AGENT-BASED MODELING AND SIMULATION OF DEHYDRATION PROCESS

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KEYWORDS

Agent-based modeling and simulation (ABMS) , Industrial system, Multi-Agent Systems (MAS), Multi-agent platform JADE.

ABSTRACT

Agent-based modeling and simulation (ABMS) is a new approach to modeling autonomous systems and interacting agents. This method is becoming more and more popular for its efficiency and simplicity. It constitutes an approach in the field of modeling complex systems. Indeed, ABMS offers, contrary to other types of simulations, the possibility of directly representing the simulated entities, their behaviors, and their interactions without having to recourse to mathematical equations. This work is a contribution in this sense, the goal is to propose an agent-based model to simulate an industrial system. The latter presents the problem of complexity, which can be mastered with the Multi-Agent Systems (MAS) approach. Our model is validated by a case study of the natural gas dehydration process. The latter is consolidated by a simulation made in the multi-agent platform JADE (Java Agent DEvelopment Framework

INTRODUCTION

Agent-based modeling and simulation (ABMS) is an approach to the field of complex system modeling. In this framework, the model is composed of autonomous interacting agents. The agents have behaviors described by simple rules, and often interact with other agents, which in turn can influence the individual and general behavior of the system (Macal and North, 2005).

Complex systems can be viewed as a set of interacting agents or entities such that the evolution of the system cannot be predicted by the pure integration of the laws governing these entities. Agents can represent organisms, humans, firms, institutions, and any other entity with the intent to achieve a goal (Abar et al., 2017; Roy et al., 2004). Agent-based models are particularly applied in the case of complex phenomena in which many agents or active entities interact to establish relationships and solve problems that may arise (Simon, 1969; Bertalanffy, 1968)

The modeling and simulation (M&S) approach is an activity that allows the study of a system using objects called models. Several authors agree to define the notions of modeling and simulation as the process of designing a model of the real world, and then conducting a set of experiments to understand its behavior or to evaluate different strategies within the limits of a set of fixed criteria for the evolution of the system (Fishwick, 1995; Sonnessa, 2004; Shannon, 1976; Ingalls, 2001; Shannon, 1998; Fishwick, 1997; Vangheluwe, 2008).

ABMS offers a way to model complex industrial systems. This paradigm is increasingly known in scientific disciplines such as agriculture, economics, ecology, biology, sociology, and many other disciplines (science, technology, engineering, and mathematics) (Roy et al., 2004). It is useful for simulating dynamic complex systems and for the observation of their emergent behaviors (Allan, 2010; Macal, 2016; Marvuglia et al., 2017).

Our work falls within this framework; we have opted for an approach that allows the modeling and simulation of complex industrial systems. The approach is based on the ABMS paradigm, depending on their importance, they may contain thousands of elements and even more. This is the case, for example, with oil complexes. So, what are the steps to follow, and what are the tools to use?

The idea is to model the natural gas dehydration system as a distributed multi-agent system and use a model based on representing all the elements of this system by agents, so that they can be simulated and implemented within multi-agent platforms and more particularly, the JADE platform.

This article is organized as follows: Section 2 presents a background on agent-based modeling and simulation (ABMS). Section 3 introduces a use case of industrial system to be modeled and simulated. Section 4 is dedicated to the proposed approach. Section 5 describes he implementation of the proposed system. Finally, we conclude this paper in section 6.

AGENT-BASED MODELING AND SIMULATION (ABMS)

Agent-based modeling and simulation (ABMS) is a new approach to modeling systems composed of autonomous agents. ABMS is one of the most prominent and practical methods of modeling since the invention of relational databases. ABMS is used in various fields including: complexity science, systems science, systems dynamics, computer science, management science, several branches of the social sciences, and traditional modeling and simulation. The theoretical foundations of ABMS and its applicable modeling techniques, make it a very capable and practical choice to simulate and model complex systems more effectively and easily.

In an ABMS, an agent is an atomic entity (Chaib -Draa, 1999). The agent can be reactive, in the sense that it has limited action capabilities, cognitive. To be precise, it can develop action plans, make decisions, and other 'intelligent' tasks, or hybrid in the case where the agent is both reactive and cognitive (Chaib-draa, 1996; Moulin and Chaib-draa, 1996; Ferber, 1997; Michel et al., 2009; Krishnamurthy and Murthy, 2006; Bond and Gasse, 1988; Franklin and Graesser, 1997; Iglesias et al., 1997; Fabrice et al., 2015).

There is no common agreement on the definition of an gent. In general, the term agent refers to an entity (hardware or software), which is different from an ordinary program in a way that it is endowed with autonomy for functioning in environments shared by other agents (Ferber, 1995;1997). An agent is autonomous, social, and self-directed. It can function independently in its environment and during its interactions with other agents for a specific range of situations of interest. Agents can recognize and distinguish the traits of other agents with which they can communicate and interact via protocols.

ABMS offers us the possibility to simulate real systems in which very complex behaviors emerge from relatively simple and local interactions between many different individuals. Therefore, ABMS seems to us to be the most adequate approach for the simulation of complex systems such as industrial processes. Indeed, ABMS will be particularly well adapted to the description of a system from the point of view of the activity of its constituents, i.e. when the behavior of individuals is complex (and therefore difficult to describe with equations).

USE CASE

Our work is realized in close collaboration with the Algerian oil and gas giant SONATRACH and in particular the Liquefied Natural Gas (LNG) units located in Skikda, in the east of Algeria. The goal is to create operational simulators of industrial systems used in the LNG. Our research team has conducted many similar projects by using different approaches (MAS, DEVS, etc.) (Seddari et al., 2013a; 2013b; 2014; 2015; 2017; 2021)

The operating principle of the dehydration system is based on the use of three molecular sieve bed dryers: the first one is in adsorption mode, the second is on stand-by (waiting) and the third is in regeneration.

The dehydration system can be divided into three subsystems: Pre-cooling and separation, Dehydration, and Filtration & regeneration. Figure 1 shows the technical diagram of this system.
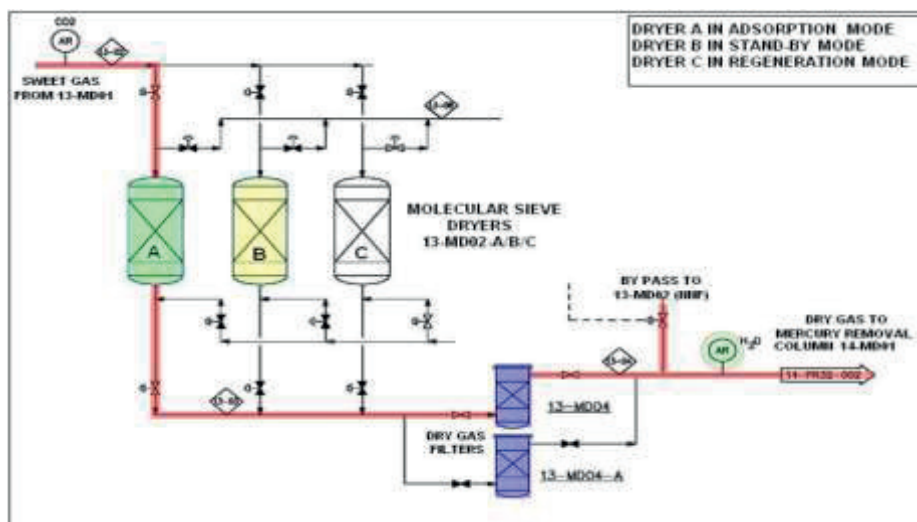
Figures 1: Dehydration System

Pre-cooling and Separation

The main function of this system is to reduce the load of 13-MD02-A/B/C molecular sieve dryers.

Cooling the NG reduces the load on the dryer by lowering the water content in the NG entering the separator drum 13-MD01 before feeding the dryer to separate and recover any water and amine coming from the decarbonization unit (unit 12). The NG at the top of the separator goes to the molecular sieve dryer arranged in adsorption mode at that time (13-MD02 A or B or C).

From the bottom of the 13-MD01, the liquids are sent to the water flash drum of the 13-MD09 dryer for further separation.

Dehydration

The dewatering system has three 13-MD02-A/B/C molecular sieve dryers. Under normal operating conditions, one dryer operates at 100% capacity in adsorption mode, the second is in regeneration mode and the third is in stand-by mode.

Gas from the 13-MD01 Dryer Feed Separator enters the top of the adsorption dryer. The wastewater in the NG is adsorbed by the dryer beds.

Each dryer is provided with type 4A molecular sieves which will each operate on a twelve (12) hour adsorption cycle. The dryer isolation valves are controlled by a sequence on the DCS. The dryer sequences are automatically programmed by a PLC from the distributed Control Systems (DCS).

Regeneration

Each 13-MD02-A/B/C dryer operates on an automatic thirty-six (36) hour cycle, controlled by the DCS. Each dryer is regenerated once its bed is saturated. This is achieved by circulating hot gas from bottom to top in the dryer.

Typical Operating Parameters

Table 1 contains typical operating variables for the dehydration system.

Table 1: Operating Variables for the Dehydration System

Tag No.	Description	Typical Value	Units
13-FFIC-1027	Nitrogen to Dryer Water Flash Drum, 13-MD09, Ratio Flow Controller	0.01	
13-FIC-1021	Dryer Water Flash Drum, 13-MD09, Water to 12-MD39 Flow Controller	1,394	kg/hr
13-FIC-1023	Dryer Water Flash Drum, 13-MD09, Water to the Oily Water Sewer Flow Controller	4,250	kg/hr
13-FIC-1048	Regen Gas Heater, 13-MC02, Regen Gas Flow Controller	Fuel gas: 90,404 / Dry Feed gas: 76,073	kg/hr / kg/hr
13-FIC-1244	Regen Gas Heater, 13-MC02, Hot Oil Flow Controller	104,347	kg/hr
13-LIC-1003	Dryer Precooler, 13-MC01, Level Controller	70	%
13-LIC-1004	Dryer Inlet Separator, 13-MD01, Level Controller	50	%
13-LIC-1022	Dryer Water Flash Drum, 13-MD09, Level Controller	36	%
13-LIC-1055	Regen Gas KO Drum, 13-MD03, Level Controller	50	%
13-PDI-1063	Regeneration Water Filter, 13-MD05, Pressure Differential Indicator	0.1	bar
13-PDI-1162	Dryed Gas Filter, 13-MD04, Pressure Differential Indicator	0.15	bar
13-PIC-1007	Dryer Precooler, 13-MC01, Propane Refrigerant Pressure Controller	6.9	barg
13-PIC-1025	Dryer Water Flash Drum, 13-MD09, Pressure Controller	4.0	barg
13-PIC-1062A	Regeneration Gas KO Drum, 13-MD03, Vapor to Fuel Gas Pressure Controller	30.3	barg
13-PIC-1062B	Regeneration Gas KO Drum, 13-MD03, Vapor to Warm Flare Header Pressure Controller	35	barg

THE PROPOSED APPROACH

The method proposed in this work is based on the use of an agent-based architecture to model the natural gas dehydration system.

The architecture defined in this work is based on Multi-agent systems (MAS), designed to simulate the operation of different dryers that compose the dehydration process.

The architecture expresses the fundamental structure of the dehydration system to be modeled and simulated. It defines the set of functional components described in terms of their behaviors and interfaces, as well as the way these components interact to properly accomplish the simulation objective of a natural gas dehydration system. Therefore, an architectural description is mainly required for the specification of the system structure.

The idea is to model the natural gas dehydration system as a distributed multi-agent system.

In the following, we will present the specifications of the different components, as well as the concepts related to their operation.

Structure of agents in the dehydration system

We will describe in what follows the structure and the functionalities of the different agents and which are:

Agent 13-FFIC-1027: The role of this agent is to regulate the flow of nitrogen to the balloon 13-MD09.

Agent 13-FIC-1021: Its role is to regulate the flow of water from tank 13-MD09 to 12-MD39.

Agent 13-FIC-1023: The role of this agent is to regulate the water flow from the 13-MD09 tank to the sump.

Agent13-FIC-1048: this agent takes care of regulating the gas flow of the regeneration gas heater 13-MC02.

Agent 13-FIC-1244: it is the agent that takes care of the regulation of the hot oil flow of the regeneration gas heater 13-MC02.

Agent 13-LIC-1003: it is the agent that deals with the regulation of the level of the pre-cooler of the dryer 13-MC01.

Agent 13-LIC-1004: it is the agent that deals with the regulation of the level of the inlet separator of the dryer 13-MD01.

Agent 13-LIC-1022: it is the agent that takes care of the regulation of the level of the water flash tank of the dryer 13-MD09.

Agent 13-LIC-1055: it is the agent that deals with the regulation of the level of the regeneration gas separation of the tank 13-MD03.

Agent 13-PDI-1063: it is the agent that deals with the regulation of the pressure of the propane refrigerant of the dryer 13-MC01.

Agent 13-PIC-1025: it is the agent that takes care of the pressure regulation of the water flash tank of the dryer 13-MD09.

Agent 13-PIC-1062A: it is the agent that deals with the regulation of the vapor pressure of 13-MD03.

Agent 13-PIC-1062B: this is the agent responsible for regulating the pressure of the steam from 13-MD03 to the hot torch manifold.

Agent 13-TIC-1010: it is the agent that deals with the regulation of the supply temperature of the inlet separator of the dryer 13-MD01.

Agent 13-TIC-1045: it is the agent that deals with the regulation of the temperature of the regeneration gas.

Valve agent: this is the agent that controls the flow of nitrogen, water, and gas to the various components of the dehydration system.

Cooling Agent (13MC-01): This agent is responsible for the cooling of the feed gas, it can communicate with the liquid propane agent (16MC-10) to regulate the temperature and can also communicate with the graphic interface to give a visual representation of the cooling agent.

Propane Agent (16MC-10): This agent controls the flow of the propane condenser valve gas (16-MC10), it can communicate with the agent (13MC-01), and can also communicate with the graphical interface to give a visual representation of the agent propane.

Separation Agent (13MD-01): This agent is responsible for the separation of liquids and reducing the water content of the gas in the dryers, it can communicate with the agent (13XV-1011) and with the graphical interface to give a visual representation of the separation agent.

Agent Reg-Valve (13XV-1011): This agent controls the flow of water winnowing unit 12, it can communicate with the separation agent (13MD-01) and can also communicate with the graphic interface.

Drying Agent (13MD-02 A): This agent is responsible for heating the gas, it can communicate with the separation agent (13MD-01) and the filtration agent (13-MD04)

Filtering Agent (13-MD04): This agent filters the gas from the dryer (13MD-02 A), it can communicate with the drying agent (13MD-02 A) and the graphic interface to give a visual representation of the filtration agent.

Security Agent: This agent is responsible for the emergency shutdown of the dehydration system, it can communicate with all the agents of our system.

In the following figure, we present the proposed multi-agent-based modeling of our industrial process.
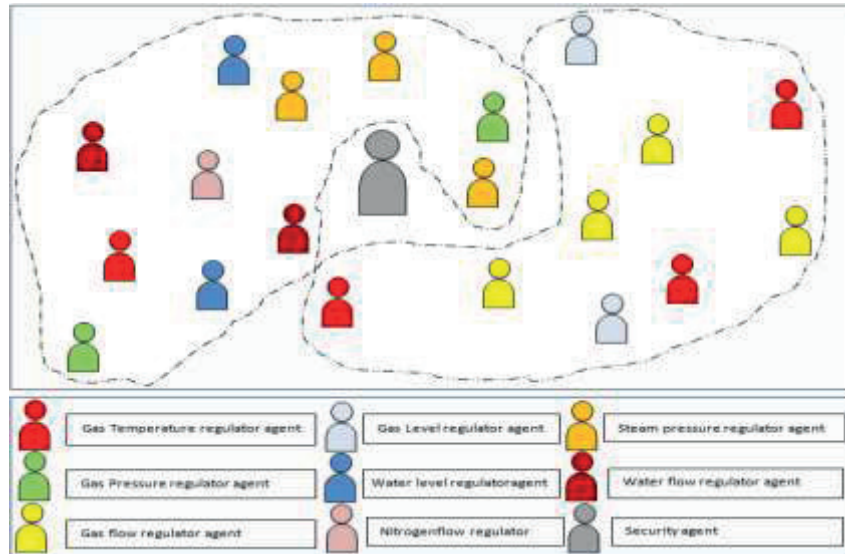
Figures 2: Dehydration System

THE SYSTEM IMPLEMENTATION

The simulator was developed by using the JADE platform (Bellifemine et al. 2008), to benefit from the power of the advanced tools offered by this platform.

The main interface of our simulator is presented in figure 3. It depicts the simulation of the dehydration system and allows the user to drive the system operation and supply it by loading different data inputs.

The simulator's graphical interfaces provide many tools permitting the operator to regulate and monitor changes in the dehydration system.

Thanks to displayed knowledge interface, the user will observe the steps of the system and may act on the input parts of the process by entering set point values and operating thresholds values and observe the behavior of the simulation consequently.

As it is intended, the simulator offers a particular range of functionalities permitting the user to follow the evolution of the dehydration system and to be ready, thus, to know its operation. Likewise, such a machine makes it potential to predict many cases: those, that square measure acceptable, and those, that square measure prohibited. further options will be further reckoning on operator needs.
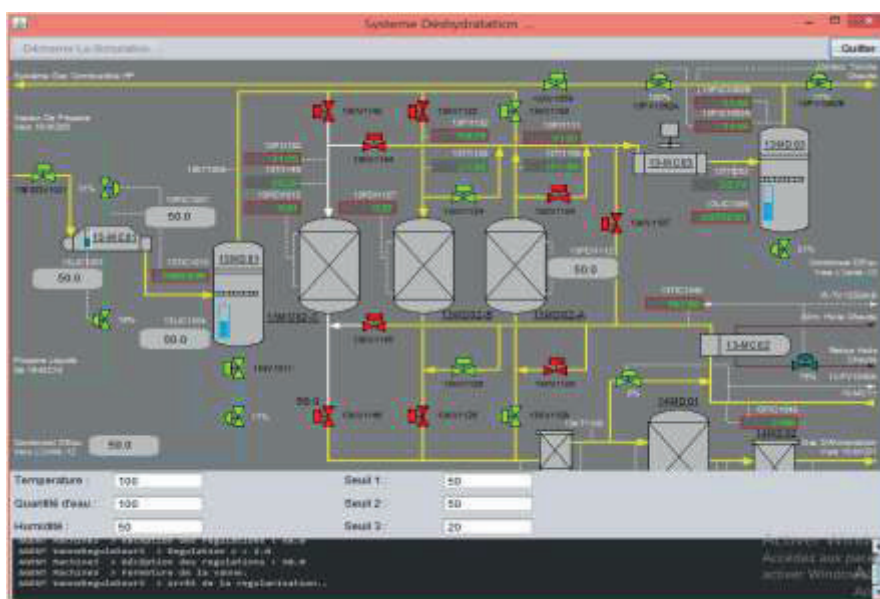

Figure 3: Graphical simulation of the dehydration system

CONCLUSION

The goal of our work is to use a rigorous and efficient method to represent and simulate a complex industrial system (natural gas dehydration process). Our approach is based on the proposal of an agent-based model, validated by the JADE platform. The major benefit of using multi-agent systems is the distribution of tasks and managing complexity. Our simulation covers the different tasks of the dehydration process such as regulation of pressures, levels, temperatures, and the control of water, Nitrogen and gas flows, etc.

The advantage of our approach is to benefit from the power of the advanced tools offered by ABMS platforms for the implementation, development, and operation of complex industrial systems. We plan to apply our approach on a larger scale by simulating more complex systems and industrial processes, starting with the accessible sources and the great opportunities SONATRACH is offering to researchers in this field.

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