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SMART PRODUCT BLENDING SYSTEM TO MAXIMISE QUALITY

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ABSTRACT

PETRONAS developed a uniquely fast and exact automated fuel blending system that has accelerated the release of quality certification and achieved the perfect gasoline product blend for a Malaysian Refinery. Blending is a critical production process. Up to 13 different hydrocarbon streams from various feedstocks must be precisely blended to produce petroleum products such as Unleaded Gasoline RON 95. The ratio between flow velocities of different blending component streams is of great importance to ultimately achieve the target quality of the product. The ratio is determined based on the individual quality of the blending component. The underlying concept of this innovation is based on the strategy of an online blending with intelligent and fast chemometrics multivariate data analytics to make the necessary adjustment in the ratio of the blending components to meet the product quality. One of the integral parts of chemometrics multivariate data analytics is a spectroscopic analyser equipped with calibration models which enable multivariate prediction. The integration of the spectroscopic analyser and customised blend property control is an authoritarian system whereby it provides real-time data on fuel quality and enables online blending monitoring and control to happen seamlessly. PETRONAS has crafted an automated and integrated online blending system. This innovation has resulted in a more innovative product blending with zero re-blend and minimal quality giveaway in line with Industry 4.0 Best Practice.

Keywords: *Chemometrics multivariate modelling, online blending, spectroscopy*

INTRODUCTION

Product blending is a complex process that involves much more than the simple mixing of blending components. Gasoline is one of the products produced via the blending process by utilising as many as 13 blending components. The blending process requires meticulous planning to select the optimal combination of blending components to produce gasoline, directly impacting the economics [1]. Gasoline is blended to comply with a minimum of ten different quality specifications such as research octane number (RON), vapour pressure, density, olefin, benzene, oxygen, aromatics, oxygenate, initial, intermediate, and final boiling points, etc.; at the same time meeting Euro 4 and Euro 5 Gasoline Specification.

Conventional product blending is carried out using Blend Ratio Controller (BRC), which only controls the volume of blending components based on the established blend recipe. The adjustments are made according to laboratory analysis. During the blending process, PETRONAS refineries take manual samples at 10%, 50%, and 95% of blending to monitor the quality of the blended product. These samples will be sent to a laboratory to perform critical analyses such as RON, vapour pressure, and initial, intermediate, and final boiling points using conventional analysers. The lab requires approximately 3 hours to complete these analyses, during which the blending will continue without any adjustments.

One of the conventional blending challenges is the final gasoline product not meeting the required quality specification or high product quality giveaway, leading to a high re-blend rate and high demurrage cost. In addition to these challenges, laboratory analysis for the final gasoline product quality certification requires at least 8 hours to complete, including labor-intensive lab analysis and multiple analysers.

To address the gasoline blending challenges holistically, PETRONAS has innovatively crafted an automated and integrated online blending system for refineries while not compromising the quality of the end product.

MATERIALS AND METHODS

Figure 1 illustrates the phases involved until the deployment of the Smart Product Blending System successfully. The process evolves from a descriptive system to an authoritarian system where comprehensive online blending is delivered.

Design of Experiment (DOE)

DOE is a planning stage, whereby activities and requirements have to be charted and essential decisions made, which will set the basis for all the other phases. One of the important decisions that must be performed in the most accurate and precise manner is determining parameters and respective range of concentration for each quality specification for the calibration model development. This is an imperative aspect of multivariate calibration model development as it will provide required quality specification results for online blending monitoring and control.

Next is, the decision on several samples required and various blending process condition that has to be acquired for calibration model development. An adequate number of samples can successfully define the relationship between FTNIR spectra and excellent method analysis results for calibration model development.

Descriptive

In this stage, chemical properties are modeled with the intent of learning the underlying relationship and structure. This is a qualitative analysis that describes data variation and identifies the presence of clustering that may exist due to the usage of different types of crudes or process variation.

Regression

Development of calibration model for each parameter happens at this stage. The success of the following two stages is highly dependent on the accuracy of

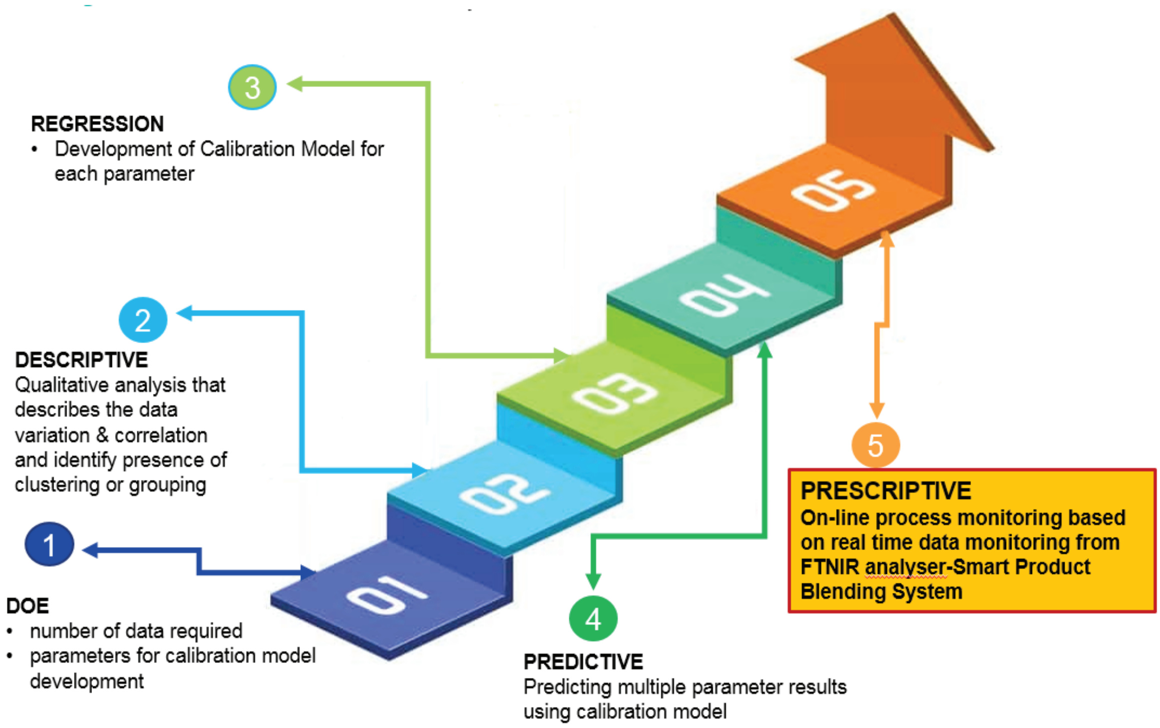

Figure 1 Chemical Analytics Protocol for Smart Product Blending System

the calibration model. Calibration model validation must be performed using statistical tools to ensure the precise, accurate, and robust calibration model. Once satisfactory model performance results are achieved, the models will be used to predict unknown samples.

Predictive

Calibration models are uploaded into an online FTNIR analyser for quality specification results prediction of unknown samples. This predictive system aids continuous monitoring of the blending process. Periodic verification of the predicted results is essential to confirm the calibration model and online FTNIR analyser performance is as per requirement.

Prescriptive

Leveraging on the continuous monitoring of the blending process, Smart Product Blending System can elevate a predictive system to an authoritarian system by integrating instrumentation with online analysers to perform seamless monitoring and control.

RESULTS AND DISCUSSION

System Architecture

The underlying concept of this innovation is based on the strategy of an online blending with intelligent and fast chemometrics multivariate data analytics to make the necessary adjustment in the ratio of the blending components to meet the quality specification of gasoline. The analytical technology application comprises spectroscopy technology and chemometrics multivariate modeling methodology, while instrumentation control includes Blend Property Controller (BPC) and Tank Quality Estimator (TQE). BPC, BRC, and TQE are installed at Distributed Control System (DCS), a computerised control system for a process or plant.

Fourier Transform Near Infra-Red (FTNIR) analyser coupled with the calibration model developed using a chemometrics multivariate application is installed to perform the online quality measurement and continuously monitor gasoline product quality

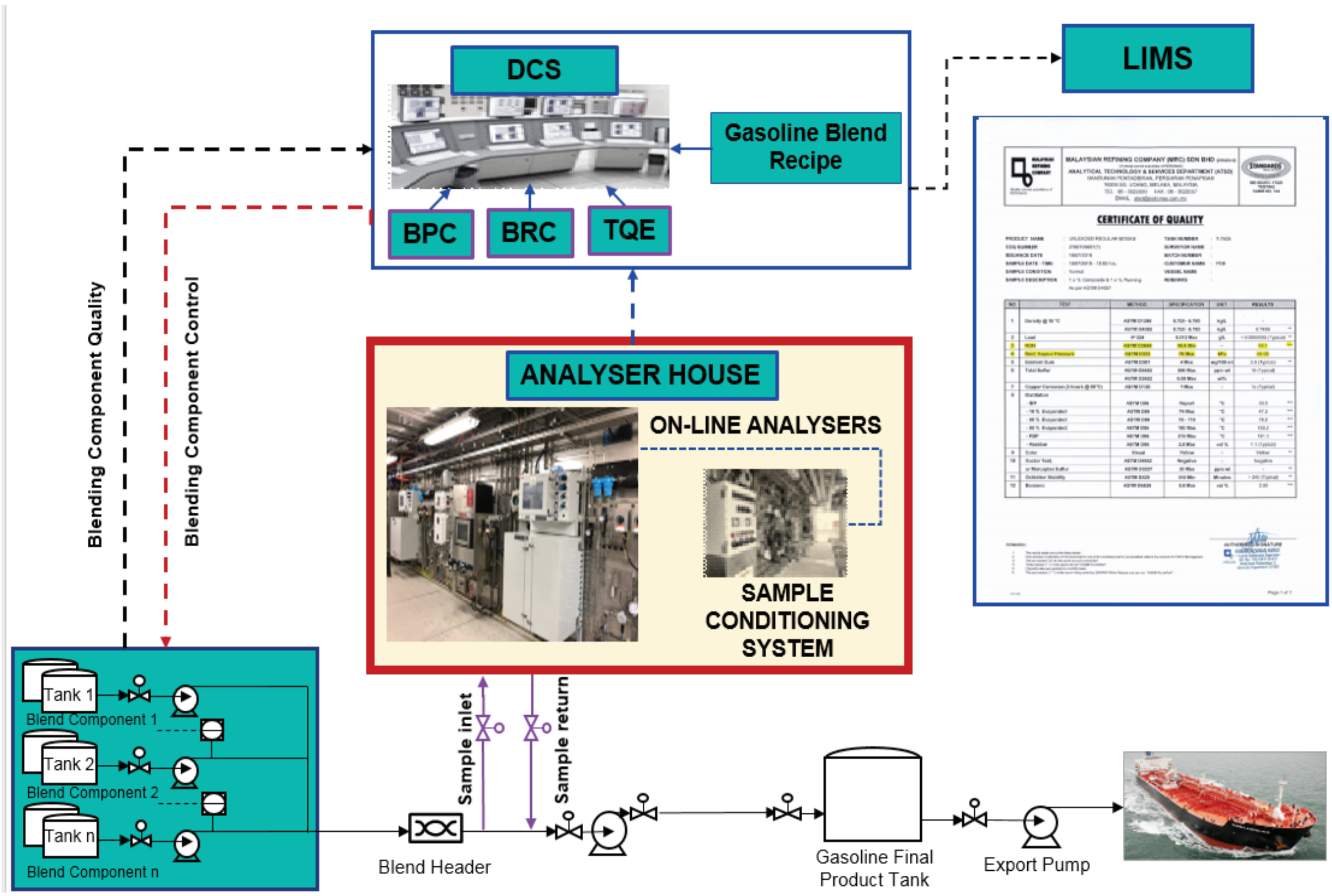

Figure 2 Overall Architecture of Smart Product Blending System

blending process. The use of chemometrics multivariate calibration models enables the FTNIR analyser to produce results for all the quality specifications such as RON, vapour pressure, density, olefin, benzene, oxygen, aromatics, oxygenate, initial, intermediate and final boiling points simultaneously in a single analysis, every 4 minutes' cycle time.

Each blending component contributes distinctively to each quality specification. The manufacturing cost for each blending component is also different [1]. BPC controls the critical constraint quality specification such as RON and vapour pressure to achieve the target value based on the input it receives from the online FTNIR analyser. It makes necessary adjustments through minimising the high-cost blending components and maximising low-cost blending components without jeopardising the final product quality. This facilitates real-time control of the blending process, which results in a successful blending process at all times, with zero re-blend.

TQE, on the other hand, is an algorithm tool used to estimate the final gasoline product tank's quality, based on averaging of continuous gasoline quality specification results it receives from the online FTNIR analyser and the tank heel quality. Upon completion of the blending process, TQE calculates Tank Average Value (TAV), the final quality specification of a specific tank, to be used for certification. TAV is automatically updated at Laboratory Information Management System (LIMS) to produce the final product certification. Hence, reducing the final product certification analysis duration to a mere 30 mins instead of 8 hours.

Value Creation

Besides improved online blending monitoring and control, Smart Product Blending System has other significant benefits as well. Post-implementation of this innovative system, the PETRONAS refinery has recovered accumulated savings of USD 130 million over 10 years.

This system can address many pain points faced by refineries, namely high product quality giveaway or off-specification product quality, leading to high re-blend rate and demurrage cost.

Two critical constraint quality specifications are RON and vapour pressure which need to be controlled throughout the gasoline blending process to minimise the quality giveaway as much as possible and to avoid off-specification product quality. Quality giveaway refers to a higher value of gasoline than specified in the quality specification [2]. Monetised value for the RON giveaway is USD 1.00 /bbl per 0.1 Octane Number and for vapor pressure is USD 0.40/bbl per 1.0 kPa. Post-implementation, this advanced system has significantly reduced giveaway tenfold for RON from the highest octane number, which is 0.23to 0.03. RVP giveaway has dropped from the highest, which is 7.4 kPa, to 1.2 kPa. Figures 3 and 4 illustrate give away comparison before and after system implementation.

Other benefits of this system are a reduction in product inventory holding cost and product storage availability. In line with value engineering, the implementation of this system paves the way for free-up availability of existing product tanks or eliminate any hold-up tank. This saves capital cost and also provides flexibility to other users of the existing tanks. The Refinery and Petrochemical Integrated Development (RAPID), PETRONAS's most significant project, to date has benefitted once-off capital cost saving of USD 10 million by eliminating three new product tanks at the refinery.

Besides that, Smart Product Blending System has successfully resolved arduous and time-consuming manual sampling and manual laboratory analysis during the actual blending activity.

CONCLUSION

The system is aligned with Industry 4.0 Best Practice to increase efficiency and minimise product quality giveaways, translating to attractive economic returns. It has a high potential to be replicated in the gas processing and petrochemical industry, especially for final products such as LPG or individual Butane or propane product.

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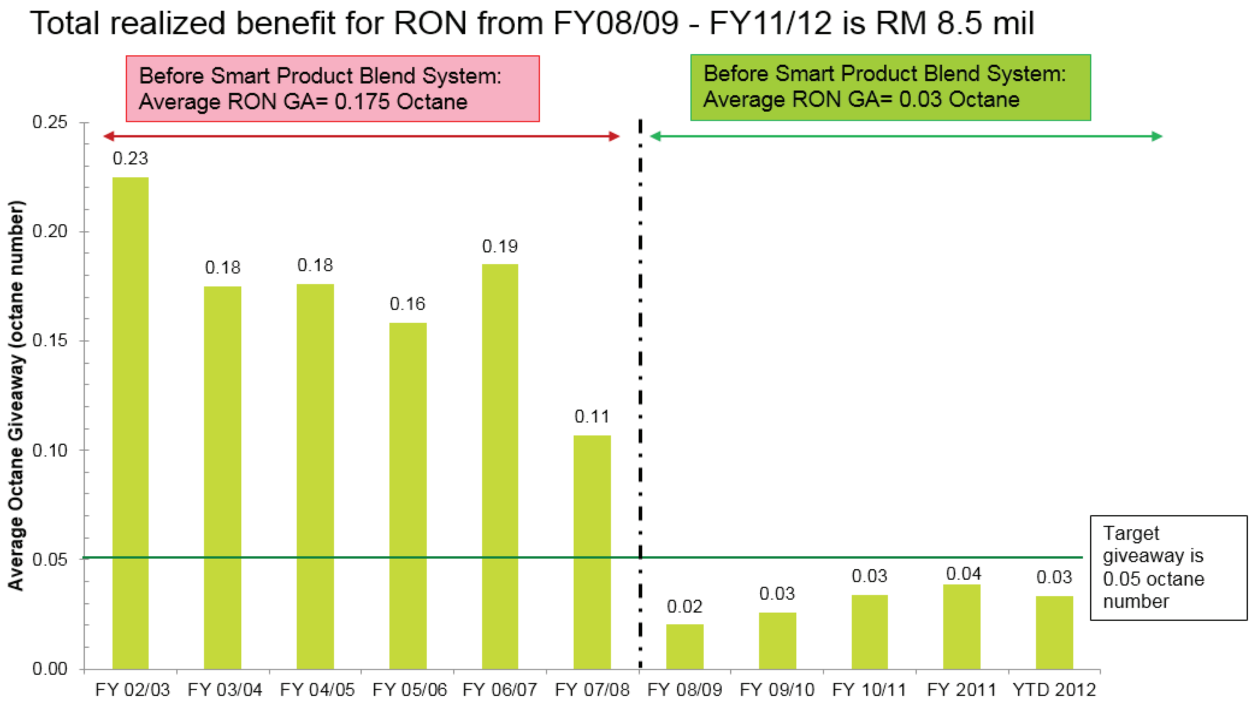

Figure 3 Reduction in RON Giveaway After Smart Plant Blending System Implementation

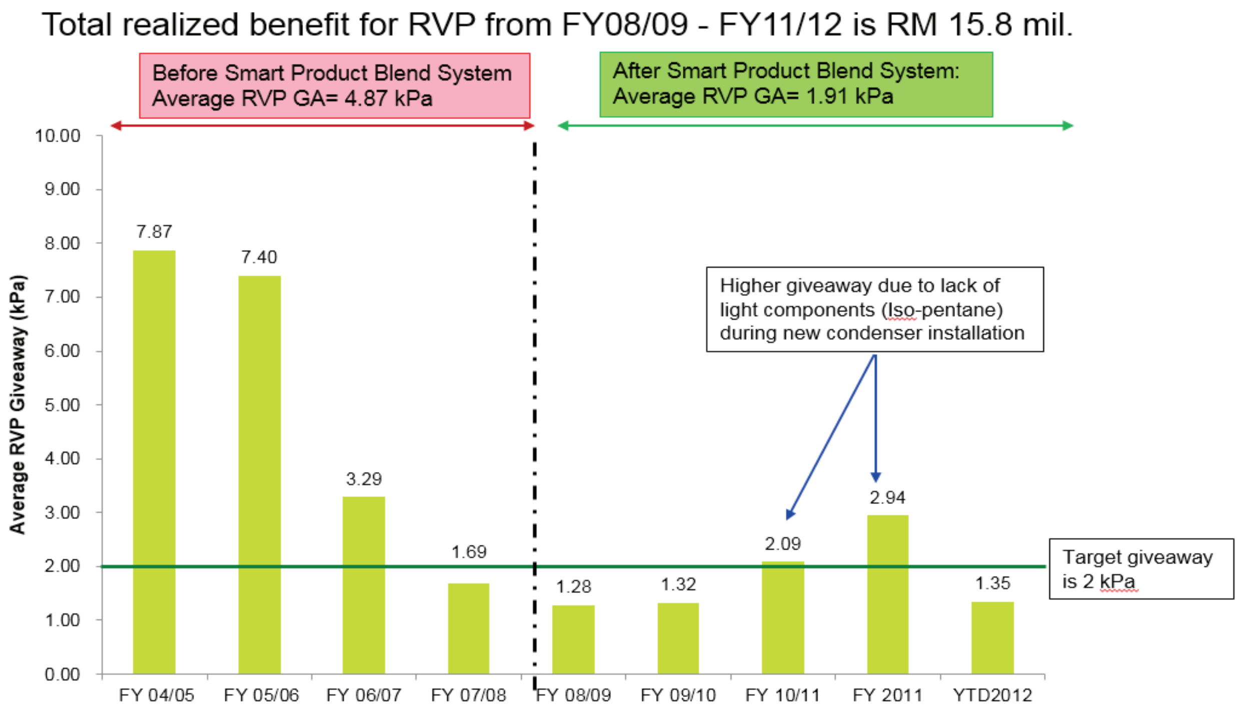

Figure 4 Reduction in RVP Giveaway After Smart Plant Blending System Implementation

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