Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2018, 5(1): 24-34

Research Article ISSN: 2394 - 658X

Graphical Modeling and Automation of a Single Screw Extruder

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ABSTRACT

The aim of this paper is about single screw extrusion graphical modeling, and automation. At plastic era, industrial processes of polymer shaping are becoming more and more complex, with an increasing demand in terms of safety, robustness, productivity gains and quality. This implies a new integrated automation design which is no longer limited to local regulation strategies but combines communication and systems interconnection. A programmable logic controller represents a key factor in industrial automation. It's an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon a custom program from STEP7 software, to control the state of devices connected as outputs. In fact, in order to automate, to simulate a kind of process, we must first describe the phenomena by a suitable model. The bond-graph approach is based on the decomposition of systems, into sub systems that exchange of power. This approach allows a graphical presentation from which we can deduce the mathematical models. The visualization system for both the automation levels shall be through Human Machine Interface. SIMATIC WinCC system is for Supervisory Control and Data Acquisition of the extruder.

Key words: Single screw extrusion, Modeling, Bond-Graph, Supervision, STEP7, WinCC

INTRODUCTION

Always persons look for comfort. This reflection can appear remote from a topic of industrial sciences, however it is the base of the evolution of sciences in general, and automation in particular. The man initiated by thinking, designing and carrying out. When it was necessary to multiply the number of manufactured objects, to produce in greater numbers, the automation of tasks is then emerged: to replace the man in the painful, delicate or repetitive actions, thus it ensured the survival of the installation. At plastic era, single screw extrusion consists of conveying the solid polymer then to melt and to submit it to a pressure inside a sheath. The comprehension and the automation of physical phenomena which are put into play during the process of single screw extrusion of elastomer constitute the aim of this work.

This study focused on the modeling and automation of different actions in an extrusion chain. The objective is the development of an automatic system for control and regulation of an extrusion unit. The presentation of this study begins with an overview of the automation principles. Subsequently we will detail the design of the single screw extruder, its block diagram, and its operating principle. This justifies the made approximations and specifies the used algorithms. The section on the graphical modeling by bond graph tool follows. A review of the automation techniques with its strengths, limits and the prospects of what it has not been possible to achieve during this study. Several automation software and supervision can be used and among which we include the SCADA, ProTool, PCS7, Step7 and WinCC. Our choice is target on the two latest programs. In fact, the automation systems that we have used are products of SIEMENS.

GENERAL INFORMATION ON AUTOMATION

In modern technology, the automatic systems occupy an important place. Thanks to their applications, it is possible to order complex devices, such as chemical and atomic engines, gas turbines, generators and electrical motors, plane, satellite rocket [1]. Automation, derived from the verb to automate, to make automatically the operation of something in order to reduce or remove the human intervention in the process of industrial production and data processing [2]. The industrial automation is the implementation of automatic means that work alone or without human intervention for the realization of a manufacturing process [3].

Automated Systems

A system of production is said automated when it can manage independently a predetermined cycle of work which is broken down in sequences and/or in steps thanks to a control section (a logical 'brain'). The operator is part of the system or not, depending on the degree of automation [4].

It is generally admitted that an automatism is composed of two subset figure (1):

- A decision organ appointed the command field which may be composed of electrical or electronic circuits. It is capable of processing the information that receives in order to give the corresponding orders.
- An organ performing the actions ordered by the control unit, named operative part.

Components of the Industrial Automation

Programmable Logic Controller (PLC)

The Programmable Logic Controller (PLC) is today the most widespread constituent of the automatisms. For these reasons we are going to try to integrate this control device to meet the needs for automation of the extrusion machine. It is a specialized computer to automate industrial processes, where the oldest automated systems employed hundreds or thousands of relays. A simple PLC is enough now, the PLC, which represents the brain of the command, is programmed by taking into account the digital and analogue inputs that it receives via its input modules. After execution of the program located inside, it sends the appropriate commands via the outputs modules to the various actuators and pre actuators equipping the machines to be controlled [5].

Industrial Sensors

The sensors are automatic components which have for purpose harvesting the information on the operative part and to rebroadcast to the command part so that it can deal with.

Automation Objectives

The automation of systems has allowed to the rights to delete works that are difficult, dangerous repetitive, or even impossible to achieve (hostile environment: radioactive, gaseous, chemical, ambient pressure or depression, excessive temperatures, explosive atmosphere…). In addition, it allows reducing the cost of products by increasing the productivity, by a decrease in times of manufacture, inspection, intervention, maintenance, to manage the stocks in real time and to make the remote maintenance.

DESCRIPTION OF THE SINGLE SCREW EXTRUDER

Operating Principle

Extrusion is a technique of transformation of the thermoplastic matters being in various forms. It allows to obtain objects semi-finished or finished within a system screw/barrel called extruder. Single screw extrusion consists in convoying solid polymer then to melt and to subject it to a pressure thanks to the action of a screw which turns inside a heated barrel. The polymer is then 'forced' in a die of extrusion then cooled, which defines the type of extrusion Fig. 1 [4].

The single screw extruder is by far the most widespread machine in the processing industry of thermoplastics. It principle of operation is based on the friction effect of the plastic on metal under suitable conditions. There is a wide variety of extruders and are constituted of the following items Fig. 2: a sheath, barrel or cylinder generally horizontal, a screw-cylinder with their equipment, a group engine, top of extrusion carries die, an equipment of thermoregulation, a frame or control room which we will try to automate within this work.

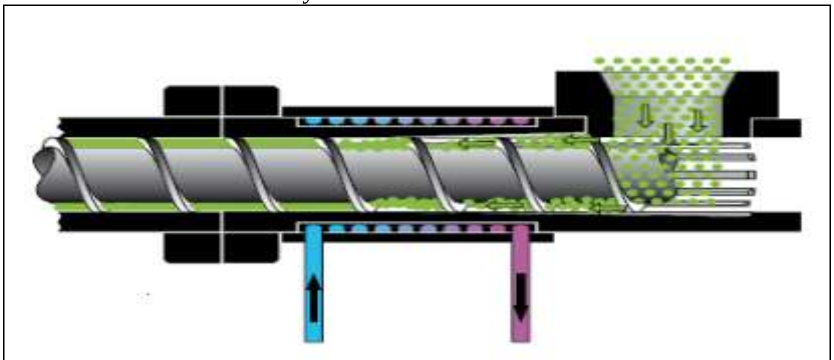

Fig. 1 Schematic diagram of the extrusion within an extruder [4]

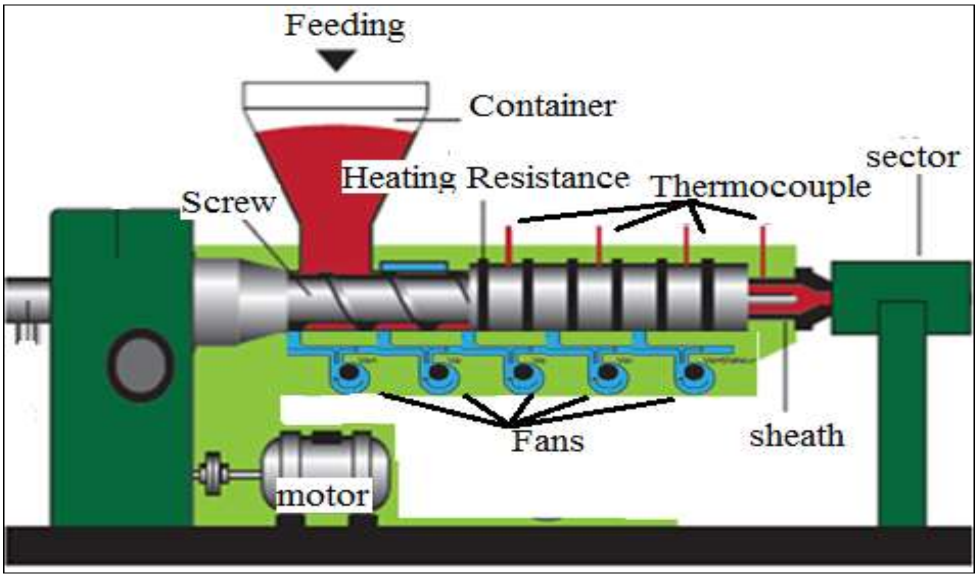

Fig. 2 Diagram of the single screw extruder [6]

Specifications
The objectives of this project are:
- The study of the parameters of the single screw extruder
- The Development of the operating sequences according to these parameters.
- The collection of technical documentation necessary for the establishment of the program of automatism.
- The development of the program and simulation.

This study must satisfy several requirements that have been laid down according to the problems often encountered when using the extruder. The extruder to be automated is an industrial single screw extruder manufactured by the German company Battenfeld kuhne Extruder work Gmbh type B125FK and it has traditional elements of mounting: hopper, barrel, collars heating thermostats. The old feeding system is manual (i.e.) a worker filled the hopper manually [6].

We are going to propose a feeding system which is composed of two section engines and an engine of mixing: The suction raw material engine (94% raw material), the additive suction engine (6% dyes), the engine of malaxation (lasted 1min) and containers matters (hopper, container).

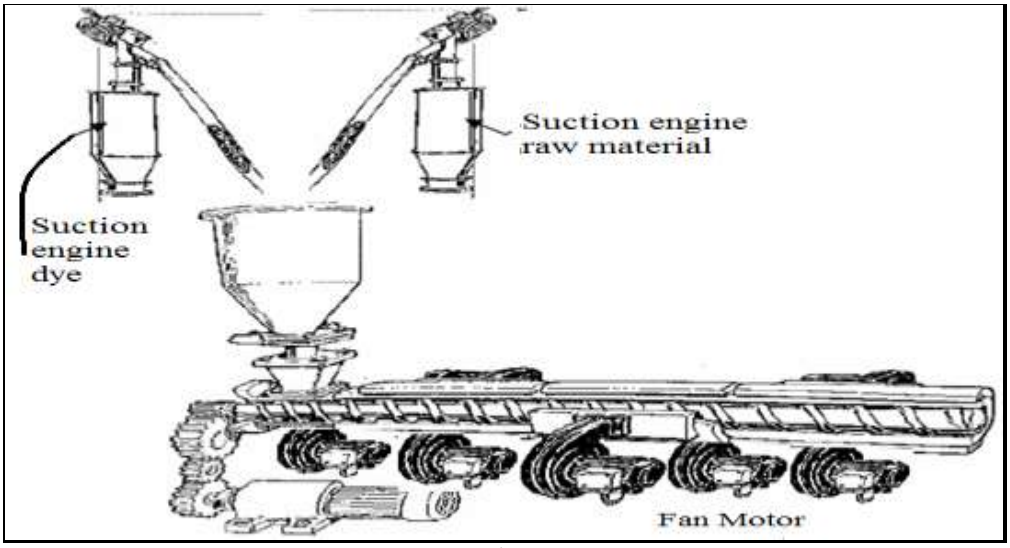

Fig.3 Cross-sectional view of the single screw extruder [6]

Table -1 Thresholds of the Temperature in The Heat Zones

Zones	Z1	Z2	Z3	Z4
Temperature	50°C	120°C	100°C	70°C

We propose to equip the hopper with a system of detection of level by sensors and indicators. Once the matter in the hopper reaches the minimum level, the suction engine of the raw material and the additive suction engine will start, then the engine of malaxation starts for well-defined periods. The cooling of the cylinder can be assured by forced circulation of air around the cylinder or the fluid introduced into the tubing of movement around the cylinder. The matter coming from the hopper arrives in the barrel, is pulled by the screw. We used an extrusion screw intended for the extrusion of thermoplastics. The principal engine is an asynchronous motor. The barrel is heated by the collars of heating which are divided into several heating zones. The matter is compressed and heated; it passes from the solid state in a pasty state throughout the screws. The temperature regulators, thanks to the collars and the fans, make it possible to preserve the desired and constant temperature. The associated barrel has 4 heat zones Table -1. The fans are triggered if the actual value exceeds a certain threshold of the set point. In the figure (3), is given an image to the extruder after the introduction of modifications in order to make these functions automatic.

EXTRUDER GRAPHICAL MODELING BY BOND GRAPH

To Modeling is a procedure which allows, from experimental facts and/or fundamental laws construct a model. The design of a system model is the representation of the real system by a graph. It is pointless to insist on the importance of the modeling as long as science has always been the main objective of obtaining models. In fact, in order to automate, to simulate a kind of process, we must first describe the phenomena by a suitable model, that is to say find a system of equations whose resolution provides the results closest to the real system. The Bond-Graph approach is based on the decomposition of systems, into sub systems that exchange power. The elements BG correspond either to a phenomenon of transformation, dissipation, or energy storage. This approach allows a graphical presentation from which we can deduce the mathematical models associated in the form of a transfer matrix and linear or non-linear state equation]. Thanks to this decomposition and the graphical representation, it is easy to decompose the system into parts or sub-systems and to make a return on any sub-system to improve its design or take account of a physical phenomenon neglected or not taken into account. The model Bond Graph may then be considered as an intermediate model between the physical system and the mathematical model that is associated with it.

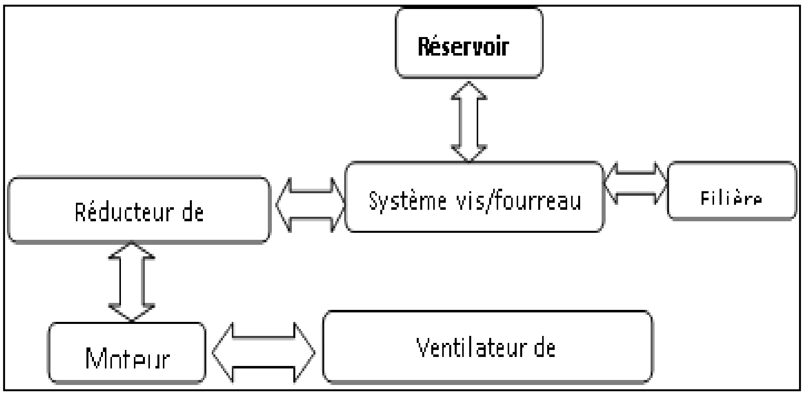

Fig.4 Word Bond Graph

Word Bond Graph

The BG with word represents the technological stage of the modeling. This step is to build the architecture of the system by the Assembly of the different sub-systems, the basic elements of this model are simple technological process. Figure (5) gives the BG to word [7].

Bond Graph of Sub Systems

The Model BG of the asynchronous motor is represented by the figure (6) with Rsa, Rsb, Rsc are stator resistances respectively of the phase A, B, C and Rra, Rrb, Rrc represent rotor resistances respectively phase A, B, C. Isa, Isb, Isc: Inductances of the stator and, Irb, Irc: Inductances of the rotor.

The model BG of the screw /barrel represents: The source of flow by: SF: SF4. The temperature of the zones: T1, T2 and T3 are modeled by R. The moment inertia: I: I1, I2, and I3. The heating collars by the flow sources SF: $(\dot{H})$. The cooling by sources SF: SF1, SF2 and SF3 (Fig.6).

The reducer in our system is used as a power transformer which converts electrical energy into mechanical energy and also varies the speed of rotation of the screw (Fig.7). We simulate the global bond graph model (Fig.8).

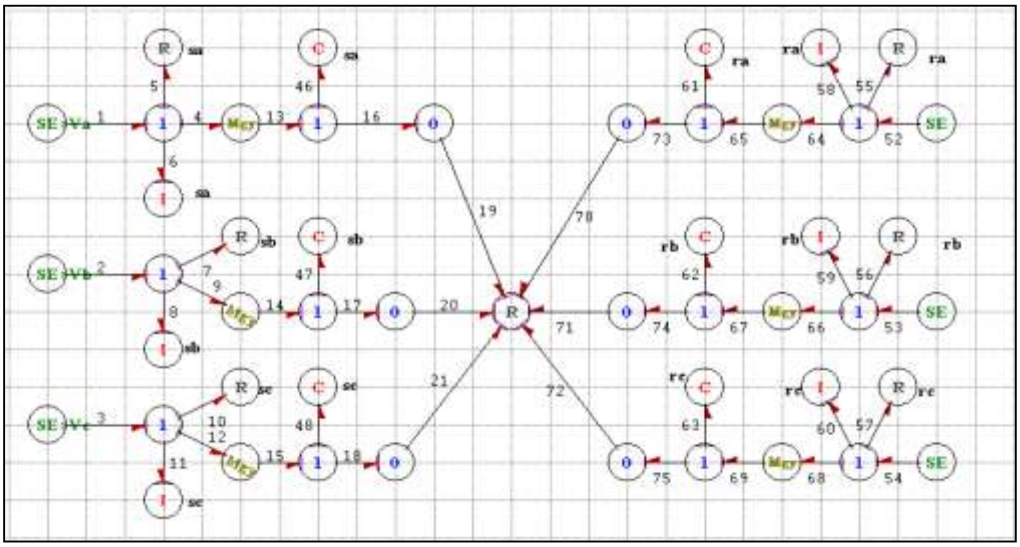

Fig.5 BG Model of a three-phase asynchronous machine

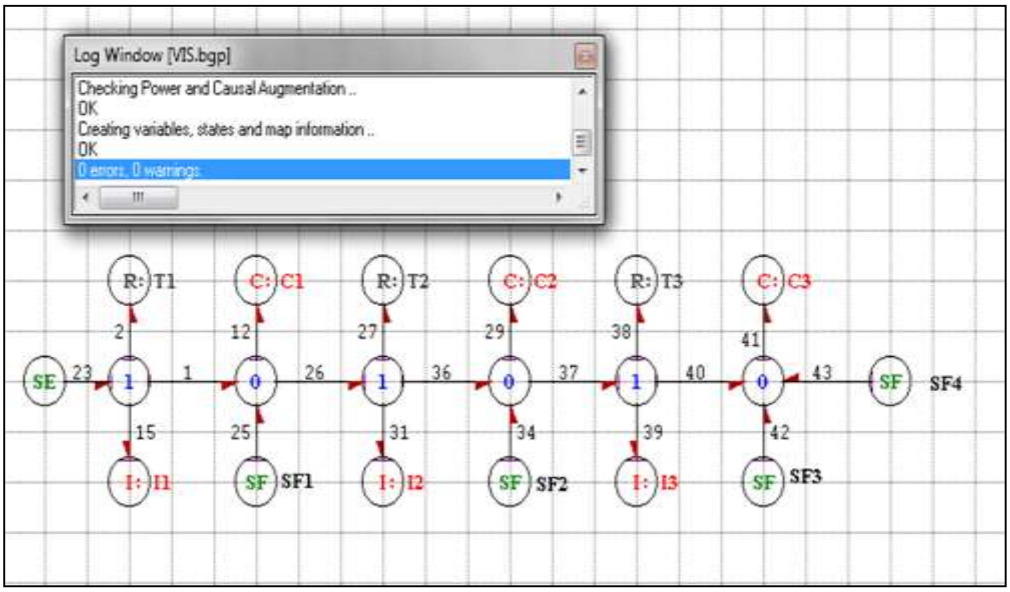

Fig.6 Screw/barrel BG model

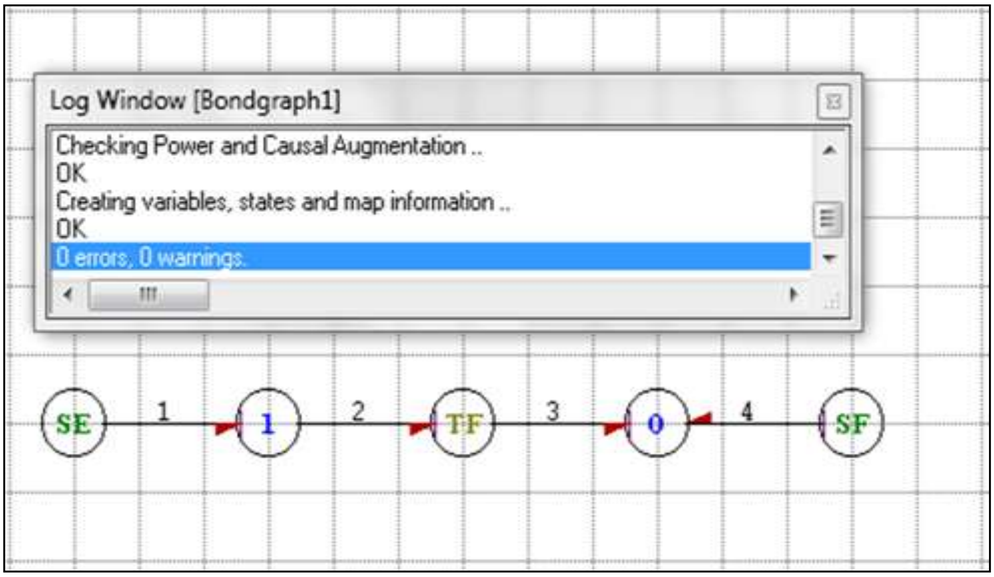

Fig.7 Bond graph of a reducer of the dimmer

Global Bond Graph Model

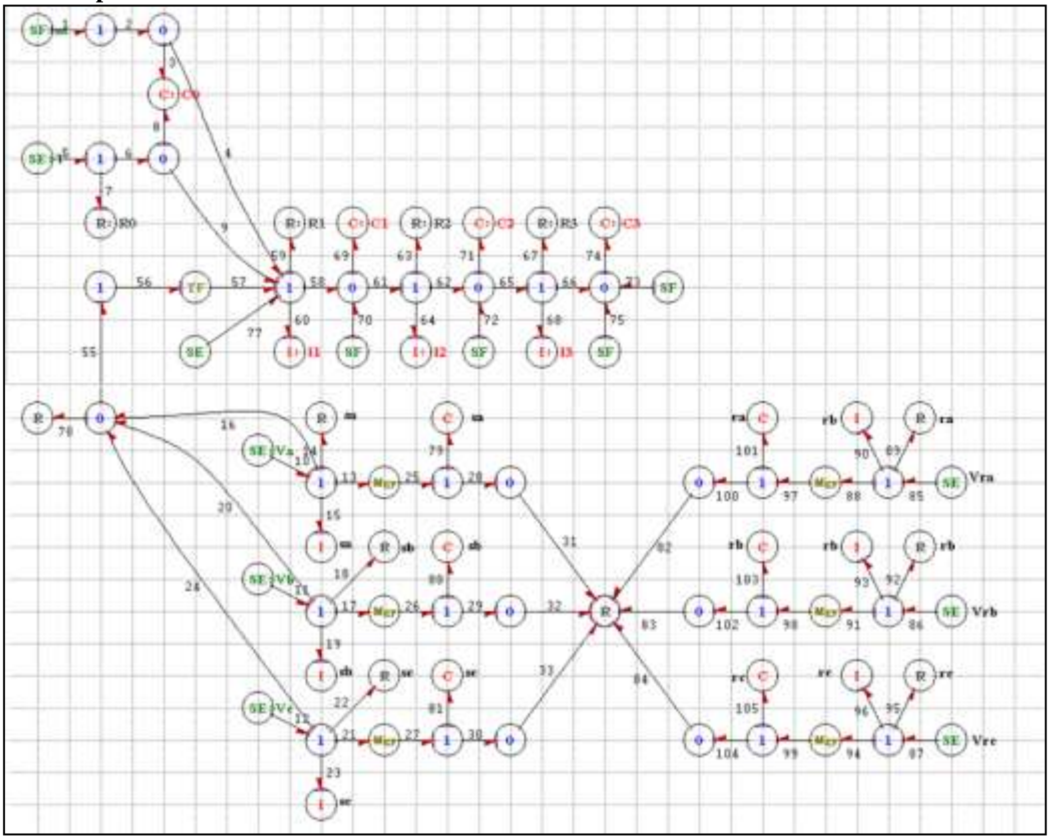

Fig. 8 Global Bond Graph model

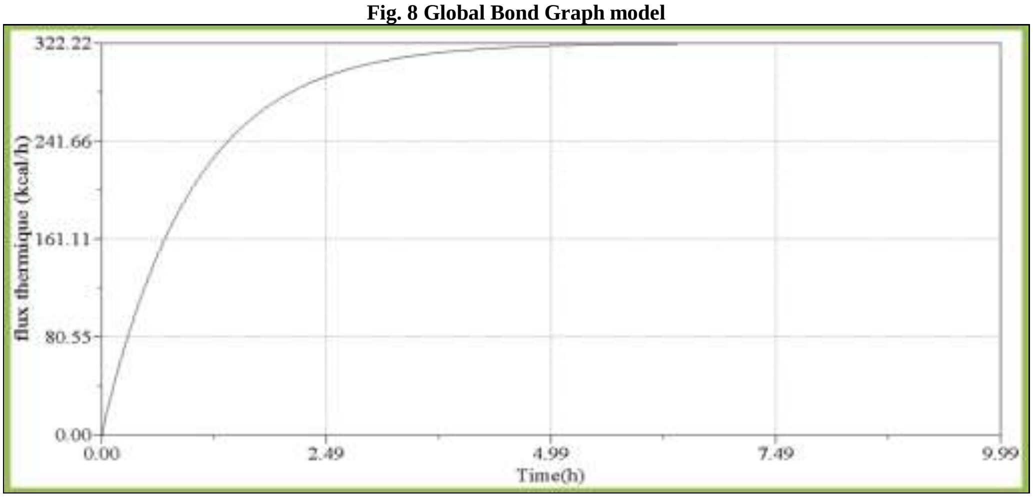

Fig.9 Thermal Flow of the fluid

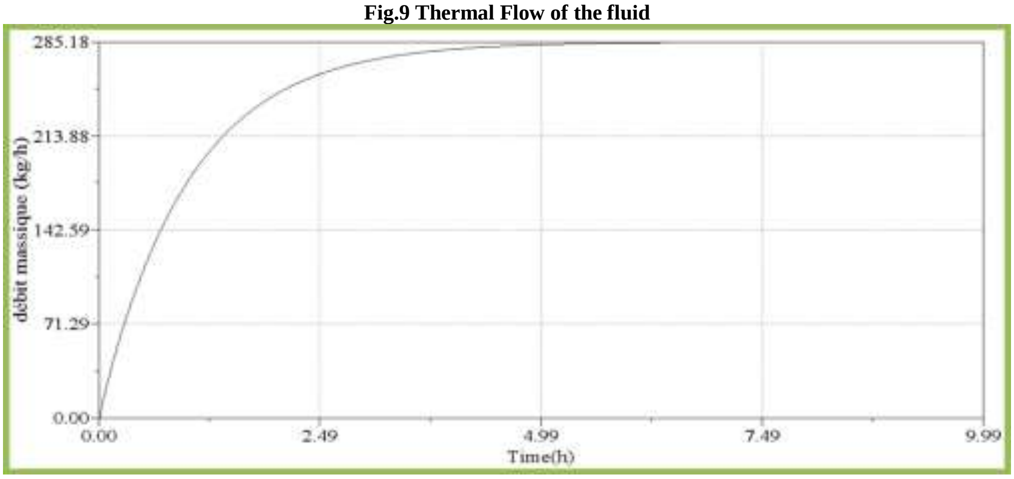

Fig.10 Mass flow of the fluid

SIMULATION RESULTS

SYMBOLS (System Modeling by Bond graph Simulation Language), is software for modeling and simulation specially to simulate the behavior of dynamic systems, such as: electrical, mechanical, hydraulic system. The evolution of thermal flow of the fluid is represented by the figure (9). The thermal flow varies in a progressive way of t=0 h up to t=4 h and after t=4.99 h the heat flow will be constant at 322.22kcal/h. because the quantity of heat in the area of fusion is greater than the amount of the crop feed area. The temperature of a substance is 0°C at the beginning of escorts and will increase the period of fusion and for this we observed the increase of the curve and bitter the saturation. The development of mass flow in the fusion zone is represented by the figure (10).

AUTOMATION BY STEP7 AND SUPERVISION BY WINCC

To control the unit of extrusion, we carry out a program which we will introduce in the PLC thanks to the programming software of automation systems SIMATIC STEP7. The STEP7 software is the programming tool of automation systems: SIMATIC S7-300, SIMATIC S7-400, SIMATIC WinCC. STEP7, it offers all the functionalities necessary to configure, parameterize and program the API [7]. So we will start to automate the function of extrusion and food according to the specifications. The principal engine (of the screw) will start if the zones of heating reach a certain threshold, the pushbutton walk is inserted and its protection is assured by figure (11). The network 3 is identical to the network2 because the second vacuum cleaner (for dye) works on the same chart except that its operating time is different. In the following we will use the memory bits for not cluttering up our program. The phases of mixing and feeding of the screw are shown in figure (13, 14).

The level detector triggers the operation of the engines according to the following model Figure (12). It was suggested here an indicator to indicate the sequence of food steps. The network 7 figure (9), is a block call FC1 from the OB1. For the cooling of the barrel, it is proposed the following structure of the programs. We give here an example of a cooling program for only one zone, the other zones function according to the same program but with different thresholds (Fig.16, 17, 18). To test a program without connecting the PC with API hardware, it is enough to activate the simulator S7-PLCSIM.

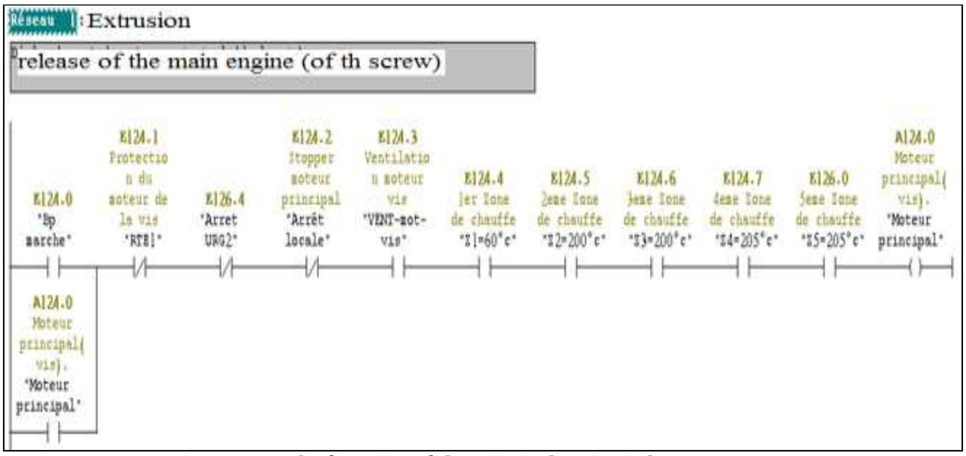

Fig.11 Network of starting of the principal engine in language CONT

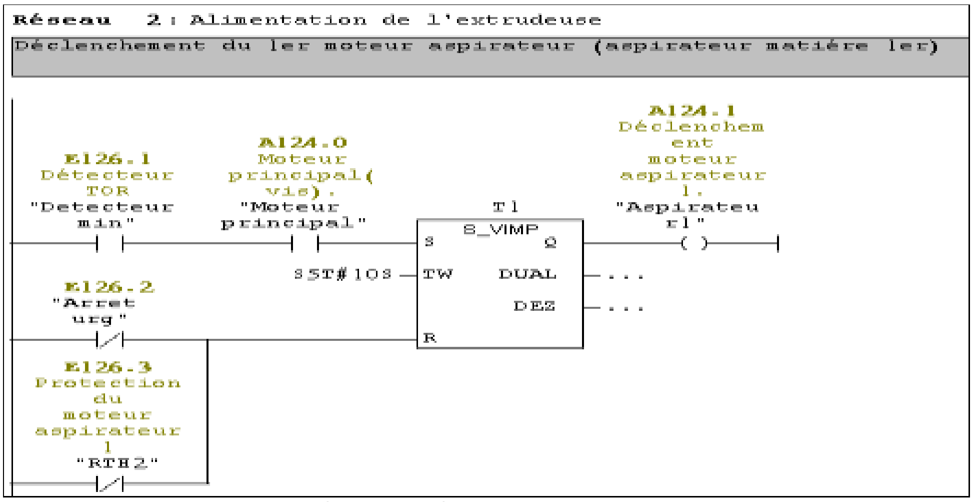

Fig.12 Network of operation of the suction engine 1 in language CONT

```
Réseau  4 : Alimentation de l'extrudeuse
Utilisation d'un bit dans la mémoire appelé Mémento

      U(
      O      "Detecteur min"          E126.1          -- Détecteur TOR
      O      M       0.0
      )
      UN     "clapet"                 A124.4          -- Clapet d'alimentation
      U      "Moteur principal"       A124.0          -- Moteur principal(vis).
      =      M       0.0
Réseau  5 : Alimentation de l'extrudeuse
Déclenchement du  moteur de malaxage (pour mélanger les deus matiéres)

      U      M       0.0
      UN     "Aspirateur1"            A124.1          -- Déclenchement   moteur aspirateur 1.
      L      S5T#7S
      SV     T       13
      U(
      ON     "Arret urg"              E126.2
      ON     "RTH4"                   E126.6          -- Protection du moteur malaxeur
      )
      R      T       13
      NOP    0
      NOP    0
      U      T       13
      =      "Moteur malaxage"        A124.3
```

Fig.13 Networks of the use of a flag and triggering of the malefaction

```
Réseau  6 : Alimentation de l'extrudeuse
Ouverture du clapet pour alimeter l'extrudeuse

      U      M       0.0
      UN     "Aspirateur1"            A124.1          -- Déclenchement   moteur aspirateur 1.
      UN     "Moteur malaxage"        A124.3
      L      S5T#15S
      SV     T       2
      UN     "Arret urg"              E126.2
      R      T       2
      NOP    0
      NOP    0
      U      T       2
      =      "clapet"                 A124.4          -- Clapet d'alimentation
```

Fig.14 Program of opening the valve of matter in the extruder

```
Réseau  7 : Voyant clignotant
La sortie A124.5 est un voyant qui nous informe sur les different
etapes; ceci en clignotant avec differentes frequences.
      U(
      O      "Aspirateur1"            A124.1          -- Déclenchement   moteur aspirateur 1.
      O      "Apirateur2"             A124.2          -- Déclenchement  moteur aspirateur 2.
      )
      U      M       10.1
      O
      U      "Moteur malaxage"        A124.3
      U      M       10.7
      O      "clapet"                 A124.4          -- Clapet d'alimentation
      =      A       124.5

Réseau  8 : Titre :
Appel du bloc FC1.

      CALL   FC      1
      NOP    0
```

Fig.15 Networks for indicator and call of block FC1

```
OB1 : REGULATION DU TEMPERATURE DE LA VIS
Commentaire :

Réseau 1 : Titre :
Fréquence d'échantillonnage

        UN      M       2.0
        L       S5T#20MS
        SE      T       3
        NOP     0
        NOP     0
        NOP     0
        U       T       3
        =       M       2.0
```

Fig.16 Sampling rate

```
Réseau 2 : Titre :
Lecture des entrées analogiques:les températures des zones,au niveau des
entrées analogiques PEWx et transférer au niveau des mémento MWy.

       U     M      2.0
       =     L     20.0
       U     L     20.0
       SPBNB _001
       L     "Capteur tmpérature Z1"       PEW752
       T     MW    12
_001:  NOP   0
       U     L     20.0
       SPBNB _002
       L     "Capteur tmpérature Z2"       PEW754
       T     MW    14
_002:  NOP   0
       U     L     20.0
       SPBNB _003
       L     "Capteur tmpérature Z3"       PEW756
       T     MW    16
_003:  NOP   0
       U     L     20.0
       SPBNB _004
       L     "Capteur tmpérature Z4"       PEW758
       T     MW    18
_004:  NOP   0
       U     L     20.0
       SPBNB _005
       L     "Capteur tmpérature Z5"       PEW760
       T     MW    20
_005:  NOP   0
```

Fig. 17 Reading of data from temperature sensors

```
Réseau 3 : Titre :
Si l'entrée analogique est supérieur ou égale à un seuil le bit TOR de la
sortie  A125.Y est a 1 donc le moto-ventilateur se declenche

       U(
       L     MW    12
       L     65
       >=I
       )
       SPBNB _006
       L     255
       T     MB    30
_006:  NOP   0

Réseau 4 : Titre :
Si l'entrée analogique est inférieur ou égale à un seuil le bit TOR de la
sortie A125.Y est a 0 donc le moto-ventilateur s'arrête

       U(
       L     59
       L     MW    12
       >=I
       )
       SPBNB _007
       L     0
       T     MB    30
_007:  NOP   0

Réseau 5 : Titre :
Declenchement de la ventilation de la 1ER zone

       U     M     30.0
       =     "Moto-ventilateur1"          A125.0
```

Fig. 18 Release of ventilation

SUPERVISION OF THE PROCESS WITH A HUMAN MACHINE INTERFACE « HMI »

SIMATIC WinCC is a supervision system of process which offers powerful functions of automatisms monitoring. WinCC offers complete functionalities SCADA under Windows for all the sectors since the single-user configuration until the multi-user systems distributed with redundant waiters and solutions multi sites with Web customers [7]. From Graphics Designer we will create a view of supervision according to the following figures:

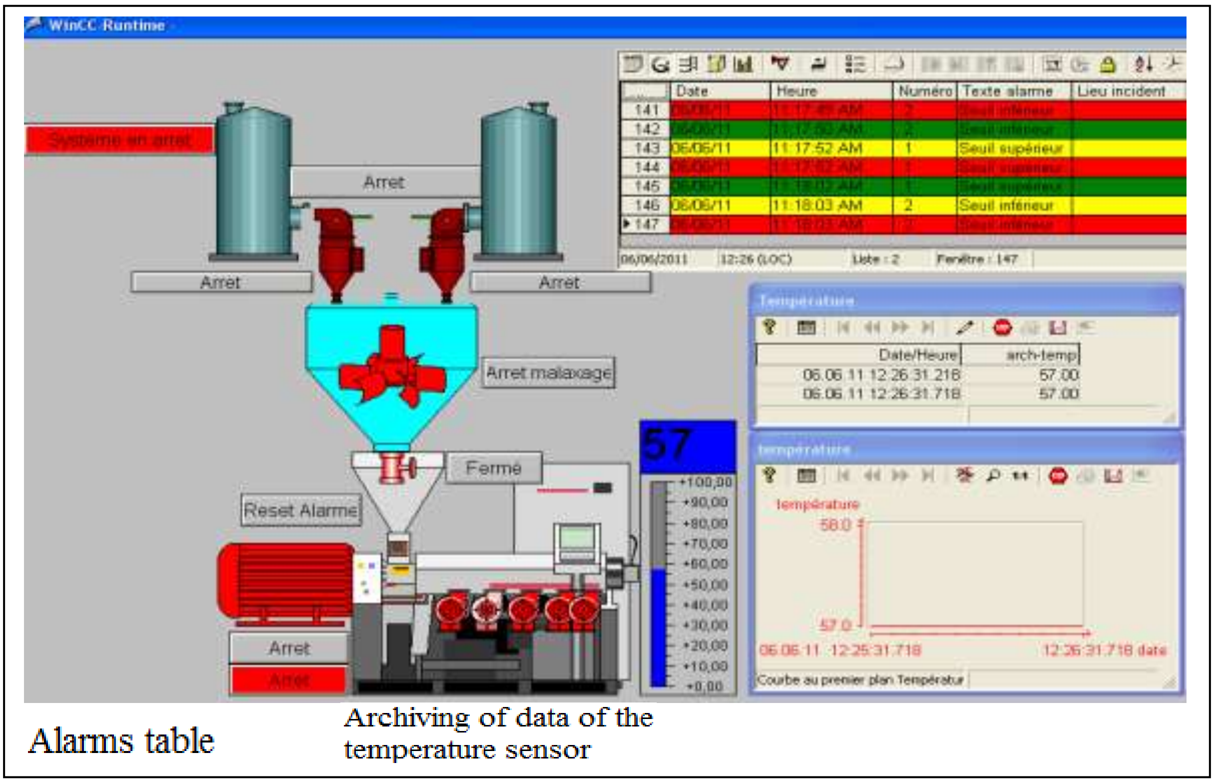

Fig.19 Supervision of the process in stop

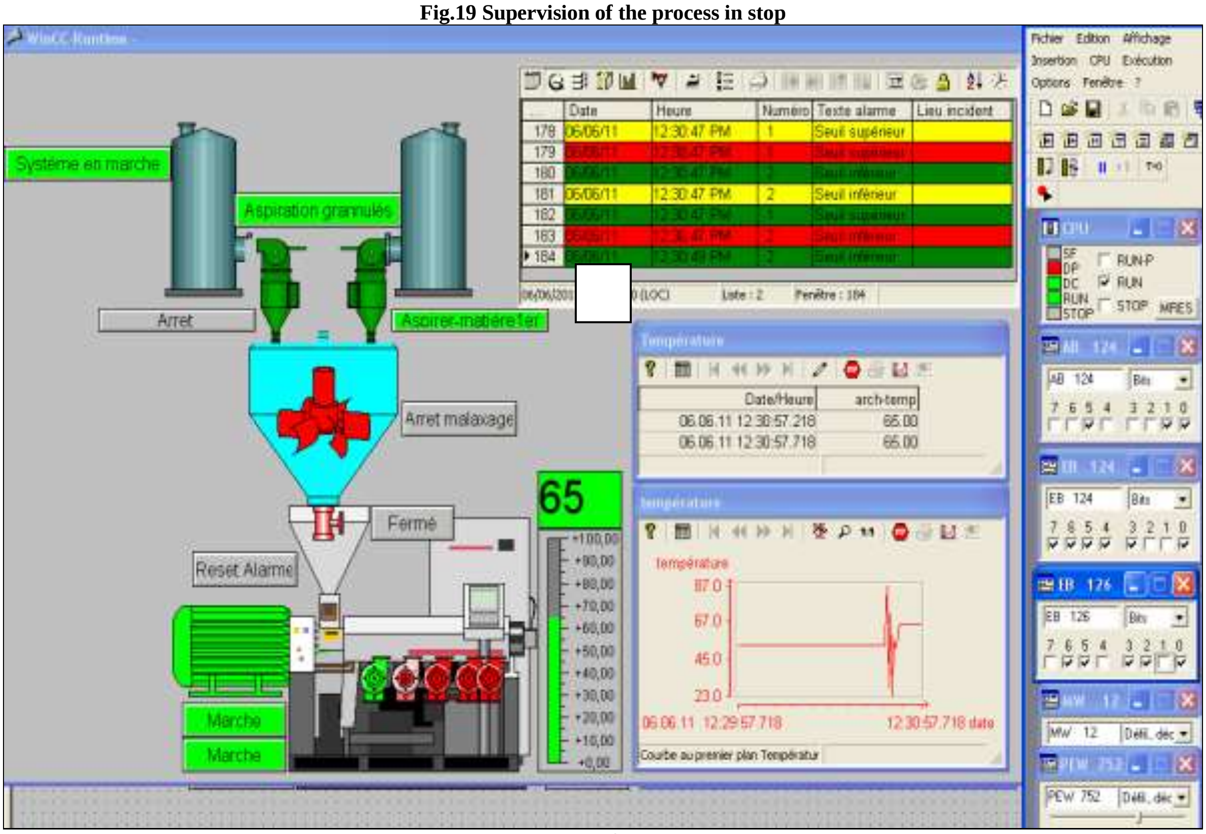

Fig.20 Supervision of operating process

CONCLUSION

The primarily drawn points during this study are:

- Fitted with powerful software, the programmable logic controller's forma processing and control units of a great flexibility.
- The API makes it possible to manage automated systems, using languages standardized in industrial environments, even severe.
- The basic software for the programming of automation systems STEP7, is efficient software thanks to its flexibility, it provides a high consistency of data on the whole the engineering process. .
- Human/machine interface (HMI) SIMATIC WinCC fulfills the requirements of supervision and piloting of the processes for solutions for all the sectors and all technologies.
- In an automation project expectations are in general very strong and at the height of the investments made on the one hand, and on the other hand, automation can affect all or part of the operations. That is why a phase of needs analysis is essential and must be conducted with precision by following an approved methodology. This phase should absolutely not be neglected or treated too quickly.
- The automation is a solution for the future
- Extrusion of thermoplastic is widely employed in industry, the control of the quality passes through an understanding of the different phenomena concerned within the process. The long-term objective is the taking into account to a full range of operation. In addition, the thermal behavior of the process greatly influences the quality of the product at exit of die, from where the need for a command at the same times on the viscosity and the temperatures of the sleeves with a take into account the various interactions

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