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An Efficient Approach to Industrial Multivariable System Modeling and Control

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Abstract: This paper proposes a new control approach to deal with an industrial multivariable system, in real environments. The present system is realized in line with the flow and the level subsystems, where each one of them needs to be distinctively modelled. In view of this results, the control concept in two different techniques including sequential loop closing control (SLCC) and diagonal dominance control (DDC) schemes are proposed to implement on the system, through the Profibus network, as long as the OPC (OLE for process control) server is utilized to communicate between the control schemes presented and the multivariable system.

Key words: Multivariable system · Diagonal dominance control · Sequential loop closing control · Profibus network · OPC server

INTRODUCTION

A real multivariable system including the flow and the level subsystems has been dealt with, in this paper. In such a case, some constraints in designing the control scheme for a real multivariable system have to first be analyzed. These problems, in their general forms, could be outlined as interaction analysis, choosing the appropriate sensors and actuators, choosing the system sample time, realizing the suitable control action to the system and so on. In view of the control system theories, some notable progresses have been extensively investigated in the 1950s-1960s, where the advanced methods in the field of the process control have been gradually acquired, at this interval of time. Even though these control theories are now generalized to the appropriate schemes, the some points are ambiguous in the multivariable systems, as long as we want to control them, in real environments [1-7]. Based on the matter presented, analyzing the system interaction, realizing the appropriate control action, matching the control scheme with the system and other related items could relatively be defined, as the main problems. Regarding the control scheme proposed, both the flow and the level parameters of a real multivariable system, which has the applicability in industrial and academic domains, have been analyzed. In this way, at first, each one of the subsystems is surveyed to model, where the chosen models are identified the same behaviour as the corresponding ones. Then, the subsystems mentioned here are integrated with each other to realize the multivariable system. In order to realize the control scheme, the multivariable system must precisely be presented based on the subsystem modeling results. In the same way, the Profibus network has been realized, in this strategy, to communicate between the system and the control scheme, while the OPC (OLE for process control) server is implemented on its control scheme. To analyze the initial communication between the multivariable system presented and the control scheme, the desired set point is manually implemented on the control scheme. Hereinafter, the system sensor outputs have been achieved, through the Profibus network, in the control scheme. In case of the results, the multivariable control scheme has been finally realized in two separated concepts including diagonal dominance control (DDC) and sequential loop closing control (SLCC) schemes in line with the multivariable model results obtained, where the validity of the proposed control schemes are tangibly pointed out.

The remainder of this paper is organized as follows. The multivariable system description and the proposed multivariable control scheme are given in Sections 2 and 3, respectively. The test results and the concluding remark are finally presented in Sections 4 and 5, respectively.

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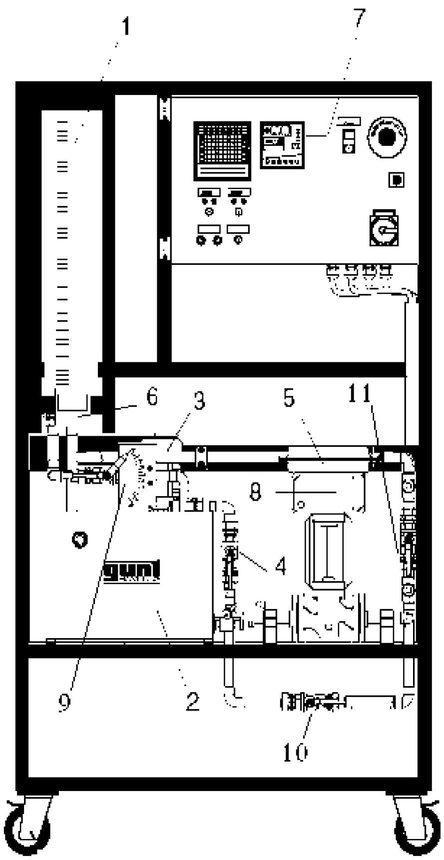

Fig. 1: The schematic of the level subsystem

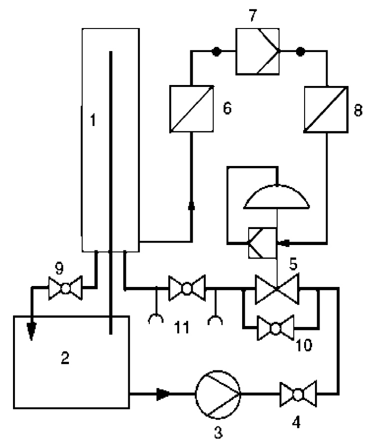

Fig. 2: The P&ID diagram of the level subsystem

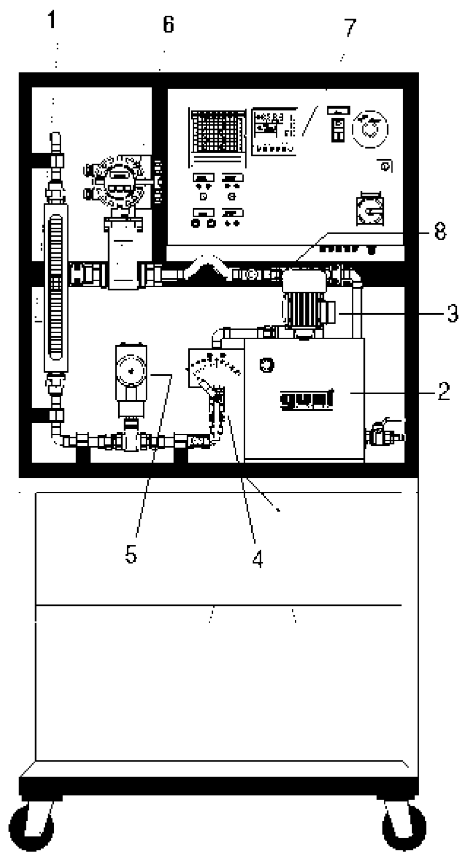

Fig. 3: The schematic of the flow subsystem

The Multivariable System Description: The present system is composed of the level and the flow subsystems, where each one of them is realized as an industrial case [8-10]. In this way, at first, these subsystems are distinctively represented and are correspondingly modeled, where an overall system could be organized by integrating them with each other. The overall system could be realized, in several situations, including SISO, cascade and multivariabe systems by adjusting the corresponding parameters. The details of the subsystems and also the overall system are given in the proceeding sections.

The Level and Flow Subsystems: The level subsystem, in its present form, is a device that is used to adjust the level of the fluid to desired value by an external control action. The schematic and the P&ID diagram of the subsystem presented are shown in Figs. 1 and 2, respectively. As it can be seen from the figures, the subsystem is composed of several devices that are fully addressed as level cylinder (1), fluid tank (2), pump (3), inlet valve (4), control valve (5), pressure transducer (6), external controller (7), current/pressure transducer (8), outlet valve (9), by-pass valve (10) and finally hose connections for the cascade control (11), respectively.

The flow subsystem, in its present form, is a device that is used to adjust the flow of the fluid to desired value by an external control action. The schematic and the P&ID diagram of the subsystem presented are shown in Figs. 3 and 4, respectively. As it can be seen from

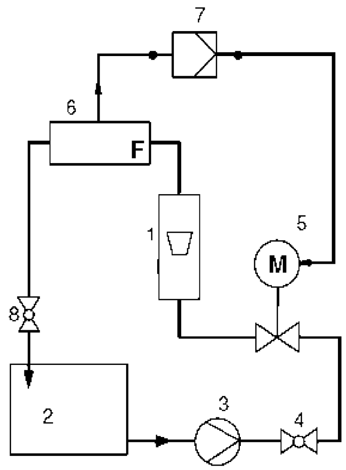

Fig. 4: The P&ID diagram of the flow subsystem

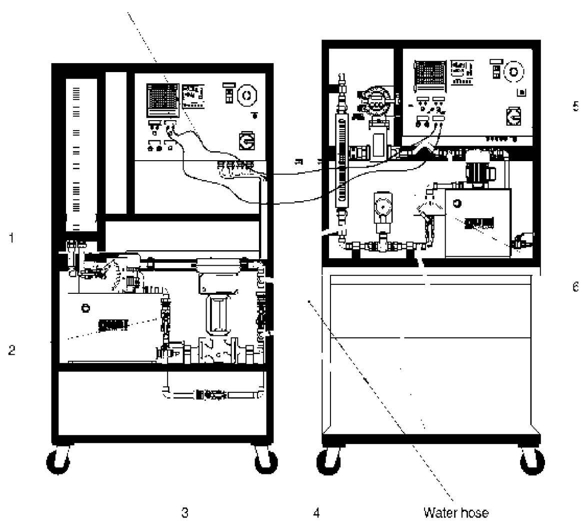

Fig. 5: The schematic of the overall system

the figures, the subsystem is composed of several components that are fully addressed as conical glass flow meter (1), fluid tank (2), pump (3), inlet valve (4), control valve (5), flow transducer (6), external controller (7) and finally outlet valve (8), respectively.

The Overall System Modeling: The overall system modeling is composed of the level and the flow subsystems entitled subsystems#1 and subsystems#2, respectively, in this paper, to organize a multivariable system with interaction between them, as shown in Fig. 5.

In this investigation, the pressure of the fluid pump of the subsystem#1 is greater than the pressure of the fluid pump of the subsystem#2. Hereinafter, the fluid of the subsystem#1 is pumped to the tank, while this fluid is correspondingly pumped to the subsystem#2, through the inlet valve 6 and the hose connection, which is stated in the present subsystem for this purpose. In fact, this fluid is added to the fluid of the subsystem#2, while it is entered to its tank corresponding to the outlet valve 5 and is also entered to the tank of the subsystem#1, through its hose connections. In line with the results obtained here, the interaction between subsystems could correspondingly be changed, while the valves 1, 2, 5 and 6 are positioned in the several distinctive degrees. In the same way, the interaction of the subsystem#1 over the subsystem#2 could gradually be increased, if the valve 6 is progressively opened, while valves 1, 2 and 5 are positioned in a fixed degree. Also the interaction of the subsystem#2 over the subsystem#1 could gradually be increased, if the valve 5 is progressively opened, while valves 1, 2 and 6 are positioned in a fixed degree. Hereinafter, by varying the valves 5 and 6, the overall system could be organized to the multivariable system. In this investigation, it has been decided to use the pump of the subsystem#1 for having the interaction between two subsystems, through the valve 5, where valves 1, 2 and 6 are completely opened. In such a case, the main reason in adjusting the valves presented is to solve some problems such as tank over flow, disturbance in performance of the pumps and the valves and other related items, which we were encountered with them in the procedure of the present investigation. In this regard, the other related adjustments are not completely able to model the system. As a consequence, the fluid which is entered to the subsystem#2 corresponding to the interaction between subsystems could progressively be increased, provided that the valve 5 is gradually opened, while valves 1, 2 and 6 could be positioned in a fixed degree. In addition, the overall system could be organized as a SISO system, once the valves 5 and 6 are completely closed. To organize an overall system, which has the appropriate interaction to challenge with the proposed multivariable control scheme, the valve 5 is positioned in 150 degrees, in this investigation. Now, in order to model the overall system, in association with the results of both the subsystem#1 and the subsystem#2, we need to model the connection between two subsystems and the valve 5, as well. As it can be seen from the Fig. 5, two separated hose connections are stated in the overall system. For modeling them, the valves 1, 2, 5 and 6 are first opened to enter the entire fluid flow to the tank. Regarding the orifice relation, its result is related to the pipe and the hose connections, while the hose connections could be modeled and the model of the pipe is also obtainable such as previous method. After modeling all the subsystems, the overall system as a multivariable system is modeled based on the investigated results.

The Proposed Multivariable Control Scheme: The multivariable control scheme is realized based on the needs of several industrial and academic environments to have the complex controller [11-13]. Here, we implement two separated methods including the DDC and the SLCC schemes on the system.

The SLCC and DDC Schemes: The SLCC scheme is one of the methods in realizing the multivariable control scheme in industrial and academic environments. In this method, an input and an output of the industrial system, which has the multiple inputs and the multiple outputs are first chosen. Then, an appropriate controller in line with the classical control theories is designed; regardless the effect of the other existed loops and also the corresponding transfer functions of the system. After that, the second input output pair of the system is used to design for realizing the appropriate controller. Based on the matter presented, one input-output pair by one is used to complete the designing of the control scheme, while the finalized results are achieved in using a diagonal matrix transfer function. In this case, the scalar transfer function corresponding to the all input-output pairs of the system are positioned, in the matrix principal diagonal. Regarding the DDC scheme, it is the perfect method, in organizing the multivariable control scheme with respect to the previous one. The main concept of the control scheme realization is to organize a pre-compensator matrix, given in a static manner or in a dynamic manner that is stated in sequence with the main matrix transfer function of the system.

The Test Results: The investigation outcomes are implemented on the real multivariable system presented, in order to verify its validity. At first, this system needs to be presented in line with the paper contents and then both the proposed control schemes are applied to the system. In this regard, as mentioned before, the level and the flow subsystems entitled the subsystem#1 and the subsystem#2, respectively, are used to organize the system presented, while its parameters could be adjusted to desired values by the inlet and the outlet valves, manually. These parameters can organize the system with interaction between the subsystems, where the proposed control scheme must acceptably be challenged with this real system. Now, to model the multivariable

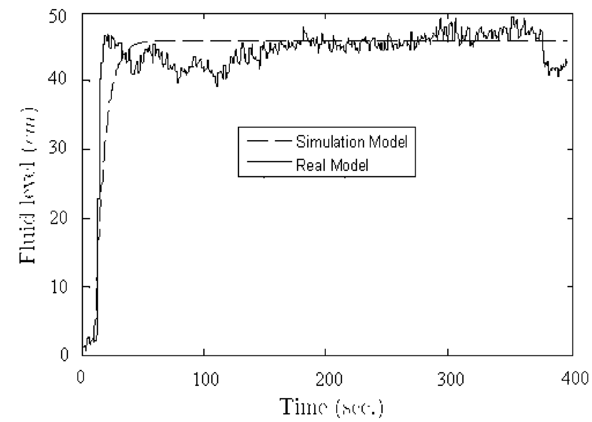

Fig. 6: The tracking performance of the subsystem#1 w. r. t. the corresponding real subsystem

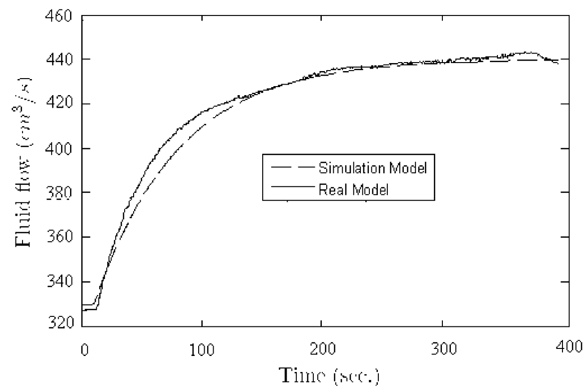

Fig. 7: The tracking performance of the subsystem#2 w. r. t. the corresponding real subsystem

system, its components must be analyzed. Regarding the fluid tank, by choosing the several positions for the pneumatic valve, the fluid level and the fluid flow are correspondingly varied, while the outlet valve could be positioned in a fixed degree. By running the investigated programs, the tracking performance of the subsystem#1 with respect to the corresponding real subsystem is shown in Fig. 6, while the tracking performance of the subsystem#2 with respect to the corresponding real subsystem is also shown in Fig. 7, respectively.

As it can be seen from these figures, the two inputs-two outputs system in addition to the two separated feedback loops are used, in this paper. Now, by running its program, the results which are related to the pump performance are achieved. Regarding the results, Fig. 8 points out the diagram of the outlet fluid level, in the real system, while Fig. 9 points out the diagram of the output fluid flow, in the real system. In the same way, Fig. 10 points out the diagram of the first control action in the control valve, while Fig. 11 points out the diagram of the second control action in the control valve.

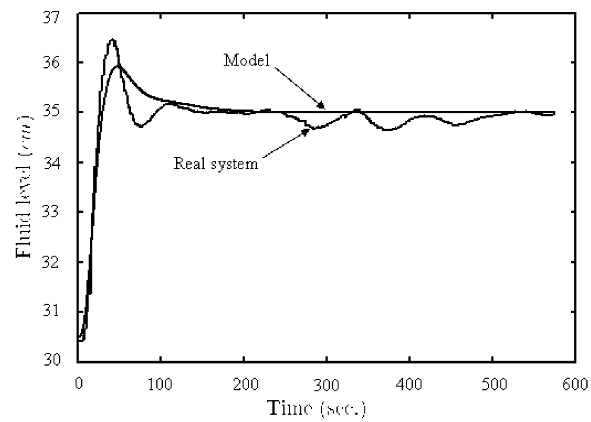

Fig. 8: The outlet fluid level of the SLCC scheme

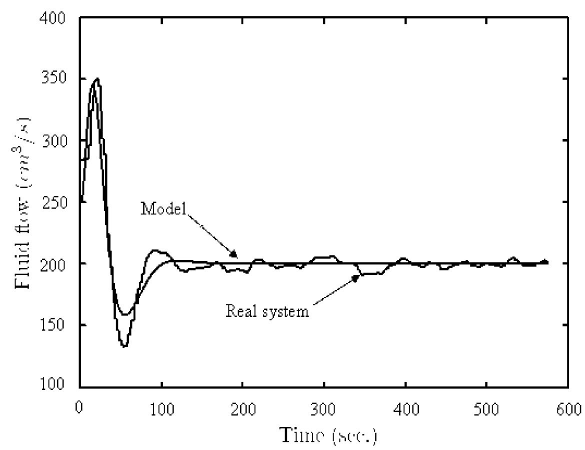

Fig. 9: The outlet fluid flow of the SLCC scheme

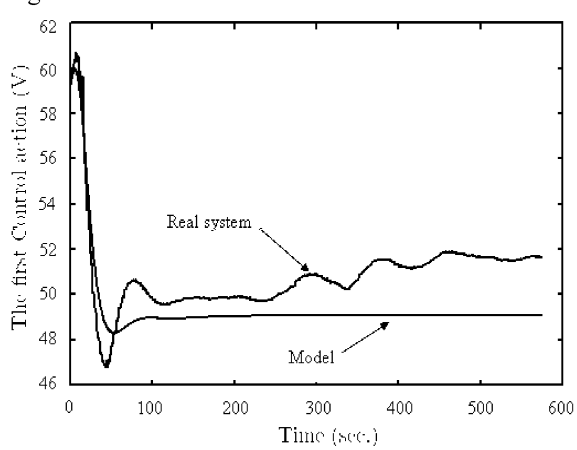

Fig. 10: The first control action of the SLCC scheme

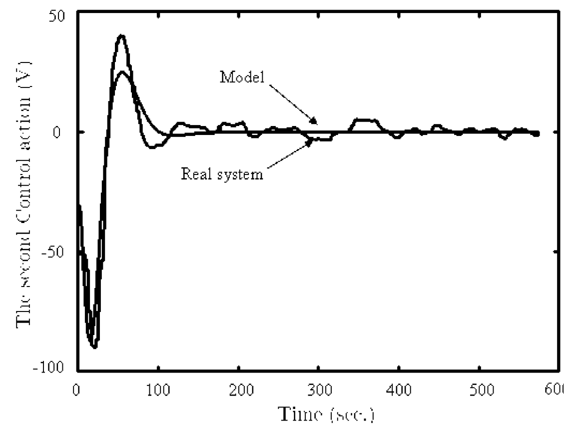

Fig. 11: The second control action of the SLCC scheme

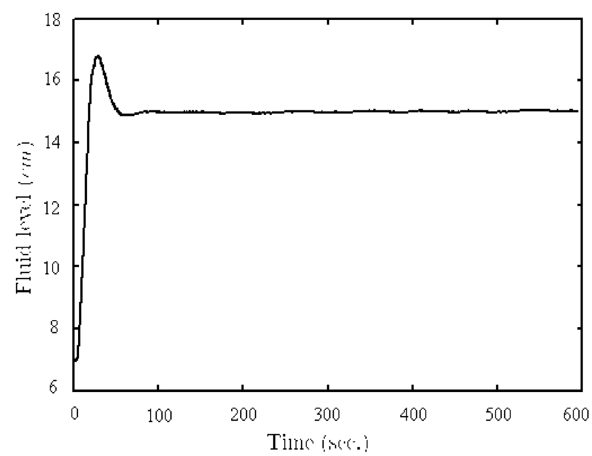

Fig. 12: The output fluid level of the DDC scheme

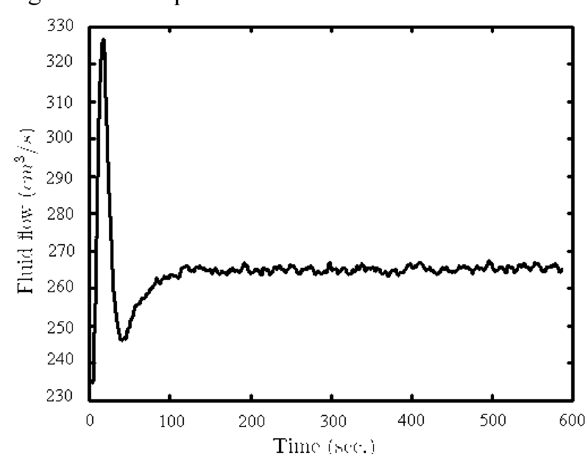

Fig. 13: The output fluid flow of the DDC scheme

Concerning the DDC scheme, Fig. 12 points out the diagram of the outlet fluid level in the real system, where Fig. 13 points out the diagram of the output fluid flow, in the real system. Also, Fig. 14 points out the diagram of the first control action in the control valve and finally Fig. 15 points out the diagram of the second control action in the control valve, respectively. In this research, the present control scheme is the same type as the previous control scheme.

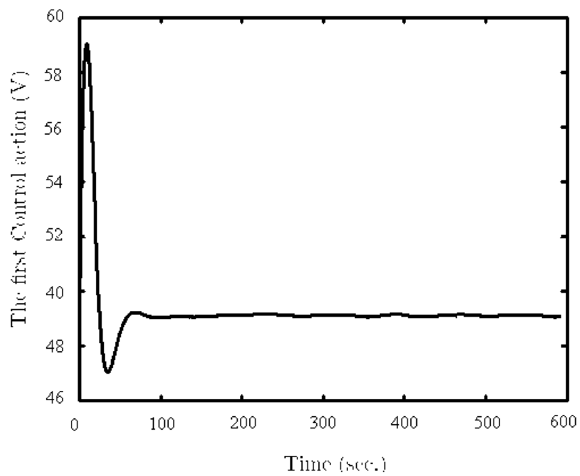

Fig. 14: The first control action of the DDC scheme

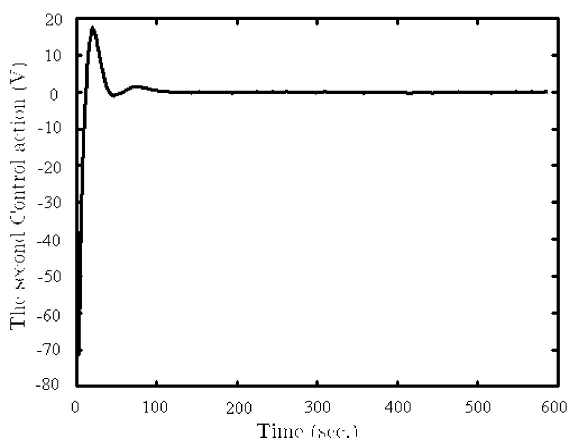

Fig. 15: The second control action of the DDC scheme

CONCLUSION

A real multivariable system, which is realized based on the flow and the level subsystems, has been thoroughly analyzed, in this paper. At first, each one of the subsystems is presented through sufficient models. Then, the multivariable control scheme in two distinctive techniques, namely the sequential loop closing control and the diagonal dominance control schemes are investigated to implement on the system through the Profibus network, as long as the OPC server is used to communicate between the control schemes proposed and the system presented.

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