Automation control of EBW installation by SIMATIC S7-300 PLC

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In this work the automatic control of the vacuum and cooling systems, together with electron beam initiation, of the located in the IE-BAS equipment for electron beam welding, evaporation and surface modification by SIMATIC S7-300 PLC is considered. The control and management based on the development of engineering support system using existing and proposed additional technical means of automation is developed. Experimentally obtained are transient characteristics, which can be used for the optimization of the indicators, which are critical for the duration of the reaching working regime mode and stopping the operation of the installation. The automation of the available equipment, which aims the improvement of its efficiency and the repeatability of the obtained results as well as stabilization of the process parameters, should be integrated in an Engineering Support System, which consists besides the operator supervision from several subsystems for equipment control, data collection and acquisition, information analysis, system management and decision support.

Автоматично управление на инсталация за електроннолъчево заваряване с програмируем контролер SIMATIC S7-300 (Елена Колева, Володя Джаров, Петър Йорданов). *В тази работа е разгледано автоматичното управление с програмируем контролер SIMATIC S7-300 на вакуумната и охлаждащата системи, заедно с инициирането на електронен лъч, на намиращото се в ИЕ-БАН оборудване за електроннолъчево заваряване, изпарение и повърхностна модификация. Разработени са контрол и управление, базирани на инженерна поддържаща система с използване на налични и предложени допълнителни технически средства за автоматизация. Получени са експериментално преходни характеристики, които могат да се използват за оптимизирането на параметри, които са критични за продължителността на времето за достигане до работен режим и времето за спиране на инсталацията. Автоматизацията на наличното оборудване, което цели повишаването на нейната ефективност и повторяемост на получените резултати, както и стабилизирането на параметрите на процеса, трябва да бъде интегрирана в инженерна поддържаща система, състояща се освен от наблюдение от страна на оператора и от няколко подсистеми за контрол на оборудването, събиране и обработка на данни, информационен анализ, системно управление и вземане на решения.*

Introdiction

The electron beam has developed over the years into a flexible and economic manufacturing tool. With the advanced development of computer control the number of electron beam applications has significantly increased. For the electron beam welding (EBW) technologies [1] new applications the EBW plants has developed into a complex equipment containing highly stabilized power sources and electronic blocks, reliable and effective vacuum system, technology chamber with precision 3D manipulators with up to 9 degrees of freedom, becoming truly software controlled programmed manufacturing tools with high efficiency and excellent reproducibility. Technological data gathered during the process enable quality monitoring and support improving the testing process of the manufactured components as well as their recording for future analysis of the relations of the adjusted process parameters with the quality and stability of the welds.

In this paper more in detail the automation of the equipment control of electron beam welding installation by programmable logical controller (PLC) SIMATIC S7-300 is considered, which practical realization will help the implementation of fully integrated Engineering Support System (ESS) [2].

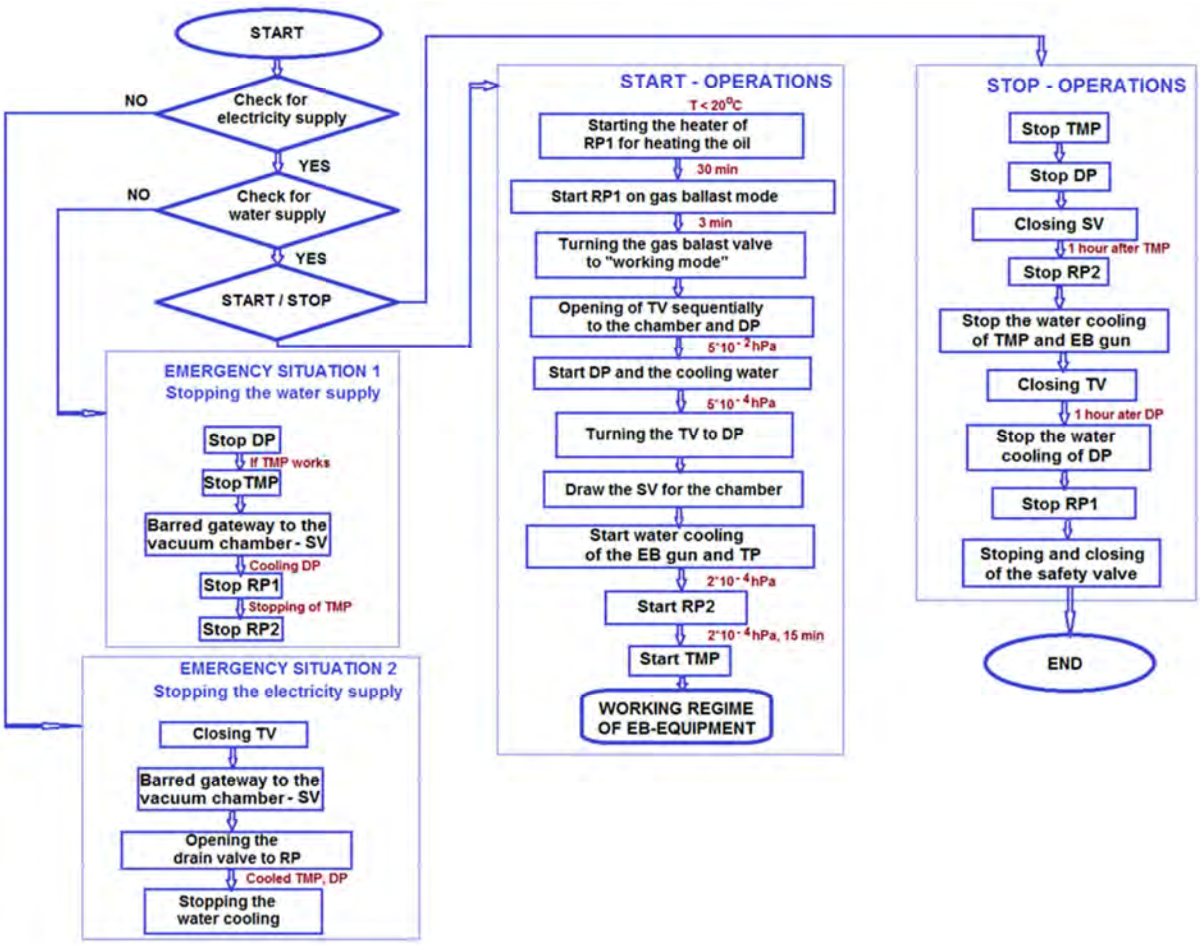


Fig. 1. Control algorithm for control of EBW installation: start, stop and emergency situations. (RP – rotary pump, TMP – turbo-molecular pump, DP – diffusion pump, SV - spooled valve, TV three-way valve)

EBW control algorithm

From system engineering point of view, the EBW is a complex system of processes that can be engineered to accomplish specific business and technological objectivities. The main features of EBW plant, which must be taken into consideration by the ESS development are the following: vacuum level ($5*10^{-4}$ hPa); power density (2 kW/cm^2) available for welding of different materials, local superheating, precise control of movement of the beam and the welded samples, as well as automation of the process.

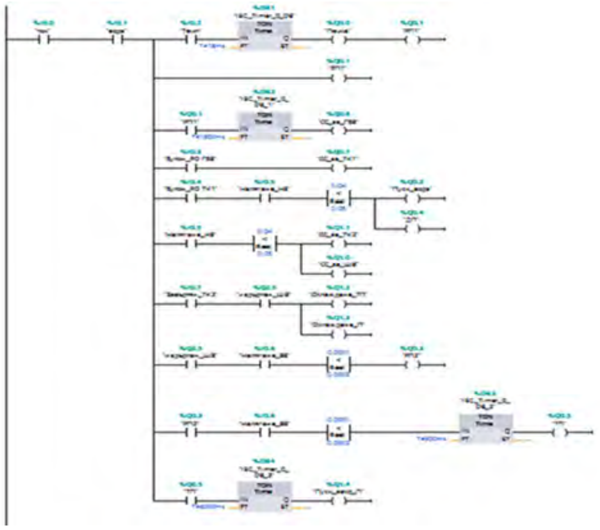
The EBW vacuum and cooling systems control algorithm, as sequence of operations at starting and shutting-down the EBW equipment, timing and performance criteria, as well as the actions in two major emergency situations - suspension of water supply and electricity cuts are presented in Fig. 1. The timing and performance criteria for each separate operation, if they are available, are presented above the corresponding block.

At starting of the EBW installation it is necessary to take into account the ambient temperature, which is a condition for the initial heating of rotary pump (RP1) oil. If the temperature is above 20 °C, we move to the next operation and start the RP1 on gas ballast mode. The check for availability of electricity and water must be carried out continuously by appropriate technical means.

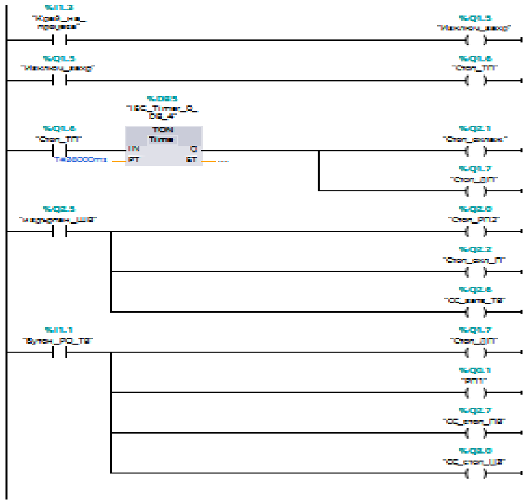
In order to improve the operation of the EBW installation in emergency situations we recommend building of sound and light alarms, additional air-cooling for the diffusion pump and the use of alternative supply (UPS).

Fig. 2 presents the ladder-diagrams for SIMATIC S7-300 PLC for the star and stop operations and the considered two emergency situations. The start operations include continuous checking for suspension of water supply and electricity cuts.

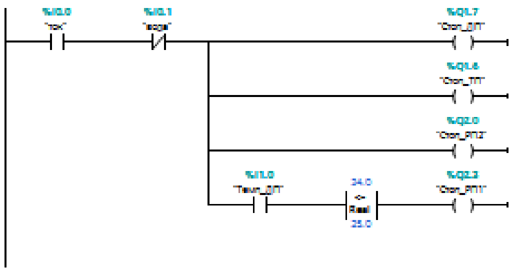
The control algorithm can be presented also in the form of functional block diagrams, like the one, shown in Fig. 3 for emergency situation 2 – stopping the power supply.



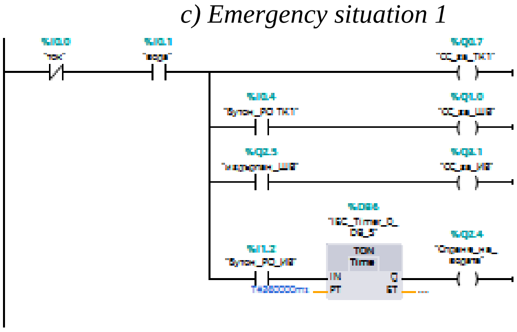
a) Start operations



b) Stop operations



c) Emergency situation 1



d) Emergency situation 2

Fig.2. Ladder-diagrams for SIMATIC S7-300 PLC

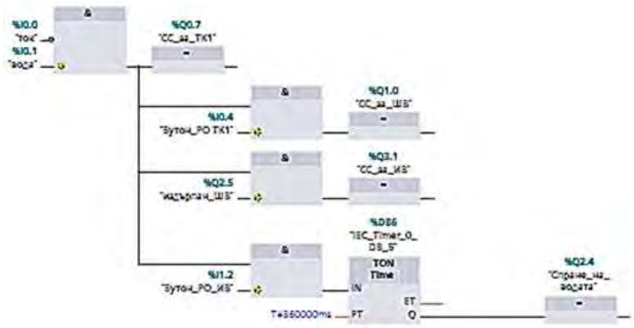


Fig. 3. Functional block diagram – emergrncy situation 2

In order to avoid the damage of elements of EBW installation the duration for the reaction to emergency situations should be less than one minute, which is difficult in case of manual control of operations.

The main input/output signals used for the realization of the algorithm are:

a) input signals digital (D) or analogue (A) – DI or AI come from:
   - sensor for high pressure - AI;
   - sensor for low pressure – AI;
   - sensor for electricity supply – DI;
   - sensor for water supply – DI;
   - sensor for temperature – DI.

b) output signals – digital DO:
   - start/stop of the diffusion pump;
   - start/stop of the turbo-molecular pump;
   - start/stop of the rotary pump RP1;
   - start/stop of the rotary pump RP1;
   - start/stop of the cooling of the diffusion pump;
   - start/stop of the cooling of the turbo-molecular pump;
   - start/stop of the cooling of the electron gun;
   - open/close the spooled valve;
   - positions of the three-way valve.

The control algorithm is realized by Siemens TIA Portal.

Optimization and management of the time duration of one welding cycle is associated both with optimal management of available technical means and the introduction of new ones with more flexible management, with better parameters or support functions.

The main aim of developing ESS [3] for EBW plants is to integrate and organize the knowledge for the EBW processes and plants and to use this knowledge to improve the modeling and control capabilities, their efficiency, adaptability, flexibility and re-configurability. The automation of the equipment control sub-system is only a part of the fully integrated ESS. Generally the structure of the ESS is defined to have the following elements (sub-systems): Data Collection and Acquisition (DCA), Information Analysis (IA), Decision Support System (DSS) and System Management (SM). They should be integrated with the System for Equipment Control (EC) in order to realize working ESS. Equipment Control (EC) (automation and/or manual) is usually designed by the EB equipment producers. It includes sources of actual measurement of data for the state of the EBW equipment by sensors or other measuring devices – Monitoring agents (MoA).

Conclusions

The automation of electron beam welding installation by programmable logical controller (PLC) SIMATIC S7-300 is considered. This is an important practical task for enabling the quality monitoring of the manufactured components on the available EBW equipment. Its practical realization will help the development and implementation of fully integrated Engineering Support System (ESS) for control and management of different EB processes on the considered installation.

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