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Modern Solutions for Monitoring and Control of Hydrotreated Diesel Oil Additivation Phase

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Abstract: The aim of this study was to identify the optimum solutions for additives dosage in Diesel Oil Hydrotreating Unit. The additivation phase in HDS unit has it`s own importance due to the fact that facilitate production of commercial Diesel fuel improving quality specifications for this product. The main performance criterions considered to establish the reliable solution were: reduction of additives technological consumption through accurate dosage, achievement of quality specifications for commercial Diesel oil, elimination of dead time due to bad control of additivation phase. The new concept was verified through dynamic simulation in similar conditions with industrial proces using two consecrate simulation programmes Hysys and Aspen Dynamics. Keywords: optimal control, ratio controller,dynamic simulation.

1. Introduction

Hydrotreating is a catalytical process for oil cuts having as main targets elimination of sulphur, oxygen and nitrogen based compounds from several oil products converting these compounds into H_2S, H_2O şi NH_3.Hydrotreating process of gasoil includes as it is indicated in figure 1 the following technological phases:

- reaction phase.
- hydrogen rich gas separation, compression and recycle phase.
- hydrotreated gasoil stripping phase.
- additivation phase recently added in the process (the additivation of product directly into the technological line to the tank farm offers the reduction of energy consumption necesary for mixing the oil product with additive into the storage tank),[1].

Commercial Diesel oil used as fuel results after additivation of hydrotreated stabilized product.The Diesel fuel (EN 590) includes additives to adjust several quality characteristics: cetanic number, cloud point and lubricity presented also in table1, [2].

Additives injection rates and type of additives are specific to every refinery and represent confidental informations related to the market strategy.

The classical solution for additive dosage is based on small capacity reciprocating pumps. The control of additive injection for the pump is realised mechanically through piston scroll adjusting operation done by the field operator. This solution although cheap induces dead time in operation and may compromise the product quality due to inaccuracy of method. When the Diesel oil feed flowrate to the reaction phase is modified and also the hydrotreated Diesel oil to the tank farm variates (increasing or decreasing), situation often present in normal operation of unit, this classic additives injection system showed bad performances due to high inertia induced. Considering concurential conditions on today`s oil products global market, aspects regarding to the lack of quality may generate serious commercial problems to oil processing companies, [2].
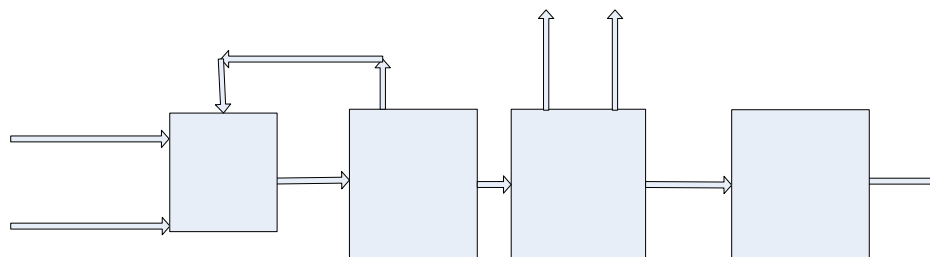

Figure 1.Simplified flow diagram of Diesel oil Hydrotreating Unit

Table 1 Quality specifications for commercial diesel oil

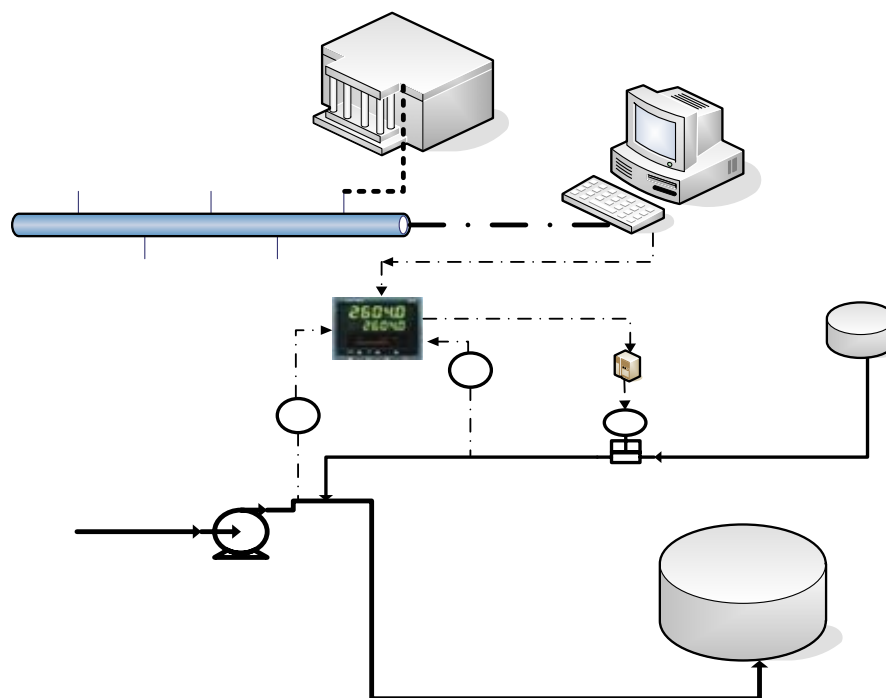| Product type	Quality specifications	Units of measure	Quality characteristics values
Diesel oil EN 590	Density at 15 ^{0}C	kg/m^3	820-845
	Distilare: % v/v distillate at 250 ^{0}C	% v/v	<65
	% v/v distillate at 350 ^{0}C	% v/v	min. 85
	95 % v/v distill at	^{0}C	max. 360
	Cetanic number	-	*min.51*
	Cetanic index calculated	-	min.46
	Cloud point	^{0}C	*Summer season: Clasele: A B C +5 0 -5 Winter season: Clasele: D E F -10 -15 -20*
	Lubricity, (wsd 1,4) la 60 ^{o}C	μm	*max. 460*
	Copper strip corrosion	class	1
	Water content	mg/kg	max. 200
	Sulphur content	mg/kg	max. 350

Figure 2 Technological system proposed for monitoring and control of additivation phase.

2.**Experimental**

In order to eliminate all the technological deficiences generate by the classical system still present in many refineries in this study it was considered important the implementation of automated additive dosage system including as main control device a flow ratio controller The flow ratio controller includes a specific control technique for process variables based on a fixed ratio (the setpoint).

The controller adjusts a secondary flowstream continuously calculating the ratio between the main stream (master variable) and the stream wanted to be controlled, correcting the curent ratio value between both flowstreams. In our case the master variable is flowrate of hydrotreated Diesel oil pumped to the tank farm and the controlled variable is additive flowrate adjusted according to the ratio controller setpoint, [3].

In figure 2 it is presented the proposed technical solution for monitoring and control of commercial Diesel oil additivation phase.

The ratio controller used, figure 3, as main element of rigouros control for hydrotreated Diesel oil additivation offers many privileges for this technological phase like: flexibility, precision in operation, stability. All the advantages mentioned determines us to conclude the necessity to revamp the old system including the solution proposed.

It was considered the oportunity to use the tandem ratio controller-variable speed drive associated to the electrical drive of injection pump. The variable speed drive offers flexibility in operation through continuous modification of pump`s drive speed determining a proper additive dose injected according to process requirements.The ratio controller may be also interconnected through a serial interface RS 232 or RS 485 to a computer (with HMI functions like supervising and remote setpoint). The PC through HMI facility offers to the operator in charge with additivation phase the posibility to adjust the setpoint of ratio controller (in fact ratio of additive flowrate/Diesel oil flowrate). If the refinery where it was implemented a similary system with the one proposed in this study has a distributed control system (DCS) the advantages of the new system are important due to comunication compatibility between local remote setpoint PC and central control room. The additivation system may be supervised not only locally but also hierarchically by refinery shift supervisors from central control room of the refinery,[4,5].

In order to verify the proposed technological solution regarding to ratio controller utility it has been used for modelling the system in operation two dynamic simulators Aspen and Hysys Dynamics.
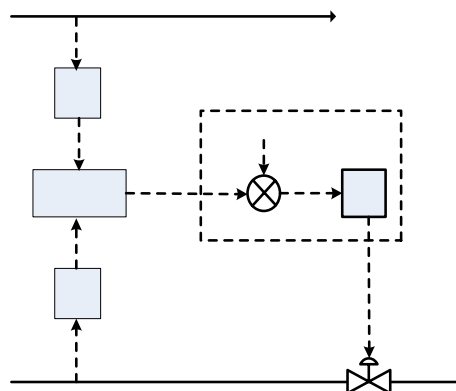
3. Results and discussion

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Figure 3. Ratio controller concept.

Simulation conditions:

The simulation had to identify the differences between both systems the classical and the proposed version: the classical system where the field operator adjust the additive dosage mechanically after he started up the pump and the proposed version where the ratio controller manages during the time the additivation phase.

The technological schemes according to the dynamic simulation model are presented in figure 4 and 5. The thermodynamic model used for simulation was SRK.

In table 2 it is presented the distillation curve specific to hydrotreated Diesel oil and used as input data for simulated model.

Table 2 Distillation curve for hydrotreated Diesel

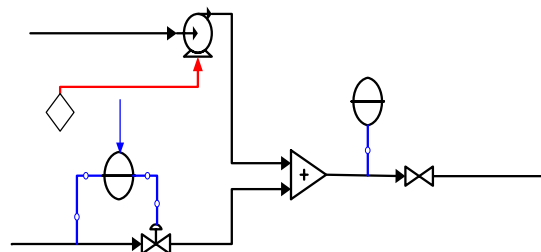| T, ^{0}C	190	213	244	260	284	324	362
% vol	0	10	30	50	70	90	97
d_4^{20}=839 kg/m^3							

Figure 4. Simulated technological scheme for classical version
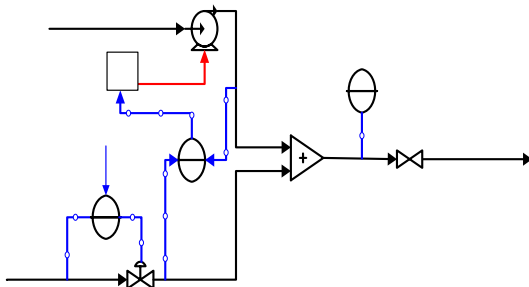
Figure 5. Simulated technological scheme for proposed version

To determine the flexibility of proposed control system for additivation phase it has been done several simulations for both variants in presence of the same disturbance in the system step variation of hydrotreated gasoil flowrate from 50 to 75 t/h (situation that curently occur due to the market request in the technological process).In these conditions it was monitored the system`s response regarding to the additive concentration on stream .The concentration of additive on stream was recorded continuously with on line analyser (AIC 100),facility offered by the dynamic simulator, [3].

In table 3 are summarized input characteristics for the most important streams part of dynamic model simulated.

Table 3   Characteristics of simulated model`s streams

Parameter	Unit of measure	(1) Hydrotreated Diesel oil	(2) Cetanic number additive	(4) Additivated Diesel oil
Flowrate	kg/h	50000	25	50025
Pressure	barg	1.1	1.1	1.1
Temperature	^{0}C	50	40	50
Ratio additive/Diesel oil	kg additive/kg Diesel oil		$5*10$	

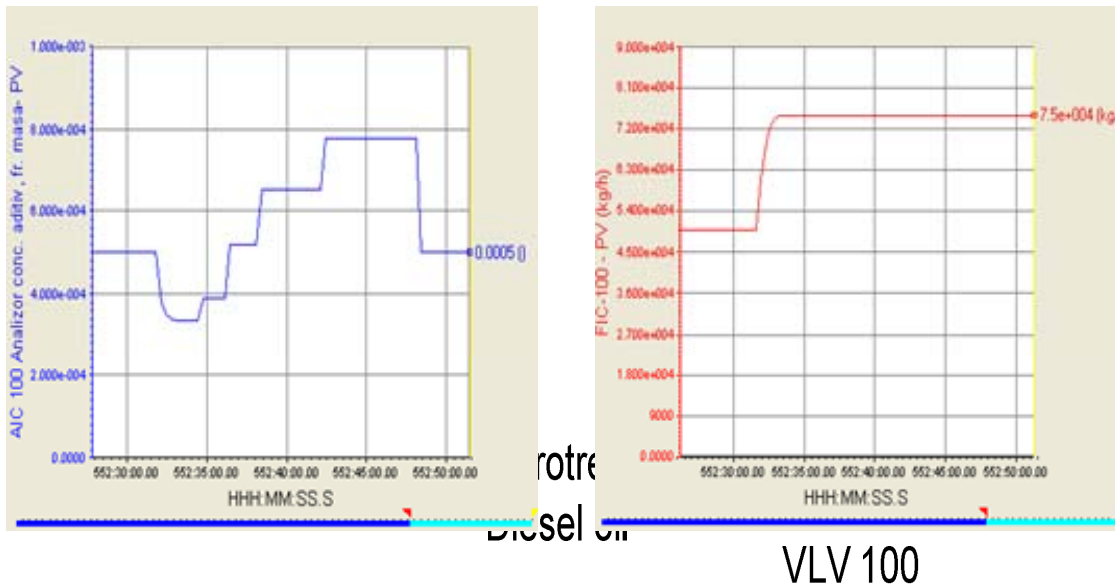
Figure 6. Additive concentration on stream (left side trend) when hydrotreated diesel oil flowrate has
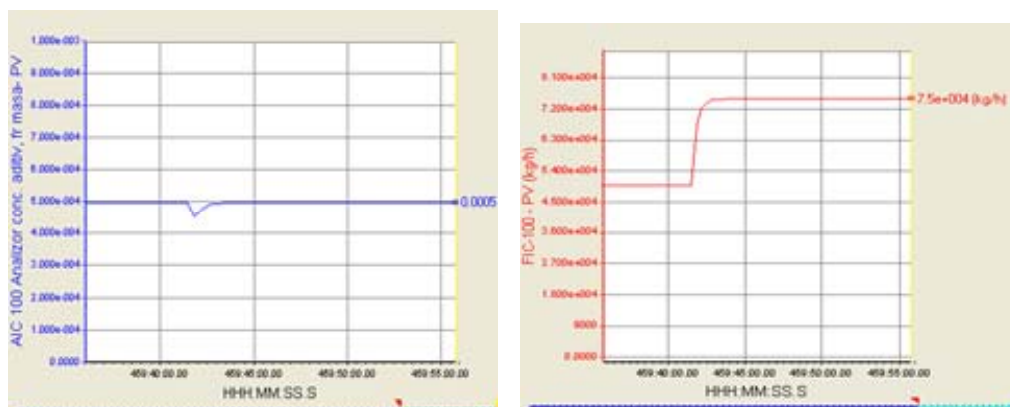a step variation from 50 t/h to 75 t/h (case whithout ratio controller)

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Figure 7.Additive concentration on stream (left side trend) when hydrotreated diesel oil flowrate has a step
variation from 50 t/h to 75 t/h (proposed version with ratio controller)

To determine the flexibility of proposed control system for additivation phase it has been done several simulations for both variants in presence of the same disturbance in the system step variation of hydrotreated gasoil flowrate from 50 to 75 t/h (situation that curently occur due to the market request in the technological process).In these conditions it was monitored the system`s response regarding to the additive concentration on stream .The concentration of additive on stream was recorded continuously with on line analyser (AIC 100),facility offered by the dynamic simulator [3].

Trends resulted from simulation were presented in the figures 6 şi 7 and from a rigurous analysys results a better flexibility for proposed system. The transitory regime untill the effect of disturbance was completly eliminated is shorter for proposed control version. The time indicated in the trends on axis marked HHH:MM:SSS in which proposed system was capable to eliminate the disturbance (additive concentration achieving the initial simulation condition $5*10^{-4}$ kg additive /kg gasoil) is shorter than the old controlling system`s case.In figure 6 in the variation trend of additive`s concentration from hydrotreated Diesel oil stream it may be observed that the transitory regime is longer. In this second case the quantity of low quality product is higher and financial losses for refinery is significant.This second trend shows the response of the classic system obtained through simulation when the field operator try to adjust the additive flowrate mechanically.

4. **Conclusions**

During the simulation it was considered the influence of disturbance over one of those three additives used for commercial Diesel oil, but in the same way the solution may be addopted also for the other two additives (cloud point and lubricity additives). The situation is more unfavorable regarding to the dosage precision when the field operator whithout a modern control system must manage all the additives for commercial Diesel oil. Field operator has to recalculate all the necesary injection additive`s doses in order to eliminate the effect of disturbances.This operation decrease also the precision in operation for classical injection systems.

The proposed variant facilitate a modern and optimum control reducing the human involvment in operation and also eliminating dead time from the process. In this new control model the operator will only monitor the process PC`s display and will refill the additive storage vessels.Implementation of such a new control system for additives dosage offers many advantages, the most important are: achievement of quality standards for commercial Diesel oil low technological consumptions of additives according to the technical design specifications. Control and monitoring systems similar with the one proposed may be adopted for all three additives used in process with significant results.

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