SYSTEM FOR ELECTROTINNING PROCESS DIAGNOSIS BASED ON VIRTUAL SENSORS AND INTERNET TECHNOLOGY

AUTHORS

V. Ferrari, F. Sanfilippo (*),
N. Di Biase, E. Musella (**),
N. De Abajo, J. Gonzales (***)

(*) Centro Sviluppo Materiali SpA – Via di Castel Romano, 100 - 00128 Roma (Italy)
(**) SESM – Via Gianturco, 31/C – 80146 Napoli (Italy)
(***) ACERALIA – Centro Desarrollo Tecnologico; Ap.do 90; 33400 – Aviles (Spain)

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ABSTRACT

In industrial systems with high technological or operational complexity, the role of operators is more and more critical. They need deeper and deeper specialisation and a continuous oversee of both process and plant to achieve high efficiency and correct working.

The software tools of artificial intelligence can powerfully help for a correct operating of a process. Particularly, it has been evidenced that the availability for operators of automatic tools for the interpretation of measurements is much more useful than having new data.

Virtual sensors are a sound answer to this requirement. They are software solutions able to interpret the field signals and to propose a qualitative/quantitative synthesis of the data to the operator. In the event of drawbacks in the process operation they can give also a diagnosis that helps the operator to restore the standard condition quickly.

The results, made available on Intranet/Internet network, are open to any qualified terminal. This is a noteworthy increase of the advantages deriving from the adoption of the system.

In this paper, a real case of virtual sensor application for process diagnosis is described. The system, developed by CSM, SESM and Aceralia, has been applied to the continuous electrotinning line of Aceralia in Aviles (Spain).

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INTRODUCTION

In industrial systems with high technological or operational complexity, the role of operators is more and more critical. They need deeper and deeper specialisation and a continuous oversee of both process and plant to achieve high efficiency and correct working.

The software tools of artificial intelligence can powerfully help for a correct operation of a process. Particularly, it has been evidenced that the availability for operators of automatic tools for the interpretation of measurements is much more useful than having new data.

Furthermore, it is demonstrated that the growth of sensors number in complex plants does not determine a better analysis of process management. Conversely, very often the overload of information results in lack of process management. When great amount of data are acquired, the user may be no longer able to perceive those signals that indicate degradation in process management.

The use of software tools able to analyse data on-line can help the operator to have a qualitative/quantitative synthesis of process management. These software tools are the “automatic” translation of an expert of the process, able to understand whether the process itself is running in a *correct*, *acceptable* or *degraded* way. This is achieved through the synoptic reading of data and historical trend of the operating conditions.

These software tools are *virtual sensors* which measure and elaborate parameters such as: *quality of process management, trend of consumption, production efficiency, degradation forecast*. Besides, it is evident that the plant user has more helpful information when the results of the virtual sensors are provided with diagnostics and with description of the necessary procedures for restoring the optimum operation conditions.

The development of the system on an Internet technology basis, gives further advantages by simplifying the diffusion of results. Just think to the possibility for each user of gaining information, already filtered on the basis of the level of interest, at the most convenient location (possibly at home), and of communicating the necessary actions in broadcast or single mode.
In the following, an application of virtual sensors for process diagnosis based on Internet technology is described. It is a quality diagnosis system applied to the electrolytic tinplate line in Aceralia Works (Aviles, Spain).

THE PROPOSED SOLUTION

The optimum solution for an *on-line expert* analysis of process data must employ rule-based programming technologies, based on fuzzy logic. It can be demonstrated that systems developed with traditional techniques do not represent the best solution to manage diagnostic and/or decisional problems in complex domains. On the contrary, most of diagnosis problems are solved efficiently using rule-based systems, similarly to the way a human expert should do, integrated with the qualitative modelling of reality and with fuzzy logic approach.

The solution selected for the case under consideration, implies exactly the above concepts: thus, the virtual sensors operate under fuzzy logic and the anomalies diagnosis is realised with the use of rules.
A virtual sensor is a software tool based on mathematical models, fuzzy logic, statistical analysis. It analyses data on-line with the process and proposes a result in percentage terms. The result is given with graphical user-friendly representations, which can be immediately understood (e.g. green = good condition, red = alarm condition).

The functional architecture and the processing flux of a diagnostic system based on virtual sensors is described in details in Figure 1.
The virtual sensor elaborates data continuously to determine possible degradation in the process management.

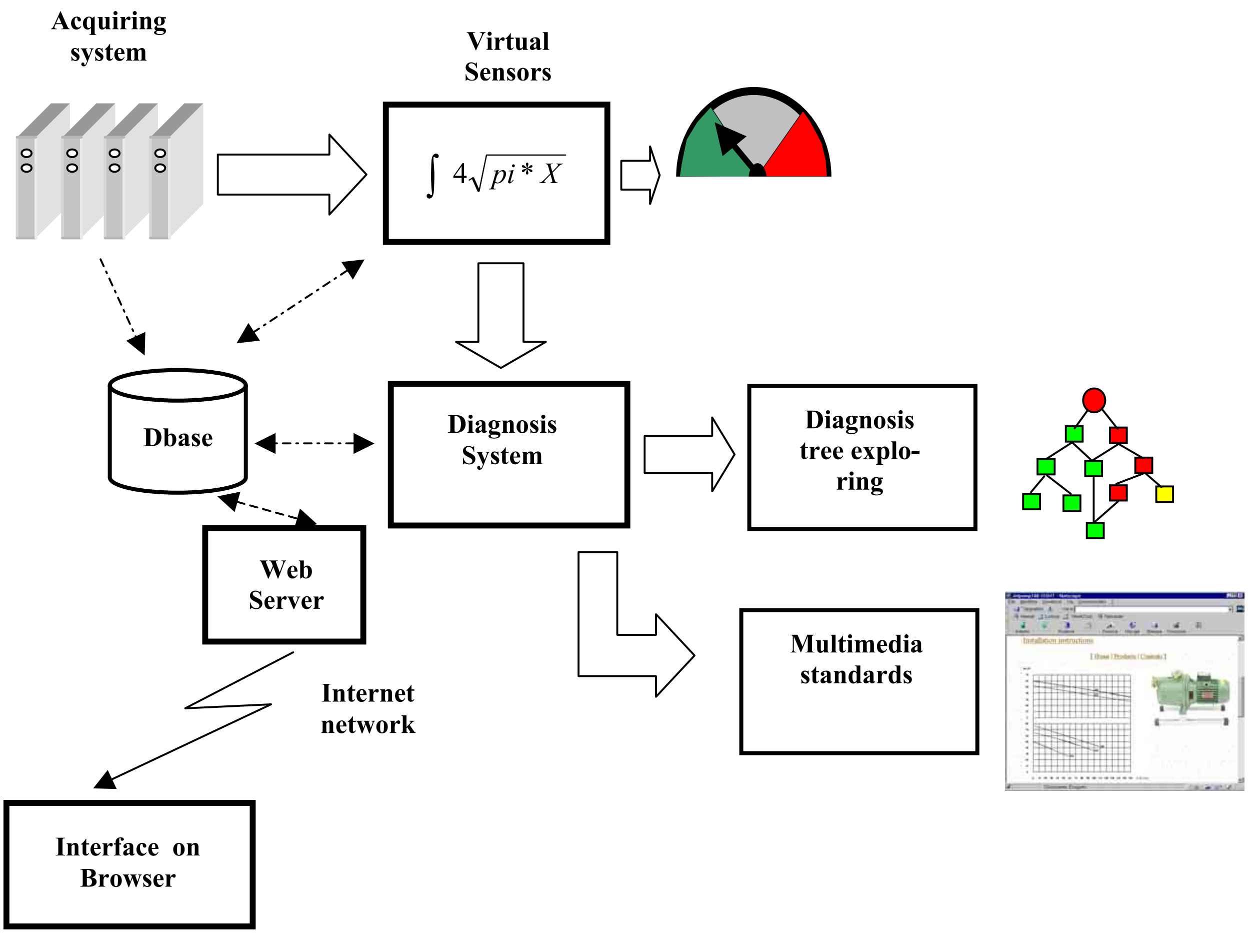

Figura 1:Processing Flux of the System.

In event of performance loss, the diagnosis system helps the user in finding the causes (see Figure 2). Finally the system of multimedia technical documentation gives the information to restore the optimum conditions.

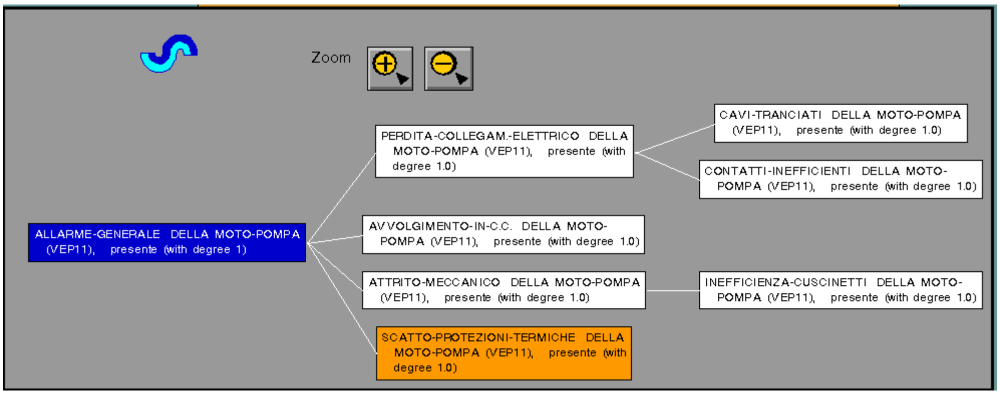

Figura 2: Diagnosis Interface

All the primary information and those elaborated by the system are stored in the database. Through the network, these information are available to all users with different filtering levels.

The diagnosis system uses, as development means, the "*DimmiTool*", developed at SESM laboratories. It is a tool able to build diagnosis systems, which allows to insert rules in graphic mode and gives the possibility to use a rich library of components and an interface already set for the end-user.

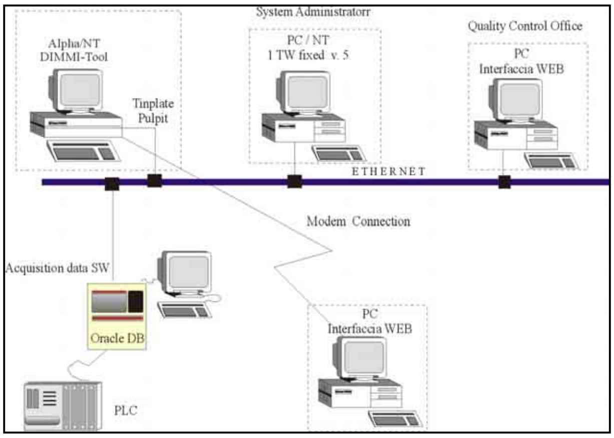

Figura 3: System HW Architecture.

DimmiTool is based on G2 (by Gensym Co.), the diffused shell for expert systems for industry. The system for multimedia documentation is built with the support of Internet technology; each operating procedure is built with html pages including videos, drawings, photos, etc..

The path among information is not pre-determined. It is defined by the user, by hypertext links, according to his needs. Information are accessible at every location, configured for Internet type communications. The entire system is set to spread the results in an Internet architecture; a Web server operates in connection to the database. Clients can establish a connection with the server to get information, values produced by virtual sensors, diagnosis results.

REAL CASE DESCRIPTION

The implemented project concerns the development of an on-line, real-time expert system for the electrotinning line number 2 in Aceralia Works (Aviles – Spain) and is related to diagnosis aspects of product quality. The tinplate line No.2 in Aceralia is composed of the following sections:

- *entry section* which levels the coil, through a combined action of draw and bend, and makes the process continuous, by welding the head of a coil with the tail of the previous one [1];
- *pre-treatment section* which realises the cleaning of the coil through an electrolytic alkaline degreasing and an electrolytic acid pickling, necessary because the coil is usually dirty with oil, grease and solid particles coming from the rolling process;
- *treatment section (tinplating)* with nine vertical electroplating cells, which increase the tin thickness on the coil surface at each step, thanks to an electrolytic process, until the desired layer thickness is obtained, when exiting the last cell;
- *exit section* with a differential marking treatment, useful to determine the side with higher tin coating thickness, a melting-brightening treatment which gives the tin coating a bright surface, better resistance and forms the Fe-Sn alloy that gives the sound adhesion to the base metal [2], and an electrostatic oiling which provides lubrication to the coil surface to minimise abrasion damages and to facilitate mechanical operations.

Aceralia plant users were interested in a system which could guarantee benefits in terms of:

- improving product quality;
- increasing productivity;
- increasing operating safety;
- increasing the availability of specialised personnel;
- diffusion of plant maintenance information;
- diffusion of plant data by Internet network.

By analysing these user requirements, the knowledge was engineered. In the building of an expert system, the operations of knowledge acquisition and formalisation are the most critical.
The working method chosen in the engineering phase is the FMEA (Failure Mode and Effect Analysis).

The FMEA is an inductive method to analyse failure modes, in other words it proceeds from down to the top.

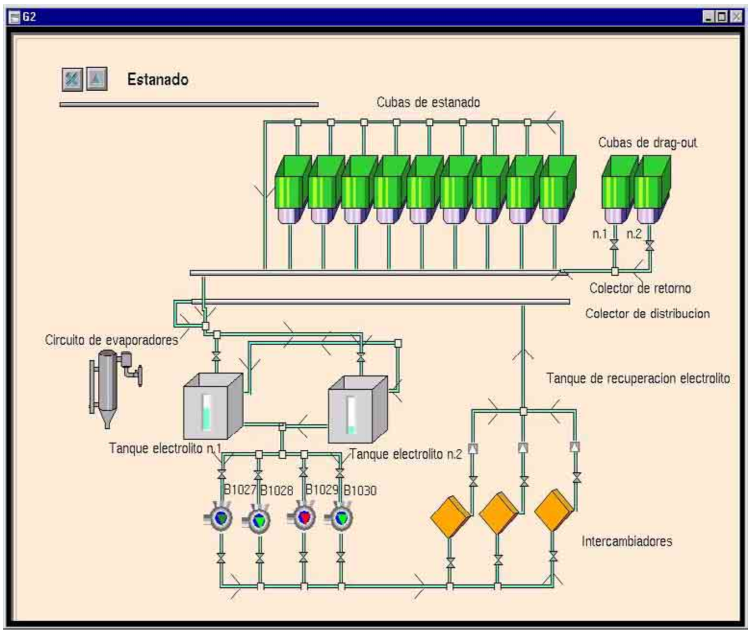

Figura 4: Synoptic Interface Example

The analysis starts from the basic structure of the system and particularly from those elements of the system for which accurate information about failure mode and its causes are available. By analysing the functional relationships among these elements, it is possible to identify the possibility of propagation of each type of failure and predict its effects on the production performance of the entire system.

The result of FMEA analysis is a collection of tables which contains, for each element of the system, the failure modes, the causes, the effects and the necessary countermeasures. Moreover, since the developed system uses object oriented programming technologies, it is evident that failure mode tables are the better tool to define the classes of maintenance. In fact, the generic class for the maintenance will be characterised by failure modes, by causes and by effects on other objects. Once finished the phase of knowledge acquisition and formalisation, the system was implemented on the basis of the users requirements.

MAIN FUNCTIONALITIES

Some of the main implemented functions are described hereafter:

Qualitative estimation of process management: it is very important for the operator to know how the plant is working; for this reason a global index (virtual sensor) has been defined for each part of the plant. This global index "I" is a weighted mean of partial indexes "i" relevant to main parameters of a given section of the line. They consider the distance between the actual operating point and the optimum operating point. The weights are corrective coefficients which evaluate the importance of the correspondent variable on the global process. The partial index i is calculated by a Gaussian function:

$$i = \exp \frac{(x - \delta)^2}{(2\Delta^2)}$$

where δ and Δ are the best value and the operating range of the variable under check, respectively.
The global index *I* and the partial index *i* range between 0 and 1. When *I* is equal to 1 the relevant variable has a value equal to its optimum value. It is clear that the global index *I* tends to its maximum value when all partial indexes *i*, which contribute to the calculation, have a high value and, consequently, all single variables are near to their optimum value. Both the global index and the partial indexes are monitored and graphically represented (see figure 5).

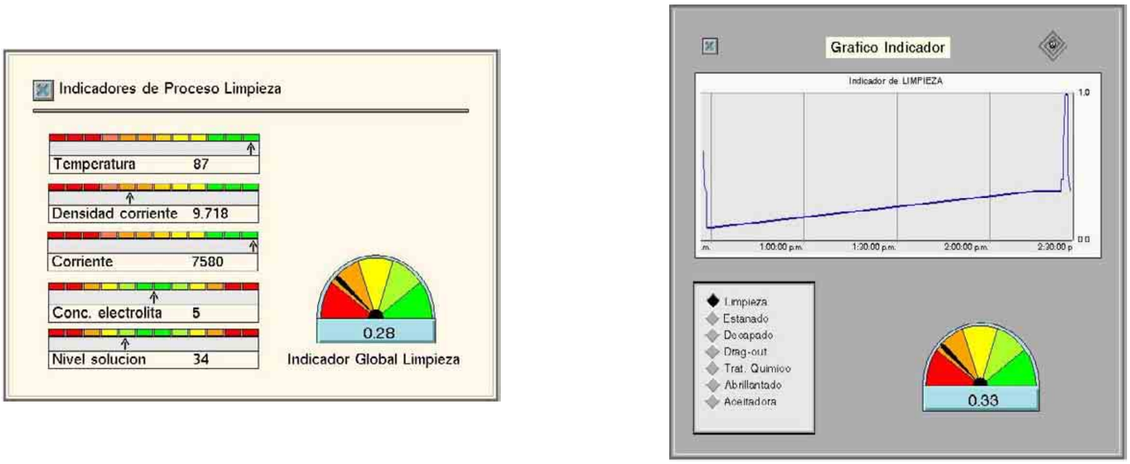

Figura 5:Partial indexes graphic view and Global index trend of the electrolytic cleaning section

- ***Statistical analysis of the alarms***: the system produces automatically an alarm whenever a variable reaches a value out of the operating range; by analysing the alarm distribution it is possible to know the causes of process degradation.

- ***Production optimisation***: an algorithm has been developed (Fig.6) to calculate the maximum line speed matching the number of available electrolytic cells, the required tin thickness and the current density.

- ***Analysis of anodes consumption***: the system elaborates a prevision for the consumption of tin anodes; it suggests the user, by a friendly graphical interface, if and when it is necessary to substitute each anode.

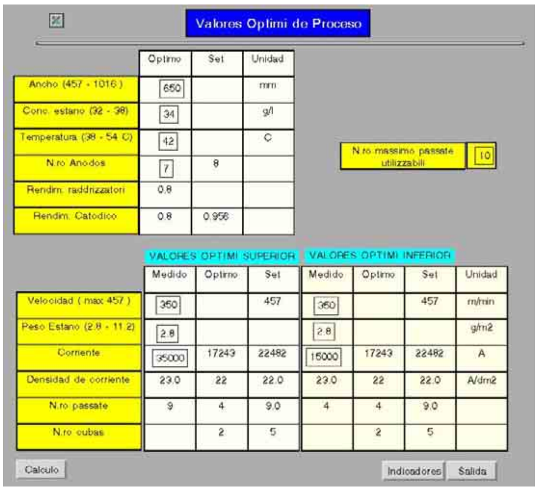

Figura 6: Optimum line speed procedure according to tin thickness, current density and number of electroplating cells

CONCLUSIONS

The design of a diagnosis system, based on virtual sensors and Internet technology, has brought to a realisation judged very positively by end-users.

In particular, the fact that the system produces synthetic and simply accessible information, has been well appreciated.
The system is already viewed as a tool for information interchange at different hierarchic and managerial company levels. The end-user is thinking about its application also in other plants.

ACKNOWLEDGEMENTS

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