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TEMPLATE FOR PROPOSAL UNDER DERRI

User-Project Proposal:

User-Project Acronym	DEMS
User-Project Title	Diagnostics of Electrical Machines and Systems
Main-scientific field	Energy efficiency, renewable sources.
Specific-Discipline	Electrical machines and systems reliability

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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)

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Date of submission	29 February 2012
Re-submission	YES_____ NO___X____
Proposed Host TA Facility	USTRAT (United Kingdom) – VTT (Finland)
Starting date (proposed)	First week of July

Summary of proposed research (about ½ page)

The Laboratory of Electromechanical Energy Conversion, Department of Electrical and Computer Engineering, University of Patras has great experience in the scientific fields of Electrical Machines and Electric Machines Drives. Issues related to electrical machines electromagnetic and thermal analysis using finite element methods (FEM), condition monitoring of electrical machines and fault diagnosis of electrical machines have been studied.

Using FEM several models of “healthy” and “faulty” induction electrical machines have been created and their behavior has been studied under several operating conditions. Moreover, through experiments the fault diagnosis of electrical machines is done using a variety of diagnostic methods.

Regarding our FEM models, we need to check their accuracy, through further experimental measurements. Mainly, focusing on faults and diagnostic methods that have been studied with analytical calculations and simulations. More specifically, experimental testing concerns the study of various faults in electrical machines operating as motors as well as generators and fed by symmetrical and not, sinusoidal voltage supply or power electronics.

So, the target of the proposed research is to conduct measurements on electrical machines, mainly induction and synchronous, on an equipped laboratory in order to validate the developed

FEM models, to expand our diagnostic techniques and exchange of the knowhow on such issues.

State-of-the-Art (about 1 ½ page)

During the last years, the main research conducted in the Laboratory of Electromechanical Energy Conversion, University of Patras is related to issues which have to deal with electric machines, drives and power electronics. In the frame of diploma and doctoral thesis as well as various research programs electric machine models using finite elements methods (FEM) analysis have been developed, while issues related to condition monitoring and fault diagnosis of electric machines have been extensively studied [1]- [18].

The manufacturers and users of electrical machines initially relied on simple protection such as overcurrent, overvoltage, earth-fault, etc. to ensure safe and reliable operation. However, as the tasks performed by these machine grew increasingly complex, improvements were also sought in the field of fault diagnosis. It has now become very important to diagnose faults at their very inception; as unscheduled machine downtime can upset deadlines and cause heavy financial losses [19]-[20].

The major faults of electrical machines can broadly be classified as the following:

- stator faults resulting in the opening or shorting of one or more of a stator phase winding;
- abnormal connection of the stator windings;
- broken rotor bar or cracked rotor end-rings;
- bent shaft (akin to dynamic eccentricity) which can result in a rub between the rotor and stator, causing serious damage to stator core and windings;
- bearing and gearbox failures;
- shorted rotor field winding;
- static and/or dynamic air-gap irregularities;

An electric machine can be simulated using FEM in two or three dimensions. The model should be accurate and its parameters should be easily identified and modified, to simulate various operating conditions of the machine. Detailed induction and synchronous machine simulations have been carried out in order to examine the behavior of the machine under normal or faulty operations using the OPERA software and FEM analysis. The simulation results that are extracted can be used for the enhancement of the design of the machine and its more reliable operation.

Moreover, using the electric machine equipment of the Laboratory of Electromechanical Energy Conversion, University of Patras, extensive research has been carried out on the condition monitoring and fault diagnosis of electric machines. Several electrical and mechanical faults such as, broken bar/end ring fault, static/dynamic eccentricity and stator faults, are examined using several diagnostic methods. These are motor-current signature analysis (MCSA), torque and power analysis using signal processing techniques such as FFT and Wavelets. The experimental results are compared to these extracted from the FEM analysis in order to improve the diagnostic methods and the design of the machine.

With advances in wind turbine technology and government decisions that are favorable to ‘green’ or renewable power, wind turbines are an increasingly viable economic alternative to conventional fossil-fuelled power generation. Generally speaking, there are currently four major generator types used in the utility level wind turbine generators, namely: Induction Generators (IG), Doubly-fed Induction Generators (DFIG), Field Excited Synchronous Generators (FESG) and Permanent

Magnet Synchronous Generators (PMSG) [21]. However, because of the variable load of wind turbines and the aggressive operating environment, wind turbines are subject to relatively high failure rates and their condition monitoring signals are highly variable and subject to large dynamic range. For induction machines, about 40% failures are related to bearings, 38% to the stator and 10% to the rotor [22]. So developing economic condition monitoring and fault diagnosis techniques for them would be highly desirable. The most common signals used for fault diagnosis of wind generators induction machines are stator current and power signals, torque signal analysis, vibration analysis, acoustic emission analysis, temperature analysis [23].

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Detailed Description of proposed project : Objectives – Expected Outcome – Fundamental Scientific and Technical value and interest

The scope of this project is the experimental verification of electric machine faults, as well as a comparative research of the advantages and disadvantages of different diagnostic methods. Also, the study of the behavior and electromagnetic variables of the electric machines will be taken into consideration for electric machine design improvement. The study concerns induction and synchronous machines. The proposed work can be divided into the following stages:

A) Induction Machine Rotor Faults

In this stage, it is proposed to study broken bar and end-ring faults in induction machines and more specifically double cage induction machines. The bibliography is quite poor concerning double-cage induction machines and their fault detection techniques. The double cage induction machines are most commonly manufactured with different upper and inner bar and cage material. In these machines rotor faults appear mostly in the upper bars making the fault difficult to diagnose especially at low slip operation. Two identical induction machines are required, a healthy and a faulty. A DC generator coupled to the induction machines will be used as mechanical load. *The stator current, electromagnetic torque and external magnetic flux density will be monitored under various conditions. The results will be analyzed with the application of the Wavelet and Fast Fourier Transformation. Also, thermal measurements of the operating machines and drives are required. The aim here is to compare the traditionally used MCSA diagnostic method to others that probably will offer more reliable results.*

Also, in this session it is proposed to study rotor short-circuit faults that may appear in induction machines operating as wind-generators. Since wind-generators are most commonly wound induction machines, rotor faults could be severe and lead to the malfunction of the machine as well as reduction of the grid power quality. For this case, it is proposed to monitor the machine's output power by a power analyzer. Also, for prompt fault detection, measurements of the external magnetic flux density are required.

B) Induction Machine Eccentricity Faults

It is known that the most common fault in electric motors is the eccentricity fault, mostly concerning the machine's bearings. Also, analytical calculations have shown that this type of fault has greater severity in the case of two-pole induction machines. When an eccentricity fault appears in two-pole induction machines, there appears a homopolar axial magnetic flux which penetrates the machine shaft inducing bearing currents. Those induced currents reduce the bearings' life-time since they provoke temperature increase in the bearings and as a consequence aging of the lubricant. For this purpose, measurements of the bearings temperature

at nominal speed for healthy and faulty condition should be taken. The results can be indicative of the fault for diagnosis purposes but also could offer a life expectancy of the bearings.

Furthermore, in many cases where the electric motor operates as wind generator, observations have been made concerning the presence of environmental forced eccentricity (e.g. ice on the turbine's blades). So, it is proposed to perform measurements of the output power and external flux density in operating wind turbine generators.

C) Induction and Synchronous Machine Stator Faults

Stator faults are of great importance since they often lead to serious damage of the electric machine. FEM analysis carried out by the authors, has shown than the stator fault consequences are strongly dependant on the location of the fault. More specifically, short-circuits can happen between conductors of the same stator slot or between conductors inside adjacent slots. For both cases the conductors belong to the same phase. There are cases where there is low severity of the fault and other cases, where the machine will stop its operation in seconds and is seriously damaged. So, the prompt detection of stator faults is of great importance.

For this purpose, an induction as well as synchronous machine are needed. A variable resistance connected to one phase will be used to create asymmetry of the stator rotating magnetic field and simulate the stator fault. In this case, the torque and magnetic flux density will be measured and compared to the results of the motor under healthy operation. The aim here is to validate different harmonics of the torque and the magnetic field as to their utility to identify the fault in time.

D) Fault Diagnosis in Inverter-Fed Induction Motors

The experimental procedures described earlier concern the study of Induction Machines fed by a symmetrical sinusoidal 3-phase voltage supply. A series of the same experiments is proposed to take place, but in this case with inverter-fed induction machines.

E) BLDC Machines as Wind-Generators

Synchronous machines with permanent magnets find use in several applications nowadays such as: electric vehicles and low power wind-generators, due to their improved efficiency, low noise operation and high power to weight ratio. Their design specifications are of great interest and consist a modern research area.

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

Electric machines' fault diagnosis is a modern scientific area, with high impact on industrial applications. The monitoring of various electromagnetic characteristics of the functioning electric machine offers lower maintenance cost. Furthermore, the reliable identification of electric machine's faults, especially at an early stage, prevents more severe machine damage or total machine breakdown. The Laboratory of Electromechanical Energy Conversion has published in previous years, several papers on this purpose and deals with electric motor faults and diagnostics research nowadays. The theoretical backup is based on both analytical calculations and FEM analysis. Several diagnostic methods, which have been proposed in the Laboratory of Electromechanical Energy Conversion, have also been verified experimentally. The aim of the proposed research is the experimental validation of new methods, already studied through simulations and analytical calculations. Secondly, the research team is interested in mutual

know-how exchange in this scientific field with the proposed hosting Laboratories.

Proposed Host TA Infrastructure/Installation – Justification

The type of TA infrastructure has been presented in previous paragraphs. By examining the characteristics of each TA infrastructure, we believe that the TA infrastructure of USTRAT in United Kingdom and VTT in Finland can provide us the necessary equipment for our measurements. The User team has a great experience in condition monitoring and diagnostics of electromechanical systems and in wind energy technologies. On this basis our TA User team has significant interest in this research field.

Synergy with ongoing research

A research project, financially supported by the University of Patras, entitled "Study and redesign of an asynchronous motor with optimized behavior" is elaborated now. Part of this project is the study of faults in the induction motor and their diagnosis. Furthermore, Ass. Prof. Dr. Joya Kappatou is in contact and collaboration with several researchers in the field of Electrical machines and fault diagnosis, e.g. Prof. Claude Marchand, Universite Paris-Sud 11 and Prof. Antonios Kladas, National Technical University of Athens.

Dissemination – Exploitation of results

Our goal is to infer important conclusions from this research project and publish our work in international scientific journals as well as to present it at international conferences.

Time schedule

As mentioned previously, our aim is to make measurements related to the fault diagnosis of electric machinery systems and to exchange the related knowhow on this research field with the team of the hosting infrastructure. We believe that the time required for our measurements is 10 days. The target starting date would be the late June or early July 2012.

-It has to be noticed that the estimated cost per day of each member of the team will be at around 200 Euros, while the cost of air tickets (arrival and departure) will be at around 400 Euros per person.

Description of the proposing team (as long as needed)

Lead User of Team: Dr. Kappatou Joya

Dr. Joya Kappatou was born in Argostoli, Greece. She received the diploma in Electrical Engineering from the University of Patras, Patras – Greece and the PhD from the same University in 1991 in the field of Electrical machines and Power Electronics. She is Assistant Professor in the Electrical and Computer Engineering Department of the University of Patras.

Her research interests include electrical machines, power electronics, modeling and design using FEM, faults diagnosis in electrical machines.

She is in charge of the Electrical Machines Laboratory Courses, while she also teaches three theoretical Courses: Electrical Machines I, Electrical Machines II and Electrical Machine's Dynamics. Dr. Joya Kappatou has directed several diploma theses (more 35 until now), she is directing two (2) PhD theses, while she has been a member of supervising committees of seven (7) PhD theses.

Dr. Kappatou is the author and co-author of ten (10) international and national journal publications, as well as of twenty-eight (28) international and national conference papers. She speaks English and French.

Member of team: Gyftakis Konstantinos

Mr. Konstantinos N. Gyftakis was born in Patras, Greece, in May 1984. He received the diploma in Electrical and Computer Engineering from the University of Patras, Patras, Greece in 2010. He is a PhD candidate in the Department of Electrical and Computer Engineering, University of Patras. His research activities are in FEM design, fault diagnosis and optimization of electrical machines. He is an IEEE member, member of IEEE PES and Magnetics Society, member of the HELIEV (Hellenic Institute of Electric Vehicles) and finally member of the Technical Chamber of Greece. He is the author of two international journal papers, one paper in international scientific book and six international conference papers. He speaks English and French.

Member of team: Pallis Ioannis

Mr. Ioannis K. Pallis was born in Athens, Greece, in August 1985. He received the diploma in Electrical and Computer Engineering from the University of Patras, Patras, Greece in 2010.He is a PhD candidate in the Department of Electrical and Computer Engineering, University of Patras. His research activities are in design of electric machines, thermal analysis and loss calculation of electric machines. He is member of Technical Chamber of Greece since 2010. He speaks English and French.

Member of team: Spyropoulos Dionysios

Mr. Dionysios V. Spyropoulos was born in Patras, Greece, in September 1985. He received his Diploma degree in electrical and computer engineering in 2009 from the University of Patras, where he is currently working towards the Ph.D. degree in electric drive systems at the Electromechanical Energy Conversion Laboratory. His current research interests include electric drive systems, power electronics, electric machines and drives monitoring. Mr. Spyropoulos is a Member of the IEEE and a Member of the Technical Chamber of Greece. He speaks English and German.