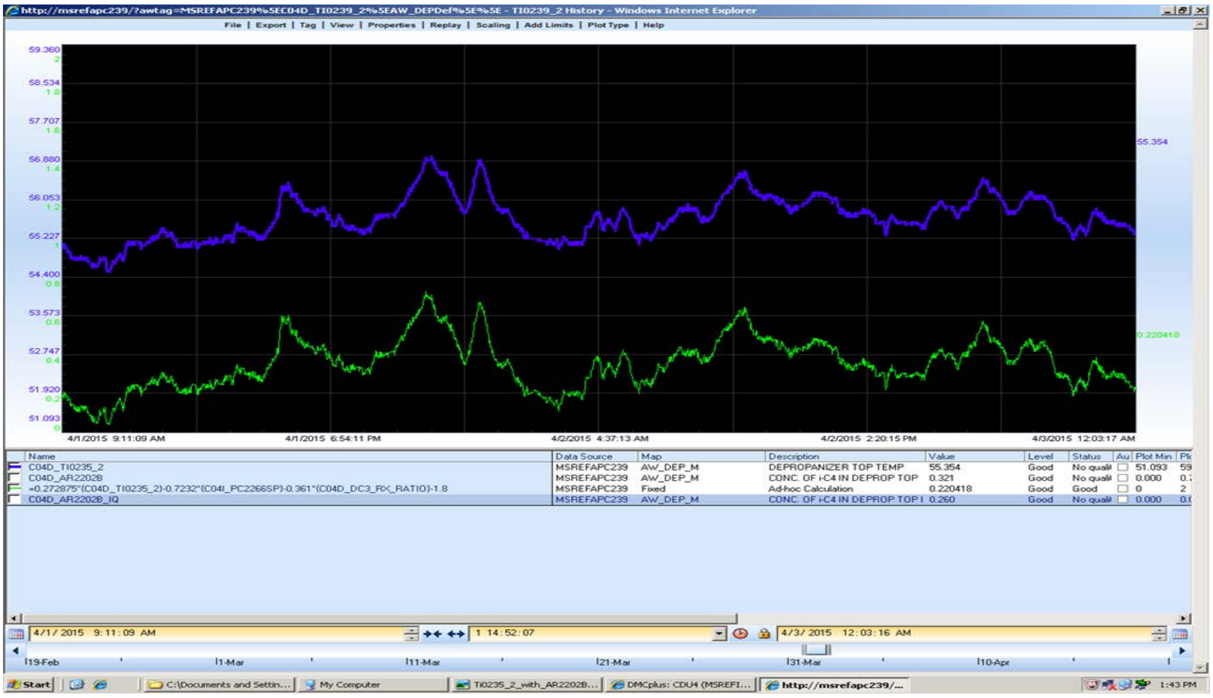
One-minute data collected for each of the following four variables used for developing the proposed inferential correlation model:

- Field analyzer data for i-C4 percentage (Dependent Variable).
- DE-Propaniser tower Reflux to feed ratio (Independent Variable).

- DE-Propaniser tower top pressure (Independent Variable).
- DE-Propaniser tower top temperature (Independent Variable).

Figure 3 shows the behavior of the behavior of the proposed inferential vs DE-Propaniser tower top temperature (TI0235_2) changes.

- TI0235_2 (DE-Propaniser tower top temperature) shown in "Blue ".
- Proposed Inferential (AR2202B_IQ) shown in "Green".



Name	Data Source	Map	Description	Value	Level	Status	Au	Plot Min	Pl
C04D_TI0235_2	MSREFAPC239	AW_DEP_M	DEPROPANIZER TOP TEMP	55.354	Good	No qualit	☐	51.093	59
C04D_AR2202B	MSREFAPC239	AW_DEP_M	CONC. OF i-C4 IN DEPROP TOP	0.321	Good	No qualit	☐	0.000	0.:
=0.272875*(C04D_TI0235_2)-0.7232*(C04I_PC2266SP)-0.361*(C04D_DC3_RX_RATIO)-1.8	MSREFAPC239	Fixed	Ad-hoc Calculation	0.220418	Good	Good	☐	0	2
C04D_AR2202B_IQ	MSREFAPC239	AW_DEP_M	CONC. OF i-C4 IN DEPROP TOP I	0.260	Good	No qualit	☐	0.000	0.(

Figure 3: Proposed inferential (AR2202B_IQ) vs DE-Propaniser Tower Top Temperature (TI10235_2) Changes.

3.1. LINEST Correlation [2] Developed for New Inferential

$(A*TI0235\_2) + (B*PC2266) + (C*DC3\_RX\_RATIO) + BIAS$

Where:

Table 1: Gains

Parameter	Gain
A	0.272875
B	-0.7232
C	-0.361
BIAS	-1.8

Table 2: Used Blocks

Block Name	Description
TI0235_2	De-Propaniser tower top temperature
PC2266	De-Propaniser tower top pressure
DC3_RX_RATIO	Reflux to Feed Ratio

The LINEST correlation [2] parameters were tuned and adjusted based on observed process changes. Before implementing the proposed IQ model, the accuracy of the on-line prediction monitored and plotted for more than one month to ensure full accuracy.

4. Proposed Inferential Predicted Values vs the Actual Analyzer Data and Top Temperature Changes.

Figure 4 shows the behavior of the behavior of the proposed inferential vs DE-Propaniser tower top temperature (TI0235_2) changes and field analyzer (AR2202B)behavior where:

- TI0235_2 (DEC3 tower top temperature) shown in “Orange”.
- AR2202B (Field Analyzer) shown in “Red”.
- Proposed Inferential (AR2202B_IQ) shown in “Yellow”.

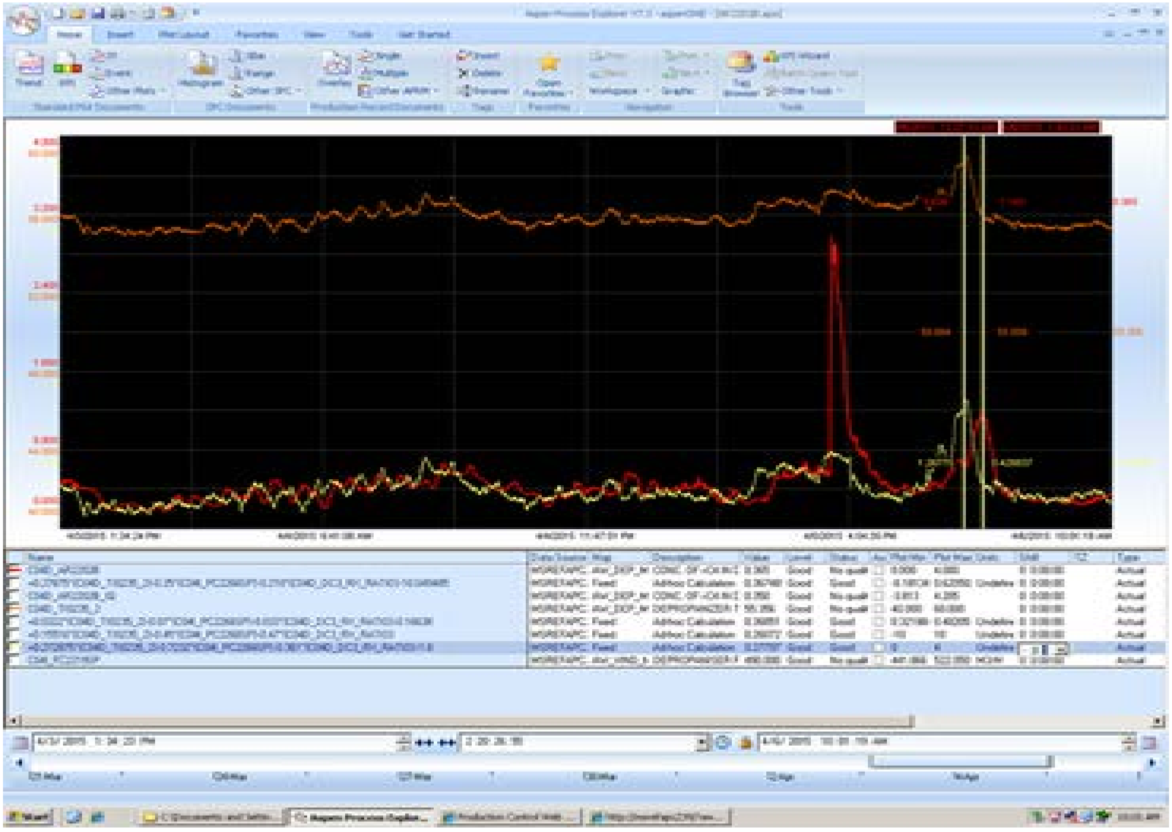


Figure 4: Proposed inferential IQ model (AR2202B_IQ) vs DE-Propaniser tower top temperature (TI0235_2) changes and Field Analyzer behavior (AR2202B)

5. Behavior of Dependent Variable vs Changes of Independent Variables

Figure 5 shows the model created to reflect the changes of dependent variable (AR2202B) vs the three Independent variables changes, where:

Table 3: Variables Type

Variable Name	Variable Type
AR2202B_2	Dependent Variable
TI0235_2	Independent Variable
PC2266	Independent Variable
DC3_RX_RATIO	Independent Variable

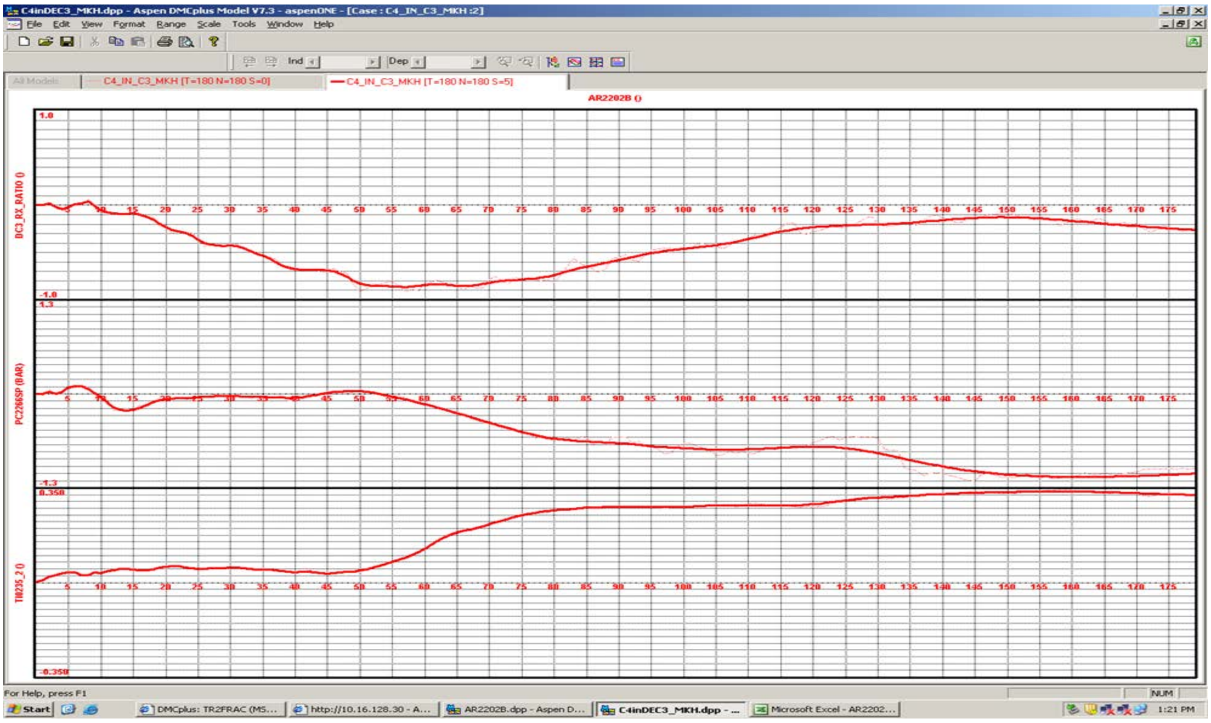


Figure 5: Proposed inferential (AR2202B_IQ) Model

The model above shows the correct GAIN as follows:

- Negative gain for the change Reflux Ratio (DC3_RX_RATIO).
- Negative gain for the change of Tower Pressure (PC2266)
- Positive gain for the change of top temperature (TI0235_2).

6. Implementation of New Predicted IQ Model Result in DCS Graphic Display

It was noted that, in case of any change of DE-Propaniser process parameters, the field analyzer will produce confusing results for i-C4 percentage due to the its delay in producing its result.

Implementing the proposed IQ on-spot prediction result into the DCS graphic for the operation of Gas Train DE-Propaniser tower will guide the operator to take the right action in the right time in order to make the necessary changes when the process parameters or the conditions of the DE-Propaniser tower change.

Figure 6 shows the configuration of the proposed inferential result in the Gas Train DE-Propaniser tower control graphic shown in “Blue “.

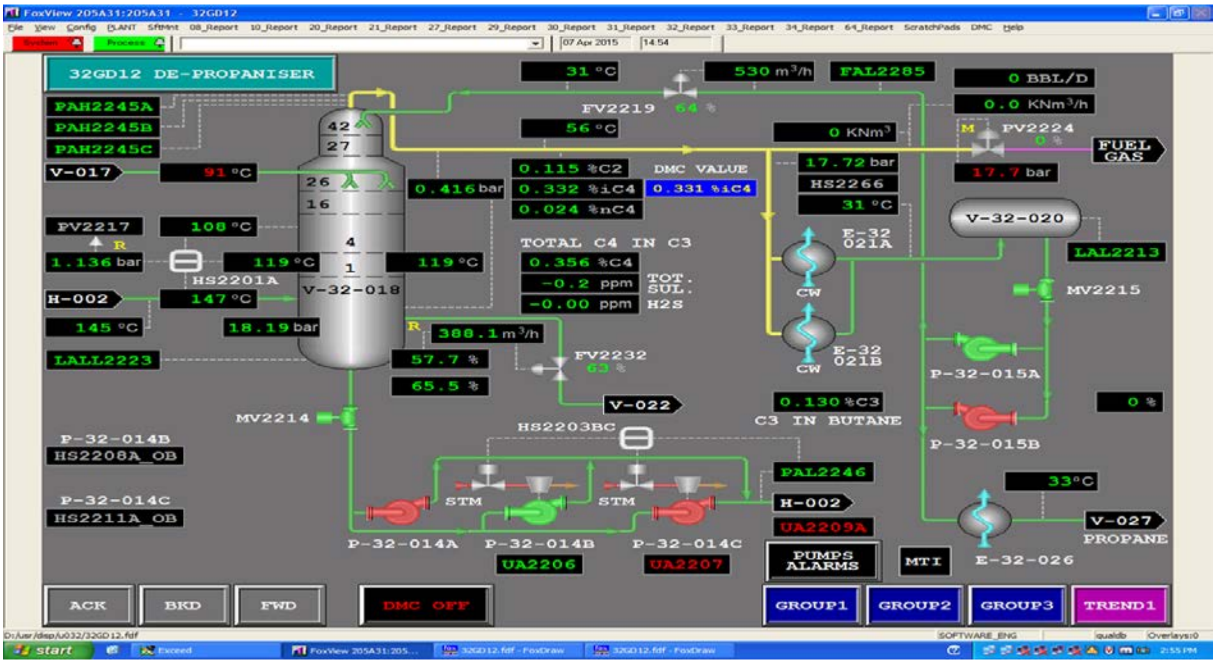


Figure 6: Configuration of Proposed inferential result in DEC3 Graphic display.

7. Benefits Calculation and Saving

To examine the effectiveness of the new IQ model, the data collected for the old IQ case study from March 26, 2015 to April 11, 2015.

The Gas Train plant process units designed to run for 8000 hours (minimum run hours per year) as normal operation.

The average DMC uptime (the percentage of time that the DMC was actively online during normal operation hours) is 70% of the time used during the benefits calculation.

The April 2015 parity price for fuel oil was $383.84 per ton.

The benefits calculated from the observed outputs are:

- Averaged fuel gas consumption during the old IQ period: (A) 2998.701 kg/hr.
- Averaged fuel gas consumption during the new IQ period: (B) 2907.375 kg/hr.
- Saved fuel gas consumption *(C) = (A-B) = 91.336 kg/hr.*

- Because the feed rate was different in both cases, a normalized value of C was used for calculations *(D) = 91.336 * (602.316/627.644) = 87.64 kg/hr*
- Gas Train units run time per year = 8000*0.7 = 5600 hours
- Benefits realized = *D * Fuel Gas Price * Runtime/year= (87.64/1000) * 383.84 * 5600 = $188,382/year*

Table 4: Summary of the results

	Old IQ	New IQ	Flow Different	Normalize (Kg/hr)
Feed Flow(M3/H)	627.644	602.316	25.328	
FG Flow(KG/H)	2998.701	2907.375	91.326	87.64

	Price ($/Ton)	Benefits ($/hr)	Up time/year (hr)	Final Benefits ($/year)
Benefits based on fuel oil parity price (April 2015**)**	383.84	33.46	5600	188,382

8. Conclusion

In this study, using the appropriate variables in designing IQ models is necessary for realizing substantial gains in both the efficiency and the economy of process control.

The proposed IQ model can be adapted and used for any separation process.

Acknowledgment

The author would like to thank Miss Wadha Ahmad Mohd Alkhateeb, Manager Technical Services, Kuwait National Petroleum Company and Mr. Muhammad Abdulaziz Ghufran, Team Leader, Process Engineering, for their support.

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