INFORMATYKA EKONOMICZNA BUSINESS INFORMATICS 1(27) • 2013
ISSN 1507-3858

Jozef B. Lewoc
BPBiT Leader (Leading Designer) Agency
e-mail: leader@provider.pl

Antoni Izworski, Sławomir Skowroński
Wrocław University of Technology
e-mail: {antoni.izworski; slawomir.skowronski}@pwr.wroc.pl

Antonina Kieleczawa
Institute for Power System Automation
e-mail: tosia@iase.wroc.pl

Georgi Dimirovski
Dogus University
e-mail: gdimirovski@dogus.edu.tr

Iwona Chomiak-Orsa
Wrocław University of Economics
e-mail: iwona.chomiak@ue.wroc.pl

COMPUTER INTEGRATED MANUFACTURING AND MANAGEMENT SYSTEMS. AN EMERGING APPLICATION OF CONTROL AND MANAGEMENT

Abstract: An approach to factory automation is the basis for a case study of Computer Integrated Manufacturing and Management systems (CIMMs). The paper presents some experience in large-scale systems and the current state-of-the-art for the domain. A feasible approach is proposed, based on prospective user expectations and the system development with the use of so-called first thread for which the standards facilitating the development of subsequent systems should be developed, and people acquainted with both manufacturing and management problems should be educated. There is also depicted some research work intended for facilitating the design and implementation of future CIMMs.

Keywords: computer system, manufacturing, management, robustness, performance.

1. Introduction

In the case study country (Poland), it has been tried for a long time to solve together the problems of manufacturing and management (including factory automation). Even the very first original Polish application of computer control systems [Wojsznis, Lewoc 1971] covered some problems of production control, factory automation and management. The two last original case study country projects in the domain of computer control systems and networks [Lewoc, Misiak, Tomczyk 1989ab; Izworski, Lewoc, Skowronski 2006; Lewoc, Izworski, Skowronski 2006a; Izworski, Lewoc, Piwowar 2001] were, in fact, the large-scale CIMM systems for big manufacturing plants. Unfortunately, due to the down-economy period in the case study country, when the political change occurred there (roughly 1990), the projects were abandoned.

After the political change mentioned above, the case study country became widely open to possible technology transfer from well-developed possible technology providers from Western countries. But they never tried to resume the above mentioned projects. First of all, they were interested in lay labour only in the "technology transfer beneficiary countries" [Lewoc 2005, 2006; Lewoc, Izworski, Skowronski 2006b; Lewoc et al. 2008ab; Han et al. 2008] and never in the continuation of local projects. Secondly, there were hardly any references confirming that they had anything at all to offer in the CIMMs domain. Thirdly, in the case study country, they simply proved to be losers. Although in Lower Silesia and, specifically, in Wroclaw, the capital of the province and the city of the case study country with IT, ICT and automation industries, where many people witha deep knowledge and wide experience in these domains are still available, or perhaps just due to that, all the big Western ICT and automation corporations failed and had to move out (in shame, if this means anything to big corporations).

Considering the above, a group of designers, research workers and implementation engineers involved earlier in the development and implementation of computer automation system and networks, especially for the electric power industry in the case study country (the most successful one in the country in the ICT and computer automation pioneering era [Izworski, Lewoc, Piwowar 2001; Lewoc 2005, 2006; Lewoc, Izworski, Skowronski 2006b; Lewoc et al. 2008ab; Han et al. 2008]) (the Team) decided to resume their activities to continue the work begun in the late nineties. Due to the lack of financial resources for the development and implementation of the final large scale projects, a decision was made to get financing from other activities (e.g. translation) and use it for working out the designs (up to feasibility studies, inclusively) and for the necessary applied research work.

The final product of the team were prestigious publications in order that the design and research work of the team may be verified effectively by the most competent designers and researchers around the world, and the results of the work may be spread among other designers and researchers to support the development of CIMMs.

The team decided to submit a paper on the earlier design and research work on CIMMs [Lewoc et al. (in press)] for possible publication in a prestigious technical journal (TJ); however, the paper was not published. Of the excuses given by the TJ [Zurawski 2007], the team could understand only two: "for example, ISA 95/IEC 62264 is a must for a reference in this area" and "it should be better to separate concerns and to have two specialised systems supporting each other".

The two TJ remarks touch the very basis of design and research work for large-scale novel systems. The authors recognise two basic approaches to the development of large-scale innovation: bythinking and byorganising. The first consists in the unassertive recognition of the lack of knowledge at the very beginning when an innovation is to be developed, defining the reasonable minimum configuration to be developed to learn as much as possible of the innovation and in attempting to control the whole project to ensure as low losses as possible. The design and implementation team, on the basis of their results obtained on the minimum configuration, developed standards and procedures enabling the fast and economic development of future implementations.

2. The CIMMs system

2.1. General

Large-scale and very large-scale systems have become a very serious social concern. Some people discuss even the global systems. But if one looks at normal industrial enterprises, the situation seems to be rather poor. On the one hand, there are Computer Integrated ManufacturinG systems (CIMGs) developed by companies specialised in the automation of industrial processes and Computer Integrated ManagemenT systems (CIMTs) systems developed by other companies, involved in the automation of managerial activities. CIMGs and CIMTs are developed on heterogeneous hardware and software and, usually, the suppliers do not provide effective interconnections between their systems.

2.2. Goals of the first CIMMs implementation

The utilitarian goal is to develop and implement the first thread on the CIMM network enabling a pilot interconnection between the CIMMGs and CIMMTs of an exemplary manufacturing enterprise. The scientific goal of the first implementation is to develop standards for design, investigation and implementation of CIMMs for industrial enterprises. The overall goal is to enable the optimum operation of the enterprise involved, upon some objective criteria.

2.3. The first thread

The general structure of any CIMM system could be planned only in a very general way at present [Izworski, Lewoc, Skowronski 2006]. Therefore, it is not reasonable to design a solution for all possible CIMM problems at the very beginning of the design process, since it would require a lot of unnecessary and expensive work. Thus, the *first thread* in the CIMM system, i.e. the minimum set of tasks needed for the development of an interconnection of the CIMMGs and CIMMTs, useful and profitable for the enterprise involved, should be defined – feasible to be designed, worked out and implemented by a finite team. Based on these experiences and standards worked out, it should be possible to design and implement further CIMM threads.

The best candidate for the beginning of the first CIMMs thread seems to be the Working Media Department, which exists in every medium andlarge manufacturing enterprise. The basic evidence for this is: the high share of working media in total enterprise costs; the similar problems existing in many enterprises; a lot of experience in the power industry CIIMGs may be applied directly for CIMMs; power saving and sustainable energy problems which are very important now make CIMMs even more attractive; the Department's knowledge of all personnel in the enterprise is of importance for CIMMs' development. The first thread in CIMMs under design and investigations will be called the *System Media*.

2.4. System media

The basic **working media** (variables) proposed for the System Media include: **electric power** (active and reactive power, voltage, current), **gas** (flow, calorific value), **fuel** (weight), **water** (flow, temperature), **steam** (flow, temperature, pressure), **compressed air** (flow, temperature), **waste water** (oxygen demand, heavy metals, suspended solids, oil content, pH, flow), **waste gases** (flow, CO content, SO_x content, NO_x content).

The general structure of the System Media is presented in Figure 1. This structure is commonly used in the power industry.

The Media software consists basically of the monitoring system software (the controller software are standard process variable acquisition and primary processing

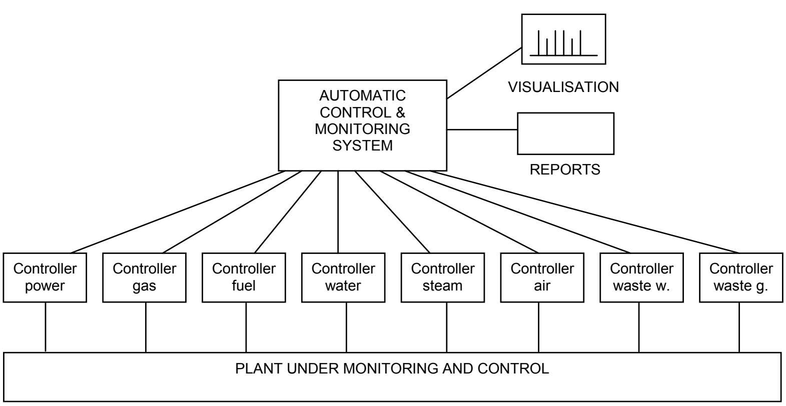


Figure 1. General structure of the system

Source: own elaboration.

programs). The operating system should be selected taking into consideration its dependability features (e.g. QNX [ONX 2007]).

The software architecture of the System Media (Monos – Monitoring operating system) based on the operating system QNX and the application software to be developed is presented in Figure 2.

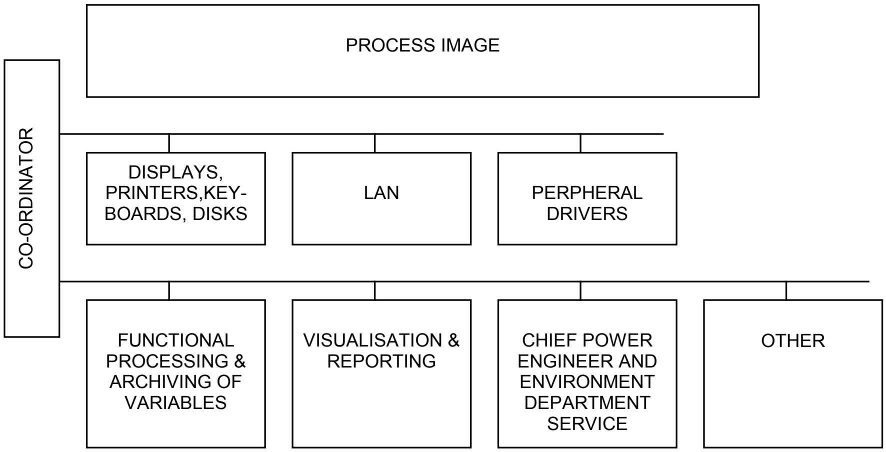


Figure 2. Software architecture of the media

Source: own elaboration.

From the start, the most attractive final stage of the first thread seams to be the accountancy department calculating the working media costs per a single product or by per a small production lot, and the first thread can be as depicted in Figure 3. (Note that it does not need to revolutionize the CIMTs – the only thing needed here is to provide the CIMGs of Figures 1 and 2 with working medium consumption settling programs and to charge individual users with medium costs in minute cycles and not in monthly cycles, as done at present.

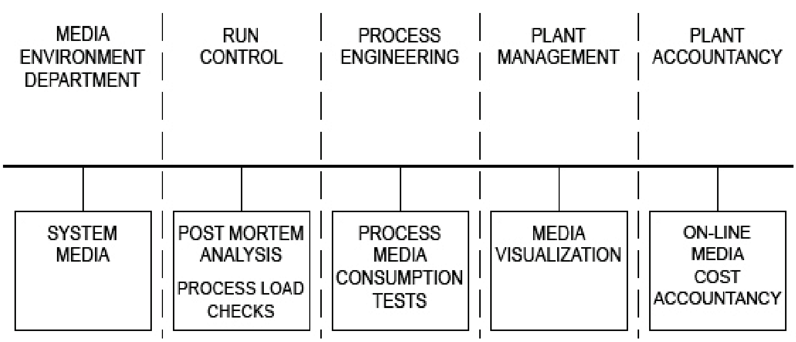


Figure 3. The first thread through CIMMs

Source: own elaboration.

Thus, the first thread starts at the system MEDIA discussedabove. It should be complemented by the post mortem analysis and process load/consumption tests, vitely needed by the runcontrol departments responsible for the preparation of adequate run conditions, and of the process media consumption tests to evaluate process engineering designs, especially for new products. The interconnection between the system MEDIA and the plant management level should befacilitated by displaying standard MEDIA screens for the managerial staff, thus increasing the observation possibilities of the latter.

The design and implementation of the first thread should enable the recognition of the manufacturing and management knowledge needed for teams of specialists of both domains to work out the design and implementation as well as research standards and procedures in order to design and implement the next threads of CIMMs more effectively and at cost price – most probably much lower than those needed for the by-organisation method.

2.5. Economic benefits

In the power industry it is commonly assumed that a monitoring and control system results in benefits of a dozen or so percentage points of the energy under its control. Considering the fact that, in the System Media case, in addition to control and monitoring, management optimization should be also taken into consideration, it can be quite safely assumed that the System Media will provide benefits not lower than 20% of the media consumed (discharged in the case of waste water under its control).

2.6. Management support

The most attractive functionality of the managerial part of CIMMS in the first thread seems to be the Accountancy Department calculating the working media costs per single product or a small production lot as presented in Figure 2. There is no revolution needed to organize it, the only thing needed is to develop the settling programs for working out the medium consumption values for the System Media of Figure 1 and to charge individual users with the working media costs in, e.g. minute and not monthly cycles.

And, last but by no means least, the on line media cost accounting should be the first step towards cost accounting per product or a production lot. This does not require writing new accountancy systems, the idea is that the system MEDIA “sells” media in conformity with current readings of the variables under control, thus enabling on-line monitoring of media used and associating the costs with individual products or production batches. This function is the most needed, at present, by all management and manufacturing experts with which the Team discussed the needs and requirements for the future CIMMs.

Making use of the intelligent solutions of CIMMs in the network monitoring consumption, one may improve the logistic processes connected with the determination of the production needs in the context of the number of the production orders granted, planned distribution and sales, etc. The integration of the current consumption with monitoring of the store levels and automatic production and transmission of the demand for the appropriate media enable the automation of the operating management layer [Franasik et al. 2001]. In this context, a natural consequence is the increase of interest in aiding the strategic layer management. The development and implementation of the information basis tools, including the visualization modules for the simulations and forecasts proposed, that will be validated in the real time, will have its share in increasing the credibility and accuracy of the simulated forecasts.

2.7. Development of CIMMs

CIMM should, and most probably will, become a domain of industrial and scientific organisations. Due to the connection of the CIMG and CIMT domains, many new problems will certainly appear. In the domain, the design team have been involved, until now, in research work directly connected with the design and development of novel computer systems and networks, including the System Media itself, i.e. robustness and performance evaluation [Izworski, Lewoc 2003; Lewoc, Izworski, Skowronski 2006c, 2007] and in studies of cultural aspects of automation [Izworski, Lewoc, Piwowar 2001; Lewoc 2005; Lewoc, Izworski, Skowronski 2006d]. But a lot of room can be seen in the CIMMs area for research work connected with the development of effective methods of running enterprises on the basis of the new information delivered by CIMMs. Examples may be the use of on-line information on media consumption for troubleshooting on the total enterprise level, validation of production processes (technology), optimisation of production schedules, etc.

3. System Media typology

3.1. General

There can hardly be found scientific support for designers to determine system/ network topology. In the authors' opinion, the overall topology may and should be defined on the basis of system robustness; computer system designers should think, like their colleagues working in the automatic control, how the system will behave not only in normal operating conditions but also when some, perhaps serious, disturbances occur. In other words, they should think in the category of optimization under uncertainties.

This leads to the notion of robustness (in the well known automatic control sense of the word) [Maciejowski 1989]. It was decided to apply the m function, i.e. the structured singular value, as the measure of the robustness and, consequently, of the quality for the System Media, though many authors reported serious problems connected with the computation of the structured single value (e.g. [Maciejowski 1989; Ferreres 1999; Fu 1997]).

For the star topology, the basic configuration of the System Media is shown in Figure 4a. For this case study, as well as for other investigations of System Media stability, it can be assumed that the concentrators introduce some known delay only. Therefore, it may be assumed that:

$$G_{S,i} = k_i \, e^{-s\,T_i}, \; i = 1 \ldots n, \; T_i \geq 0 \tag{1}$$

For the other case of the common-medium network (e.g. Ethernet), the basic configuration is shown in Figure 4b.

For the common-medium topology case, an equivalent diagram may be drawn (see Figure 5). Here, Formula 2 is valid.

$$G_{R,i} = e^{-s \sum_{m=1}^{i} T_m}, \; i = 1 \ldots n, \; T_i \geq 0 \tag{2}$$

From the point of view of this paper, it is of very helpful consequence that the transmittances and disturbances of the time delay type only may be considered: for the unit circle, all values are eigenvalues and computation of the structured singular value [Doyle 1982] becomes rather easy. For a more detailed description of the investigations and results see [Izworski, Lewoc 2003].

The general conclusions of the investigations are that the System Media may be implemented on the hardware of the star topology, operating at a moderate data transmission rate but still ensuring high robustness in comparison with the common-medium topology. In addition, the robustness would be even better due to the increased resistance to disturbance at lower transmission rates.

3.2. CIMMs performance

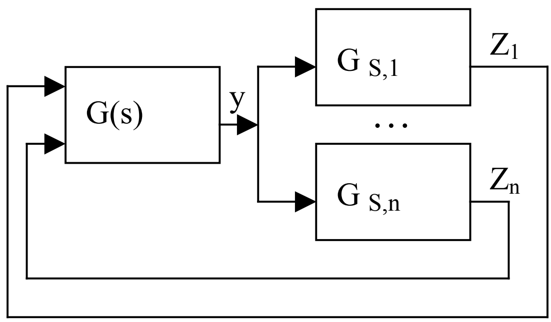
When thinking about CIMMs performance evaluation/prediction, one has to remember that such a system combines the CIMG part, where, usually, the basic performance measures are the maximum possible realisations of time delays, and the CIMT part, where the designer is interested primary in throughput. Thus the investigations are more difficult than usual. In addition, the known analytical methods [Robertazzi 2000; Surfozo 1999] cannot be recommended to designers of actual systems as they are too complex and incomprehensible. Therefore, the authors decided to investigate CIMMs with their own approximate method for actual computer networks [Lewoc, Izworski, Skowronski 2007].

Assuming that the delays in transmission links are insignificant, the hardware structure of the CIMM system may be presented as in Figure 6.

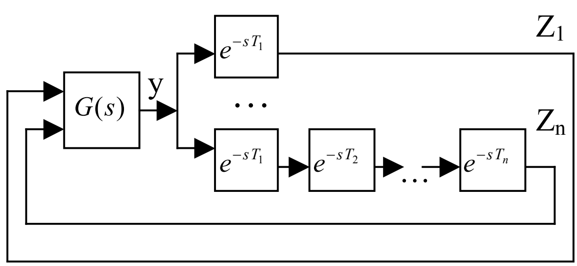
Upon the network of Figure 6, there is a stretched set of closed routes. For all closed routes, the balance equations [Lewoc 1990] have been defined, approximating the unknown variables as if they had the uniform distribution on some finite interval.

Some exemplary results are presented in Figure 7 (the throughput value in the closed route 166; note the saturation at the mean thinking time, M_{166} value of ca. 2 ms, due to the high traffic intensity at that point) and Figure 8 (the mean round-trip delay in the closed route No. 279 versus the mean thinking time in the 279th closed route, showing no saturation).

The method is simple and straightforward, especially in comparison with those presented in [Robertazzi 2000; Surfozo 1990] and features with an isomorphic mapping of actual computer networks into the queuing networks under investigation. Some method accuracy considerations are given in [Lewoc 1990; Lewoc, Izworski, Skowronski 2006c, 2007]. The results of the approximate method were compared with those of available accurate analytical methods, internal network measuring tools and event-driven simulation. The relative error of the method exceeding 5% was never found. Thus the method may be considered an adequate tool for actual network designers, from the point of view of its accuracy.



a. Basic diagram for the star case



$$i = 1 \ldots n,\ n = 8,\ \bigwedge_{i=1\ldots n} T_i \geq 0$$

b. Basic diagram for the common-medium case

Figure 4. Diagrams for the star and common-medium configurations

Source: own elaboration.

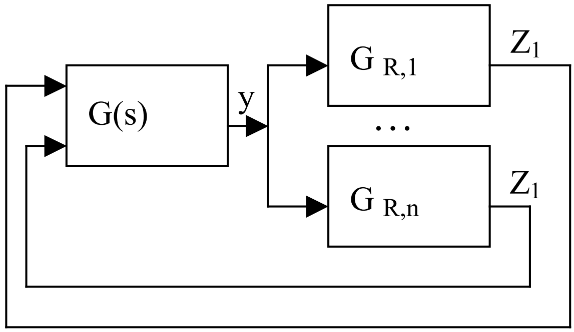


Figure 5. Equivalent diagram for the common-medium topology

Source: own elaboration.

4. Conclusion and further work

CIIMs are vitally needed, especially for medium and large-scale manufacturing plants and extensive work on them should be commenced as soon as possible.

The work described in the present paper may constitute a base for future design and implementation work on CIMMs. Since CIMMs are novel in the computer science of the world, various scientific and technical methods should be verified for them. The authors are thinking, in the first place, about system security and software maintenance.

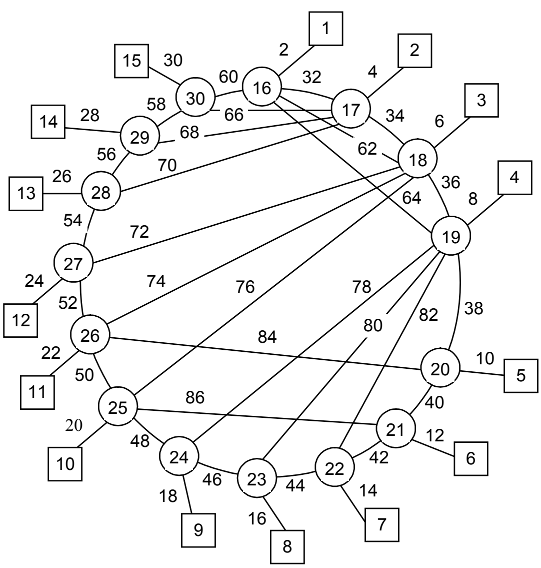


Figure 6. Numbering of links and nodes

Source: own elaboration.

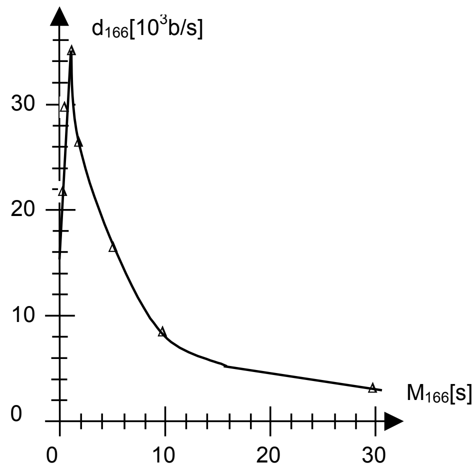


Figure 7. d_{166} versus M_{166}

Source: own elaboration

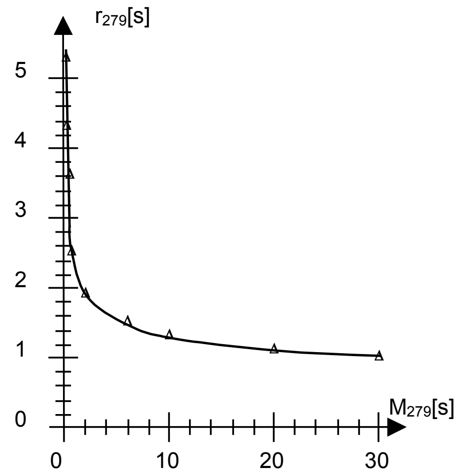


Figure 8. r_{279} versus M_{279}

Source: own elaboration.

5. Acknowledgements

The work presented in this paper was done under the scientific and technological sponsorship of merits of the Technical Committee SWIIS (Supplemental Ways for Improving Social Stability) of the IFAC Federation.

This paper was presented on the ETAI Conference: Jozef B. Lewoc, Antoni Izworski, Slawomir Skowronski, Antonina Kieleczawa and Georgi Dimirovski, Computer Integrated Manufacturing & Management Systems – An Emerging Application of Control and Management. IX National Conference with International Participation, ETAI, Ohrid, Macedonia, ETAI, 2009.

References

Bicz T. et al., Initial evaluation of time delays during interrogating-mode work in computer system R-32 and Odra 1325, *MERA Unit Bulletin* 1983, November (in Polish).

CCITT, Red Book, 1984.

Doyle J.C., Analysis of feedback systems with structured uncertainties, [in:] *Proceedings of the Institution of Electrical Engineers*, Part D, 129, 1982, pp. 42–50.

Ferreres G., *A Practical Approach to Robustness Analysis with Aeronautical Applications*, Kluver/Plenum, 1999.

Ford H., *Public Message*, Chicago 1919.

Franasik L. et al., System media – a step toward computer integrated manufacturing and management systems, *Modelling, Measurement and Control* 2011 (AMSE Press), vol. 22 no. 3, pp. 37–46, 2001.

Fu M., The real mu is hardly approximable, *IEEE Trans. Auto. Control* 1997, Vol. 42, No. 9, pp. 1286–1288.

Han M.-W. et al., *Power Industry Computer Control System Design and Implementation Problems: A Case Study of Poland*, IFAC Congress, Seoul 2008.

Izworski A., Lewoc J.B., Robust performance case study: Topology of System Media, Control Applications of Optimisation IFAC, Visegrad 2003.

Izworski A., Lewoc J.B., Piwowar B., *Some Aspects of Technology Transfer – A Case Study*, SWIIS'01, IFAC, Vienna 2001.

Izworski A., Lewoc J.B., Skowronski S., *Development of Computer Integrated Manufacturing and Management Systems, Information Control Problems in Manufacturing*, IFAC, Saint Etienne, 2006.

Kuberska A., Lewoc J.B., Misiura L., *A Semigraphical Visual Display for Power Dispatching Purposes*, Work with Display Units, Stockholm 1986.

Kuberska A., Tuła J.M., Lewoc J.B., *Power Dispatching Oriented Microcomputer Data Presentation System*, Relcomex, Książ Castle 1987.

Lewoc J.B., *Performance Evaluation Problems for Actual Computer Networks*, AMSE Monographs, Tassin 1990.

Lewoc J.B., *A Case Study: Practical Ethical Aspects for Technology Transfer and Change in Computer Control System Development*, IFAC Congress, Prague 2005.

Lewoc J.B., Izworski A., Skowronski S., Alsis case study: computer integrated manufacturing and management systems, [in:] *Applications of Large Scale Industrial Systems*, IFAC, Helsinki-Stockholm, 2006a.

Lewoc J.B., Izworski A., Skowronski S., *Ethical and Cultural Aspects of ICT Change in Power System Automation: A Case Study of Poland*, International Stability through Automation'06, IFAC. Prishtina, 2006b.

Lewoc J.B., Izworski A., Skowronski S., *An Internal Internet Traffic Modelling/Performance Measuring Tool. Mathematical Modelling*, IMACS, Vienna 2006c.

Lewoc J.B., Izworski A., Skowronski S., *Economic, Ethical and Cultural Aspects of ICT Change in Power System Automation: a Case Study of Poland*, International Stability through Automation'06, IFAC, Prishtina, 2006d.

Lewoc J.B., Izworski A., Skowronski S., *Performance Modelling of a Computer Integrated Manufacturing and Management System*, Eurosim Congress, Ljubljana 2007.

Lewoc J.B., Kieleczawa A., Izworski A., Skowronski S., *Automation, Control and Supervision of Combined Heat and Power Systems: A Case Study of Poland*, International Stability through Automation, IFAC, Prishtina 2006.

Lewoc J.B., Kieleczawa A., Izworski A., Skowronski S., *Computer Integrated Manufacturing Systems – An ICT Technology in Enterprise Integration*, submitted to IEEE Trans. Ind. Inf. (in press).

Lewoc J.B., Misiak K., Tomczyk A., A complex automation and management network for power plants, [in:] *Energy Systems, Management and Economics*, IFAC/IFORS/IAEE, Tokyo, 1989a.

Lewoc J.B., Slusarska E., Tomczyk A., A distributed data base for real-time control/monitoring of power plants, [in:] *Distributed Databases in Real-Time Control*, IFAC/IFIP, Budapest 1989b.

Lewoc J.B. et al., *A Case Study: History of Polish Computer Applications in Power System Control*, IFIP Congress, Milan 2008a.

Lewoc J.B. et. al., *The Role of IASE in Design and Development of Pioneering ICT Systems for the Power Industry in Poland*, 14th WOSC Congress, Wrocław 2008b.

Maciejowski J.M., *Multivariable Feedback Design*, Addison-Wesley, 1989.

ONX, *Wikipedia*, 2007, en.wikipedia.org/wiki/QNX.

Robertazzi T.G., *Computer Network and Systems. Queuing Theory and Performance Evaluation*, Springer-Verlag, 2000.

Ryle M., *Private Message*, Cambridge 1970.

Stallings W., *Data and Computer Communications*, Prentice Hall, 2007.

Surfozo R., *Introduction to Stochastic Networks*, Springer-Verlag, 1999.
University of Cambridge Computing Laboratory, The Phoenix System Technical Reports, Cambridge, 1970–1980.
Wojsznis W., Lewoc J., Metal movement control system in a rod-mill, [in:] *Materials of the 4th Comecon-Country Conference on Production Process Automation in Black Metallurgy*, Publication I/33, Zaporoze 1971 (in Russian).
Zurawski R., *TII, Decision on Manuscript ID TII-0704-0056*, May 2007 (unpublished).

ZINTEGROWANE SYSTEMY ZARZĄDZANIA PRODUKCJĄ – JAKO NARZĘDZIE KONTROLI ORAZ WSPOMAGANIA PROCESÓW PRODUKCYJNYCH

Streszczenie: Głównym kierunkiem automatyzacji przedsiębiorstw produkcyjnych jest wdrażanie zintegrowanych systemów łączących przede wszystkim zdalne zarządzanie produkcją z modułami zarządczymi (CIMMs). Artykuł niniejszy przedstawia doświadczenia autorów zawiązane z wdrażaniem dużych systemów automatyzacji produkcji oraz stan obecny omawianej domeny. Zarówno w ujęciu historycznym jak i aktualnie sukces funkcjonowania takich systemów uzależniony jest od właściwego rozpoznania potrzeb użytkowników, które powinny stanowić podstawę do skonstruowania standardów funkcjonowania takiego systemu. Ponadto kluczowym problemem jest tworzenie odpowiednich zespołów analityczno-projektowych, które powinny składać się z ludzi o szerokim wykształceniu jak również ugruntowanym doświadczeniu związanych z wdrażaniem dużych, skalowalnych systemów do automatyzacji i zarządzania produkcją (CIMMs)

Słowa kluczowe: zintegrowany system komputerowy, automatyzacja produkcji, zintegrowane zarządzanie, niezawodności i wydajności.