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TEMPLATE FOR PROPOSAL UNDER DERRI

User-Project Proposal:

User-Project Acronym	C-PoS FRT
User-Project Title	Combined FRT and Power Smoothing Control Method for Full-Converter Wind Turbines Employing Supercapacitor Energy Storage System
Main-scientific field	Wind Energy, Energy Management Control
Specific-Discipline	Control of Power Electronics

Lead User of the Proposing Team:

Name	Charis Demoulias
Phone	+302310995960
E-mail	chdimoul@auth.gr
Nationality	Greek
Organization name, web site and address	Aristotle University of Thessaloniki, Department of Electrical and Computer Engineering, Electrical Machines Laboratory, http://eml.ee.auth.gr, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece
Activity type and legal status* of Organization	Higher Education Institute
Position in Organization	Assistant Professor

* Higher Education Institution (1) – Public research organization (2) – Private not-for-profit research organization (3) – Small or Medium size private enterprise (4) – Large private enterprise (5) – other (specify)

Additional Users in the Proposing Team:

Name	Spyros Gkavanoudis
Phone	+302310994358
E-mail	gavanoudis@gmail.com
Nationality	Greek
Organization name, web site and address	Aristotle University of Thessaloniki, Department of Electrical and Computer Engineering, Electrical Machines Laboratory, http://power.ee.auth.gr, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece
Activity type and legal status* of Organization	Higher Education Institute
Position in Organization	PhD Candidate

* Higher Education Institution (1) – Public research organization (2) – Private not-for-profit research organization (3) – Small or Medium size private enterprise (4) – Large private enterprise (5) – other (specify)

(Repeat for all Users)

Date of submission	28/06/2012

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Re-submission	YES________ NO___**X**____
Proposed Host TA Facility	TA6 *Fraunhofer Institute for Wind Energy and Energy System Technology*
Starting date (proposed)	15th December

Summary of proposed research (about ½ page)

As wind plants increase in size and number they have a greater impact on the grid while they displace other conventional generation units. The capability of a wind turbine to withstand short-duration grid faults and other disturbances is referred to in the literature as fault ride-through (FRT) capability or low voltage ride-through (LVRT) capability. Most utility administrators have revised their grid codes in order to address the latest FRT requirements. Previous research has focused on the improvement of FRT capability as long as the generator is still connected to the grid. The existence of distributed generation units in the power system has consequences for the conventional protection devices, as they might become blind to overcurrents and short circuits. This research proposes the disconnection of the wind power unit when a fault occurs in the grid and the voltage does not recover within a time limit. The energy produced during the fault is stored in a Supercapacitor Energy Storage System, allowing the generator to stay functional for a period of time, despite being disconnected from the grid. In this way, the normal fault-clearing process can take place. Just after reconnection, the generators are able to supply the grid with power, ensuring reliability of the power system. Furthermore, the ESS is exploited to absorb the output power fluctuation due to wind speed deviation.

Experimental measurements from the test facilities will help the evaluation of the proposed Fault ride-through capability method as well as its ability to smoothen output power fluctuation due to wind speed variations. Longer fault duration can be tolerated, while the protection system clears the fault through the normal process. Furthermore, output power fluctuation is expected to be significantly reduced.

State-of-the-Art (about 1 ½ page)

Low Voltage Ride Through requirements have been developed by many utility grid administrators. Usually these characteristics are described through a voltage profile (LVRT reference curves) above which the wind turbine generators WTG should stay connected to the grid. Moreover, reactive current boosting during and after faults aims at supporting the grid voltage, for the purpose of enabling non-LVRT compliant power units and other decentralized generators to stay connected. Common point of all previous work is that the WTG should stay connected to the grid. [1-3]

Fault Detection: Forcing a wind turbine generator to stay connected could lead to undetected grid faults. The grid protection system might measure a lower current during the fault, due to the contributions of the generators to the fault current. As a result, the fault detection happens too slow or not at all. [4, 5]

LVRT strategies: In order to be able to meet the LVRT requirement, the control system and the hardware has to be modified to manage the energy produced by the WTG during the low-voltage event. Without energy management, the power produced by the WTG under fault conditions will remain within the electric machine, resulting in an increased mechanical speed. Options available to handle the energy that the grid cannot absorb depend on the type of WTG used. The most commonly used LVRT solutions are listed as follows [6-9]:

1. In Fixed speed wind turbines (FSWT) using Squirrel Cage Induction generators a Static Var Compensator (SVC) or static synchronous compensator (STATCOM) at the point of common coupling (PCC) is used to support reactive power.
2. In Full Converter Driven WTG, dumping the energy in a resistor, which is typically connected to the dc bus, regulating the dc bus to within ±10% of its nominal value;
3. Pitch angle control. The rate of pitch angle change is usually designed at a slow value (around 10^o/s) to prevent excursion of wind speed on the WT blades. The reaction of pitch controller is very slow in case of transient fault and ineffective when the mechanical power output should be reduced as fast as possible to prevent the speed acceleration.
4. In a DFIG, a commonly used solution is to shorten the rotor windings through a resistor (Crowbar) and operating the machine as a conventional induction machine;
5. Dumping the energy in an electrical storage device, for example, supercapacitor, superconducting magnetic energy storage, and batteries.

Energy Storage Devices: The most common implemented technologies for short-term energy storage are Lead-acid Batteries, Flywheels, Supercapacitors and Superconducting Magnetic Energy Storage (SMES). Flywheels and supercapacitors both offer similar characteristics and are both suitable for wind energy applications. They represent a storage device that has a high energy density and presents a good efficiency. In addition, they have a much higher life cycle than batteries. [10-13]

Power smoothing: In a full-converter driven WTGs power smoothing is achieved by controlling the dc link voltage level. This could be done either by raising the dc link voltage or by keeping it constant and storing the excess of power in an energy storage system. Consuming the excess of energy on a resistor is unadvisable but is used often. [14-17]. To produce a smoothened output power reference signal many technics (e.g. power ramp control, Low Pass Filter, Simple Moving Average) can be used.[18]

List relevant References

[1] Rahmann, C., Haubrich, H.-J., Moser, A., Palma-Behnke, R., Vargas, L.; Salles, M.B.C., “Justified Fault-Ride-Through Requirements for Wind Turbines in Power Systems”, IEEE Transactions on Industry Applications, vol. 26, no. 3, August 2011

[2] Erlich, I., Bachmann, U., “Grid code requirements concerning connection and operation of wind turbines in Germany” Power Engineering Society General Meeting, 2005. IEEE

[3] Boemer, J.C.; van der Meer, A.A.; Rawn, B.G.; Hendriks, R.L.; Ciupuliga, A.R.; Gibescu, M.; Kling, W.L.; Ferreira, J.A.; , "Fault ride-through requirements for onshore wind power plants in Europe: The needs of the power system," Power and Energy Society General Meeting, 2011 IEEE , vol., no., pp.1-8, 24-29 July 2011

[4] Vermeyen, Pieter, “Effect of Distributed Generation on Fault Detection and Ripple Control”, ESAT - ELECTA, Electrical Energy Computer Architectures Campus Library Arenberg, PhD Thesis

[5] M. Megdiche, Y. Besanger, J. Aupied, R. Garnier, and N. Hadjsaid, “Reliability assessment of distribution systems with distributed generation including fault location and restoration process," in Proc. CIRED, 17th International Conference on Electricity Distribution, May 2003.

[6] Nguyen, D.H.; Negnevitsky, M.; , "A review of fault ride through strategies for different wind turbine systems," Universities Power Engineering Conference (AUPEC), 2010 20th Australasian , vol., no., pp.1-5, 5-8 Dec. 2010

[7] [8] Mohd. Hasan Ali and Bin Wu, "Comparison of stabilization methods for fixed-speed wind generator systems," IEEE Transactions on Power Delievery, vol. 25, no. 1, pp. 323-331, 2010.

[8] S.M. Muyeen, R. Takahashi, T. Murata, J. Tamura, M.H. Ali, Y. Matsumura, A. Kuwayama, and T. Matsumoto, "Low voltage ride through capability enhancement of wind turbine generator system during network disturbance," IET Renewable Power Generation vol. 3, no. 1, pp. 65-74, 2009.

[9] S. M. Muyeen, R. Takahashi, Mohd. Hasan Ali, Toshiaki Murata, and Junji Tamura, "Transient stability augmentation of power system including wind farms using ECS," IEEE Transactions on Power Systems, vol. 23, no.3, pp. 1179-1187, 2008.

[10] Smith, S.C.; Sen, P.K.; Kroposki, B.; , "Advancement of energy storage devices and applications in electrical power system," Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE , vol., no., pp.1-8, 20-24 July 2008

[11] Spahic, E.; Balzer, G.; Hellmich, B.; Munch, W.; , "Wind Energy Storages - Possibilities," Power Tech, 2007 IEEE Lausanne , vol., no., pp.615-620, 1-5 July 2007

[12] Naswali, E.; Alexander, C.; Hai-Yue Han; Naviaux, D.; Bistrika, A.; von Jouanne, A.; Yokochi, A.; Brekken, T.K.A.; , "Supercapacitor energy storage for wind energy integration," Energy Conversion Congress and Exposition (ECCE), 2011 IEEE , vol., no., pp.298-305, 17-22 Sept. 2011

[13] Black, M.; Silva, V.; Strbac, G.; , "The role of storage in integrating wind energy," Future Power Systems, 2005 International Conference on , vol., no., pp.6 pp.-6, 18-18 Nov. 2005

[14] Esmaili, A.; Nasiri, A.; , "Energy storage for short-term and long-term wind energy support," IECON 2010 - 36th Annual Conference on IEEE Industrial Electronics Society , vol., no., pp.3281-3286, 7-10 Nov. 2010

[15] Xiao Li; Changsheng Hu; Changjin Liu; Dehong Xu; , "Modeling and control of aggregated Super-Capacitor Energy Storage system for wind power generation," Industrial Electronics, 2008. IECON 2008. 34th Annual Conference of IEEE , vol., no., pp.3370-3375, 10-13 Nov. 2008

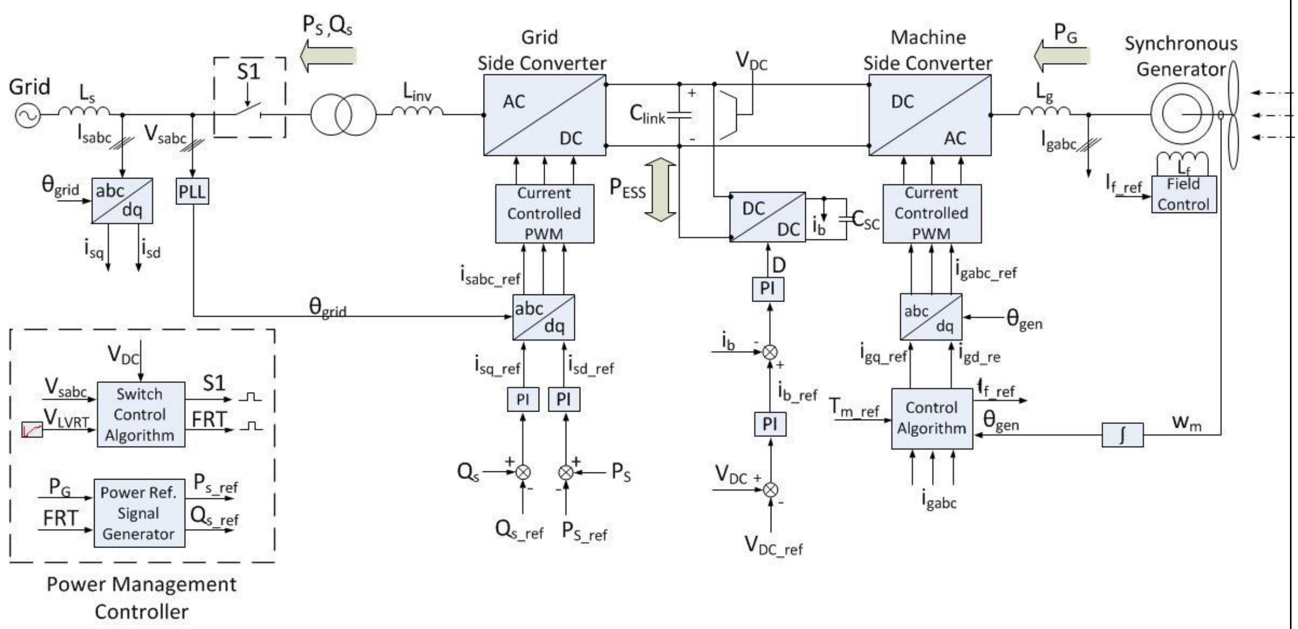
[16] Wei Li; Joos, G.; , "Performance Comparison of Aggregated and Distributed Energy Storage Systems in a Wind Farm For Wind Power Fluctuation Suppression," Power Engineering Society General Meeting, 2007. IEEE , vol., no., pp.1-6, 24-28 June 2007

[17] Guoyi Xu; Lie Xu; Morrow, D.J.; , "Wind turbines with energy storage for power smoothing and FRT enhancement," Power and Energy Society General Meeting, 2011 IEEE , vol., no., pp.1-7, 24-29 July 2011

[18] Esmaili, A.; Nasiri, A.; , "Power smoothing and power ramp control for wind energy using energy storage," Energy Conversion Congress and Exposition (ECCE), 2011 IEEE , vol., no., pp.922-927, 17-22 Sept. 2011

Detailed Description of proposed project : Objectives – Expected Outcome – Fundamental Scientific and Technical value and interest (2-3 pages)

The aim of this proposal is the development of a combined Fault ride through and power smoothing method for full-converter wind turbines, employing a Supercapacitor Energy storage system. The Energy Storage System (ESS) is used in order to store the energy produced during severe grid faults. This allows the generator to stay functional for a period of time, despite being disconnected from the grid. The key point of this method is the disconnection of the wind turbine driven generator in case the fault duration exceeds the maximum duration for which the generators should remain connected to the grid, according to the grid code requirements. The amount of energy that cannot be absorbed from the grid is handled through a control algorithm ensuring the safe function of the machine. Disconnection is performed in such a way as to allow the protection equipment of the grid to detect and clear the fault smoothly. Immediately after the fault clearance, the wind turbine generator reconnects to the grid and supplies active and reactive power without the necessity of a restart. Furthermore, the ESS can quickly absorb power fluctuations due to wind speed variation. Energy stored in the supercapacitor ESS is redirected to the grid-after the fault clearing- in order to improve output power quality.



The topology of the proposed Fault Ride-through control scheme and the power system is shown in the figure above. In a fully rated converter based WT, the generator is connected to the ac network through a full-sized back-to-back converter, which completely decouples the generator and the ac system. The converter system is composed of two voltage source converters, at the machine side (MSC) and the grid side (GSC) and a dc link capacitor. The main control objective of the MSC is to regulate the electromagnetic torque of the generator in order to control the shaft's speed. The control objective of the GSC is to regulate active power from/to the dc-link and the reactive power exchanged between the GSC and the power grid. The ESS is connected to the common DC link capacitor via a bidirectional half-bridge buck/boost DC/DC converter.

Both in a variable-speed squirrel cage induction generator (SCIG) and in a synchronous generator with external excitation, full-scaled converters are required to adjust the rotational speed of the generator. For the squirrel cage induction generator (SCIG) an indirect vector control in the rotor flux oriented frame is implemented. Field-oriented control is also implemented to control the synchronous generator with external excitation. The MSC control block takes as input the 3-phase currents and voltages at the machine side.

The control objective of the GSC is to regulate active and reactive power exchanged between the GSC and the power grid. This is achieved by means of current regulation in a synchronously rotating reference frame. The power reference signals for the active and reactive power controllers are obtained from the Power Management Controller (PMC).

A bidirectional DC/DC converter is used to control the charging and discharging of the ESS according to the level of the dc link voltage and the operating mode (FRT, Power Smoothing). The DC/DC control block takes as inputs the dc-link voltage, the supercapacitor voltage and the supercapacitor current.

A power management controller (PMC) is fed by several signals coming from the Power system and performs the following operations:

A. Detection of symmetrical voltages sags. In this study it is supposed that a fault occurs on the grid if a voltage variation greater than ±10% is detected, according to standard EN 50160.
B. Control the state of switch S1. The state of the switch is determined by constantly measuring the grid voltage magnitude at the point of common connection (PCC) and comparing it with the low-voltage ride through reference curve. In case the grid voltage falls below the LVRT reference curve, switch S1 opens to disconnect the WTG from the grid.
C. Generates the power reference signals for the grid side converter. The reference signals are generated according to the operation mode of the system and the state of charge of the supercapacitor.
D. Control of the ESS charging/discharging.
E. Resynchronization. Disconnecting the WTG/PCS from the grid implies the need to develop a fast and efficient resynchronization procedure. By employing a hysteresis-band current controlled Voltage Source Converter (VSC) at the grid side, the synchronization procedure is simplified. Inserting a delay in the reclosing of the switch smooth reconnection with almost no transient should be achieved

Indicative type of TA infrastructure used to fulfill the objectives:

- 2 types of generators
- 1 DC machine
- 2 full controllable 3-phase inverters
- 1 DC/DC buck/boost converter
- 1 dc link capacitor
- 1 Supercapacitor
- 3-phase sinusoidal grid with controlled amplitude
- 1 controllable switch

Number of test carried out:

1. The performance of the proposed FRT control scheme is tested when riding through different levels grid voltage disturbances. Two cases are examined:
   - The level of symmetrical voltage dip is above the LVRT reference curve and does not cause disconnection of the generator. Limited power is transferred to the grid, depending on the voltage dip level. The rest of energy is stored in the ESS to avoid rising of the dc link voltage.
   - The level of voltage dip causes disconnection of the generator. The total amount of generated power is stored in the ESS.

   In both cases, different fault time periods are tested
2. Testing the ability of the system to achieve smooth resynchronization to the grid, after fault clearance, when a hysteresis-band current controlled VSC is used.
3. Sinusoidal variation of the mechanical torque in order to simulate wind speed fluctuation. The variation should cause a controlled (frequency, magnitude) sinusoidal variation of the

generated power. The ability of the system to smoothen middle frequency (0,01 -1Hz) power fluctuation is tested.

4. Testing two different types of generator in order to prove that the proposed FRT scheme is independent on the type of the used WTG.

Originality and Innovation of proposed research – Broader Impact (1-2 pages)

Disconnecting the Wind Turbine Generator (WTG)/Power Conversion System (PCS) from the grid under certain conditions allows the proposed FRT method to comply with the latest LVRT grid code requirements. Furthermore, it can be used in a power network where traditional protection devices are used, as it disconnects the WTG from the grid, allowing the protection system to clear the fault safely. This will facilitate the integration of wind parks in the total power production.

Moreover, it takes advance of the supercapacitor in order to smoothen the generated output power. A complete algorithm is developed to maximize the Fault Ride Through capability of the system and at the same time provide the grid with quality power.

After the completion of the test measurements, it will be proved that the proposed model can be used with any type of converter driven ac generators

Real time measurements will reveal many practical problems that may arise in the process and will identify possible restrictions from the hardware devices such as metering devices, controllers etc.

Proposed Host TA Infrastructure/Installation – Justification (about one page)

The Host Infrastructure should afford all the required equipment to implement the proposed Fault Ride-Through and power smoothing method. Two types of inverter driven generators (Synchronous and Asynchronous) should be available in order to prove that the proposed control scheme is independent on the type of the generator used. Two back-to-back inverters (with a dc-link capacitor) rated at the generators power are required. The inverters should be fully controllable in order to implement the proposed control scheme. A second capacitor which will be used as energy storage device is needed as well as a DC/DC converter to control the charging and discharging of the capacitor. A controlled power source that will simulate the grid voltage dips should be available. Finally, a controllable switch is needed in order to connect/disconnect the WTG. Finally, it would be desirable the ability to download the control algorithm from PSIM to the inverter microprocessors, as the proposed control scheme is simulated in PSIM software.

The test facility should be also equipped with a high speed data acquisition system with a time step of a few μs. Measuring devices should be available providing the ability to monitor currents, voltages active and reactive power at desired nodes. Finally suitable protection devices should be available in order to ensure that no operational limit is surpassed.

From the available host infrastructure, Fraunhofer Institute for Wind Energy and Energy System Technology seems to be suitable for the proposed study.

Synergy with ongoing research (about ½ page)

No other similar project is ongoing in the Electrical Machines Laboratory.

Dissemination – Exploitation of results (about ½ page)

Once the test measurements are completed, a report with the obtained results will be exported. These results will be included in our final work where the test measurements will be used to support the theoretical analysis. Part of the results of this project will be published in international conferences and scientific journals.

Time schedule (about ½ page)

Tasks	Time
1. Familiarizing with the available equipment. The proposed topology will be built and the all the tests will be designed in detail.	First Week
2. The performance of the proposed FRT control scheme is tested when an induction generator is riding through different grid voltage disturbances. Several test measurements will be carried out for various fault time periods and level of grid voltage dip.	Second Week
3. The same scenarios as in 2 will be tested when a synchronous generator is used.	Second Week
4. In cases 2 and 3 the ability to smoothly re-synchronize to the grid (after disconnection from the grid) will be tested.	Second Week
5. The effectiveness of the proposed power smoothing method will be tested. Various power fluctuation scenarios will be considered. The quality of the generated power will be evaluated for various storage capacities and power fluctuation conditions.	Third Week
6. By the end of the experiments a complete test report will be exported. The experimental results will be compared to the theoretical analysis and the software simulation results.	Third Week

Description of the proposing team (as long as needed)

Spyros I. Gkavanoudis was born in 1983. He received the Dipl. in electrical engineering from the Aristotle University of Thessaloniki, Thessaloniki, Greece, in 2008.
Currently, he is a Ph.D student at the Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki. His research interests are in the fields of power electronics, distributed generation and renewable energy sources.

Charis S. Demoulias was born in 1961. He received the Dipl. and Ph.D. degrees in electrical engineering from the Aristotle University of Thessaloniki, Thessaloniki, Greece, in 1984 and 1991, respectively. Currently, he is an assistant Professor in the Electrical Machines Laboratory, Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki. His research interests are in the fields of power electronics, harmonics, electric motion systems, and renewable energy sources. His main published papers are the following:

[1] C. Demoulias, P. Dokopoulos, D. Tampakis, "Transient forces in three phase gas cables", Archiv fuer Elektrotechnik 68 (1985) Seite, 241-248

[2] P. Dokopoulos, D. Tampakis, C. Demoulias. "Short circuit forces in three phase tubular bus bars with steel enclosures", etz Archiv, Band 7, Heft 11, November 1985, Seite 357-362.

[3] C.S. Demoulias, P.S. Dokopoulos "Transient behavior and self-excitation of wind-driven induction generator after its disconnection from the power grid" IEEE Transactions on Energy Conversion Vol.5, No 2, June 1990, pp 272-278.

[4] C.S. Demoulias, P.S. Dokopoulos “Electrical transients of wind turbines connected to a power grid” IEEE Transactions on Energy Conversion, Vol.11, No 3, September 1996, pp 636-642

[5] Petros S. Dokopoulos, Charalampos S. Dimoulias, Iordanis M. Manousaridis and Athanasios X. Patralexis ‘Improvement of Power Quality in a Grid with Wind Turbines using Inductive Storage’, Wind Engineering, Volume 23, No. 4, 1999.

[6] C. Demoulias, D. Labridis, P. Dokopoulos, K. Gouramanis, “Ampacity of low voltage power cables under non sinusoidal currents”, IEEE Trans. On Power Delivery. January 2007, Vol. 22, No.1, pp. 584–594.

[7] C. Demoulias, K. Gouramanis “Voltage Multiple-Zero-Crossings at Buses Feeding Large Triac-Controlled Loads”, IEEE Trans. On Industrial Electronics, Vol. 54, Issue 5, October 2007, pp. 2853-2863

[8] Charis Demoulias, Dimitris P. Labridis, Petros Dokopoulos, Kostas Gouramanis, “Influence of metallic trays on the ac resistance and ampacity of low-voltage cables under non-sinusoidal currents”, Electric Power Systems Research, May 2008, Vol. 78, No.5, pp.883-896

[9] Kostas Gouramanis, Charis Demoulias, Dimitris P. Labridis, Petros Dokopoulos, “Distribution of Non-Sinusoidal Currents in Parallel Conductors Used in 3-Phase TN-S Systems”, Electric Power Systems Research, May 2009, Vol. 79, No.5, pp. 766–780

[10] Charis Demoulias, Dimitris Goutzamanis, Kostas Gouramanis, “Analysis of the Voltage Harmonic Distortion at Buses Feeding Office Loads”, IET Science Measurement and Technology, July 2009, Volume 3, Issue 4, p. 286-301

[11] Charis Demoulias, “A new simple analytical method for calculating the optimum inverter size in grid-connected PV plants”, Electric Power Systems Research, 80 (2010) 1197–1204

[12] Papaioannou I. T.; Alexiadis M. C.; Demoulias C. S.; Labridis D. P.; Dokopoulos, P. S., “Modeling and Field Measurements of Photovoltaic Units Connected to LV Grid. Study of Penetration Scenarios”, IEEE Transactions on Power Delivery, Volume: 26, Issue: 2,

2011, p. 979 – 987, DOI:10.1109/TPWRD.2010.2095888

[13] Dan I. Teodoreanu, Charis Demoulias, Miklos Palfy, Alison Murray "SPORE – An European Project for Social Objectives in Remote Places in Romania" 16th EC-Photovoltaic Solar Energy Conference, 1-5 May 2000, Glasgow, UK.

[14] Dan I. Teodoreanu, Maria Teodoreanu, Bogdan Atanasiu, Charis Demoulias, Miklós Palfy: "PV Systems for social objectives installed in remote places in Romania. Performances and operational experience", 17th European Photovoltaic Solar Energy Conference, Munich, Germany, November 2001.

[15] C. Demoulias, "Harmonics in Spinning Mills: Causes, effects and solutions", Proc. of UPEC 2003 Conference, Thessaloniki, September 2003.

[16] C. Demoulias, S. Samoladas, K. Gouramanis "Harmonics induced problems in theatrical-lighting installation: real case measurements and proposed solutions", Proc. IEEE PowerTech 2005 Conference, St. Petersburg, June 2005, Paper 301

[17] Σ.9 K. Gouramanis, C. Demoulias, "Cable Overheating in an Industrial Substation Feeder Due to Untransposed Power Cables - Measurement and Simulation" The International Conference on Computer as a Tool, 2005, EUROCON 2005. Volume 2, 2005 Page(s):1438 – 1441

[18] Athanasios S. Dagoumas, Antonios G. Marinopoulos, Filippos S. Kianidis, Charalambos S. Demoulias, and Petros S. Dokopoulos, "Influence of Distributed Generators on the Harmonic Level of a 20kV Distribution Network.", ICEM 2006 Conference, Chania, 2006

[19] Charis Demoulias, Dimitris Goutzamanis, Kostas Gouramanis, "Voltage Harmonic Distortion at Buses Feeding Office Loads.", Proc. IEEE PowerTech07 Conference, Lausanne, June 2007, Paper 347

[20] I.T. Papaioannou, A.S. Bouhouras, A.G. Marinopoulos, M.C.Alexiadis, C.S. Demoulias and D.P. Labridis: "Harmonic Impact of Small Photovoltaic Systems Connected to the LV Distribution Network," EEM 08 (5th International Conference on the European Electricity Market), Lisbon, Portugal, May 28-30, 2008.

[21] Charis Demoulias, Zoe Kampouri, Kostas Gouramanis, «Natural Canceling of Current Harmonics in Office Loads and its Effect upon the Transmission Capacity of Distribution Cables», Proc. International Symposium on Industrial Electronics 2008, Cambridge, UK, June 2008.

[22] I.T. Papaioannou, A.S. Bouhouras, A.G. Marinopoulos, M.C. Alexiadis, C.S. Demoulias, D.P. Labridis "Harmonic Modeling and Simulation of Small Photovoltaic Systems Connected to the LV Distribution Network" MedPower 2008, November 2-5 2008, Thessaloniki, Greece.

[23] I.T. Papaioannou, M. Alexiadis, C. Demoulias, D. Labridis, P. Dokopoulos "Harmonics induced in low-voltage networks by photovoltaics" 3rd International Conference on Integration of Renewable and Distributed Resources, Nice, France, December 10-12, 2008

[24] Ioulia T.Papaioannou, Minas S. Alexiadis, Charis S.Demoulias, Dimitris P.Labridis,

P.Dokopoulos, «Modelling and Measurement of Small Photovoltaic Systems and Penetration Scenarios», IEEE Power Tech 2009 Conference, Bucharest, Romania, 28 June- 02 July 2009

[25] Mesemanolis, A.; Pontikidis, D.; Demoulias, C.; «A new modulation technique for reduced harmonic distortion of current in PV inverters», EUROCON - International Conference on Computer as a Tool (EUROCON), 2011 IEEE, Lisbon, Portugal. DOI: 10.1109/EUROCON.2011.5929199

[26] Vlachopoulos, S.; Demoulias, C.; "Voltage regulation in low-voltage rural feeders with distributed PV systems", EUROCON - International Conference on Computer as a Tool (EUROCON), 2011 IEEE, Lisbon, Portugal. DOI: 10.1109/EUROCON.2011.5929198

[27] Konstantinos O. Oureilidis, Charis S. Demoulias, "Microgrid Wireless Energy Management with Energy Storage System," accepted for presentation at the UPEC 2012 Conference, London, 4-7 September 2012.

[28] Spyros I. Gkavanoudis, Charis S. Demoulias, "A new Fault Ride-Through Control Method for Full-Converter Wind Turbines Employing Supercapacitor Energy Storage System," accepted for presentation at the UPEC 2012 Conference, London, 4-7 September 2012.

[29] Emmanouil A. Bakirtzis, Charis Demoulias, "Control of a micro grid supplied by renewable energy sources and storage batteries," accepted for presentation at the ICEM 2012 Conference, Marseille, France, 2-5 September 2012.

The **Electrical Machines Laboratory** belongs to the Energy Section of the Electric and Computer Engineering department of the Polytechnic School of Aristotle University of Thessaloniki and was founded by Professor Ioannis Xypteras in 1984.

The staff of the Laboratory includes two Assistant Professors, two assistants and five Post-Graduate Students. The **Electrical Machines Laboratory** has two main facilities, one in Building D' 5th floor (110 sq.m.) and one in Building E΄, 2nd floor (100 sq.m.).

The laboratory serves educational and research needs in the fields of electrical machines (design, modelling, analysis of operation), power electronics (design, construction and design, power converters) drive systems and electrical machinery (control of electric motors and generators, inverters, solar power, wind turbine control systems, etc.).

The Electrical Machines Laboratory serves for:

- Laboratory exercises for six semester courses of the undergraduate studies,
- Laboratory diploma theses
- Doctoral theses
- Research papers and research programs
- Providing services to individuals and organizations

The aim of the research department of the laboratory is to produce new knowledge, which can be incorporated in the educational process and promote the science of electrical engineering.