Monitoring of Processes in an Induction Heated Electro-Technological Installation

Stanimir Y.Yordanov[1], Nikolay D. Madzharov [2]

Abstract: **This paper describes a general structure of a computer-implemented, object-oriented software system is describe. The system uses artificial intelligence mechanisms and is intended for the control of technical objects that function both in predictable and random environments. The structural and regular nature of the suggested system can be use for creation dedicated computers which operate on non-Von Neumann's principles and mechanisms of generating neural-network structure.**

Keywords: **Real-Time problems; RTS System Kernel functions; Automatically programmed RTS, Neural network identification and control**

I. Introduction

Contemporary industry has at hand a wide spectrum of methods for ensuring quality of output. On the other hand technological process has a substantial impact on both the structure and the construction of active control systems. The questions here is the choice of the most appropriate method for the specific case. One possible solution for reducing quality assurance costs is the optimization and management of production processes by active monitoring of the basic production parameters [5].

In the basis of this direction is real time observation of production processes. Based on of the alteration of a certain number of quantities, one can judge about the final production output. This control method is characterized by high reliability, reduction of defects due to the possibility for an immediate reading of any change in the normal production progress, as well as the possibility for anticipating of the occurring changes [4]. For this purpose it is necessary to create specialized software for the realization of the active monitoring method. The present paper describes the application of an active monitoring system in an electro-technological installation for food processing industry.

II. Object Description

A number of contemporary electro-technological processes with inductive heating when producing packaging for food industry are characterized by a wide range of inductors, mainly low-impedance ones, working in a specific sequence of heating. Having in mind the high precision of processes and the quality of the end product, a strictly defined voltage should be supplied for the respective inductors. This condition places requirements to the power sources for the cases when it is necessary to rapidly switch from one inductor to the other with exact co-ordination of voltage and power.

[1] Stanimir Y.Yordanov is with the Technical University of Gabrovo, H.Dimitar str. 4, 5300 Gabrovo, Bulgaria e-mail: sjjordanov@tugab.bg Pfone: 0035966223571

[2]Nikolay D. Madzharov is with the Technical University of Gabrovo, H.Dimitar str. 4, 5300 Gabrovo, Bulgaria e-mail: madjarov@tugab.bg Pfone: 0035966223557, Fax: 003596624856

There exist several approaches to satisfy those specific requirements. Most often it is power supply represented by transistor power supply with autonomous inverters (AI) feeding the various inductors, according to the diagram on Figure 1, which is used in this paper

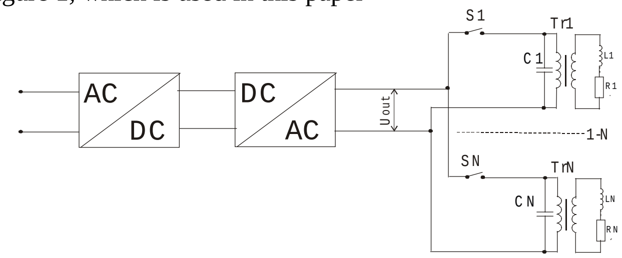

Fig 1: A principle diagram of a induction heating installation

Which consists of:

- AC/DC block– rectifier and DC/DC converter (PWM-type), intended to ensure necessary DC voltage of the AI.
- DC/AC high-frequency power supply, intended to convert direct into high frequency alternating energy about 550kHz
- the system with individual transformers and tank circuits

As it can be seen the supply source is switched by the electronic switches S1 – SN to the coils L1, R1 – LN, RN, which have their own output transformers Tr1–TrN and matching capacitors C1-CN. Individual power for a given inductor is specified by the autonomous inverter (AI) direct currency control. In this case the AI output voltage is invariable and is controlled in narrow limits and by the output transformers Tr1–TrN and the matching capacitors C1-CN is maintained the predefined value of the equivalent resistance of the tank circuit, working in resonance or near-resonance. More detailed information on the generator function can be found in [1 in 2].

Functional capabilities of the system with individual transformers and tank circuit are good, but the presence of appliance complexity is apparent, also exploitation inconveniences and in some cases reduced reliability. To solve the problem instead of a parallel, rather a parallel-serial tank circuit is used together with a system for active monitoring of processes.

III. Selection of analysis parameters

The object of production is cartons for liquid products. For their manufacturing it is necessary to be made three seams. Each seam is a volume of foil with thickness 0.008 mm, which has to be heated and also plastic which has to be melted. It is obvious that to have a quality seam i.e. to melt the plastic at the required temperature, a specific power quantity has to be applied for a given time at the place of seaming. Power can be easily calculated if the parameters of the inductor are measured – the current, the voltage and the phase shift between them, i.e. $P = U.I.\cos\varphi$. The power depends on the mutual position of the inductor and the foil to be welded and obviously it is a major criterion, by which the quality of the manufactured carton can be judged. If P is less than necessary, an uneven, thin seam will be produced, if P is higher, the seam will overburn and again will not have the required quality. Less P occurs at a longer distance between the inductor and the foil, the reason for which could be simply mechanical.

Assessment of power is made on the basis of voltages of the secondary coil of the transformer and the inverter.

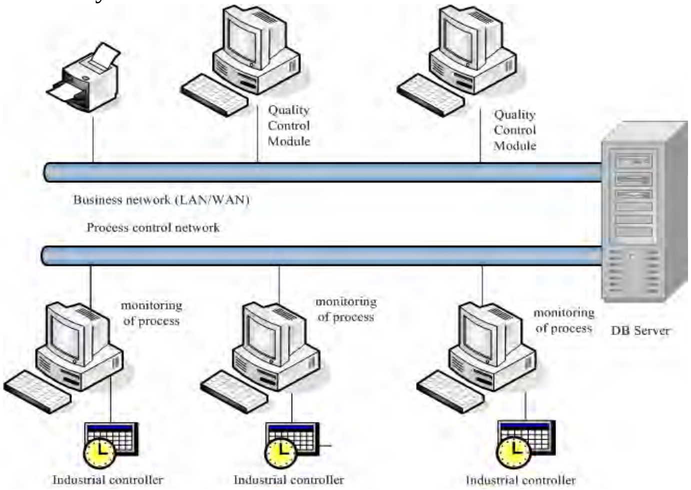

Fig.3. The structure of system.

Based on these arguments the system for quality assessment of cartons manufacturing is built, namely by measuring the principal electric parameters of the system *inductor-welded foil*, to calculate the power transmitted in each seam and by subsequent computer data processing to control the quality of cartons as a whole and to provide an estimation of its level.

IV. Structure of a software system for active monitoring.

The structure for active monitoring of processes is shown on Figure 3.

The system consists of the following modules:

- Operating control module – designed to collect data, during the manufacturing process up to their importing to the main database. The latter resides on the same computer as the Operating control module.
- Local Database – this keeps data received during production up to its import to the Main Database. It resides in the same computer as the Details Quality Control and Assessment Module.
- Main Database – it keeps data about the process flow of all manufactured details, as well as the data received after analysing the preceding data. The time for keeping the data is defined by the specific character of manufacturing and the corporative policy regarding this information. It is situated on a separate file server.
- Details Quality Control and Assessment Module – designed to perform an analysis of manufacturing data and yield a conclusion about production quality. Based on data received, an analysis of the tendency on quality managemnt and decisions are taken on the manufacturing process.
- Module for design of active processes monitoring – its purpose is to build up the topology of the monitoring system.

V. System Implementation

a) System Structure

The separate functions are realized bt three software modules: Active Monitoring and Process Management Module - *Control Manager*, Data Statistical Processing and Keeping - *Quality Manager* and a Module for Database Creation and Editing of supported technological processes - *Library Manager*. A key stage in system realization is the choice of platform for its realization.

The present system is realized on Windows NT. The prerequisites for the choice of this platform are:

- popular and easy to use graphic interface
- widely distributed applications, servicing and maintenance of devices (serial, parallel and network) and a specialized interface (for animation), which can be used to sell the new products and applications faster.
- Possibility for operating on a wide range of cheap PC platforms, which reduces application costs.
- a wide range of software instruments and a large number of experiences developers which reduces development costs
- whole and continuous interaction between the hardware elements, the OS and the software means RTS
- time necessary for developing of an efficient software application
- The necessary human working hours for RTS designing, adjustment and servicing
- Low-level drivers are already created
- Windows NT comprises all aspects of network integration and file management
- The known technologies and management algorithms allow for an easy implementation

The active monitoring system is designed for real-time operation. Hence a basic parameter in its implementation is the reaction time. After performing an analysis of the processes in the induction-heated electro-technological system for the food processing industry the following conclusions were reached at regarding the quantities, characterizing the manufacturing process. These are the power in the secondary coil of the output transformer and the inductor. With three seams it is apparent that to assess the suitability of the package four parameters of the welding operation need to be monitored.

The process of collecting and analysis of data is performed in a sequence, shown on figure 4.

The time for data processing is defined by the necessary technological period for each stage like transformation of analogue signals, data receiving and buffering T_o, data processing T_1; visualization and saving T_2; object feedback T_3.

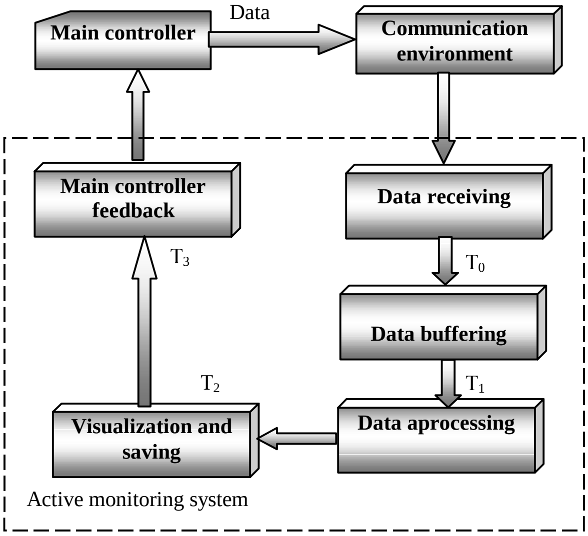

Fig. 4. Flowchart of data flow in the software system

b) Analysis of the system processes

The duration of a work cycle is in the order of 150 ms. Therefore the data analysis should be performed within this period. The *Quality Control* module (Fig 5) can function at 0.1 ms clock as timed by a PC.

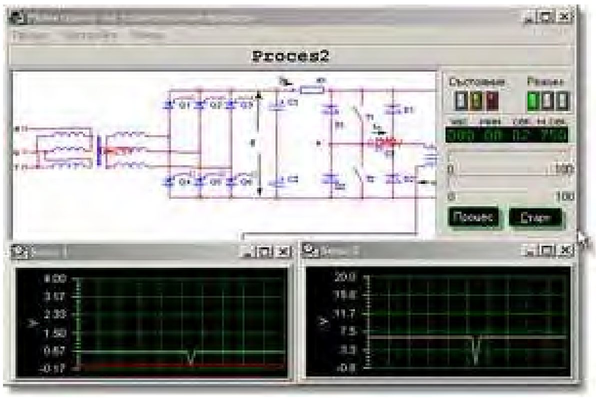

Fig 5. Quality Control module

Therefore 1500 quantity points will be available for process analysis. This data is pretty large and the processes are comparatively inertial. After the performed analysis, a conclusion is drawn that 10 quantity points are enough for processes identification or discreteness of 15 ms. For a higher precision the discreteness clock is set to 1 ms.

Two approaches for process analysis are used. With the first one the data is processed in real time by a module based on a neural network (Fig 6) and with the other the analysis is performed subsequently by the statistical control module *Quality Manager* (Fig 7).

The system operates with a huge quantity of data. From the analysis performed for a manufacturing cycle 57600 bytes will be necessary and for a twenty-four hour period about 33177600000 bytes or 30.8990 GB will be necessary.

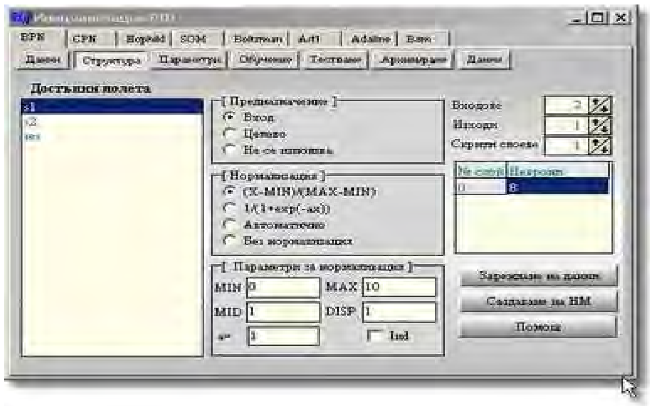

Fig 6. Choice of a neural network structure

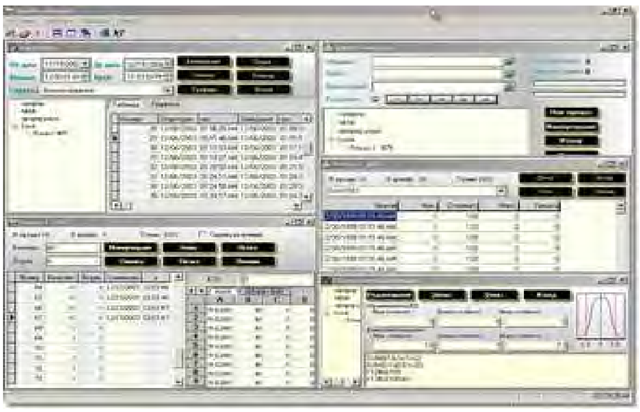

Fig. 7. The Quality Manager module

To limit the quantity of data saved in the database several approaches are used. With the first of them in the database is written only data overflowing a given interval, set in the process of system calibration. It is obvious that this approach is suitable for evaluating of the *fit – unfit* type, however it is not suitable for to analyse the tendency of process alteration. The second approach is based on the introduction of a mechanism for data compression which consists of the following.

At discretisation (квантуване) of input processes $f(t)$ their discrete equivalents are formed $f^*(t)$ by special algorithms, allowing to remove the surplus information. We are speaking about those discrete amplitudes of $f^*(t)$, which could be excluded from input into the computer memory. In this way memory is saved without reducing the informative content of $f^*(t)$.For this case e so called compression coefficient is entered

$$K = \frac{N_c}{N} \quad (1)$$

where $N_ç$ is the number of essential amplitudes of $f^*(t)$, respectively $f(t)$, for a given interval [0,T], and N is the total amount of amplitudes of $f^*(t)$, within the same interval. These values are obtained with a set constant discretisation time Δt.

In the present system as meaningless are considered those amplitudes of $f^*(t)$, which differ insignificantly from the last amplitude considered as meaningful. If the amplitude $f^*(n)$s considered meaningful (it is the first amplitude of the process, for which it is obligatory), then $f^*(n+1)$ is also considered meaningful if the following inequality is fulfilled:

$$\left| f^{*}(n) - f^{*}(n+1) \right| \geq \delta \qquad (2)$$

where δ is the significance level of the separate amplitudes one to another. In the course of a single time interval *t* after the moment $t=n.\delta\ t$ the zone limited by the quantity f={$f^{*}(n)+\delta, f^{*}(n)-\delta$}, shows where should reside the following meaningless (insignificant) amplitude $f^{*}(n+1)$.

The algorithms by which it could be defined that a given amplitude is meaningful or not, are various. Though it is clear, that they should be based on the analysis of the dynamic properties of real time processes. As a conclusion it could be deducted that with a carefully selected data compression algorithm the effect from sparing computer memory when processing the information could be substantial. This effect is especially apparent with non- stationary processes, entering at the input of the active monitoring system. In the present system δ is chosen from the following dependency $\delta = (y(T_2) - y(T_1))/4$, where $y(T_1)$ and $y(T_2)$ are respectively the values of the signal at two pre-selected points when describing the borderline deflections.

c) Analysis of the processes by artificial neural networks.

To perform a real time analysis of the process an artificial neural network is used with backward distribution. This type of network is chosen regardless of the fact that the training process is very slow. This type of networks can function with a huge amount of data. For the purposes of the present idea this is very important. Moreover the training process itself is steady enough. That is, if in the training data a series of incorrect information is supplied and afterwards a series of corrected data is provided, the final result of the teaching will not be altered, with the exception that the training time will be changed. The applied training methods affect all data, which is why increasing training data will alter the training period. Besides that the backward distribution method does not give way to the other methods when dealing with a small data quantity; the precise training methods would yield a smaller error at the time of training but at operation time the error would be commensurable.

A major indicator for control quality is the error level. When having networks with equal error level it is advisable to select the one with a simpler structure. The necessity of multiple experiments leads to the fact the control set starts playing a key role as a correcting factor. This enforces the choice of a new control sequence. The network was tested with them to make sure that training is real, and is not an artifact of the training process. Of course the test set should be used only once. Its repeated usage turns it into a control set.

Working out of the network in the constructed system after choosing the input variables consists of the following steps:

- Choice of an initial network configuration (for example an intermediate layer of elements equal to half of the sum of inputs and outputs times three minus one).
- Performing a series of experiments with various configurations, keeping the best of them. In the package *Cunami Neural Networks* an automatic keeping the best network during the experiment. For each configuration several experiments have to be performed, to make sure that we haven't fallen into a local minimum.
- If at training it proves that the network is under-trained, additional neurons and intermediate layers are added.

If there is re-training (the control error starts going up), some of the elements have to be removed. Neural networks function with a certain amount of data, distributed in a given range. For this reason input data are scaled into a certain range and the missed data are replaced by average values.

VI.Conclusion

Quality management of production is a fundamental priority in industry. In the present article a method for achieving these aims is described. The high efficiency of this solution consists of the analysis of production based on the processes running during the production cycle. This allows for an immediate reaction to the alterations of processes, as well as for anticipating any change in the execution as a result of the alteration of some quantities. In this way it is possible to directly exert influence on processes during its run. The proposed solution functions on a Windows NT Platform, which is an additional prerequisite for the low price of the system. The software application, which ensures the efficiency of the execution is based on RTS Kernel, operating with regular constant objects. In this case a higher reliability and efficiency during operation is achieved. Using artificial neural networks in the control and management module makes the system exceptionally flexible and applicable with a wide range of electro-technological systems.

References

[1] Todorov T.S., Madzharov N.D., Aleksiev D.T., Ivanov P.T., Autonomous inverters, Gabrovo, 1996 – (in Bulgarian)

[2] Madzharov N.D., Development and research of the autonomous inverters with energy dosing. Dissertation on scientific degree “Doctor”, Gabrovo, 1997.

[3] Todorov T.S., Madzharov N.D., Alexiev D.T., Ivanov P.T., Adaptive Resonant Inverter for Electrothermics, Proceedings PCIM’95, Power Conversion, Nurnberg, Germany, 1995, pp. 379-391

[4] Yordanov S., T. Todorov, System for quality control and monitoring of the main variables of electrothechnical systems, Int. Conf. ET2000 –Sozopol (in Bulgarian)

[5.] Yordanov S. The Real-Time Expert Control Systems International Conference on Computer Systems and Technologies - *CompSysTech’2002*

[6]. Yordanov S. Aplication of Self Organizing Maps-SOM in systems for active monoring quality. International scientific conference 2003, Gabrovo –(in Bulgarian)

[7.] Rudner V.I.,D.L.Laveles Modern power supplies, road matching, process control and monitoring. Inductoheat 1997

[8] By Ray L. Cook, R.L.Myers. Process monitoring for more effective induction handening control. MAN-Modern Application News, August 1995.