Development of a NIR project in the petroleum industry

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Introduction

With the aim of being competitive, the Petroleum Companies need to reduce process costs to the maximun.[1] The use of on-line NIR analysers allows them to control these processes in a more effective way, so providing real-time process stream characteristic data.

Analysers must fulfil the refineries demand of rapidity, repeatability and reliability. In addition, they must be robust enough to stand the process environment (vibrations and temperature variations) with a minimum of maintenance and the maximum of effective working hours.

The carrying out of a NIR project requires the effort and commitment of a multidisciplinary team. The team must be constituted by workers from different areas of the Company, and each of them must understand his tasks, and the final target and objective, which must be established and coordinated by a unique management. This is the only way to achieve the success in a NIR application. An example of NIR application is the on-line control of gasoline or diesel blendings.

Installation of on-line control systems based on NIR spectroscopy

General considerations

We are starting putting into account general considerations, which are not exhaustive, and to which more considerations can be added. We would like to point out that the system we are referring to is an industrial application and not a scientific development. Therefore, the project is a result of an initiative created by a team in a plant. This initiative could be due to the following reasons: the necessity of real-time data in the advanced control systems and plant optimisation; the necessity of a concrete unit control; or sometimes, to the decreasing of the analytical costs.

This leads immediately to the necessity of justification of two of the aspects of the project:

Technical feasibility of the measure needed to give a solution to the demand, and that in consideration of the accuracy and reliability of the obtained data, the measurement response time, in frequency and in delay of them, the inactivity periods of the system due to maintenance, failures, etc.

Economical feasibility of the project and its best option before other possible solutions that can also satisfy the demand proposed by the plant team.

These two factors begin to mix together when one has to compare them with alternative systems. For example, if one's demand is to know the octane characteristics of a gasoline and he is thinking in two alternative systems, one of them on-line engines and the other based on NIR spectrometers, these techniques are so different that a homogeneous analysis is not easy, unless one of the systems proves better than the other in all possible comparisons.

To choose among various systems one must compare the following aspects: the difference in precision, the use or no use of chemometric techniques, the installation and maintenance costs, the necessity of qualified personnel, the inactivity hours, the contribution of complementary information, the complexity of the data quality acceptance systems and so on.

Once the decision of choosing the solution of a NIR system is taken, it remains the selection of the system to be implemented. This selection is divided into two parts:

The first part refers to the type and model of hardware to be used:

Type of spectrometer

Analysis multiplexed system, if control of more than one line is required

And, Sample Conditioning System, if necessary

The second part refers to the design of the kind of assistance with which the system is going to be installed and maintained. This specially is associated to which kind of assistance the Company needs, both internal and external.

The external assistance could be contracted through the same supplier or through a different entity, being public or private.

Sometimes, certain suppliers insist on offering both, hardware and external assistance. Nowadays, this is not usual, and almost all the suppliers are open to different ways of collaboration. But, sometimes, the necessity of using some kind of softwares or parts of the instrumentation makes necessary some defined sort of contractual relation, in order to maintain them updated.

Although technical factors should prevail, cost factors are seriously taken into consideration. Generally, the system selection is a decision in which many factors play a part.

The selection of the type of spectrometer, traditional dispersive, Fourier Transform, Diode Array or Acousto Optic Tunable System, is normally related to the specifications in stability, repeatability, resolution, accuracy, signal to noise ratio, and so on, that the different manufacturers usually give and in the selection one must take into consideration the necessity of models used in different control units, if more than one exist. In this case, the application necessities are not always the same and the selection can be different in each case.

The same happens with the selection of a multiplexed system. The selection of a mechanical, optical or even mixed multiplexer, depends on the type of application.

The cell cleaning time delays for the mechanical systems, the multiplication of cells and the costs for the optical systems, lead to a dependence between the selected multiplexer and the type of sample one is going to treat. For example, it is not the same to clean a cell used to analyse a property of platformate A and B, as a cell in which one tries to measure in a consecutive way the vapour pressure of a gasoline and then the initial boiling point of a Light Cycle Oil.

Obviously, if the selection of the type of probe is an in-line one, then, the optical multiplexer is required.

The Sample Conditioning System design is normally associated to the sample, the presence of water, solids and so on. The necessity of pressure, flow and temperature control is normally a well-known matter within the plants.

Here, there are two aspects to be noted. Firstly, anticipate a simple measurement system of samples external to the system which one wants to measure, as a control for measurement model development or model transfer. Secondly, anticipate sufficient automatic and manual sampling points for their analysis in the laboratory.

Finally, it remains a point to be treated, the availability of a system in the laboratory, which should be twin optical with the plant system.

It is advised to acquire this system for the following reasons:

1. - It means a support in the initial model development, although the on-line system is assigned for it.

2. - It is a control instrument for the on-line system, to detect deviations of this system that are not attributed to the model.

3. - It works as a bank test for new applications.

4. - And finally, it is a support to the laboratory work.

With regard to the second point that has been quoted before, relating to the different types of assistance, this is an issue to be decided according to each installation resources availability. Every possibility is admitted here, the Company could take up all the assistance, assuming the model development and maintenance, communications and exploitation software. The Company could as well take the decision of contracting all the services from an external entity. In any of the two possibilities the spectrometer maintenance must be shared by the Company and the external entity.

Generally, it is always preferable to have a professional team in the Company with an adequate knowledge of the system, and all the necessary tools for its function, in order to carry out the tasks. The team should have at least a full knowledge of maintenance, being it mechanical, communication, as well as modelling. If the Firm lacks such qualified technical team, it should start creating one for the future.

All this decision-making has influence, and at the same time is determinant on the selection of the supplier.

There are varieties of offers today from the suppliers, which call for preselection. At this point a knowledge of the application field is important as well as a constant contact with the suppliers and a frequent check of the state of the art result to be vital. It is important to compare the information from the suppliers with that of the users close to the application chosen to get a more objective information related to the reliability and the quality of the suppliers, and specially to find out if there had been any problems in the development of their systems.

The contact with different possible suppliers must clarify which of them have the experience and reliability necessary to be taken into consideration in an offer request.

The following point requires a bit of reflexion:

It is generally clear that the NIR technique has been firmly established and its usage wildly approved.

However, the installation of on-line control NIR systems, at least in some of our plants, has some different characteristics in comparison with that of conventional on-line control systems, such as temperature, flow and pressure control analysers, sulphur analysers, cloud point analysers, etc.

In all these conventional systems, of which there is a lot of experience in plants, the installation, calibration and maintenance responsibilities are perfectly shared among the team.

There is an organized structure, with the necessary resources, in charge of these system performances.

To start up the installation of an on-line control NIR system for the first time in a plant, there must be a team of skilled technicians on spectroscopy, chemometric, information technology, etc. The technicians in charge of the maintenance of conventional analysers lack some of the skills, which the NIR technicians have.

On the other hand, since the plant team is not very familiarized with NIR systems, at least in the first moment, it needs more time than the one needed for other types of installations to get used to its applications.

Obviously, the different tasks that must be carried out require the collaboration and co-ordination of different areas or groups within the Company, such as analysers, maintenance, processes, information technology services, analytical laboratories, and so on.

Unfortunately, all these groups are normally in charge of other tasks that usually require urgent solutions, therefore they could have not enough time to carry out their new responsibilities, specially when an increase in human resources is not predictable, as sometimes happens. And here lies the main problem. It is important that all the groups involved carry out the responsibilities of the tasks they are in charge of, and prepare the necessary resources to do them.

For that, the personnel capability and skills and the time employed by the project manager are very important.

To obtain a successful project, the following main factors should be taken into consideration:

Distribution of tasks in a clear and effective way, in order to create and maintain a co-ordinated working group.

Provision of personnel and technical resources at each step of the project,

And the establishment of an easy and effective co-ordination among the different groups that are involved, among the groups within the Company as well as the external support groups that could exist.

It is not so important to which group the leader of the project belongs to, as his capacity to understand the problem and its different aspects, specially his capacity to encourage the team to assume their new responsibilities.

One should not forget that probably, the selection of the human team, is the most important and difficult factor to obtain a successful project, the sample conditioning system is as important as the analyser or even more, and the profitability of the NIR system is justified as long as it is coupled to an optimiser system.

Development of a NIR system installation project in a refinery

The following example shows how the development of a NIR project in a Refinery could be.[3]

It is a NIR system installation project in the gasoline blending line in one of our plants.

In the installation of the on-line NIR system some steps were taken: the study of the necessity; the feasibility study; offer request; installation of the NIR system, commissioning, start-up, and site acceptance test.

Firstly, a necessity was detected and analysed. This necessity appeared in a moment in which there was an installation project of an optimiser system in the gasoline blending. This system required information, almost at real time, of the gasoline qualities that was being formulated, especially those related to the Octane Indexes.

By then, the Octane Index measurements were being made off-line in the laboratory with some hours of delay that led to a quality give-away in the formulation of the gasoline. This was due to the necessity to work with a security margin of about 0.5 in the Research Octane Number in order to get the established specifications, unless one wanted to have a final intermediate tank retouches to obtain the recommended quality.

A study group was created with representatives of the different groups involved in the project.

This group decided to work with on-line systems instead of off-line systems, and studied two possibilities of them, on-line engines and NIR systems.

With regard to the on-line engines, we can quote the following advantages:

They are similar methods to the recommended sale standard, and also,

They are well-tested systems

However, among the disadvantages of the on-line engines, it is worth to point out the followings:

The investment and maintenance costs are high

The maintenance is also high,

And finally, the system precision is low

On the other hand, among the advantages of the NIR systems we can quote the followings:

They provide information at almost real-time speed

They have lower costs than the on-line engines

They have a high repeatability

The system maintenance is low,

And finally, they offer the possibility to analyse various streams and various variables of each of them.

Unfortunately, the NIR systems have also some disadvantages, as for example:

These systems are not so well tested as the on-line engines.

The measurement system is quite different to the sale standard, and

They require the use of chemometric techniques.

It was decided to study the possibility of installation of a NIR system. For this reason, a feasibility study was started by the study group.

There was in the Company former experience on this type of control. Previously it was tested on an on-line NIR system in several of our refineries with acceptable results.

We spoke to different suppliers and visited some users of the system who had moved from control in laboratory and on-line engines to NIR control systems. All their comments were documented.

A previous cost estimation and system profitability were made and we obtained a favourable result to the installation of the system.

The study group checked the additional possible applications which could be obtained and it concluded the control of seven of the main streams which were implicated in the gasoline blending: commercial gasoline, reformate, alkylate, isomerate, naphtha from two Fluid Catalytic Cracking units, and MTBE, and the control of the Octane Indexes (Research Octane Number and Motor Octane Number), distillation (Initial point, 10 %, 50 %, 90 %, End point), Reid Vapour Pressure and MTBE percentage (in the case of the commercial gasoline and the MTBE streams).

After the search for possible suppliers and after speaking to a few number of them, and from the information we could collect about their experience and specialization in the field and the opinion of various users to which we had access, we requested three of the suppliers for an offer.

Once the offers were received, it was necessary to ask for explanations about some technical issues, which were not sufficiently explained in the offers.

When the explanations about the three offers were received, they were deeply studied and the offer was assigned to one of the suppliers for the amount of $ 650.000 for the purchase of a system, which included:

NIR analyser to measure 9 variables of 7 streams

12 channel Optical multiplexer, 5 of them remained free for new applications

Sample Conditioning System

Exploitation and communication programmes

Laboratory system, which was twin optical with the process system

And, training and specialization course of three days on hardware, software and maintenance.

The different tasks were efficiently distributed among the groups involved in the project, and all of them assumed their new responsibilities.

Our Company was in charge of the sampling and the laboratory analyses, which started five months before the project start up. Around 120 samples per stream were collected and their spectra were recorded in a NIR analyser.

Our Company developed the initial multivariate calibration models for each parameter of each stream. Besides, it carried out the model on-line installation, tuning, validation and maintenance.

The supplier was in charge of the construction and installation of the laboratory system, the process system and the sample conditioning system.

The supplier also offered us a 10-day technical assistance for the system start-up.

It assumed the responsability of training the Company personnel in process spectrometer maintenance. The treated issues were: operation, hardware and spectrometer configuration. The training personnel were provided by the supplier. It offered us the possibility of receiving the training in our facilities or in his and we chose the first option.

The process spectrometer maintenance was carried out by both, the Company and the supplier.

A meeting was held with the supplier for the project start-up, known as kick-off meeting. In this first meeting, among other things, a working plan was established which included activities related to engineering, hardware design, programming, sampling and modelling. These activities were collected in a time schedule with their progress in time, as we can see in Table 1:

Table 1. Time schedule for the NIR project

Process NIR Project Management Schedule	Timeline (months)									
TASK	1	2	3	4	5	6	7	8	9	10
Laboratory system reception	▌									
Sampling & laboratory analyses	■	■	■	■	■	■				
Process system construction & reception	▐	■	■	■						
Installations and SCS construction & assembly	▐	■	■	▌						
Initial model development				■	■					
Process system installation					▌					
Model on-line installation & tuning						■				
System start-up						■	■			
System validation & commissioning								■	■	
Data and model follow-up & maintenance										→
Training						▌				
Follow-up meeting date				▌						
One-year assistance										→

We had some delays in the project in comparison with what was established during the kick-off meeting:

The Sample Conditioning System arrived two weeks late.

During the sampling campaign, there was a change in one of the streams composition, so the sampling was extended for an additional month. This led to a delay in the model development of about one month. Finally, the total project lasted 10 months.

Conclusions

A considerable number of NIR system application projects have been carried out and others are being carried out at this moment in our Company. Some applications have been implemented in our laboratories, pilot plants and industrial processes.

The development of these projects has allowed our Company to accumulate technical know-how in chemometric methods and to have practical experience in NIR process installations. This has created favourable conditions to obtain the biggest advantages in the application of these new technologies.

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Reference

1. G. Büttner, The use of NIR analysis for refineries. Analyst, 125, 367-374 (2000).