



Digital Control of Centrifugal Air Compressors

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The air installation consists of high-capacity centrifugal compressors which pumps in parallel in an industrial pipe. The total air flow rate of the compressors in the pipe can be adjusted by acting on the air suction valve of each compressor so that the shut-off or opening of the compressor valve can regulate the flow rate of each compressor, which results in total flow control. The problem is to replace the analog control of the compressors with a digital control. If we have two types of compressors in the plant, the automatic setting involves closing or opening the suction valve of the compressors in a certain order so that besides the total objective to pump a particular flow we also have high energy efficiency.

Keywords: digital control; air flow control; energy efficiency

1. Introduction.

The compressed air plant consists of air compressors with a flow rate that can vary between 240,000 Stm³/day and 310,000 Stm³/day at a pressure of max 15 bars. The plant is used for extracting oil. Every compressor has a local control panel and is driven by a station control panel that centralizes and coordinates the compressors operation. The plant has a station panel that controls the local compressor panels and process computers that monitor the station's operation. The first type of compressor, has the following features:

- Motor type MAB 2000 asynchronous, 1500 rpm, 6kV, 2MW;
- Max flow rate: 310,000 Stm³/day;
- Max working pressure: 15 bar;
- 4 centrifugal compression stages.

The second type of compressor has the following features:

- Motor type MAS 2-4 asynchronous, 1500 rpm, 6kV, 2MW, manufactured by IMGB
- Working pressure: 15 bar;

- Flow rate: 285,000 Stm³/day;
- 5 centrifugal compression stages.

The overall airflow required in the application is between 1,500,000 Sm³/day and 2,000,000 Sm³/day. Flow regulation is obtained by closing or opening the air intake valve of each compressor.

The total flow rate QT had to be equal to the total flow of compressors in operation, according to the equation:

$$Q_T = Q_1 + \dots + Q_{10}. \quad (1)$$

Automatic adjustment means changing the position of the valves so that the total flow QT will fit in the total prescribed flow QS with a deviation of 25,000 Stm³.

$$Q_s - 25000 \text{ Stm}^3 < Q_T < Q_s + 25000 \text{ Stm}^3. \quad (2)$$

When the pumped flow falls within this range, a green lamp fixed on the station cabinet is lit and the process of changing the position of the valves ceases.

Between the time of detection of a difference between the total flow rate and the prescribed flow rate of more than 25,000 and the moment of air inlet air action, there is a delay that prevents continuous compressor valves from operating close to this limit.

Figure 1 shows the compressors 2, 3, 6, 7, 8, 9 in operation which ensure the current flow rate of the station Q = 1687.6 thousand Sm³ / day. Compressors 1, 4, 5, 10 are switched off.

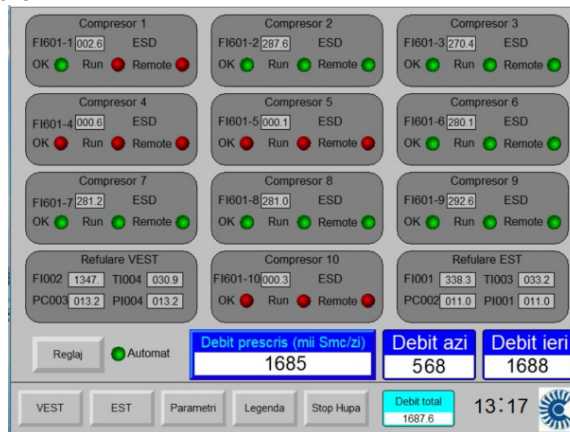


Figure 1. Flow control panel [4]

2. Comparison between analog and digital control

Now the command for the suction valve and the flow feedback information for each compressor are transmitted via analog signals by a connecting cable between

the cabinets. Also, state information and start and stop commands of each compressor are physically transmitted via another cable.

Figure 2 below presents the existent architecture of the system. Computers PC1 and PC2 are redundant and are used for acquiring data regarding the operation of the compressors.

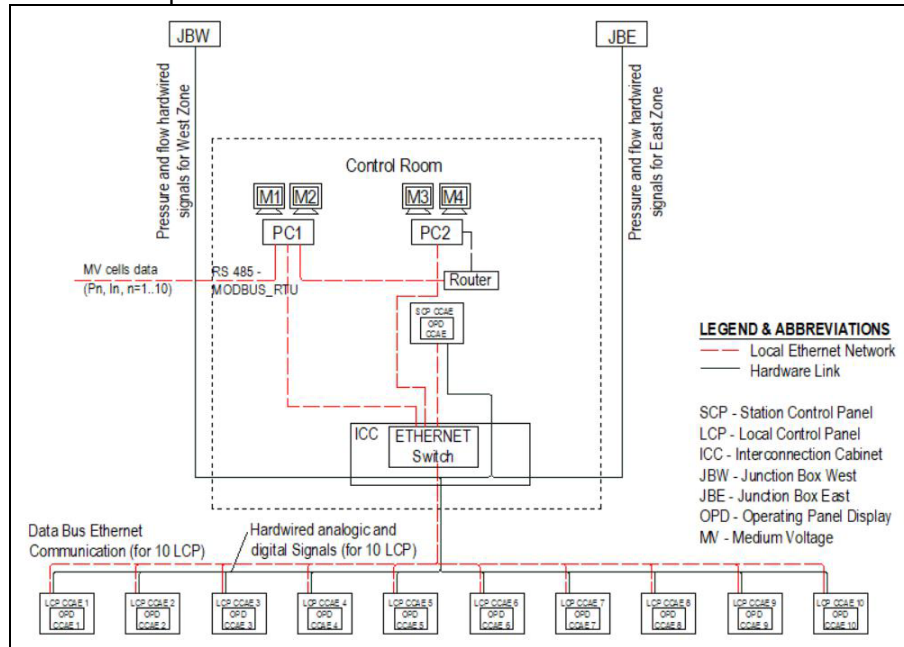


Figure 2. Existent architecture of air compressor control system

The process is driven by the station cabinet. It takes up the flow from each compressor and transmits the position of the flow control valves to the compressor cabinets. The suction valves will automatically shut down in the succession of C1, C3, C5, C7 five-stage compressors which have up to 20% higher energy consumption, then C2, C4, C6, C8, C9, C10 four-stage compressors, which are more energy efficient. To pump a larger flow when needed, the suction valve of the compressors will open in the reverse order.

The implemented algorithm consists of a comparison between the proposed flow rate and the instantaneous flow rate. If they do not coincide within a certain limit, then the plant automation transmits to the compressor's automation that the inlet air valve must be actuated to open or close.

If adjustment in the required direction cannot be made to this compressor, the software moves to the next available compressor.

In the analogue communication solution between the station control cabinet and control cabinets of the compressors is used the control cables for each compressor.

Taking into account that these cables have a length between 10 m and 50 m and they are connected in the marshaling cabinet of the installation, it can be estimated that the material savings are at least 80% of the construction value required for the station coordination.

It also reduces the cost of work required to install, connect and test the cables. The marshaling cabinet becomes less complicated and its function may be taken over by the station cabinet.

3. Digital control of the installation

By using a digital transmission mode of the commands via the network cable, the use of a large amount of cables and the presence of the marshaling cabinet, whose function is taken over by the station cabinet, is not necessary.

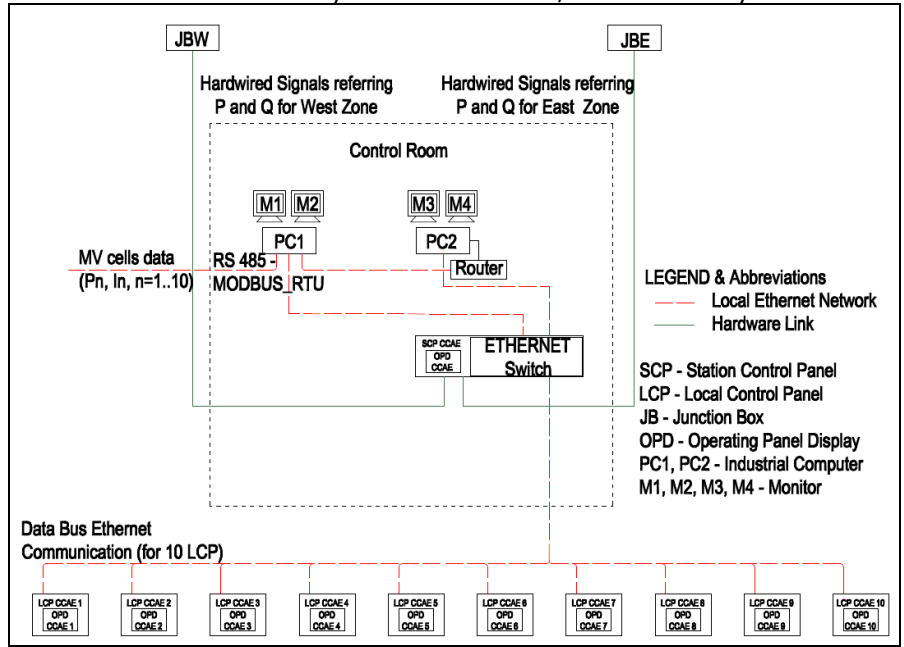


Figure 3. The new architecture of air compressor control system

The software used to implement the digital information and command exchange is the same as the one in which the programs running on the programmable logic controllers of the compressor and station control cabinets were designed.

A more specific feature of this software allows the exchange of values between two programmable machines.

In this way, the programmable compressor automatics will provide the flow of information of each local machine while, the station automation will return the new suction valve position values for each compressor.

Thus, based on the same algorithm implemented in the station automation, the total station flow rate will be adjusted by varying the local flows of compressors in operation (figure 3).

The addition of the transmitted and received data between the station controller and the one from each compressor is done as in figure 4.

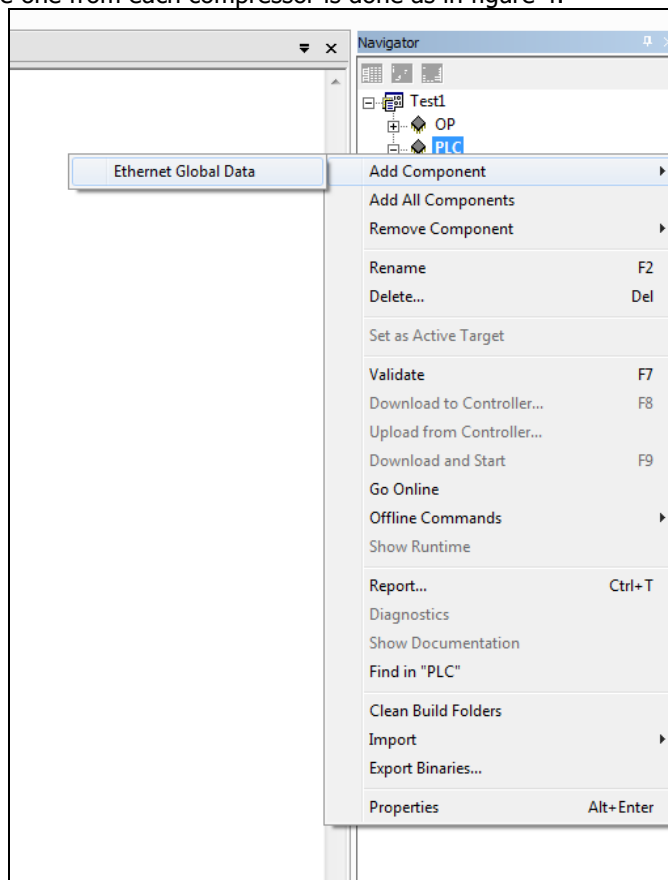


Figure 4. Addition of the Ethernet Global Data [2]

To control the compressor, the position of the valve, Lva parameter, is added like in figure 5, to the Consumed Exchanges Data.

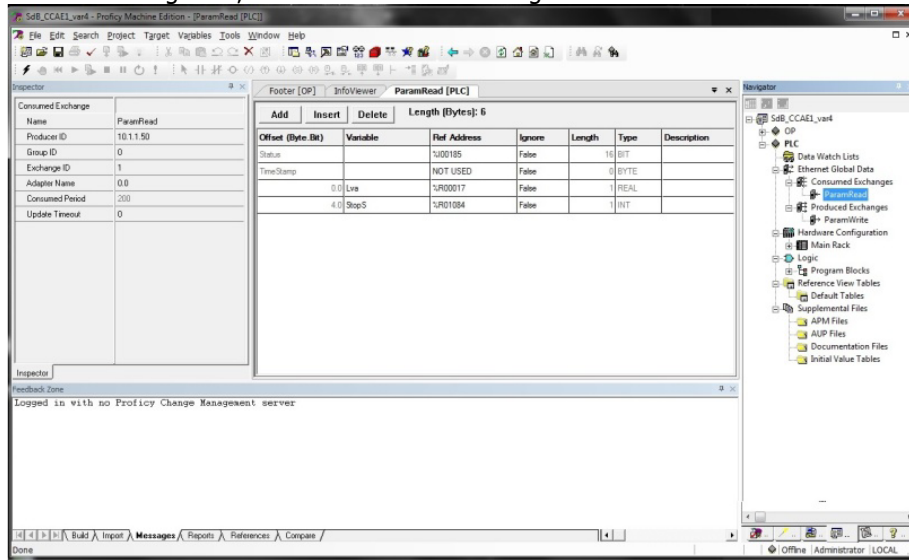


Figure 5. Addition of the Consumed Exchanges Data

For the total calculation, from each compressor in operation, the local Qar pumped flow is added to Produced Exchanges Data, as in figure 6.

Modifying the software from the controller of each compressor as above should be done in the same way with the station controller software, but in the opposite direction.

In the central cabinet the position of the valve is passed to the produced data (figure 7) and the flow for each compressor is passed to the consumed data (figure 8).

In this way the control information passes thru Ethernet connection without need of the other cables.

The flow of each compressor received in the consumed variables are summarized and compared to the prescribed flow. Depending on the result and the compressor that has to be driven based on the preset order, the variables produced are written. These are transmitted to the compressors in the variables consumed by them and, depending on their size, the air intake valves act. Then read the flows into the variables produced and they are transmitted to the station machine. The solution to connect the control cabinets of each compressor to the central cabinet by Ethernet cable in a star configuration is the easiest but has the disadvantage of losing information when a cable is interrupted mechanically or because of cable electromagnetic interference.

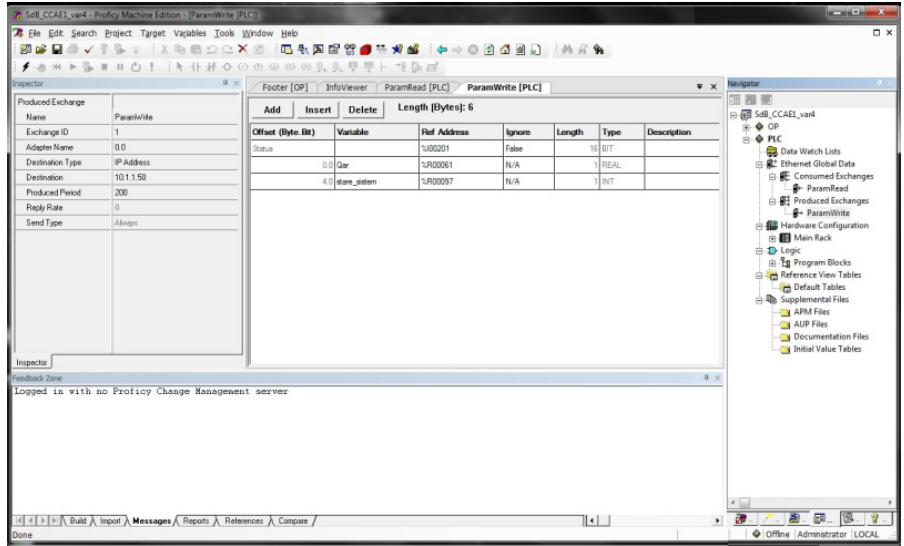


Figure 6. Addition of the Produced Exchanges Data

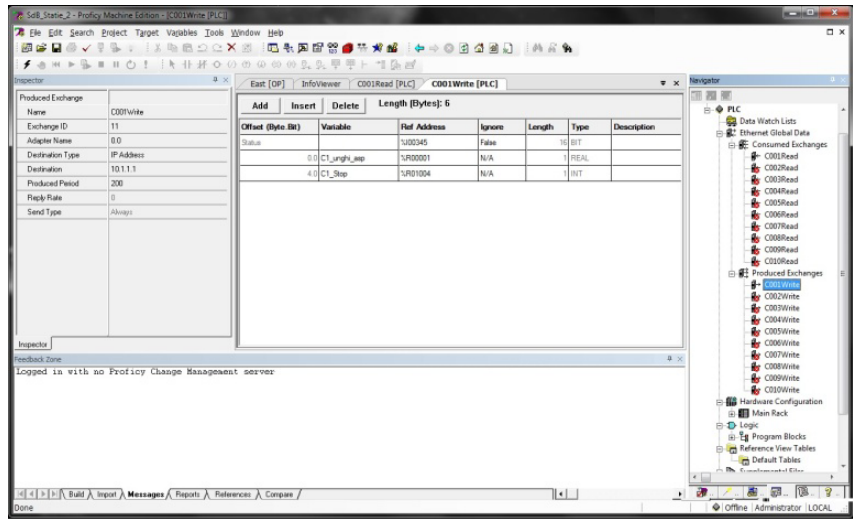


Figure 7. Addition of the Produced Exchanges Data for Station Control PLC

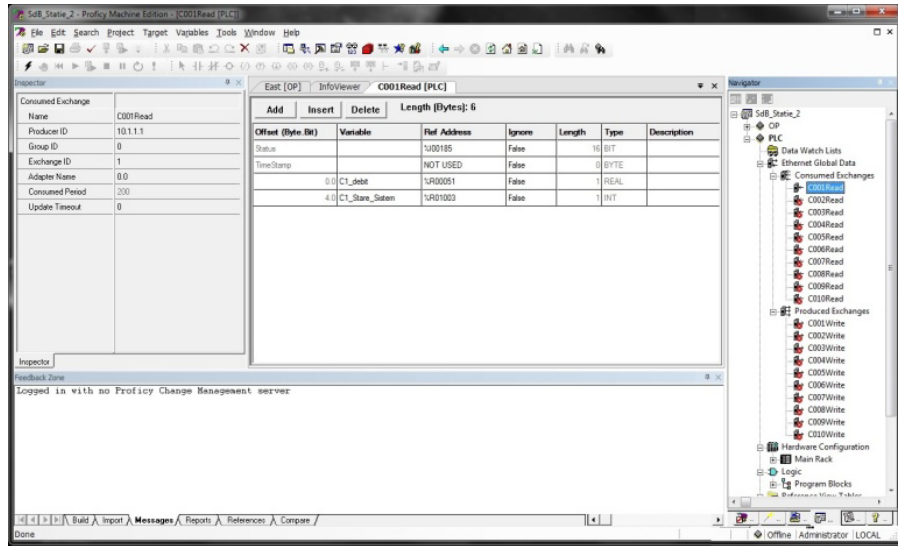


Figure 8. Addition of the Consumed Exchanges Data for Station Control PLC

A ring architecture (figure 9) solution of the local area network between compressor control cabinets has the advantage of being more reliable in terms of communicating with a local control cabinet, as the data packets have two available paths.

At cable interruption there is a second alternative to reach that cabinet. The communication reliability obtained in this way is made at the cost of using more complicated network switches with management.

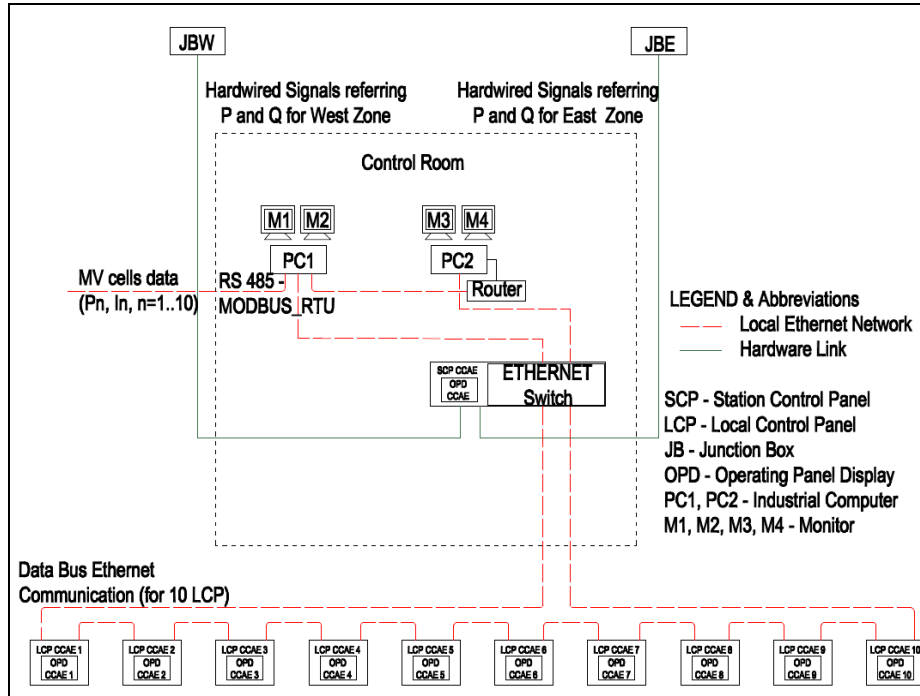


Figure 9. Ring topology

4. Conclusion

The revamp of air compressor installation will replace analogue control with digital air flow control of the centrifugal compressors. The digital control solution of the station can be implemented via Ethernet cable with both star and ring connection of local control cabinets. After analyzing the advantages and disadvantages of each solution, the star Ethernet connection architecture was chosen over copper wires to be implemented in the actual upgrading of the station.

Another non-wired digital control solution involves installing Access Points on each local compressor cabinet and establishing a connection with a central router. Besides the more complicated management of this network, there is the danger of interrupting the connection between the point of a more distant and central point cabinet due to interference with the powerful electromagnetic fields of the 2 MW motors that drive the compressors.

The control is done so that four-stage energy-efficient compressors will be used intensively and, if necessary, compressors with five stages. In this mode of control only high energy efficiency compressors (4 stages) can see an intensive

use. In the course of subsequent modifications it is taken into consideration the creation of a ring system topology for redundant communication.

References

- [1] Ungureanu M., *Maintenance of Mechanical System'* course, București, 2015.
- [2] ***** *Proficy Machine Edition*, GE Fanuc Automation, GFK-1868P, 2011.
- [3] ***** *VersaMax PLC, User's Manual*, GE Fanuc Automation, GFK-1503C, 2001.
- [4] Niculescu F., *Compresoare centrifugale CCAE–Cap.2 Automatica CCAE*, Bucuresti, Romania, 2015.
- [5] Niculescu F., Valcu C., Gazdac A., Borzea C. *Data recorder system for maintenance to rotary blade machines – "HolderPPS*, Jurnal TURBO, Vol.IV, Nr 1, 2017.
- [6] Young M., *The Technical Writer's Handbook*, Mill Valley, CA: University Science, 1989.
- [7] Niculescu F., *Compresoare centrifugale CCAE – Camera de comanda si control*, Bucuresti, Romania, 2015.
- [8] Codoban R., *Manual de operare si mentenanta – Compresor 15-300*, Bucuresti, 2015.

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