

Automation of Nitrogen Plant using PSA Technology

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Abstract- Today most of the industrial processes are controlled by the use of PLC. They are used in industrial like petroleum, gas, chemicals etc. The air, flow, temperature etc in these industries can be controlled, using PLC and SCADA. This paper mainly highlights with the manufacture and control of Nitrogen in plant automation using PLC and SCADA.

Keywords: programmable logic controller, carbon molecular sieve, pressure swing adsorption, supervisory control and data acquisition, Adsorption

1. INTRODUCTION

In past year for the production of nitrogen from atmosphere where designed using the Dynamic performance using air separation unit. Dynamic optimization provides a useful framework for the assessment of control performance limitations. It presents an approach toward identifying the design characteristics of air separation plants that limit agility. The drawbacks of this system design are specified and limit to control performance in response to variations in electricity price [1]. Non – cryogenic industrial gas processes includes adsorption process, chemical process, polymeric membrane and iron transport membrane (ITM) technology.

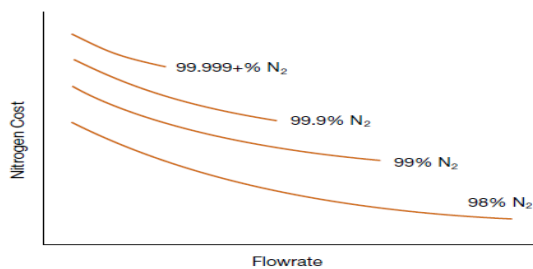


Figure 1. Nitrogen purity and flow rate requirements can affect nitrogen cost.

The detailed explanation of cryogenic processing with descriptions about compression cycles, pumped liquid cycles and low and elevated pressure cycles [2]. In this paper it highlight on PSA (PRESSURE SWING ADSORPTION). PSA can be cost effective method of onsite nitrogen generation for wide range of purity and flow requirements [4].

According to this paper the automation is done using industrial control system (ICS). This paper deals with Nitrogen plant automation using PLC and SCADA. A

Programmable logic controller (PLC) is a digital computer used or automation of electromechanical processes, such as control of machinery on factory assembly lines, amusement ride, or light fixtures. A PLC is a digital computer used or automation of electromechanical process. PLCs is used in many industries and machines. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory. The term SCADA usually refers to centralized systems which monitor and control entire sites, or complexes of systems spread out over large areas. For example, a PLC may control the flow of cooling water through part of an industrial process, but the SCADA system may allow operators to change the set points for the flow, and enable alarm conditions, such as loss of flow and high temperature, to be displayed and recorded.

2. PRINCIPLE OF OPERATION

Plant has two tanks of similar capacity constituting with different solenoid valves and other associated paraphernalia. When the pressure in air receiver tank exceeds 7 kg/cm², it admits to first tank through appropriate valves. Now, oxygen and other impurities are absorbed by the CMS (Carbon Molecular Sieve) and nitrogen is separated. When first tank works for 40 seconds the second one regenerates then within another two seconds both tank equalize the pressure nitrogen generated in first tank pass to the storage tank, through appropriate solenoid valves and surge vessel by releasing the impurities. Then the operation repeated in the second tank. Both tanks operate simultaneously one after another with an interval of 10 seconds. So that process is continued and Nitrogen storage tank is filled as required. A nitrogen storage tank is installed after nitrogen surge vessel for storage of nitrogen gas at pressure of 5.0 kg/cm²g. And there is an oxygen analyzer and a three way valve in between the nitrogen storage tank and surge vessel. The oxygen analyzer will check the amount of oxygen in the gas. If oxygen content exceeds 0.7% the three way valve will direct that gas to air. Else it is stored in the nitrogen storage tank. Nitrogen generates are based on well proven technology using carbon molecule sieves (CMS) developed and supplied by Carbotech- Germany. CMS is an absorbent having infinite number of small pores.

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An oxygen molecule having a smaller diameter than a Nitrogen molecule. Therefore, the nitrogen is removed to a higher degree while almost all the oxygen is adsorbed.

Plant has two tanks of similar capacity constituting with different solenoid valves and other associated paraphernalia. When the pressure in air receiver tank exceeds 7 kg/cm^2 , it admits to first tank through appropriate valves. Now, oxygen and other impurities are absorbed by the CMS (Carbon Molecular Sieve) and nitrogen is separated. Both tanks operate simultaneously one after another with an interval of 10 seconds. So that process is continued and Nitrogen storage tank is filled as required.

3. BLOCK DIAGRAM

The block diagram of Nitrogen Plant is shown in figure-2 consisting of following:

3.1 Air compressor: It sucks air from atmosphere to initiate the process the pressure inside the compressor should be between $6-8 \text{ kg/cm}^2$.

3.2 Air receiver tank: It stores the pressurized gas and also known as air buffer tank. The pressure inside the air receiver tank will be between $6-8 \text{ kg/cm}^2$.

3.3 Tower1 & Tower 2: It is the main part of the system, having similar capacity. Where each tower consists adsorption vessel packed with Carbon Molecular Sieves (CMS). At high pressures, Oxygen and other trace gases are absorbed by the CMS, allowing nitrogen to pass through. Since, oxygen molecules have smaller diameter than nitrogen molecules, they enter into the pores.

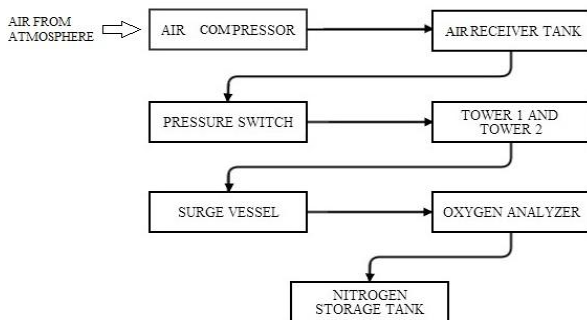


Figure 2. Block diagram of nitrogen plant

3.4 Surge vessel: It stores the nitrogen generated and also provide better performance.

3.5 Oxygen analyzer: The (dim) purity of the product is being checked continuously.

3.6 Nitrogen storage tank: It's mainly used for the storage of purified nitrogen.

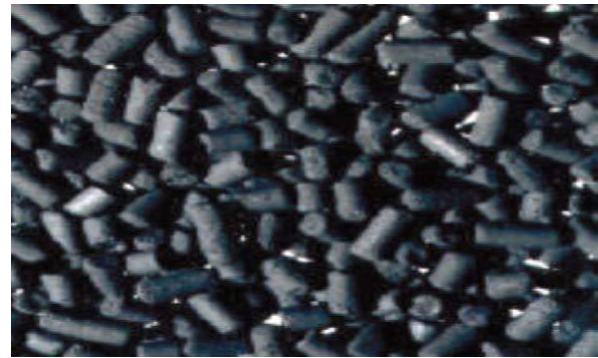


Figure 3. Carbon Molecular Sieve

4. WORKING

Plant has 2 tanks of similar capacity constitute with different valves and associated paraphernalia. When pressure in the air receiver tank exceeds 7 kg/cm^2 valve v9 will open. It admits air to tanks through valves. Figure 2 shows the complete circuit diagram of nitrogen plant. The PSA process cycle consists of two key mechanisms:

- Pressurization/adsorption
- Depressurization/desorption

In the first cycle tank 1 will be in adsorbing state. Valve V1, V4 and V7 will be open on first cycle. Now oxygen and other impurities are absorbed by the CMS and Nitrogen is separated. And Nitrogen generated in the first tank passed to the storage tank, through valve V7 and surge vessel. When first tank work for 40 seconds, second one regenerated.

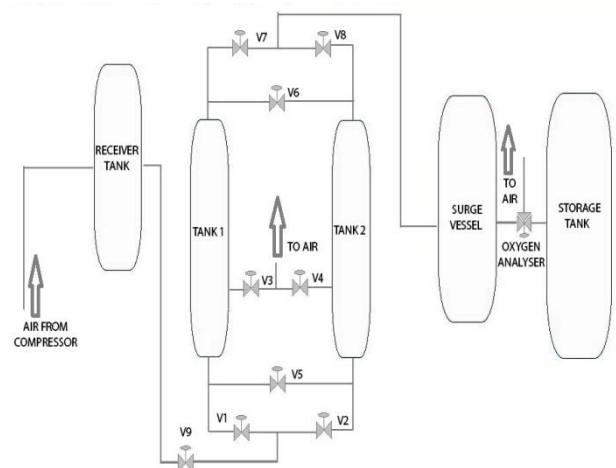


Figure 4: Circuit diagram of nitrogen plant

Within another 10 seconds both tank equalize the pressure. The valve V5 and V6 will open. And will equalize the pressure in two tanks. After 10 second equalization second cycle will start. The tank 2 will goes to adsorbing state. And valve V2, V3 and V8 will open. Then operation repeated in the second tank while first tank goes under regeneration where adsorbed gases are desorbed to atmosphere. After that there is an equalization step. It will take 10 seconds. This operation alternatively repeated in both tanks

A nitrogen storage tank is installed after nitrogen surge vessel for storage of nitrogen gas at pressure of 5.0 kg/cm^2 . And there is an oxygen analyzer and a three way valve in

between the nitrogen storage tank and surge vessel. The oxygen analyzer will check the amount of oxygen in the gas. If oxygen content exceeds 0.7% the three way valve will direct that gas to air. Else it is stored in the nitrogen storage tank.

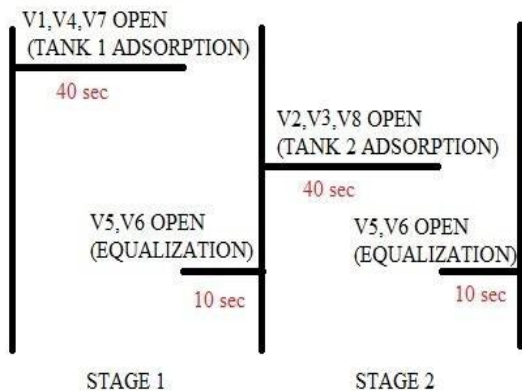


Figure 5: Timing diagram of nitrogen plant.

Figure 5 shows the timing diagram of nitrogen plant. There are 2 stages for a complete cycle of the plant. It needs 100 seconds for one complete cycle. Each tank will tank 40 seconds for adsorption. For equalization it will take 10 seconds. After every adsorption step there will be an equalization step.

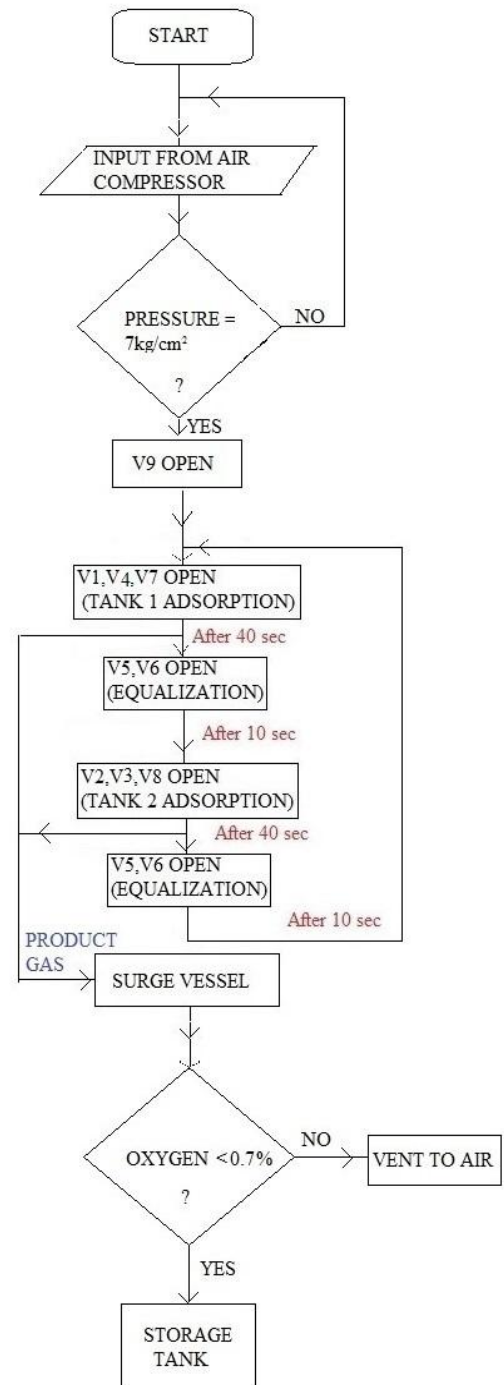


Figure 6: Flow chart of nitrogen plant

Flow-chart diagrammatic is been shown in the Fig.5. This flow-chart gives the entire idea for the working principle of the automation. Initially process starts from the air receiver tank. When pressure in the air receiver tank exceeds 7kg/cm^2 the valve V9 opens and it starts operation. The PSA^[5] process cycle consists of 2 key mechanisms:

- Adsorption
- Desorption

When first tank 1 works for 40 seconds the second one regenerates. At this time adsorption take place for tank 1

and valves V1, V4 and V7 were open. Simultaneously all other valves gets closed for the process to take place. Nitrogen generated in first tank pass to the surge vessel for a temporary storage. Within another 10s both tank equalize the pressure with valves V5 and V6 were open. Next 40s adsorption take place for tank 2 and at this time first tank regenerated and the impurities gets released through the silencer. Nitrogen generated in tank 2 reaches the storage tank through valves V2, V3 and V8. Next 10s both tank equalize the pressure similarly as above. This operation alternatively repeated in both tanks. After the process of storing in the surge vessel it gets transferred to the main storage tank. But in between these surge vessel and storage tank there is a special device known as the oxygen analyzer for analysis of oxygen content in the purified product. When the amount of oxygen is less than 0.7%, it reaches the storage tank. Otherwise it is vented back to air. Then from storage tank it is used for further uses.

6. SCADA IMPLEMENTATION

The SCADA system was designed with a software package that has helped to ensure future upgrade capability and compatibility. The controlling is being done using mainly 10 types of valves, also consist of receiver tank, surge vessel, and main storage tank. In the given figure, the green color indicate the flow of nitrogen and the red color indicates the waste gas.

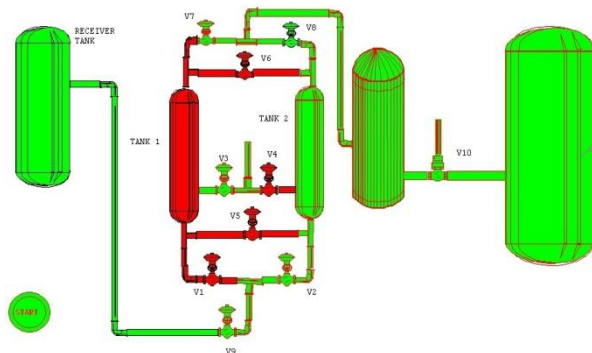


Figure 7: SCADA implementation

7. CONCLUSION

As per the project “nitrogen plant automation using PLC & SCADA” highlights the process of manufacture and quantity control with the automation process in the industry.

9. FUTURE WORKS

Increased power efficiency in PSA nitrogen generators is being driven both by process improvements and enhanced adsorption materials. A large range of flow and purity combination can be met by adjusting the size of the air compressor and adsorption vessels containing the CMS. The plant flow rate can be reduced by inserting an “idle” step in the cycle thus saving plant power.

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