UDC 621.3

USAGE OF ARTIFIC NEURAL NETWORK IN REMOTE DC MOTOR SPEED REGULATION

T. Vince
Technical University of Košice
Park Komenského, 3, Košice, 04200, Slovak Republic. E-mail: tibor.vince@tuke.sk

The article presents possibilities of remote DC motor regulation via Internet and deals with artificial neural network utilization in such a regulation. Due to the development of Internet technique and speed increase of transmission, the inexpensive convenient communication approach is provided for the remote control system. The paper also handles the advantages and disadvantages of Internet as a control and communication bus at different levels of the information hierarchy. The article also presents remote regulation response measured data.

Key words: DC motor, remote regulation, artificial neural network.

ВИКОРИСТАННЯ ШТУЧНОЇ НЕЙРОННОЇ МЕРЕЖІ ДЛЯ ВІДДАЛЕНОГО КЕРУВАННЯ ШВИДКІСТЮ ДВИГУНА ПОСТІЙНОГО СТРУМУ

Т. Вінсе
Технічний університет Кошице
Парк Коменського, 3, м. Кошице, 04200, Словаччина. E-mail: tibor.vince@tuke.sk

Надано можливості віддаленого керування двигуном постійного струму через середовище Інтернет, а також показано можливість застосування штучних нейронних мереж для такого виду керування. З огляду на розвиток технологій Інтернету та підвищення швидкості передачі даних, було застосовано зручний недорогий підхід до організації зв’язку при створенні системи віддаленого керування. Розглянуто переваги та недоліки мережі Інтернет як комунікаційної та керуючої шини на різних рівнях інформаційної ієрархії, наведено виміряні дані відклику системи дистанційного керування.

Ключові слова: двигун постійного струму, віддалене керування, штучні нейронні мережі.

PROBLEM STATEMENT. There is huge effort to integrate different cooperating systems in one complex system. The basic problem is communication between these different modules of the system, especially when the modules are located in different locations. According to communication requirements, appropriate communication way has to be chosen.

Continual evolution of the Internet enables higher and higher communication requirements to be fulfilled. The Internet begins to play a very important role in industrial processes manipulation, not only in information retrieving. With the progress of the Internet it is possible to control and regulate remote system from anywhere around the world at any time. Distance remote via Internet, or in other words, Internet-based control has attracted much attention in recent years.

Such type of control bus allows remote monitoring or regulation of whole plants or single devices over the Internet. The design process for the Internet-based control systems includes requirement specification, architecture design, control algorithm, interface design and possibly safety analysis. Due to the low price and robustness resulting from its wide acceptance and deployment, Ethernet has become an attractive candidate for real-time control networks.

It is necessary to regulate electric motor in such remote regulation in some cases. The goal of the article is to explore existing possibilities for Internet based real-time regulation, eventual trends, review of advantages and disadvantages of distance remote via Internet at different levels of information hierarchy and possible solutions. The article presents regulation of DC motor as an example of such a real-time regulation and discusses possibilities of utilization Artificial Neural Network (as part of Artificial Intelligence). At the end it presents some measured data from such a remote DC motor regulation via Internet.

EXPERIMENTAL PART AND RESULTS OBTAINED. Integration of information and control across the entire plant site becomes more and more significant. In the manufacturing industries this is often referred to as "Computer Integrated Manufacturing" (CIM). There is increasing use of microprocessor-based plant level devices such as programmable controllers, distributed digital control systems, smart analyzers etc. Most of these devices have "RS232" connectors, which enable connection to computers. If we began to hook all these RS232 ports together, there would soon be an unmanageable mess of wiring, custom software and little or no communication. This problem solution results in integration these devices into a meaningful "Information Architecture". This Information Architecture can be separated into 4 levels with the sensor/actuator level as shown in Figure 1, which are distinguished from each other by“ 4 Rs” principle criteria [1].

The 4Rs criteria are: Response time, Resolution, Reliability and Reparability.

Response time: as one moves higher in the information architecture, the time delay, which can be tolerated in receiving the data, increases. Conversely, information used at the management & scheduling level can be several days old without impacting its usefulness.

Resolution: an Abstraction level for data varies among all the levels in the architecture. The higher the level is, the more abstract the data is.

Reliability: Just as communication response time must decrease as one descends through the levels of the information architecture, the required level of reliability increases. For instance, host computers at the management & scheduling level can safely be shut down for hours or even days, with relatively minor consequences. If the network, which connects controllers at the supervisory control level and/or the regulatory control level, fails for a few minutes, a plant shutdown may be necessary.

Reparability: The reparability considers the ease with which control and computing devices can be maintained.

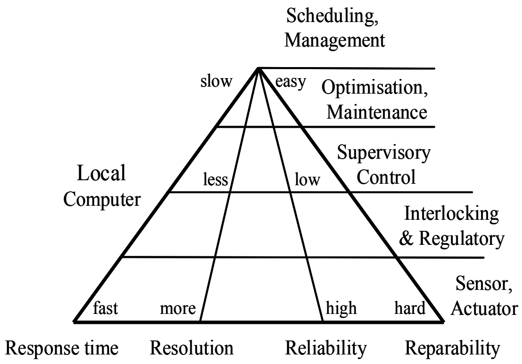

Figure 1 – Information Arichtecture

Local computer on supervisory control level is able to communicate with higher levels of information architecture via Internet, but there is also possibility to use the Internet in lower levels of the Information architecture. The Internet can be linked with the local computer system at any level in the information architecture, or even at the sensor/actuator level. These links result in a range of 4Rs (response time, resolution, reliability, and reparability). For example, if a fast response time is required, a link to the control loop level should be made. If only abstracted information is needed, the Internet should be linked with a higher level in the information architecture such as the management level or the optimization level.

An artificial neural network (ANN), often just called a "neural network" (NN), is a mathematical model or computational model based on biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase.

Since the early 1990's, there has been a growing interest in using artificial neural networks for control of nonlinear systems. Numerous applications have demonstrated that neural networks are indeed powerful tools for the design of controllers for complex nonlinear systems. Among different kinds of neural networks, the most widely used ones are multilayer neural networks and recurrent networks. In case of Internet-based Control is very important some kind of auto-adaptation.

By solving tasks in field of electric drives we meet following basic problems: system simulations, identification of system parameters, system state quantities monitoring, drive regulations and malfunction diagnostic. There is possible successful utilization of neural network in all these fields of problem. The most important neural network attributes in this field are: various nonlinear functions approximation, parameters settings based on experimental or learning data, data processing and robustness.

Two different models are used in identification models creation: mathematics and physics analysis and experimental identification. In case of complex subjects both methods are required. Neural network can be used as direct neural model connected parallelly or serial-parallelly in learning state. Neural network can be used also as inverse identification model in dynamic system. Today's computer science performance allows to replace classical methods of parameters estimation by automatic identification. Main advantages include complex test signals generation possibilities, sophisticated identification algorithms, on-line identification possibilities etc.

The condition of the Internet is a very varying parameter and the control system controlling via Internet has to compensate the variation. One of the solutions is to employ the neural network. It is possible to teach neural network behaviour for different conditions of networks. The advantage of this solution is that neural network is a more universal tool and condition of the Internet can be used as a one of the many parameters that relate with controlling and regulation.

Adequate control software, appropriate computers on client and server site and Internet with satisfactory connection speed are necessary for successful remote regulation of DC motor via Internet adequate control software. Definition of "adequate" control software, computer and connection speed depends on concrete motor parameters. In generally, regulation of DC may be considered as real-time regulation problem and time intervals in tens of milliseconds. The time intervals may vary significantly from every regulation system. It is very important for regulation system via Internet that the regulation loop time interval may be under one millisecond, in milliseconds or may be over hundreds of milliseconds and more. In the architecture design, a remote regulation of electric motor via Internet generally includes three major parts: client, server and regulated electric motor. The general remote regulation system architecture is shown in Fig. 2. The client part is the interface for the operations.

It includes computers, control software with user interface for operators or superior system. Client computer receives state information of electric motor, connection state and other information related to the motor regulation via Internet. Received information will be processed and evaluated in remote computer.

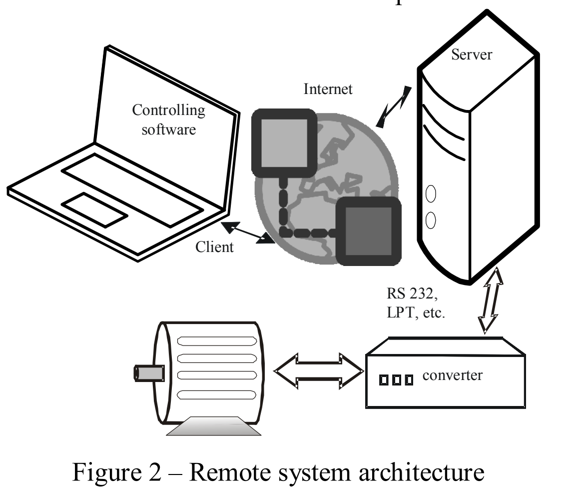

Figure 2 – Remote system architecture

The server part contains a server computer, which is connected to the converter. Server contains all required drivers and devices for communication with the converter.

Communication of server with converter could be based on several ways (RS232, Profibus, CAN, USB, etc.). Sophisticated converters may be Ethernet enabled and may be connected directly to the Internet. But if the client computer is located in outside network – not in LAN network, where the converter is located, the server computer is recommended.

The third part of system architecture is the electric motor with the converter itself. Common way for distance regulation is only start/stop of electrical motor setting wished value on remote computer. The regulator itself (for instance PI regulator) is located on server site, or is implemented in converter.

But Internet speed progress opens possibility for real-time control from client site, so there is possibility that Internet could be part of the regulation loop. There could be thousands of kilometres between client computer and server, or they could be in the same room. The difference is in the communication delay, but generally the system is the same. The communication service (the bus) can be achieved by wired connection, mostly Ethernet, or wireless – very popular WiFi.

Usage of Artificial neural network. Remote regulation via Internet is very complicated. There is a delay in system state information and also the system response delay. The most complicating factors is the fact that the delay is not constant, but varies in time.

As mentioned before, Artificial Neural Network in motor regulation can be used in many ways. For our purpose Neural Network was used for control linearization. Linearization of system control is making the regulation significantly easier.

Stuttgart Neural Network Simulator (SNNS) was used for Neural Network simulation. The software was developed at University of Stuttgart and maintained at University of Tübingen. Different neural networks were tested in simulation with different methods of teaching, different number of hidden layers, and different number of neurons in hidden layers.

Optimal to time of learning, stability and error of Neural Network, the most appropriate Neural Network appears to be Neural Network with one hidden layer containing 6 neurons and learned with back-propagation algorithm. Scheme of resultant Neural network is shown in Fig. 3.

Effect of Neural Network on system control is presented on Fig. 4. Fig. 4 presents system response – rpm on control signal. The darker curve presents system response without Neural Network. The lighter curve presents response with Neural Network. It is obvious that lighter curve is significantly more linear than a dark one. Beginning of the lighter curve is intentionally nonlinear. The purpose of non-linearity is a reserve for DC motor inactivity. If there wasn't the reserve, even small error of Neural Network could cause that motor would rotate very slowly, when it should be inactive.

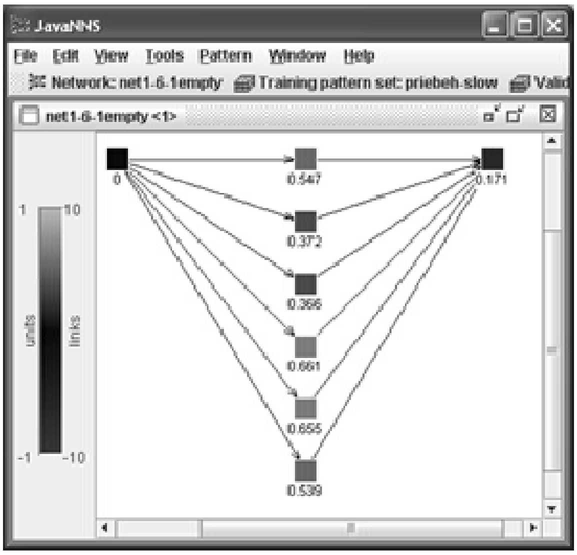

Figure 3 – Neural Network Architecture

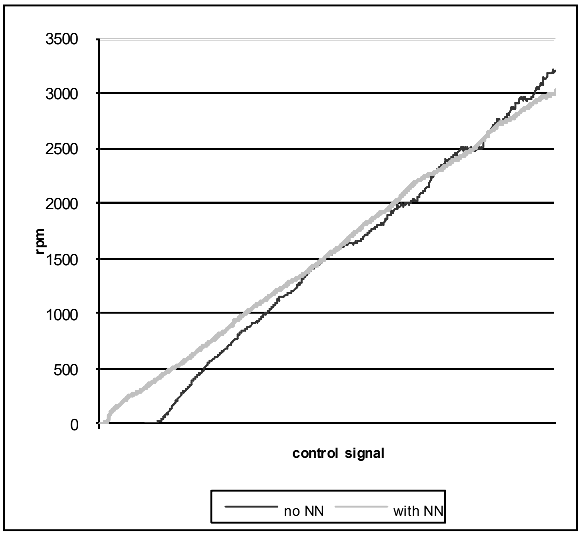

Figure 4 – Regulation response differences using NN

Fig. 4 shows that system response with NN has more advantages: lighter curve shape is more linear, there is smaller zone of insensitive, when system doesn't response on control signal, when control signal is under certain level. Significant advantage is that NN could take in consider more constraints, for example maximum rpm etc. In this case the maximum rpm should be 3000 rpm.

Fig. 5 shows system response on remote regulation. System is regulated by PI regulator tuned for local regulation – doesn't take in consider a time delay caused by Internet. As Figure 5 shows, darker shape – using NN has lower overregulation and faster reach wished value.

Remote regulation measurement in this case was performed in network condition when there was average 15 ms delay in communication between server and client computer.

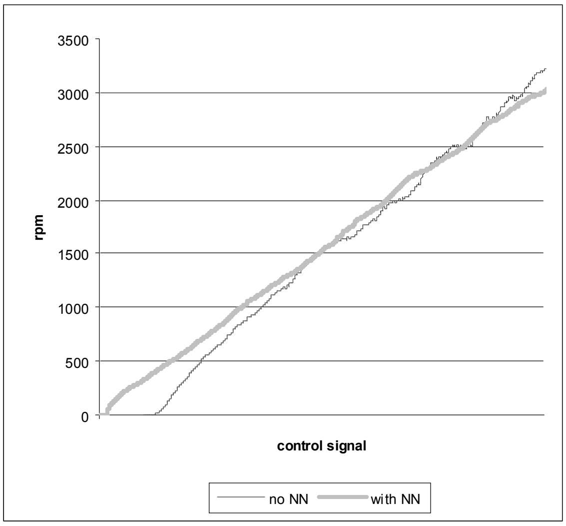

Figure 5 – Regulation with 15ms delay

CONCLUSIONS. Many control elements have been embedded with Internet-enabled functions. Today's technology allows possibility that regulation system could be connected directly to the Internet (without a necessity of a server computer). When Ethernet as a bus is compared with other standard types, the most powerful advantages include nearly unlimited size of bus, possible huge distance, open system of the Internet protocols and accessibility of the Internet. As measured data shows, utilization of Artificial Neural Network in remote regulation could be a useful contribution. The highest advantage of Artificial Neural Network is a possibility to learn even when it is in operation. So Neural Network can handle the new situations and system state.

ACKNOWLEDGEMENT.

We support research activities in Slovakia / Project is co-financed from EU funds. This paper was developed within the Project "Centre of Excellence of the Integrated Research & Exploitation the Advanced Materials and Technologies in the Automotive Electronics ", ITMS 2622012005.

REFERENCES

1. Yang S.H., Tan L.S., Chen X. Requirements Specification and Architecture Design for Internet-based Control Systems // *Proceedings of the 26th Annual International Computer Software and Applications Conference (COMPSAC'02).* – 2002.

2. Hall E. Internet Core Protocols: The Definitive Guide // *O'Reilly & Associates.* – February, 2000. – USA. – ISBN 1-56592-572-6.

3. Kováč D., Vince T., Molnár J., Kováčová I. Modern Internet Based Production Technology // *In: New Trends in Technologies.* – Croatia: SCIYO Publisher, 2010. – 20 p. – ISBN 978-953-307-212-8.

4. Kováčová I., Kováč D. Industrial Electrical Engineering – Modeling of Converters // *In: 1st part, book.* – Published by TU of Košice*,* 2011. – 66 p. – ISBN 978-80-553-0617-9.

5. Kováčová I., Kováč D. Industrial Electrical Engineering – Modeling of Converters // *In: 2nd part, book.* – Publiser TU of Košice. – 2011. – 68 p. – ISBN 978-80-553-0618-6.

6. Molnár J., Bučko R., Bačko M.: Automatic measurement system in automobile based on Internet // *In: Transactions of KMOSU.* – 2010. – Iss. 4. – № 2. – PP. 166–169. – ISSN 2072-8263

ИСПОЛЬЗОВАНИЕ ИСКУССТВЕННОЙ НЕЙРОННОЙ СЕТИ ДЛЯ УДАЛЁННОГО РЕГУЛИРОВАНИЯ СКОРОСТИ ДВИГАТЕЛЯ ПОСТОЯННОГО ТОКА

Т. Винсе
Технический университет Кошице
Парк Коменского, 3, г. Кошице, 04001, Словакия. E-mail: tibor.vince@tuke.sk

Представлены возможности удалённого управления двигателем постоянного тока посредством Интернета, а также показана возможность применения искусственных нейронных сетей для такого вида управления. С учётом развития технологий Интернета и повышения скорости передачи данных, был применён удобный недорогой подход к организации связи при создании системы удалённого управления. Рассмотрены преимущества и недостатки сети Интернет как коммуникационной и управляющей шины на разных уровнях информационной иерархии, и приведены измеренные данные отзыва системы дистанционного управления.

Ключевые слова: двигатель постоянного тока, удалённое управление, искусственные нейронные сети.

Стаття надійшла 23.07.2012.
Рекомендовано до друку
д.т.н., проф. Клепіковим В.Б.