

# Research And Construction of Solution of Speed Synchronizing for Multiple Motors using Profinet Industrial Communication Network

Nguyen Duc Dien<sup>#</sup>, Tran Ngoc Son<sup>#</sup>, Pham Van Huy<sup>#</sup>, Nguyen Cao Cuong<sup>#</sup>, Roan Van Hoa<sup>#</sup>

<sup>#</sup>University of Economics - Technology for Industries, Viet Nam

## Abstract

*Profinet industrial communication network was used by most of the factories to manage and control production lines. The paper introduces a solution of speed synchronizing for a multi-motor system using Profinet industrial communication network. Profinet network system is set up between the following devices: 03 PLC S7-1200, 02 inverters G120C PN, 01 HMI KTP700; Solution of speed synchronizing for multi-motor system operates according to the principle of master/slave control, the speed of the front engine is the reference speed for the rear engine. The surveyed results evaluated by running the model experiment, observed directly on the HMI screen, showed that the system works well, following requirements.*

**Keywords** — Profinet communication network, PLC S7-1200, Human Machine Interface, inverter G120C PN, PID.

## I. INTRODUCTION

Today's industrial communication networks are used by most factories to manage and control production lines. Depending on the purpose and demand for use, the plant uses the appropriate communication network model. Profinet industrial communication network has been applied to control production line systems. It is an open protocol standard for industrial Ethernet developed by the international PROFIBUS & PROFINET association. Profinet network has full points of Profibus and Ethernet networks [1]. In the production and processing lines, there are stages of feeding, quantifying, packaging, and labeling products; the system's stability, the accuracy and consistency of actuators (or the synchronization between the stages) are very important to product productivity, quality, and aesthetics. Many reasons are leading to the lack of synchronization and inaccuracy in the operation of the chains and conveyors in the production process; The reason may be that the equipment in the line is worn out, aging (so the transmission speed is not as guaranteed as the design), possibly due to uneven materials, uneven feeding devices, maybe due to the unstable power supply parameters [2]. It is essential to adjust the motors to run synchronously, ensuring

high accuracy and synchronization between the stages in the chains and conveyors.

Some studies on the co-speed control system for many motors, as presented in [2], [3]; however, only the simulation results have been published, and the experiment has not been verified. In [4] experiment with speed synchronization problem for many motors using 01 PLC, the results also give good control quality. About the industrial communication network Profinet; [5], [6] have given experimental models of Profinet communication network between PLCs, HMIs, PLCs, inverters, which have performed the communication problem and have not had a specific control object; [7] has given an experimental model of Profinet communication network between PLCs - inverters - HMI, but the experimental model [6] only implements the open-loop speed control problem, has no feedback speed. This paper on building Profinet communication network includes 01 PLC S7-1200 (PLC Server), 01 PLC S7 1200 (PLC Client 1), 01 S7 1200 (PLC Client 2), 02 G120C inverters, HMI screen KTP700 PN. The paper's control problem is the asynchronous speed system of motors according to the master/slave control principle. The motors are attached to the conveyor, and the inverter controls the three-phase asynchronous motors. The PID controller is built to control the speed of each motor in the system. The problem is that motors have different parameters (capacity, rated speed). Still, they need to ensure synchronous movement at a set speed or change according to the same rules to meet the production technology requirements.

The remainder of the paper is organized as follows. The second part introduces the proposed model, solution of speed synchronizing for multiple motors using Profinet industrial communication network. The third part is the control program and interface design for the HMI screen. Experimental results will be presented in the fourth section. Finally, the fifth part is the conclusion of this paper.

## II. CONSTRUCTION OF SOLUTION OF SPEED SYNCHRONIZING FOR MULTIPLE MOTORS

The model's main equipment used specifically is 03 PLC S7-1200, 02 inverters G120C PN, HMI screen KTP 700 Basic PN, 02 asynchronous motors 3 phase drive for 02 conveyors, 02 encoders, and the TIA Portal V14 SP1 software (Figure 1). The



connection structure of the above devices according to the Profinet communication network is illustrated in Figure 2. In which 01 PLC S7-1200 is Server, 02

PLC S7-1200 is PLC Client 1 and PLC Client 2, 02 inverters are connected with the PLC Clients.



Figure 1: Device layout on Profinet network practice model

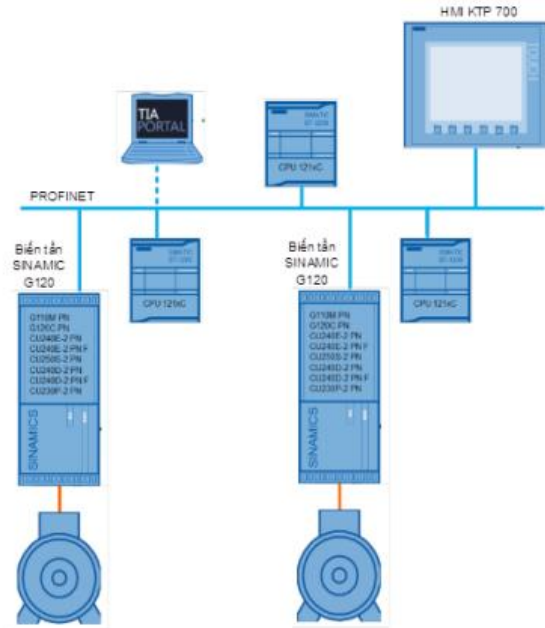
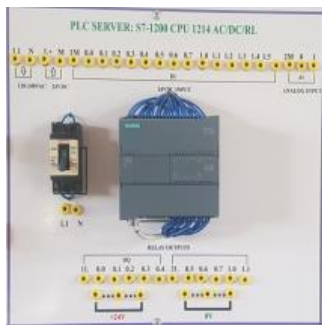


Figure 2: Profinet network connection structure between devices

**A. PLC S7-1200**

Industrial communication network model Profinet uses 03 PLC SIEMENS Simatic S7-1200 with 01 CPU 1214C AC/DC/RLY as PLC Server and 02 CPU 1214C DC/DC/DC as PLC Client 1, PLC Client 2 (Figure 3). CPU1214 has 14 digital inputs, 10

digital outputs, two analog inputs with a range of 0-10VDC. The memory size for the program and data is 100 kB. This PLC has a network card with an RJ-45 connector for PROFINET.



a) PLC Server



b) PLC Client 1



c) PLC Client 2

Figure 3: The model of PLC Server, PLC Client 1, and PLC Client 2

**B. HMI KTP 700 Basic PN**

Nowadays, HMI screens have become very familiar. Especially for the industrial field, touch screen HMI plays a very important role in the communication between humans and machines. The introduction of the Siemens HMI display marked a new step in the industry. Model using the screen SIEMENS KTP700 Basic PN (Figure 4). It is a 7-inch widescreen touch screen with 65536 color support display and eight function keys.



Figure 4: HMI screen KTP 700 Basic PN

**C. Inverter G120C PN**

The model uses Siemen's G120C PN inverter, has a built-in Profinet communication port, the inverter's power is 0,55KW, the inverter's control

modes: V/F, Vector control without an encoder. The inverter model is constructed, as shown in Figure 5.

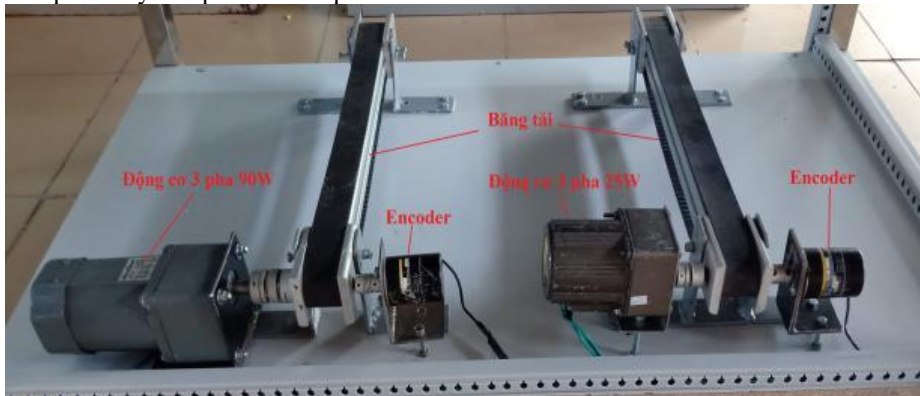


**Figure 5: Model of G120C PN inverter**

**D. Asynchronous Motor and Conveyor**

The practical model uses two three-phase asynchronous motors with gearboxes of 90W, 25W; 200V voltage; frequency 50Hz; speeds through gearboxes are respectively 50 rpm and 45 rpm. Model

of motor and conveyor with built-in encoder 1000 pulses/rev to measure motor speed is illustrated in Figure 6.

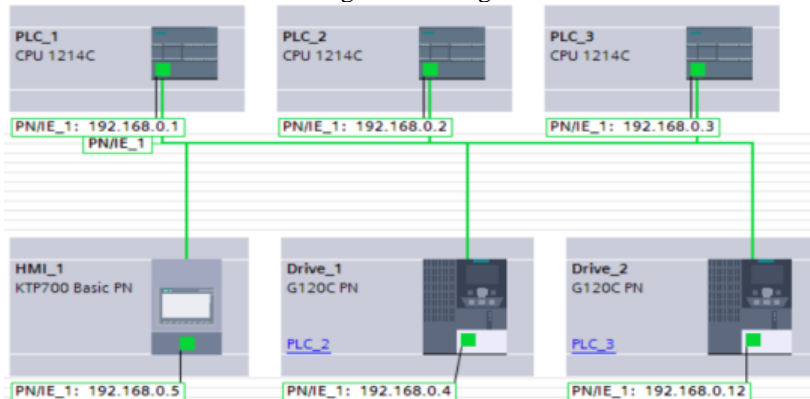


**Figure 6: Engine model and conveyor**

**E. Network Configuration**

TIA Portal V14 SP1 software was used to configure the network for devices in the Profinet network connection model. After connecting your computer to the PROFINET network and starting the

software, the TIA Portal software automatically finds available devices in the network. For these devices to connect, the model establishes IP addresses, as shown in Figure 7.



**Figure 7: Declare device connection on Tia Portal**

### III. CONTROL PROGRAMS

The general practice problem is that PLC Server transmits operation command, set speed for PLC Client 1; PLC Client 1 controls the G120C inverter that drives the motor to work according to the set speed, then returns the actual speed value to the PLC Server; PLC Server will transmit the actual speed of received PLC Client 1 at a certain rate and transmit it to PLC Client 2; PLC Client 2 controls the G120C inverter that drives the motor at the set speed. For PLC Clients to control the motor to stick to the set speed, the paper uses the PID controller and is programmed on the PLC. Profinet network communication programming algorithm between stations is illustrated in Figure 8.

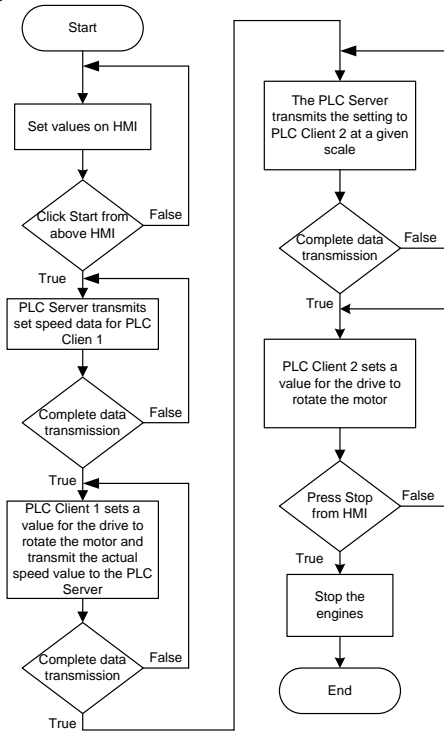


Figure 8: Diagram of the control algorithm

The control program of PLC Client stations illustrated in Figure 9 performs the task of controlling the conveyor speed stability.

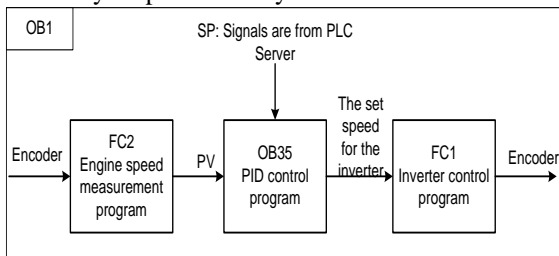


Figure 9: Program block for controlling PLC Client stations

#### A. PLC Server Program

To communicate the Profinet network between S7-1200 PLCs, the paper set up a 10-byte data exchange table such as Table 1 and Table 2.

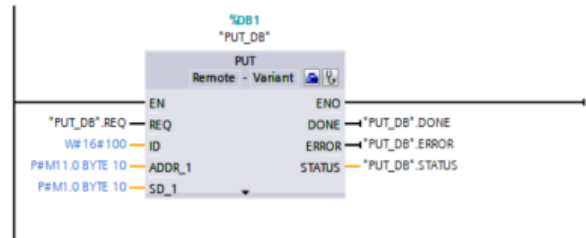
Table 1: Data exchange between PLC Server and PLC Client 1

Data PLC	Data transmission	Data received
Server	MB1 – MB10	MB31 – MB40
Client 1	MB21 – MB30	MB11 – MB20

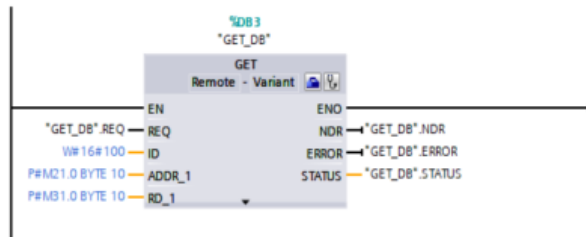
Table 2: Data exchange between PLC Server and PLC Client 2

Data PLC	Data transmission	Data received
Server	MB50 – MB59	MB80 – MB89
Client 2	MB70 – MB79	MB60 – MB69

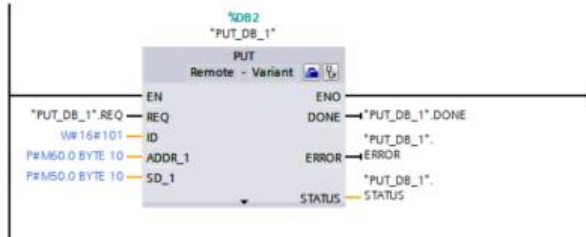
- Data transmission declaration program to PLC Client 1:



- The program declares to receive data from PLC Client 1:



- Data transmission declaration program to PLC Client 2:



- Transfer data to PLC Client 1:



- Receive data from PLC Client 1 and transmit data to PLC Client 2:

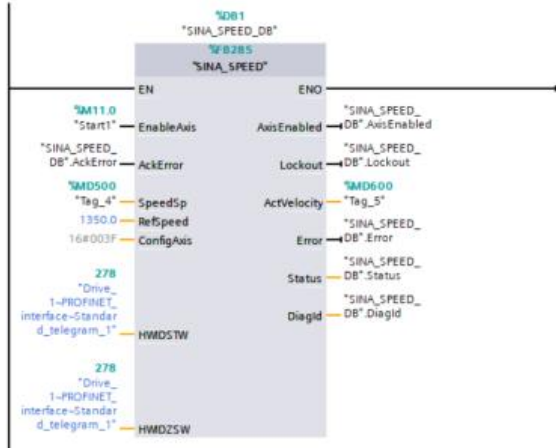




**B. Program PLC Clients**

The program of PLC Clients is very similar. The paper specifies the program of PLC Client 1.

- To transmit data between the PLC and the inverter, we use the SINA\_SPEED command block:



- To measure engine speed, the program uses a high-speed counter HSC1, converting the measurement unit to rpm.



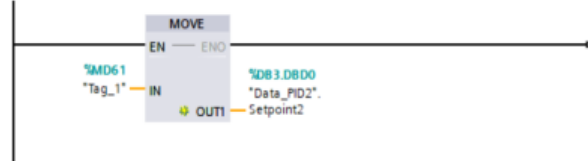
The program implements the PID algorithm: The program uses the PID\_Compact block in the TIA Portal V14 SP1 software, which has integrated anti-saturation integral [8]. The operating formula of the PID algorithm is shown as the formula [1].

$$y = K_p \left[ (b.w - x) + \frac{1}{T_i \cdot s} (w - x) + \frac{T_D \cdot s}{a \cdot T_D \cdot s + 1} (c.w - x) \right] \quad (1)$$

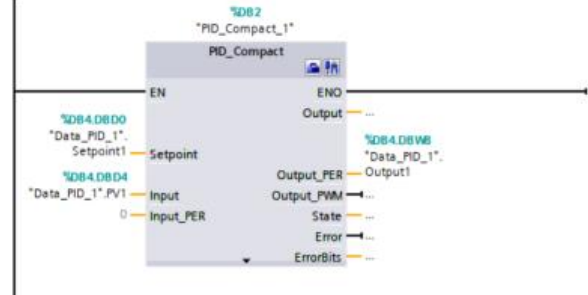
Inside: y is output value; x is feedback value; w is desired setting value; K<sub>p</sub>, T<sub>i</sub>, T<sub>D</sub> are the amplification coefficients, integral constants, differential constants; b, c are the weights of the stages P and D.

The program for implementing the PID algorithm is written on OB35 time block with a time of 100ms:

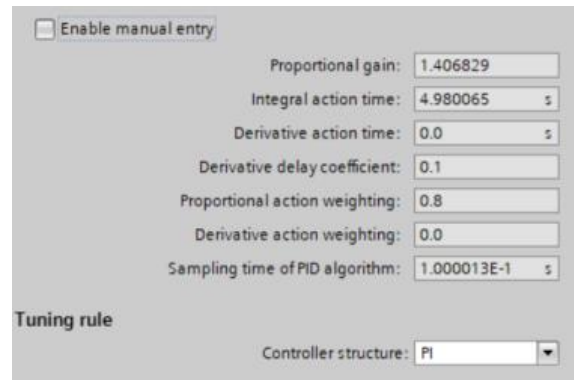
- Receive set speed data from PLC Server:



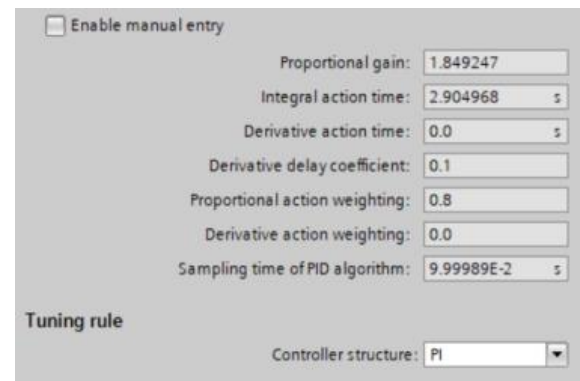
- PID Compact instruction block:



Model problem using PI controller, parameters are determined through Tuning function of TIA Portal V14 SP1, then adjusted as shown in Figure 10.



a) PLC Client 1

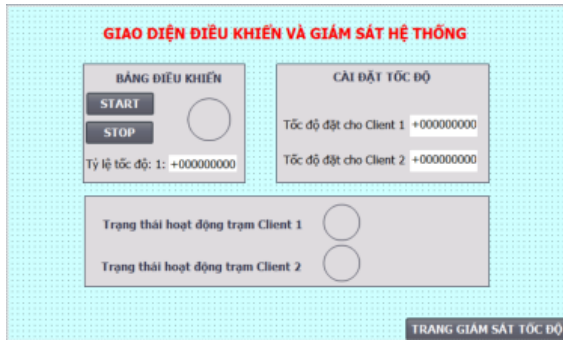


b) PLC Client 2

Figure 10: PID parameter of PLC Clients

**C. Interface Design for HMI Screens**

The HMI screen is responsible for controlling the system, setting the set speed values for the conveyors of PLC Client 1, determining the speed ratio between the two belts, and monitoring the conveyors' speed. The interface is designed with 2 screens, as shown in Figure 11: Including the main screen for set signal input control and speed monitoring screen.



a) Main interface



b) Speed monitoring interface

Figure 11: HMI screen design interface

#### IV. EXPERIMENTAL RESULTS

Connect and run the model test, as shown in Figure 12.



Figure 12: Connect the model and run the experiment

The speed setting is as follows: Conveyor of PLC Client station 1 is 45 rpm; the two conveyors ratio is 1:1 and start the system, as shown in Figure 13. Results of monitoring the belt's load's speed, as shown in Figure 14, the results show that the actual grip speed is very good compared to the set speed.



Figure 13: Installing and booting the system on HMI

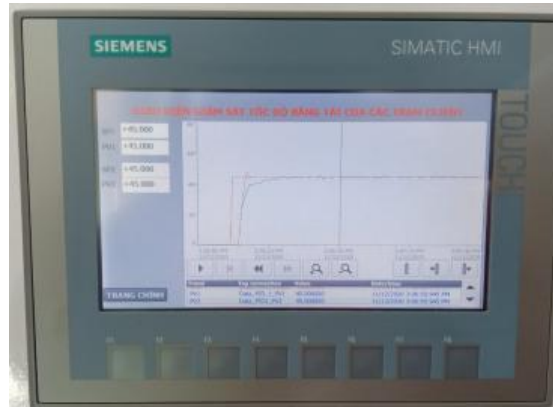


Figure 14: Results of monitoring the speed of conveyors

#### V. CONCLUSIONS

The paper presented the building controller's research problem for the multi-motor co-speed system using the Profinet industrial communication network. Profinet communication network includes 01 PLC S7-1200 (PLC Server), 01 PLC S7 1200 (PLC Client 1), 01 S7 1200 (PLC Client 2), 02 inverters G120C, HMI screen KTP700 PN. The synchronous motor system follows the master/slave control principle, which means that the front motor's output signal is put into the signal set for the rear motor. The motors' speedrunning synchronously with each other at a certain rate depends on the technological process. Experimental results show that the system's response to the PID controller adheres well to the set speed, with a small over adjustment and negligible deviation.

#### ACKNOWLEDGMENT

This study was supported by the University of Economics - Technology for Industries, Viet Nam; <http://www.uneti.edu.vn/>.

#### REFERENCES

- [1] Alexandre Baratella Lugli, Jonas Eduardo Moreira Souza Leandro De Oliveira Pessoa, Ramon Lucano Ribeiro Rodrigues And Thomás Henrique Moreno Tarifa, Industrial Ethernet Networks And Applications, International Journal of Innovative Computing, Information and Control. 12(5) (2016).
- [2] Nguyen Thi Hien, Fuzzy logic in the three-phase asynchronous motor synchronous control system, Journal of

- Science and Technology, Hanoi Industrial University, 49 (2018) 38-42.
- [3] Tripura P. and Y. S. Kishore Babu, Fuzzy logic speed control of three-phase induction motor drive," Int. Journal of Electrical and Computer Engineering. 5(12) ( 2011) 1774 – 1778.
- [4] Saher A. A. and J. R. Mahmood, PLC based multi three-phase induction motors motion controller, Int. Journal of Computer Applications, 175(1) (2017) 37 – 44.
- [5] Martin Višňovský, Róbert Rákay, Alena Galajdová, Dušan Šimšík, Creating Industrial Network with PROFINET Communication for Education Purposes, Acta Mechanica Slovaca, 21(4) (2017) 66 – 72.
- [6] Maciej Rosól, Dawid Knapik, Dariusz Marchewka, Krzysztof Kolek, Andrzej Turnau, Analysis of Industrial PROFINET in the Task of Controlling a Dynamic System, Automatyka/Automatics, 17(1) (2013) 65-72.
- [7] Vo Thu Ha, Dang Thi Tuyet Minh, Vu Huy Hien, Create a practical model using Profinet communication network for educational purposes, Journal of Science and Technology, Hanoi Industrial University, 56 (2020) 19-25.
- [8] Siemens AG, S7-1200 Programmable controller, System Manual, (2019).