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Tutorial Proposal

1. Title of Tutorial: Predictive Control - A Simple and Powerful Method to Control Power Converters and Drives

2. Abstract:

SCOPE AND BENEFITS

Up to now the control of electrical power using power converters has been based on the principle of mean value, using pulse width modulation with linear controllers in a cascaded structure.

Recent research works have demonstrated that it is possible to use Predictive Control to control electrical energy with the use of power converters, without using modulators and linear controllers. This is a new approach that will have a strong impact on control in power electronics in coming decades.

The main advantages of predictive control are:

- Concepts are very intuitive and easy to understand.
- It can be applied to a great variety of systems.
- The multivariable case can be easily considered.
- Dead times can be compensated.
- Easy inclusion of non-linearities in the model.
- Simple treatment of constraints.
- The resulting controller is easy to implement.
- This methodology is open to include modifications and extensions depending on specific applications.

The participants of this tutorial will learn:

- The basic concepts and ideas.
- Different types of predictive controllers.
- Detailed examples of predictive controllers.
- Several applications in different converter topologies.

CONTENTS (half day tutorial)

1. Introduction
2. Predictive Control Methods (Kennel)
 - a. Trajectory Based Predictive Control (Kennel)
 - b. Hysteresis Based Predictive Control (Kennel)
 - c. Long-Range Predictive Control (Kennel)
3. Predictive Control of 3phase AC/DC Converters (Kazmierkowski)
4. Constant Switching Frequency Predictive Control (Kazmierkowski)
5. Predictive Control Applied to Power Converters (Rodriguez)
 - a. Background
 - b. Current control of a three-phase inverter
 - c. Power control of an AFE
 - d. Control of a NPC converter
 - e. Control of a matrix converter

- f. Spectrum control
 - g. Voltage control of an UPS
 - h. Control of a flying capacitor converter
- 6. Predictive Control Applied to Motor Drives (Rodriguez)
 - a. Field Oriented Control Using Predictive Current Control
 - b. Predictive Torque Control
 - c. Predictive Speed Control
 - 7. Some Implementation Issues (Rodriguez)
 - 8. Predictive Control versus Cascaded Control (Kennel)
Conclusions/Discussion

3. Lead Instructor:

Title: Prof. Dr.-Ing.

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5. Instructor Bios:



Ralph M. Kennel was born in 1955 at Kaiserslautern (Germany). In 1979 he got his diploma degree and in 1984 his Dr.-Ing. (Ph.D.) degree from the University of Kaiserslautern.

From 1983 to 1999 he worked on several positions with Robert BOSCH GmbH (Germany). Until 1997 he was responsible for the development of servo drives. Dr. Kennel was one of the main supporters of VECON and SERCOS interface, two multi-company development projects for a microcontroller and a digital interface especially dedicated to servo drives. Furthermore he took actively part in the definition and release of new standards with respect to CE marking for servo drives.

Between 1997 and 1999 Dr. Kennel was responsible for "Advanced and Product Development of Fractional Horsepower Motors" in automotive applications. His main activity was preparing the introduction of brushless drive concepts to the automotive market.

From 1994 to 1999 Dr. Kennel was appointed Visiting Professor at the University of Newcastle-upon-Tyne (England, UK). From 1999 - 2008 he was Professor for Electrical Machines and Drives at Wuppertal University (Germany). Since 2008 he is Professor for Electrical Drive systems and Power Electronics at the Technical University of Munich (Germany). His main interests today are: sensorless control of AC drives, predictive control of power electronics and Hardware-in-the-Loop systems.

Dr. Kennel is a Senior Member of IEEE, a Fellow of IEE and a Chartered Engineer in the UK. Within IEEE he is Treasurer of the Germany Section as well as ECCE Global Partnership Chair (PELS).



José Rodríguez received the Engineer degree from the Universidad Técnica Federico Santa María, Valparaíso, Chile, in 1977, and the Dr.-Ing. degree from the University of Erlangen, Erlangen, Germany, in 1985, both in electrical engineering. Since 1977, he has been with the Department of Electronics Engineering, University Técnica Federico Santa María, where he is currently a Professor. From 2001 to 2004, he was the Director of the Department of Electronics Engineering. From 2004 to 2005, he served as Vice Rector of academic affairs, and since 2005, he has been the Rector of the university. During his sabbatical leave in 1996, he was responsible for the Mining Division, Siemens Corporation, Santiago, Chile. He has extensive consulting experience in the mining industry, particularly in the application of large drives such as cycloconverter-fed synchronous motors for SAG mills, high-power conveyors, and controlled ac drives for shovels and power quality issues. He has directed more than 40 R&D projects in the field of industrial electronics. He has coauthored more than 300 journal and conference proceeding papers and contributed one book chapter. His research group has been recognized as one of the two centers of excellence in engineering in Chile from 2005 to 2008. His main research interests include multilevel inverters, new converter topologies, and adjustable-

speed drives. Prof. Rodríguez has been an active Associate Editor for the IEEE Power Electronics and IEEE Industrial Electronics Societies since 2002. He has served as Guest Editor for the IEEE Transactions on Industrial Electronics in six instances [Special Sections on Matrix Converters (2002), Multilevel Inverters (2002), Modern Rectifiers (2005), High Power Drives (2007), Predictive Control of Power Converters and Drives (2008) and Special Sections on Matrix Converters (2011),



Marian P. Kazmierkowski received the M.S., Ph.D., and Dr. Sci. degrees in electrical engineering from the Institute of Control and Industrial Electronics (ICIE), Warsaw University of Technology, Warsaw, Poland, in 1968, 1972, and 1981, respectively.

From 1967 to 1980, he was an Assistant Professor at ICIE. From 1980 to 1983, he was with RWTH Aachen, West Germany, as an Alexander von Humboldt Fellow. From 1986 to 1987, he was a Visiting Professor at NTH Trondheim, Norway. Since 1987, he has been a Professor and Director of ICIE. He was a Visiting Professor at the University of Minnesota, Minneapolis, in 1990, at Aalborg University, Denmark, in 1990 and 1995, and at the University of Padova, Italy, in 1993. He was a Coordinating Professor of the International Danfoss Professor Program from 1997 to 2000 at Aalborg University, Denmark. From 1996 to 2004, he was an elected member of the State Committee for Scientific Research in Poland. He was also Head of the Centre of Excellence on Power Electronics Intelligent Control for Energy Conservation (PELINCEC 2003–2006) (European Framework Program V) at ICIE. He is the author or coauthor of over 250 technical papers and reports, as well as 13 books and textbooks. He coauthored *Automatic Control of Converter-Fed Drives* (Elsevier, 1994) and co-edited (with R. Krishnan and F. Blaabjerg) and coauthored the compendium *Control in Power Electronics* (Academic Press, 2002). He is engaged in experimental research and theoretical work on electric drives and industrial electronics.

Dr. Kazmierkowski was the recipient of an Honorary Doctorate degree from Aalborg University in 2004 and the Dr. Eugene Mittelmann Achievement Award from the IEEE Industrial Electronics Society in 2005. He was Chairman of the 1996 IEEE International Symposium on Industrial Electronics held in Warsaw, Poland. He has served as Vice-President of Publications in the IEEE Industrial Electronics Society (1999–2001). He was the Editor-in-Chief of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS (2004–2006), as well as a member of many IEEE Committees, Conference Organizing Committees. He is Past-Chairman of the IEEE Poland Section.