Modulo 2:

Riferimento a linee guida	FORM N: 7 PROGRAM EVALUATION FORM
3	Nome programma:
	Industrial Automation
3	Responsabile programma
	Giuseppe Buja
3	Obiettivi specifici del programma
	This program consists of two research lines, Power Electronics and Mechatronic Systems, each of them composed of two topics. They are Industrial Drives and Active Compensators for the Power Electronics line and Motion Control & Networking, and Drive-by-Wire for the Mechatronic Systems line, respectively. The first research line (Power Electronics) dates back in the 70's, starting with the pioneering activities on the pulsewidth modulation techniques and the microcomputer control of electrical drives and static converters. The second research line (Mechatronic Systems) has been initiated in the late 90's in parallel with the increasing demand of networked motion control systems both in the industry and in the automotive sector. The research lines are tightly associated with the teaching courses held by the academic staff of this program, which -during the five-year period under consideration- have been Electrical Drives for Automation (2001-2004) Power Electronics (2004-2005), Systems for Automation (2005) and Enertronic (2004-2005). *Research Line 1 Power Electronics, Industrial Drives Topic* The research line on the Industrial Drives topic is focused on the ac drives, especially those with the induction motor, implementing the field orientation and the direct torque control. The aim of the research line is to analyze the overall performance of the drives and to develop solutions for advancing schemes and operation of the drives. The research issues are as follows: techniques for the motor parameter identification, description of the drive behavior under the different control methods, improvement of the motor flux and torque responses both in steady state and during transients, and reduction of the component count of the control schemes with a reasonable impairment of the drive performance. By keeping on the studies of the field-oriented drives done in the previous five-year period, a research project has been directed to the identification of the magnetizing characteristic of an induction motor during the drive self-commissioning in order to tune the field orientation control to the changes in the operating conditions under flux weakening. The goals of the project were the setup of an identification technique that uses the hardware coming with the drive, keeps the motor at a standstill during the self-commissioning session, and does not use repetitive tests and multiple data processing. The activities carried out to achieve these goals have been concerned with the single-axis motor supply, the parametric modeling of the magnetic saturation of the motor, and the synthesis of an algorithm based on the recursive least-squares technique for identifying the magnetizing characteristic parameters.

Another research project that has extended all along the five-year period under consideration has been the direct torque control of the induction motor drives. One stage of the project has been devoted to the assessment of the switching characteristics of the inverter that supplies the motor and to the analysis of the drive behavior under sensing inaccuracies and parameter mismatches. This research is made somewhat complex by the non-regular modulation process of the inverter inherent in the direct torque control method and the use of control systems based on hysteretic functions. It has been therefore of interest to evaluate the effect of the drive parameters like the dc-link voltage and the sampling frequency on the inverter switching frequency as well as to predict theoretically the instability situations arising from sensing and parameter errors. In another stage of the project two novel direct torque control schemes have been proposed. The first proposal was related to the employment of only one sensor of current, placed on the inverter dc link, to control the drive. A suitable algorithm has been originated to reconstruct the motor currents, leading to a drive arrangement cost-competitive with the popular V/f schemes although exhibiting the performance of a direct torque control scheme. The second proposal was related to the challenge of smoothing the motor torque ripple of a direct torque control scheme in steady-state conditions. An effective solution to this problem has been derived from the analysis of the motor behavior consequential to an inverter switching and the idea of timing the inverter commands differently from the standard method.

Both for this research line and the next one, an intensive activity has been given to the experimental validation of the theoretical findings. A major task has been the programming of the microcontrollers (or of the digital signal processors) controlling the power electronics equipment, and has involved the numerical transposition of the control algorithms, the optimization of the code composition and the exploitation of the processor resources to deliver the control actions in due time.

Research Line 1 Power Electronics, Active Compensators Topic

The research line on the Active Compensators topic is intended to design power electronic compensators to improve the power quality of the utility system threaten by the wide use of distorting loads such as the electronic equipment with front-end line-frequency rectifiers, by installation of high-power time-variant loads such as the arc furnaces and by the progressive weakness of the utility grid owing to the increase in the absorbed power not balanced by an equal increase in the generated power. The research activities are focused on active compensators directly connected to the medium-voltage lines without the intermediate of transformers or the series connection of power devices, but through the use of multilevel converters. The envisaged compensating actions are active filtering and flicker mitigation. The subjects broached are as follows: current and voltage ratings on the semiconductor devices for different topologies of the multilevel converters, sizing of the passive components (ac-side reactors and dc-side capacitors) embedded in the compensators, control of magnitude and harmonic content of the output voltage of multilevel converters and synthesis of the control system of the active compensators.

A research project on this topic has been dealt with the active filtering of the current harmonics injected into the mains by MW-power ac drives with front-end diode rectifiers fed by a line at a few kVs. The objective was to bring down, within the limits recommended by IEEE Standard 519, the current harmonics and the associated total current harmonic distortion by means of a shunt active filter connected to the feeding line. By the project, studies have been executed on the modeling of the electric plant, including the grid, and on the usage of the instantaneous power theory to synthesize the

compensating actions delivered by the active filters. The main problems tackled have been: arrangement of current loops able to impress the required current with a minimal phase shift, regulation of the dc-bus voltage and balance of the voltages across the dc-side capacitors of a multilevel converter. A research activity has also been carried out on the control of the output voltage of multilevel converters, where the basic staircase waveform of the voltage can be exploited both to reduce the switching frequency of the modulation process and to adopt different modulation techniques for the various levels of the output voltage.

Another research project has been focused on the active compensation of the flicker phenomenon. The objective was to keep the flicker intensity below the perception limits as defined by the Standard IEC 868-0 (Flickermeter-part 0: Evaluation of flicker severity) even in case of a time-variant load absorbing a power amount that is a high portion of the utility grid capacity. This objective has been achieved by a corresponding attenuation of the mains voltage fluctuations, obtained by connecting an active compensator in parallel to the medium-voltage line supplying the load. Over the project attention has been paid to the design of compensators built up around multilevel converters with the Cascade H-bridge and the Diode Clamped topologies and to the analysis of the instantaneous power terms contributing to the voltage fluctuations. The latter analysis has lead to an effective strategy for compensating the voltage fluctuations. As a matter of fact, the full attenuation of the voltage fluctuations, attainable when the active compensator delivers the total fluctuating component of the instantaneous power absorbed by the load, necessitates a very large capacitor across the dc bus of the converter. On the other hand, the compensation of the fluctuating component of the instantaneous imaginary power alone needs a smaller capacitor but produces a satisfactory flicker mitigation only when the grid is strong. By the devised compensation strategy the voltage fluctuations in a weak grid are drastically reduced with a capacitor of about the same size as the strong grid case.

Within this topic, a research activity has been spent to explore the chance of using the neural network approach to set up measurement techniques suited to give information on the time evolution of the line frequency and current (or voltage) harmonics in real time. It has been shown that appropriate topologies and learning algorithms for the neural networks make them able to track the changes in the target line quantities with a delay from a quarter to half the mains period. A significant outcome of this research has been the formulation of analytical equations to describe the track abilities and the steady-state accuracy of the neural networks in measuring the line quantities.

The above research line has been supported by

* PRIN 2000 entitled "Active harmonic compensators for ac electric drives connected to a medium voltage grid" (PRIN are two-year long Research Programs of National Interest co-funded by the Ministry of University),
* two-year Research Project of the University of Padova entitled "Active systems for flicker compensation" (2002),
* two three-year Scientific Research Programs of the University of Padova entitled "Electrical drives for industrial automation" (1999-2001) and "Electrical systems for industrial automation" (2002-2004),
* industrial research contract entitled "Electromagnetic analysis and characterization of linear MP ironless motors".

Research Line 2 Mechatronic Systems, Motion Control & Networking Topic

The research line on the Motion Control & Networking topic encompasses two key

aspects of the application of motion systems to manufacturing processes: control and networking. The respective research activities are aimed at i) designing control algorithms able to make the motion of an object as close as possible to the reference trajectory irrespectively of any torque disturbing the motion, either entering from the working process or arising from drive imperfections, ii) upgrading the serial bus communication networks -commonly termed fieldbusses- used for the data exchange among distributed motion systems placed in the shop floor of a factory in order to meet the real-time requirements posed by the process control demands.

Regarding the control of the motion systems, the research themes are as follows: modeling of the internal torque ripple in brushless drives (cogging torques, unbalance supply of current, constructive flaws of the feedback sensor, which is typically an encoder) and investigation of techniques able to detect and counteract the disturbance torques before they alter the object trajectory. The research has concentrated on the technique called generalized torque disturbance compensation because of its capacity of estimating all the disturbance torque terms by a simple estimation scheme. A subject of research has been the digital implementation of the technique, whereas it requires the double differentiation of the position signal generated by the encoder and an appropriate choice of the control parameters. In recent times the main inconvenience of this technique, which is the low frequency band of the compensating action due to the need of using a narrow low-pass filter to smooth the differentiated position signal, has been surmounted by the availability of sinusoidal encoders with a resolution of millions of counts per revolution at a reasonable price. A new problem has then arisen: the instability of the motion systems because of the interaction between the current control loop and the compensating action. The problem has been faced by a research project that has explained the phenomenon and has found the design rules for the motion controllers to prevent both the system instability and its vibrational behavior, which is unwished-for in most of the high-performance motion applications. The setup of an inner acceleration loop to reject the disturbance torques in an early stage has been also investigated and the performance of the resulting motion system has been compared to that one exhibited by the torque disturbance technique.

Regarding the networking of the motion systems, the research themes are as follows: extension of Ethernet to the shop floor level of a factory by supporting the exchange of data in real time through the accommodation of appropriate high-level protocols, comparative analysis of the communication architectures used for integrating the electric drives in the industrial processes with real-time control of the mechanical quantities, and development of hardware/software tools to allow the CAN and CAN-based networks to integrate distributed motion systems. By a research project on the latter issue, two main results have been obtained. One result is the development of a protocol, termed SynCAN, that runs on the application layer of a CAN network. The SynCAN protocol exploits the services offered by the underlying layers to rule the communication tasks so that the nodes of a CAN network transmit the messages only in an a-priori established sequence and the transmissions take a fixed time. Another result is concerning with the nodes that occupy the bus with unduly messages, thus dislocating the regular data traffic. The software and hardware sources of the babbling idiot phenomenon have been examined. Logic circuits, commonly designated with bus-guardians, that periodically impede the bus access to the babbling-idiot nodes have been studied. A bus-guardian device has been designed for the FlexCAN architecture, a communication structure that employs commercial-off-the-shelf CAN components and, in spite of this, assures an uninterruptible data flow thanks to a redundant use of the network components. The research activity on the CAN networks has also covered the analysis of the synchronism features and the transmission performance of TTCAN, an

	evolution of the native CAN protocol launched with the end of providing a fixed time scheduling for the communication tasks. *Research Line 2 Mechatronic Systems, Drive-by-Wire Topic* Drive-by-Wire (DbW) systems are a challenging topic on the cutting edge of the mechatronic research in the automotive sector. They are all-electric systems conceived to substitute for the hydraulic and mechanical equipment that traditionally transmits and executes the driving commands in the cars. A DbW system is formed by a number of duty-different devices: a communication network for transmitting the driving data (commands, feedbacks, status), input sensors and electromechanical actuators for entering and executing the driving commands respectively, actuator sensors for providing the feedback to the closed-loop execution of the driving commands, electronics units for i) acquiring the input signals, ii) controlling both the actuator operation and the driving maneuvers, and iii) supervising the DbW system. The research line on the DbW topic encompasses the study and the design of all the devices and the overall system; the subjects investigated in detail with a research project are the communication network, the steer-by-wire systems and the introduction of the DbW technology in the industrial vehicles, specifically in the lift trucks. Another subject dealt with by the project is the design of systems that, as the DbW ones, are critical with respect to the safety. This subject has been approached with the dependability theory, which recently has received wide attention and numerous contributions because of the increasing usage, either actual or expected, of electrical/electronic devices for executing safety-related operation in both industrial and civilian applications. Regarding the communication network, the research activities have been focused on the time-triggered protocols like FlexRay and TTP, which have been on-purpose developed to give a deterministic behavior in the time and value domains to the networks. This assures both the real-time data exchange among the networked devices and the prompt recognition of the transmission faults. Since a network based on the above-mentioned protocols comes with a redounded transmissive channel, it is able to recover automatically from a fault in the bus. For a fault in the other components, a suitable architecture must be arranged for the network. The main research issues on the communication network for DbW applications have concerned with i) definition of the communication requirements of a DbW system, ii) evaluation and comparison of the transmission features of the time-triggered protocols, iii) analysis of the mechanisms utilized by the protocols to recognize a fault in the network, and iv) design of a time-triggered network for a DbW system. Regarding the steer-by-wire systems, two issues have been examined. One issue is the design of the steering control system. This system, besides directing the road wheels according to the driver commands, is in charge of delivering a force reaction to the driver in order to acquaint him with the effort needed to steer the vehicle and possibly with the road conditions. To this end, suitable transfer functions between inputs and outputs of the steering system have been defined and successively synthesized by a proper selection of the control scheme and parameters. The other issue highlights the opportunities in terms of safety and maneuverability offered by the introduction of a traction and steering by-wire system in a lift truck. From an analysis of the vehicle behavior during cornering, a supervisor control has been developed that automatically limits the speed command as a function of the steering radius and the mast loading to avoid the rollover of the truck. Another supervising control is aimed at directing the road wheels of the vehicle in an independent way during the cornering maneuver with the purpose of meeting the Ackermann condition.

	Regarding the safe design of the DbW systems, interest has been concentrated at first on the dependability theory in an attempt to organize in a unitary framework the copious literature on the matter. Afterwards several architectural solutions for both the electronic units and the electromechanical actuator of a steer-by-wire system have been examined in view of achieving a fail-operational level of tolerance under a fault in any device of the system. Architectural solutions for achieving the fail-safe level of tolerance have also been studied since they are of relevance for vehicles circulating in enclosed spaces. The above research line has been supported by * one-year Research Program for Young Researchers of the University of Padova entitled "Motion control by means of fieldbusses" (2001), * two-year Research Program of the University of Padova entitled "Study and development of deterministic communication protocols for industrial applications" (2003), * PRIN 2003 entitled "Characterization of communication buses for by-wire applications and experimentation of an advanced drive-by-wire system on a goods handling vehicle".
3	Progetti in corso
	* PRIN 2005 entitled "Study and experimentation of dependable communication networks on board train". The research project is aimed at investigating the feasibility of using a dependable communication network based on a time-triggered protocol to replace the network currently in use on board train for the exchange of data among the devices mounted in the locomotive and the railway cars. The project will proceed in two steps: i) evaluation of the existing time-triggered protocols with regard to the requirements posed by the target applications in terms of transmission specs, reliability and operative demands, and ii) arrangement of a trial network implementing the most convenient protocol and its experimentation by help of a demonstrator that emulates the transmission tasks of the equipment in a train. The project will end up by comparing the overall performance of the trial network with that in use on the basis of the specification documents and the experimental results. * Industry research contract entitled "Analysis of electric systems for the chassis control in the automotive sector and investigation of the yaw control for two-wheel vehicles". The objective of the research project is a preliminary study on either setting up or improving the chassis control systems for motorcycles, especially those aimed at making the driving safe. At first the project will analyze the stabilizing actions executed and the devices (sensors, actuators and controllers) utilized by the chassis control systems in a modern car, and will evaluate the feasibility of translating the automotive solutions into the motorcycle environment. Then the research will focus on the cornering motion of a two-wheel vehicle. The dynamics of such a motion will be formulated and the instability conditions as well as the possible control actions suited to keep the motion stable will be investigated. * Three-year Scientific Research Program of the University of Padova entitled "Advanced electrical systems for industrial automation" (2005-2007). The research activities will deal with power electronics, in particular with the industrial

	drives and the active compensators. With regard to the industrial drives, the studies on the induction motor drives implementing the direct torque control method will be kept on by pursuing the objective of improving the performance of the existing schemes. This control method is quite new and there is the space for advancing its application. With regard to the active compensators, the main objective will be the experimental test of the strategy devised in the research project for the flicker compensation described in the item "Obiettivi specifici del programma". The design of the relevant control algorithm will also be extended to the compensators equipped with multilevel converters.
4.b	Risorse personale
	[professori ordinari, associati, ricercatori e dottorandi, borsisti post dottorato, assegnasti, personale tecnico-amministrativo] Full Professor Buja Giuseppe Research Assistant Bertoluzzo Manuele Technician Baessato Massimo (part-time) Ph.D. students and research fellowship holders Castellan Simone Cortese Lino Cuogo Luca Sabbatini Stefano Sulligoi Giorgio Zago Stefano Zuccollo Alberto
5.b	Risorse finanziarie [media quinquennale]
	[la somma di finanziamento ordinario d'Ateneo finanziamenti specifici d'ateneo, finanziamenti specifici da enti di ricerca locali, nazionali e internazionali, finanziamenti da contratti con enti privati.] Research line 1: 20000 €/year Research line 2: 48000 €/year
6	Laboratorio e risorse materiali
	The experimental activities relevant to the research lines illustrated above, namely Power Electronics and Mechatronic Systems, are carried out at the Laboratory of Industrial Automation, commonly referred to as REALIA (Research and Educational Academic Laboratory of Industrial Automation). The main equipment at disposal of the research line on Power Electronics is constituted by i) induction motor drives, ii) a modular power converter set composed by a dc/ac PWM converter, a diode rectifier, a chopper and passive components (reactors, capacitors, resistors) for filtering and loading the set, iii) development boards for Texas and Analog Devices DSPs and for Freescale microcontrollers, and iv) development kits for FPGA programming. The

	main equipment at disposal of the research line on Mechatronic Systems is constituted by i) permanent-magnet synchronous motor drives, ii) development boards with FlexRay communication controller and software toolchain for programming the board controller, iii) CAN, CANopen and TTCAN evaluation boards, and iv) a battery-operated lift truck. Used by both the research lines there are measurement and testing instruments such as digital oscilloscopes, power supplies and function generators.
7	Rapporti con altri istituti di ricerca a livello locale, nazionale e internazionale
7.a	*[specificare concretamente quanto indicato sotto collaborazioni istituzionalizzate indicate al punto 1 della scheda di Dipartimento]* Institute of Technology, University of Birla (India): Prof. B.M.Karan Cesab Company (Bologna): Ing. G.Tartara
7.b	*[Indicare collaborazioni personali non istituzionalizzate ma rilevanti per il programma]* Kettering University, USA: Prof. J.Pimentel Ljubljana University, Slovenia: Prof. V.Ambrozic Trieste University, Italy: Prof. R.Menis, Dr. S.Castellan CNR Institute of Electronics and of Information and Telecommunication Engineering: Dr. S.Vitturi Centro Ricerche FIAT: Dr. M.Osella
9	Altre attività rilevanti per la ricerca, a livello di Programma
	[organizzazione di seminari e convegni, partecipazione a seminari e convegni, ecc..] * Editor of a Special Section in IEEE Transactions on Industrial Electronics, entitled "Direct Torque Control of AC Motors", 2002 * General leadership of PRIN 2003 entitled "Analysis and developement of advanced solutions for drive-by-wire guidance systems and their experimentation on a goods handling vehicle", * General leadership of PRIN 2005 entitled "Study and experimentation of dependable communication networks on board train", Honorary chairmanship of IEEE International Symposium on Industrial Electronics, 2002 * Co-chairmanship of the Steering Committee of IEEE Symposium on Diagnostics for Electric Machines, Power Electronics and Drive, 2001, 2003, 2005 * Co-chairmanship of the Program Committee of IEEE Advanced Motion Control Workshop, 2002 * Board of co-chairs of International Power Electronics and Motion Control Conference, 2002, 2004 * Membership of the Editorial Board of the International Journal of Electrical Engineering in Transportation (IJEET). * Organization of a one-day Workshop on "Energy saving in the electric systems", Padova, 2003. * Organization of a half-day Seminar on "Drive-by-wire systems", Padova, 2005.
11	Prodotti della ricerca
11.b	

RESEARCH PRODUCTS						
	2001	**2002**	**2003**	**2004**	**2005**	**Total**
Journal papers	1		3	4	2	10
Chapters in book						
Books/Notes/Reports						
Proceedings of Conferences	3	1	4	7	7	22
Patents						
Other						

11.c

Product 1: Paper on Journal
V.Ambrozic, M.Bertoluzzo, G.Buja and R.Menis, "An assessment of the inverter switching characteristics in DTC induction motor drives", *IEEE Transactions on Power Electronics,* vol. 20, n. 2, pp. 457-465, March 2005.
Impact Factor: 1.202

Product 2: Paper on Journal
G.Buja and M.Kazmierkoski, "Direct torque control of PWM inverter-fed AC motors - a survey", *IEEE Transactions on Industrial Electronics*, vol.51, n.4, pp.744-757, August 2004.
Impact Factor: 0.976

Product 3: Paper on Journal
M. Bertoluzzo, G.Buja, S.Castellan and P.Fiorentin, "Neural network technique for the joint time-frequency analysis of distorted signal", *IEEE Transactions on Industrial Electronics*, vol. 50, n° 6, pp. 1109-1115, December 2003.
Impact Factor: 0.976

Product 4: Paper on Journal
M.Bertoluzzo, G.Buja and E.Stampacchia, "Performance analysis of a high-bandwidth torque disturbance compensator", *IEEE-ASME Transactions on Mechatronics*, vol.9, n.4, pp. 653-660, December 2004.
Impact Factor: 0.652

Product 5: Paper on Journal
F.Benzi, G.Buja and M.Felser, "Communication architectures for electric drives", *IEEE Transactions on Industrial Informatics*, vol. 1, n. 1, pp. 47-53, February 2005.

P.S. Nel caso in cui le informazioni disponibili non siano compatibili con il presente modulo è possibile allegare documentazione cartacea indicando negli appositi campi i numeri dei relativi allegati.

Pubblications

Research Line 1 Power Electronics, Industrial Drives topic

M.Bertoluzzo, G.Buja and R.Menis, "Direct flux and torque control of an induction motor using a single current sensor", Proceedings of Electromotion Conference, pp. 601-605, 2001.

M.Bertoluzzo, G.Buja and R.Menis, “Self-commissioning of FO IM drives: One-test identification of the magnetization characteristic of the motor”, *IEEE Transactions on Industry Applications,* vol. 37, n° 6, pp. 1801-1806, November/December 2001.

G.Buja, “Special section on direct torque control of AC motors: Guest editorial”, *IEEE Transactions on Industrial Electronics*, vol.51, n.4, pp.742-743, August 2004.

G.Buja and M.Kazmierkoski, “Direct torque control of PWM inverter-fed AC motors - a survey”, *IEEE Transactions on Industrial Electronics*, vol.51, n.4, pp.744-757, August 2004.

V.Ambrozic, G.Buja and R.Menis, “Band-constrained technique for direct torque control of induction motor”, *IEEE Transactions on Industrial Electronics*, vol.51, n.4, pp.776-784, August 2004.

V.Ambrozic, M.Bertoluzzo, G.Buja and R.Menis, “An assessment of the inverter switching characteristics in DTC induction motor drives”, *IEEE Transactions on Power Electronics,* vol. 20, n. 2, pp. 457-465, March 2005.

G.Buja and R.Menis, “Effect of parameter and sensing errors on DTC IM drive operation”, Proceedings of IEEE International Symposium on Diagnostic for Electrical Machines, Power Electronics and Drives, pp. 15-20, 2005.

Research Line 1 Power Electronics, Active Compensators topic

G.Buja and S.Castellan, "Sizing and control of a PWM rectifier with reduced switch count", Proceedings of Electric Drives and Power Electronics Conference, pp. 194-199, 2001.

G.Buja, S.Castellan and D.Szabo, “A Novel Control Technique for Multilevel Converters with Limited Output Voltage Range”, Proceedings of International Conference on Power Electronics and Motion Control, T1-054, pp. 1-8, 2002.

M.Bertoluzzo, G.Buja, S.Castellan and P.Fiorentin, “Real-time estimation of the power system frequency by neural network”, Proceedings of IEEE International Symposium on Diagnostic for Electrical Machines, Power Electronics and Drives, pp. 87-92, 2003.

G.Buja and S.Castellan, “Active filter for high-power medium-voltage diode rectifiers”, Proceedings of European Power Electronics Conference, pp.1-9, paper 915, 2003

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G.Buja and S.Castellan, “Design of Multilevel Converters for Flicker Mitigation”, Proceedings of IEEE International Conference on Power Electronics and Intelligent Control for Energy Conservation, CD, Paper 200, pp.1-8, 2005.

Research Line 2 Mechatronic Systems, Motion Control Topic

M.Bertoluzzo, G.Buja and S.Vitturi, "Reti di comunicazione basate su Ethernet per la connessione di dispositivi di campo", Atti del 12° Seminario Interattivo di Azionamenti Elettrici, pp. 229-251, 2001.

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M.Bertoluzzo, G.Buja and S.Vitturi, “Ethernet Networks for Factory Automation”, *IEEE Industrial Electronics Society Newsletter*, pp. 5-10, December 2003.

E.Bassi, F.Benzi, M.Bertoluzzo, G.Buja and F.Calegari, “Integration architectures and communication protocols for electrical drives”, Proceedings of International Symposium on Power Electronics, Electrical Drives, Automation and Motion, pp.143-152, 2004.

M.Bertoluzzo, G.Buja, E.Stampacchia and S.Zago, “Brushless AC servo systems: internal torque disturbances and their compensation”, *Electromotion*, vol.10, n.4, pp.217-222, July-Sept. 2003.

M.Bertoluzzo, G.Buja and E.Stampacchia, “Performance analysis of a high-bandwidth torque disturbance compensator”, *IEEE-ASME Transactions on Mechatronics*, vol.9, n.4, pp. 653-660, December 2004.

F.Benzi, G.Buja and M.Felser, “Communication architectures for electric drives”, *IEEE Transactions on Industrial Informatics*, vol. 1, n. 1, pp. 47-53, February 2005.

M.Bertoluzzo, “Experimental activities on TTCAN protocol”, Proceedings of IEEE Workshp on Intelligent Data Acquisition and Advanced Computing Systems, vol.1, pp. 22-27, 2005.

G.Buja, J.Pimentel and A.Zuccollo, “Overcoming babbling-idiot failures in the FlexCAN architecture: a simple bus-guardian”, Proceedings of IEEE International Conference on Emerging Technologies and Factory Automation, pp. 461-468, 2005.

Research line 2 Mechatronic Systems, Drive-by-Wire topic

M. Bertoluzzo, G.Buja and A.Zuccollo, “Design of drive-by-wire communication network for an industrial vehicle”, Proceedings of IEEE International Conference on Industrial Informatics, pp.155-160, 2004.

M. Bertoluzzo, G.Buja and A.Zuccollo, “Communication networks for drive-by-wire applications”, Proceedings of International Conference on Power Electronics and Motion Control, vol. 6, pp.132-137, 2004.

M.Bertoluzzo, G.Buja and A.Zuccollo, “Development and testing of a communication network for a drive-by-wire industrial vehicle”, Proceedings of IEEE International Conference on Industrial Informatics, CD, Paper PD-235, pp.1-6, 2005.

M.Bertoluzzo, P.Bolognesi, O.Bruno, G.Buja, A.Landi and A.Zuccollo, “Drive-by-wire systems for ground vehicles”, Proceedings of IEEE International Symposium on Industrial Electronics, pp.711-716, 2004.

M.Bertoluzzo, P.Bolognesi, O.Bruno, G.Buja, S.Castellan, V.Isastia, R.Menis and S.Meo, “Research Project of National Interest: Analysis and development of advanced solutions for drive-by-wire systems and their experimentation on a goods handling vehicle”, Proceedings of International Conference on Integrated Chassis Control, CD-04A6030, 2004.

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