RMIT UNIVERSITY

2018 School of Engineering HDR Research Projects

Electrical & Biomedical Engineering

DR220 / MR220

Contents

Stability of Grid-Connected Inverters Based on Frequency Domain Characterisation

Electrical and Biomedical Engineering, City

Project Description

The electricity grid is under-going a radical transformation, from a highly centralized system, characterized by unidirectional power flow, to a highly complex and decentralized system with embedded generation sources and bi-directional power flow. Within this system the embedded generation sources are connected to the grid via power electronic inverters. As the density of embedded generation increases, by virtue of increasing reliance on photovoltaic solar and wind sources, these inverters will take on more significant roles, such as providing frequency control, voltage support and fault response/mitigation functions. Such support functions can only be provided by using sophisticated hierarchical control systems, which include outer-layer real and reactive power regulatory functions, and inner-layer current control loops. The conventional design philosophy for a grid-connected inverter treats the grid as an infinite-bus. This ensures that the control layers within the hierarchy are de-coupled. However, in practice the grid becomes weak as the penetration of embedded generation increases. This presents a significant hazard, as it provides a mechanism for interaction between the layers of an inverter control system.

This project will research the problem of controller synthesis and stability for grid-connected inverters. The project aim is to achieve a fundamental theoretical understanding as to how and why control layers interact, and to then develop methodologies that prevent such stability problems from occurring. The project will involve dynamic system modelling with matching simulations developed within the PSIM software environment. The control strategies developed within the project will be realised in practice using the experimental micro-grid facility available within the power electronics laboratory, and funded from the RMIT Sustainable Urban Precincts Project (SUPP) research initiative.

References:

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Microgrid Control based on Stationary Frame Current Regulated Inverters

Electrical and Biomedical Engineering, City

Project Description

The last decade has seen an explosion of research into the paradigm change of Smart Grids. A central part of this vision is the microgrid, i.e. a local combination of small-scale generators and local loads that are clustered together to operate either grid-connected or “islanded” as a stand-alone power grid. Microgrids have the potential to provide improved supply reliability, and reduced distribution losses due to the proximity of the local generation sources and loads. However, the control of a microgrid is proving to be very challenging, due to the diverse nature of the embedded generation sources and the volatility of the distributed loads. Much of the microgrid research to date addresses this challenge either by limiting the microgrid to an application subset (i.e. inverter based sources only), and/or by enforcing a common “droop” response characteristic on to all generation sources (i.e. replicating the intrinsic response of a rotating machine generator).

This project will research microgrid control considering the use of stationary frame current regulated inverters. The project aim is to achieve a fundamental theoretical understanding as to how rotating machine based sources and inverter fed sources can be integrated together to supply mixed active and passive loads. The project will involve dynamic system modelling, with validation using simulation based models developed within PSIM. The control strategies developed within the project will be realised in practice using the experimental micro-grid facility available within the power electronics laboratory, and funded from the RMIT Sustainable Urban Precincts Project (SUPP) research initiative.

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Cell Bus Voltage Regulation of Large Scale Modular Multilevel Converters (MMCs)

Electrical and Biomedical Engineering, City

Project Description

Power Electronic conversion systems use semi-conductor switches to transform electrical energy from one form to another. They are a well-established technology at low and medium voltage/power ratings in both domestic and industrial contexts, and are widely used in equipment ranging from small switched mode power supplies in electronic equipment, to large scale industrial variable speed drive systems. However, the capabilities of present generation switching devices such as MOSFETs, IGBT's and IGCT's, with voltage ratings of only a few kilo-volt (kV) at best, require the use of multilevel converter topologies with substantial numbers of series cascaded modules to directly connect at the standard 11kV and 22kV voltage levels of electrical distribution networks.

At present, the most attractive structure at these voltage levels is the Modular Multilevel Converter (MMC). This topology can overcome the device rating limitation via active regulation of the DC link voltages for each cascaded cell. The converter is then operated by independently switching the individual cells within a stair-case reference envelope, so as to synthesise a multilevel output voltage. This results in a higher apparent output switching frequency with substantially reduced harmonic content, and also significantly increases the dynamic capability of the converter.

This project will research the voltage control processes for large scale MMC systems. The project aim is to achieve a fundamental theoretical understanding of the primary and non-linear second-order processes that drive the cell voltage fluctuations for large scale MMC systems, and to establish the analytical groundwork for control strategies that can then manage this balancing process under both normal and abnormal operating conditions. The project will involve dynamic system modelling in the frequency domain, validated using simulation models of the MMC. Control methodologies developed within this project will also be realised in practice using an ARC funded experimental MMC system available within the power electronics laboratory at RMIT University.

References:

[1] A. Lesnicar & R. Marquardt, "An innovative modular multilevel converter topology suitable for a wide power range", in Proc. *IEEE Bologna Power Tech.*, vol. 3, Jun. 2003.

[2] M. Hagiwara and H. Akagi, "Control and experiment of pulsewidth-modulated modular multilevel converters", *IEEE Trans. Power Electron.*, vol. 24, no. 7, pp. 1737 – 1746, Jul. 2009.

[3] B. P. McGrath, C. A. Teixeira, D. G. Holmes, "Optimised phase disposition (PD) modulation of a modular multilevel converter using a state machine decoder," in *Proc. IEEE Energy Convers. Congr. Expo. (ECCE)*, Montreal, QC Canada, 2015, pp. 6368 – 6375.

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Sliding Mode Control Theory and Applications

Electrical and Biomedical Engineering, Information Systems Engineering, City

Project Description

Sliding Mode Control (SMC) is a control technology that helps build very simple and effective switching controller for dealing with environmental uncertainties, which are widely used, for example, in industrial control systems and robotics[1].

SMC's key design steps are as follows: 1) choose an appropriate sliding manifold representing the desired control; 2) design a discontinuous control to force the system state to reach the manifold and stay in it thereafter. The consequence of following this design is that the controlled system goes through two modes: the reaching phase before the system state enters the sliding manifold and the sliding mode phase, where the system state is forced to stay in the sliding mode after the reaching phase [2].

The aim of this project is three fold: improvement of dynamical performance of SMC, tailored industrial applications, and extension to large scale industrial control networks. We will

a) Develop new methods for controlling dynamical systems with finite-time convergence based on our terminal SMC technology [3].
b) Study discretization strategies of SMC systems for effective industrial applications [4].
c) Understand complex behaviors of SMC systems in the networked environment and develop new methods for effective control.

There will be no ethical concerns that need to be addressed or obtain approval.

References:

[1]. **X. Yu**, O. Kaynak, "Sliding mode control made smarter – a computational intelligence perspective," IEEE System, Man & Cybernetics Magazine, vol. 3, no. 2, pp. 31-34, 2017.
[2]. **X. Yu** and O. Kaynak, "Sliding mode control with soft computing: A survey," IEEE Transactions on Industrial Electronics, vol. 56, no. 9, pp.3275-3285, September 2009
[3]. Y. Feng, **X. Yu**, and F. Han, "On non-singular terminal sliding mode control of nonlinear systems," Automatica, vol. 49, no. 6, pp. 1715-1722, 2013
[4]. Z. Galias and **X. Yu**, "Dynamical behaviors of discretised second-order terminal sliding mode control systems," IEEE Transactions on Circuits and Systems – Part II, vol. 59, no. 9, pp. 597-601, September 2012

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Complex Networks and their Application in Smart Grids

Information Systems Engineering Group

Project Description

Power grids are one of the most critical infrastructures in our community and have a major role in sustainable development and economic growth. Smart grids are the next generation power systems, revolutionising the regime of existing power grids. Smart grids employ advanced monitoring, measurement, communication and control technologies to provide secure and reliable energy supply. They are highly networked large-scale systems and include many players and stakeholders. Smart grids are indeed the future in energy grids, enabling important functionality of distributed generation resources such as PVs and wind turbines.

A smart grid is a cyber-physical system in that it integrates the physical systems, (i.e., physical power system components including generation units, transfer lines and distribution networks), with cyber systems, (i.e., advanced metering infrastructure, wide area measurement, substation automation, phasor measurement units and data communication networks) [1, 2]. Recently there have been an increasing number of research studies in cyber-physical systems, many of them relevant to smart grids.

A smart grids is a network of network (i.e., multi-layer network), in which different networks including the physical power grid, metering network, demand-side management network and control network, interact. The functionality of the whole system depends on not only proper functioning of these individual networks, but also how reliably they interact. Like any other networked system, these networks are subject to random failures or intentional attacks. A failure in a connection link in one of these networks may quickly propagate, not only across that network, but also other interconnected networks. This may cause a devastating situation where a cascade of failures happens in the system, which can cause large-scale blackouts, resulting in severe socioeconomic consequences.

This project will be based on using concepts of complex networks to model and analyse smart grids. The network science, first established in the physics community, is now a mature field of science with cross disciplinary applications in diverse science and engineering fields. Behaviour of complex networks against random failures or intentional attacks have been investigated in the literature [3, 4]. Recently, attack tolerance of general multilayer networks has also been investigated [5, 6]. However, the existing results cannot be directly used in the case of smart grids, as there is still no framework characterising detailed inter-connections of different networks in smart grids. The project will first develop a framework to model a smart grid as a complex networked system, and then study its statistical and dynamical properties. As the network model is constructed, frequency/voltage control issues, vulnerability and resiliency against cascade failures will be explored.

References:

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[2] X. Yu, C. Cecati, T. Dillon, and M. Simoes, "The new frontier of smart grids: An industrial electronics perspective," *IEEE Industrial Electronics Magazine*, vol. 5, pp. 49-63, 2011.

[3] Y. Xia and D. J. Hill, "Attack vulnerability of complex communication," *IEEE Transactions on Circuits and Systems—II: Express Briefs*, vol. 55, pp. 65-69, 2008.

[4] R. Albert, H. Jeong, and A.-L. Barabasi, "Error and attack tolerance of complex networks," *Nature*, pp. 378-382, 2000.

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Enhancing the Security of the Power Systems through Utilization of Advanced Control and Protection

Electrical and Biomedical, Power and Energy Systems

Project Description

This project aims at addressing the important issue of energy security through implementation of advanced control and protection methods on various power system elements. The main focus of this project is to use Phasor Measurement Units (PMU) for developing advanced control algorithms to deal with the nonlinear nature of power systems and improve the system stability while the increasing penetration of renewable energy resources and their displacement of traditional rotational synchronous sources have increased the performance complexity and uncertainty of the interconnected power system [1, 2].

In order to address the new challenges and avoid future catastrophic failures, it is important to adapt new technologies and control methods to improve the stability and security of the power systems. This proposed project extends the previous studies and findings to provide a more secure and stable power system for the benefit of network operators, stakeholders and consumers. The project proposal is to develop and demonstrate significantly enhanced security with particular focus on the reduced inertia systems under major disturbances. The power system security is dramatically enhanced through angle based controllers where fast controls of customer loads can be joined with SVC and excitation controls for implementation of the proposed control and protection scheme. This project will investigate the best methods to implement the advanced control and protection scheme such as Wide-area Control into various system elements including the consumer loads and generation through PV systems and batteries along with the direct control transient on the wind farms [3-5].

References:
[1] A. Vahidnia, G. Ledwich, and E. W. Palmer, "Transient Stability Improvement Through Wide-Area Controlled SVCs," *IEEE Transactions on Power Systems*, vol. 31, pp. 3082-3089, 2016.
[2] A. Vahidnia, G. Ledwich, E. Palmer, and A. Ghosh, "Wide-area control through aggregation of power systems," *IET Generation, Transmission & Distribution*, vol. 9, pp. 1292-1300, 2015.
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Assessment and Improvement of the Power System Resilience to Natural and Unnatural Hazards

Electrical and Biomedical, Power and Energy Systems

Project Description

This project aims at addressing the increasingly important issue of power system resilience to the low-probability high-impact events. The power system reliability used to be the main assessment approach for the events which threaten the power system such as faults, disconnections and contingencies. However, the climate change has increased the frequency and severity of the natural events such as storms, hurricanes ad extreme weather conditions which can have significant effects on the infrastructures such as power systems. Furthermore, cyber-attacks have become a serious threat for the network dependent infrastructures where the risk and consequences on the power systems can be extremely high and costly. Due to the increasing reliance of the people on the electricity, it is highly important to assess, maintain and increase the resiliency of the power systems for such threats [1, 2].

This project will be investigating the approaches to assess the static and dynamic effects of natural and unnatural events on the power systems resilience and identify the weak points in the systems with increasing penetration of renewable energy resources. Furthermore, this project will address the methods to increase the resiliency of the system through adaptive and advanced control schemes along with optimal planning of the system considering the dynamic nature of the hazards to the system [3, 4].

References:

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DR220 (PhD)/ MR220(Masters)
Electrical and Biomedical Engineering

Image Analysis for Affordable Medical Devices; Retinal Image Analysis

Biomedical Engineering, Biosignal and Image Processing, City

Project Description

Diagnostic devices require significant infrastructure and supervision which makes many such devices unsuitable for remote communities. We are proposing the use of advanced image processing and data classification techniques for self-monitoring, portable, inexpensive diagnostic devices that are not dependent on large infrastructure or presence of experts. It will support the early diagnostics of disease, which can prevent long-term injury of the people.

Retinal micro-vasculatures share similar physiological and anatomic characteristics with other vasculatures inside the human body. Therefore retina has been used as non-invasive screening window for systemic disease assessment including hypertension, stroke and diabetes. This project will specifically use the retina image recordings to develop algorithms for detection of retinopathies associated with systemic disease conditions. The project will include implementation of the algorithm on micro-platforms for possible clinical trials.

The current projects are seeking to support the development of early stage diagnostics for disorders such as diabetes and cardio vascular problems. The team has active partnerships with Austin Hospital, Royal District Nursing Service (RDNS), Centre for Eye Research Australia and Victoria Parkinson's disease Foundation.

References:

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DR220 (PhD)/ MR220(Masters)
Electrical and Biomedical Engineering

Signal Analysis for Affordable Medical Devices

Electrical & Biomedical Engineering, Biosignals Lab, City

Project Description

Diagnostic devices require significant infrastructure and supervision which makes many such devices unsuitable for remote communities. This project will investigate the use of advanced signal processing and data classification techniques for use in portable, inexpensive diagnostic devices that are not dependent on large infrastructure or presence of experts. This will support the early diagnostics and self-monitoring of disease, which can prevent long-term injury of the people.

Current projects are working to aid the development of early stage diagnostics for neuromuscular disorders such as Parkinson's disease (PD). There are over 85,000 PD patients in Victoria and late stage diagnostics of the disease often leads to poor efficacy of pharmaceutical interventions such as Levodopa, the most commonly used medicine for treating these patients. The team has active partnerships with Neurological centers and Parkinson's Victoria which this project will support.

This project will specifically use bioelectrical data recordings in the form of electromyograms, and electrocardiograms. Instead of restricting analysis to the context of a clinical or laboratory setting, the analysis of recordings from wireless portable devices allows for monitoring in real world situations. However, analysis of data recorded outside of the controlled environment is not straightforward [1]. As such this project will need to address the issues surrounding analysis of such real world data [2] in conjunction with the changes which occur due to disease [3].

The aim of the project is to develop signal processing techniques, using analysis methods including temporal, time-frequency and information theory, which can identify features of the data in order to provide clinically relevant parameters. Having extracted features from the data these will then be incorporated into a machine learning framework for analysis and classification. A key feature of the project will be developing the framework so as to balance the need for the use of inexpensive wireless recording devices, providing real time analysis of the data, whilst also giving consistently reliable results. Once developed, this framework will then be ported to a micro-platform suitable for incorporation into wireless portable diagnostic devices.

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Image Analysis for Affordable Medical Devices; Hyperspectral Medical Imaging

Biomedical Engineering Biosignal and Image Processing, City

Project Description

Diagnostic devices require significant infrastructure and supervision which makes many such devices unsuitable for remote communities. We are proposing the use of advanced image processing and data classification techniques for self-monitoring, portable, inexpensive diagnostic devices that are not dependent on large infrastructure or presence of experts. It will support the early diagnostics of disease, which can prevent long-term injury of the people.

This project will specifically use Hyperspectral imaging technology to analyze reflectance spectrum of objects with different chemical characteristics. Hyperspectral imaging in this context means acquiring an image with a device that has, instead of three broad band color channels, a much higher number of narrow band channels which extend beyond the visible light spectrum. With illumination of known spectral qualities, a reflectance spectrum can be reconstructed for each point in the image. The analysis methods will include spatial, time-frequency and information based methods. The project will include the development of the algorithms and the implementation of these on micro-platforms for possible clinical trials.

The current projects are seeking to support the development of early stage diagnostics for applications such as chronic wounds healing, detection of the chemical changes within the tissue. The team has active partnerships with Austin Hospital, Royal District Nursing Service (RDNS) and Centre for Eye Research Australia.

References:

1. Lu, G. and B. Fei (2014). "Medical hyperspectral imaging: a review." Journal of Biomedical Optics **19**(1): 010901-010901.
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DR220 (PhD)/ MR220(Masters)
Electrical and Biomedical Engineering

Decentralised Phase Disposition Modulation of Modular Multilevel Converters

Electrical and Biomedical Engineering, Electrical Power Systems, City

Project Description

The modular multilevel converter is an attractive topology for medium/high voltage applications with large power conversion ratings, because of its scalability to high operating voltages via the series connection of 2N commutation sub-modules (N per arm), its ability to operate from a single direct-current supply without bulk bus storage capacitors, and its capability to synthesise switched waveforms with low harmonic content [1][3].

Recent work has demonstrated that compared to the more traditional phase-shifted carrier modulation, phase disposition modulation of a modular multilevel converter provides superior harmonic performance [2][3]. However, as indicated in [2], the harmonic benefit of phase disposition modulation is only achieved when the strategy is implemented on a per arm basis, and this requirement goes against the distributed and modular nature of this multilevel converter topology.

The primary aim of this PhD project is to investigate practical controller implementation alternatives for achieving phase disposition modulation on a distributed manner while still benefiting of its superior harmonic performance. The project will be conducted at RMIT Power Electronics Laboratory Facility using a three-phase six-level modular multilevel converter prototype.

References:

[1]. H. Akagi, “Classification, terminology, and application of the modular multilevel cascade converter (MMC)”, IEEE Trans. Power Electron., vol. 26, no. 11, pp. 3119 – 3130, Nov. 2011.

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Common-Mode Mitigation Techniques for Three-Phase Soft-Switched Dual Active Bridge Converters

Electrical and Biomedical Engineering, Electrical Power Systems, RMIT City

Project Description

Dual active bridge (DAB) converters are the topology of choice to transfer energy in either direction between two galvanically isolated direct-current sources [1][2]. Compared to its single-phase counterpart, a three-phase DAB converter offers the benefits of reduced AC link RMS and bridge switching devices turn-off peak currents as well as smaller DC bus filter requirements, essentially because of its inherent six- step modulation capability [1].
However the six-step modulation strategy applied to this converter topology offers as side-effect a large common-mode component, which needs to be appropriately mitigated by hardware filtering techniques. The conventional approach to address the issue is to use sufficiently large common-mode filters to prevent undesirable circulating currents from occurring within the topology.

The aim of this PhD project is to apply frequency domain analysis [2] to mathematically model the characteristic common-mode component typically present in this converter arrangement to then develop effective mitigation techniques which minimise the consequential circulating currents without requiring expensive over-dimensioned hardware. The project will be conducted at RMIT Power Electronics Laboratory Facility using a three-phase dual active bridge converter prototype built during the course of the project with the primary purpose of investigating common-mode issues and mitigation techniques.

References:

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Identification of Zero Voltage Switching Boundaries of Threephase Multilevel Dual Active Bridge Converters

Electrical and Biomedical Engineering, Electrical Power Systems, City

Project Description

Threephase dual active bridges (DABs) commonly have their interconnecting impedances built around three or five limb transformer cores, hence the per phase coupling impedances of these transformers are inherently unbalanced and so the zero voltage switching (ZVS) boundaries for the primary and secondary bridges become asymmetrical. Hence the effective ZVS region of a three phase DAB is further constrained to the region of the first phase leg to reach its ZVS boundary, irrespective of the switching conditions of the other two phase legs [1][2].

Besides allowing for switching devices with lower voltage ratings which benefit from smaller conduction and switching losses, multilevel threephase DABs also offer additional degrees of freedom which can be used to counteract the reduction of ZVS capability caused by practical threephase impedance asymmetries [3].

Previous work has applied frequency domain analysis to precisely and comprehensively identify the ZVS boundaries of threephase dual active bridge converters [4]. The aim of this PhD project is to extend the methodology presented in [4] to now identify the ZVS operating regions of threephase threelevel DAB converters. The theoretical concepts developed in this work will be experimentally validated on a threephase threelevel dual active bridge converter prototype built during the course of the project.

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Autonomous Control and Management of Microgrids

Electrical and Biomedical Engineering, City

Project Description

The world-leading economies have set ambitious mandatory targets for renewable deployment to meet their increasing energy demand and greenhouse gas emission targets [1]. The deployment of renewable is usually realized through microgrids which are formed by clustering the alternative and conventional generation technologies, storage systems, and loads. Compared with the standalone deployment of renewable, microgrids offer several benefits including optimal utilization of resources, enhanced power supply reliability and power quality [2]. Achieving of these benefits, however, require a proper control and management system of microgrids which has already been extensively researched [3]. The recent research findings suggest that the distributed and autonomous control schemes are more reliable and cost effective [4-5]. The steady-state and dynamic performance of these schemes has not been fully exploited yet for various types of emerging DERs and microgrids.

This project is to develop new autonomous control and management schemes for AC/DC microgrids to maximize their operational benefits, enhance the power supply reliability and resilience while minimizing the overall cost of the system. The steady-state and dynamic performance of proposed schemes will be evaluated taking into consideration the load requirements and emerging standards. The project involves characterization, mathematical and control model development of various distributed energy resources (DERs), simulation and experimental performance verification of considered microgrid under various operating scenarios.

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Design and Development of Next-Generation Distributed Energy Resources (DERs)

Electrical and Biomedical Engineering, City

Project Description

The future electric grids are anticipated to have a high penetration of distributed energy resources (DERs). DERs are relatively of small capacity and deployed in different forms – standalone, hybridized to form a microgrid or interconnected with utility grid [1]. Extensive research has been carried out to achieve their optimal design, control, and operation for various applications. However, with the increasing penetration of renewable, the control and operational requirements of DERs are still evolving with the emerging grid-codes and standards [2-4]. The application of converters topologies to new types of DERs such as EVs and dc generators and their control features have not been fully exploited yet [5]. This important theme of research has been proposed in this project.

The proposed project is to investigate the application of different converter topologies and control techniques to next-generation distributed energy resources (DERs). The work scope may include the impact analysis of DERs on microgrids and utility grid. The aim is to develop new DERs that are compliant with the emerging standards and grid-codes for the considered application. The project involves mathematical and control modeling of various DERs, simulation and experimental evaluation of their performance for various operating conditions.

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Power System Stability Analysis with 100% Power Electronic Interfaced Renewable Generation

Electrical and Biomedical Engineering, City

Project Description

Power system stability has been recognised as a challenging issue for secure system operation since the 1920s [1]. Many major blackouts have caused due to power system instability, and hence it is an important concern for secure operation of the power system. Over the last 20 years, the dynamic characteristics of the power system have significantly changed due to the wide-scale integration of renewables, and hence system stability has been recognised as one of the main concerns for future power systems. Recent blackout incidents in South Australia have also created widespread debate on the security of the power system with high penetration of renewables [2].

Power system stability is conventionally classified into three types: 1) transient stability, 2) voltage stability, 3) frequency stability. Integration of variable renewable power generation into power systems has a distinct impact on each of the stability issue listed above. However only limited number of studies have been conducted on 100% renewable based power grid, and hence further research studies are required to fully characterise the power grid stability with renewables. In particular, voltage and frequency stability are of paramount importance as the power electronics based distributed renewable generators have a distinct response to network voltage and frequency, in comparison to conventional synchronous generators [3]. The research studies conducted till now have major drawbacks in terms of renewable generator modelling for stability studies, and their dynamic response to various system disturbances has not been correctly represented in stability studies. As the power networks are moving towards 100% renewable generation, it is of paramount importance to investigate power system stability with renewable power generation considering the drawbacks of previous stability investigations.

The aim of this research project is to accurately characterise the dynamic stability of the power grid with 100% renewable generation. Primarily the wind and solar power generation are considered as the variable renewable generation in this research, and their aggregated response is considered for stability analysis. Therefore, detailed models of the aggregated renewable power generators are modelled using power system simulation tools, such as DIgSILENT Power Factory. Then, test network models and reduced order models of actual network models are used in this research to characterise the system voltage and frequency stability with 100% renewable generation under major system contingencies.

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DR220 (PhD)/ MR220(Masters)
Electrical and Biomedical Engineering

Designing Next Generation Recommender Systems

Complex Networks Group

Project Description

Recommendation algorithms are important parts of many systems such as e-commerce stores, entertainment platforms, online social networks and educational systems. A group of items is recommended for any target user such that the user like the items (provide positive rating), if use it. The aim of a recommender algorithm is to find proper recommendation list with the hope of maximum user satisfaction, which may also lead to maximize the revenue (e.g., through more sales to customers in e-commerce applications).

Recommender systems are divided into three groups: content-based, collaborative filtering and hybrid [1- 3]. In content-based recommender systems, items are recommended by matching their contextual information to the users' demographic information. Collaborative filtering algorithms use available information of users-items interaction history (e.g., rating history of users on items), and build the recommendation lists. It is based on finding similar taste for the target user, and completing the recommendations by searching the most similar users and/or items. Finally, hybrid recommenders use both contextual information and users-items interaction history to design more efficient recommendation algorithms.

Traditionally, collaborative filtering recommender algorithms have been designed in order to provide accurate recommendations. However, the users would like to receive recommendations that not only based on their previous tastes, but also include novel items and those from diverse fields. Therefore, recently the research community of recommender systems has made some efforts in designing such recommenders [4, 5]. However, there is yet no unique evaluation metric that can assess the performance of a recommender algorithm in terms of various criteria such as accuracy, novelty and diversity.

This research is focused on designing time-aware recommendation algorithms that can provide highly accurate and novel recommendations. To this end, first a proper evaluation metric will be developed to property evaluate performance of recommender algorithms against these criteria. Then, efficient collaborative filtering algorithms will be design that will use not only users-items interaction data, but some available contextual information such as the rating time. As users taste might change over time or items popularity might be different across time periods. The developed algorithms will be tested on available datasets.

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Link Prediction in Multilayer Networks

Complex Networks Group

Project Description

Complex networked structures are abundant in many real-world systems, ranging from biology to engineering, ecology and social sciences [1, 2]. Many observed natural phenomena can be modelled as networks where a number of individual units interact through connecting links [3]. The last two decades have seen the birth of a movement in science under the name of Network Science, which is now a mature interdisciplinary field of science. Network science, first started in the physics community, is now one of the most active research fields in many disciplines including engineering and computer science. With the current availability of big data from many natural and engineered systems, network-centric analysis is receiving increasing attention within the communities of Applied Mathematics, Statistical Physics and Computer Science.

Traditionally, a networked system was modelled as a single-layer network, in which all nodes and edges are considered to be of the same type. However, such a modelling approach can lead to incorrect description of some phenomena in many systems. Some real systems have multi-layer structures, denoted as Complex Multilayer Networks (CMN) [4, 5]. An example of CMN is social networks where the actual relationships between the members take place inside different groups (layers), or in some cases different platform such as Facebook and Twitter. CMN may exhibit completely different properties from single-layer networks. CMN are often divided into two broad categories: multiplex and heterogeneous networks. Multiplex networks are a class of CMN for which the same type of nodes are connected through different types of links (i.e., nodes have connections in different layers). The above example on social networks is a multiplex. In Heterogeneous networks both nodes and edges can be of different types. For example, in a bibliographic network, nodes in each layer can be authors, venues (journals/conferences) and topics. The nodes can have both intra-layer links (e.g., authors write a paper together, indicating links between them) and inter-layer links (e.g., an author publishes a paper in a journal).

The theory of CMN has advanced recently, and the community is now paying more attention to predictive analysis in CMN. One of the topics that has not been systematically addressed in CMN is predicting missing or spurious links. The link prediction problem, in general, tries to understand the association between two nodes and answer interesting questions such as: How does the pattern of association change over time? What are the general factors driving the associations? To what extent one can model the evolution of a network using features intrinsic to the network itself? This project will design efficient algorithms for link prediction in multilayer networks. The algorithms will be evaluated on available datasets of multilayer networks.

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Dynamic Modelling of Microgrid

Electrical and Biomedical Engineering, Power System & Control Research, City

Project Description

The need of reliable and secure smart electrical power system incorporating renewable energy sources is drawing much attention to the microgrid. Using a combination of inertial and non-inertial electrical power sources, microgrids serve consumers in the vicinity [1]. An attractive feature of the micro-grid is its flexibility. It can enhance the reliability of service to consumers by continuing to operate even when the utility grid is not available due to a grid fault or natural disaster. While these features of microgrids are attractive; they also create modelling and control challenges that are currently unsolved. When the main utility grid shuts down, the microgrid needs to ramp up generation to meet the local electricity demands and when the utility grid comes back on, the microgrid needs to resynchronise with it for smooth operation. These transitions should be made automatically, immediately, and seamlessly [2]. One major problem during such transitions is the voltage fluctuation and frequency deviations [3], especially in the presence of motor loads. These transient events are not well characterised by the current practice of state-space based modelling [4] of microgrids, making it a major theoretical and modelling limitation which constrained the potentials of microgrids.

This project will research these transients and switching events of microgrids. The aim for the project is to achieve a fundamental theoretical understanding of the non-linear processes that cause the transients and drive the voltage fluctuations and frequency deviations in microgrids and to establish the analytical and modelling frameworks for control strategies that can then manage these transients and switching events under both normal and abnormal utility grid operating conditions.

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Control of a Linear Electromagnetic Synchronous Generator Under Stochastic Ocean Wave Conditions

Power and Energy Group, City

Project Description

Recently, environmental concerns are causing electrical grids to shift away from fossil fuel energy sources to renewables such as wind, solar, tidal, and wave, among others. A caveat to this shift however is that the renewable energy sources have stochastic properties which need to be considered in the process of integration, this is to ensure the grid maintains a prescribed level of stability for the consumer. Asset diversification is one potential way to help ensure energy profiles are not at the whim of a singular resource. Oceanic sources are still at an immature technological state with poor proliferation. This leaves an immense amount of energy potential untapped, globally there are places with power densities of more than 70kW/m of wave crest [1]. Furthermore it is interesting to note that the energy density of waves are in general far greater to that of solar and wind, which is due to the time integration of solar energy creating wind, and then subsequently wave[2], [3].

One of that major factors that has stymied the development of wave energy harvesters is the inherent difficulty in efficiently converting the irregular, or stochastic, reciprocating source. Also, fundamental to the operation of an electromagnetic generator, the power generated is proportional to the square of the velocity, and only directly to the field intensity.

A recent push towards using linear electromagnetic generators to reduce the potential mechanical failure points has produced a number of linear tube machines which exhibit very high magnetic field intensities in order to compensate for the lack of speed [4]. Due to the relatively recent push, these tube machines have a poor degree of contextual control theory for wave energy systems, where rotational machines have been favoured. Exacerbating the issue of a lack of control theory is that the mechanical absorbing mechanisms (e.g. buoys/point absorbers) are taking upon new designs with non-linearity, and multiple degrees of freedom in order to help maximize the conversion efficiency for the extended potential bandwidth of waves[5], [6].

This project will research the undeveloped area of control and modelling for a tubular linear electromagnetic generator with wave energy inputs via various mechanical absorbing devices (linear, non-linear, single and multiple degrees of freedom). The aim is to understand the fundamental issue presented by slow input speeds, and how to accurately predict the stochastic input source to maximize the efficacy of the system. Specific analytical models will be established to identify how conversion efficiency can be maximized via potential control strategies, while also being able to produce dimensionless prediction of the output efficiency.

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Forecasting and State Estimation based Predictive Control of Smart Grid

Electrical and Biomedical Engineering, Power System Research, City

Project Description

Modern power grids are integrated with large amount of intermittent and distributed generation sources, loads and various energy storage systems. Therefore, to realise a smart and resilient gird, more precise and enhanced observability and controllability of the grid is required [1]. A good forecasting of future generation and loads as well as a good estimation of the real time state of the grid [2] is possible by applying novel forecasting and estimation techniques. This PhD project will focus to develop such novel forecasting and estimation technique, which requires minimum field measurements and weather data. It is expected that this novel technique will improve the flexibility, protection [3], and load and generation congestion management in the distribution and transmission power grid. It is also believed that this project will help to develop intelligent algorithms for effective power system asset management in the context of voltage control, power quality and stability in the smart grid with the large penetration of distributed generation.

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Intelligent Energy Management in the Distribution Grid

Electrical and Biomedical Engineering, Smart Grid Research, City

Project Description

Residential loads play a major role in the distribution power domain. Therefore, energy efficiency in the distribution power domain is essential. One of the key components of this energy efficiency is the intelligent energy management system, which will include extensive use of sensors, optimum and automated control of different type of loads, integration of renewable energy, e.g., PV systems, batteries and the ability to respond to real time pricing to realise the modern smart grid. However, large integration of distributed resources like roof-top PV systems, Plug-in Hybrid Electric Vehicles (PHEV), and batteries can create significant technical challenges, most notably grid voltage fluctuations, local reactive power management and optimisation for two way power flows, and integration with the real time energy pricing [1].

Therefore, the aim of this project is to develop a novel and intelligent energy management system, which will be deployed via the Internet of Things (IoT) network architecture [2]. The IoT will ensure that every component in the distribution power domain could exchange the information with the central power system. New smart buildings and smart homes will be incorporated in the distribution power domain where renewable energy generation, electric vehicle charging/discharging, and distributed energy storages will communicate and interact effectively with the central electricity grid to minimise the technical challenges.

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Optimisation of Renewable Energy Systems in Hybrid Microgrid

Electrical and Biomedical Engineering, Power System research, City

Project Description

When it comes to the planning of renewable based hybrid energy systems and microgrid, multi-objective and multi criteria optimisation and decision-making becomes an integral part. To find the optimal capacity of the system, performance and cost are optimised following a multi-objective optimisation process [1]. One of the major challenges in this process is the uncertainties related to the electric load demand and renewable power generation based on weather variations. Usually two types of optimisation processes are used: deterministic [2] and non-deterministic [3]. Deterministic optimisations are not good at including the related uncertainties in the process; on the other hand, non-deterministic ones rely heavily on time-consuming stochastic methods.

The goal of this project is to devise a robust optimisation method, which can include the related uncertainties and will not be time consuming. This optimisation process will be applied to microgrids and hybrid energy systems, which could be completely stand-alone, or grid connected. On an advance level of development, the optimisation will also take unforeseen circumstances such as grid faults, short circuits, unexpected islanding, impractical power generation or load demand in to account.

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Electromechanical Devices with Technologically Advanced Materials

Electrical and Biomedical Engineering

Project Description

Advancements in technologically enhanced materials offer a range of superior characteristics compared with conventional materials in terms of electromagnetics and thermal behavior. As an example, the development of Nano-crystalline magnetic core material are found to offer very low core losses, higher power densities at higher frequencies [1] of more than three folds per volumetric dimension. The use of such novel material for the design of electromechanical devices has not been widely investigated. While such material offers superior characteristics in the specific criteria, there may be unusable due to inferior characteristics in another domain. For example, Nano-crystalline magnetic core materials are found to be brittle and are difficult to fabricate a complete electrical machine using such material.

The proposed research project aims to study theoretical and practical development opportunities that lie within electrical machines design with the use of such advanced materials in a hybrid arrangement. By supplementing the structure of an electromagnetic core or winding with new forms of material, it will be possible to improve the overall performance and torque density without trade-off of ruggedness [2,3]. As part of this research, relevant applications that will benefit with such technology will be considered (e.g. high speed turbo generators) and performance requirements will be investigated. Different configurations of electrical machines will be investigated and scenarios via alteration in the material placement will be considered. Theoretical and practical implication on overall performance of hybrid material arrangement choices will be investigated.

It is expected that a scaled down experimental machine be fabricated based on this research project with the use of the manufacturing facilities of the RMIT Advanced Manufacturing Precinct. The advantages with the use of the new materials arrangements to optimize the design in terms of overall size and weight will be investigated and experimentally validated using the prototype machine. The developed electrical machine prototype will be subjected to rigorous dynamic load tests and aging tests to determine any degradation of the hybrid material arrangement. The project will further the fundamental understanding of new types of technologically advanced materials for electrical machine design.

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High Efficient Permanent Magnet Motors with Wide Torque/Speed Range

Electrical and Biomedical Engineering

Project Description

Permanent magnet machines designed for high starting torque as well as wide speed range operation naturally encounter contradictory design criteria. That is, low speed operation with high starting torque will require high permanent magnet flux linkage. However, the same motor in high speed region will produce high back-EMFs that will require field weakening operation. The need for field weakening operation requires application of a demagnetization field. This will create more copper losses. Traditionally the best design efficiency is achieved by balancing the PM flux linkage and field weakening requirements. As a result, design of a machine to achieve high efficiency over a wide speed range is found to be a challenge.
This research project will investigate new techniques to achieve high efficient wide speed range operation based on the use of low coercivity magnet (LCM) material in combination with traditional high coercivity magnet (HCM) material. LCM material is either magnetized positive or negative, or brought to a demagnetized state by application of a momentary high strength field. Under low speed operation, these magnets are magnetized in the positive direction where a high torque per ampere is produced. However as speed is increased, the LCMs are deliberately demagnetized and then eventually magnetized in the negative direction to weaken the effective field seen by the stator winding. This thereby will reduce or completely eliminate the need of a continuous demagnetization field for field weakening during the high speed range. This operational strategy will add an additional dimension of flexibility on the machine design process and it is anticipated that higher efficiencies than the state-of-the-art PM machines can be achieved over a wide speed range with this form of dynamically magnetized permanent magnet machines.

Previous studies with AlNiCo magnets are designed into the stator of a motor [1] and referred to as a memory motor. In [2], the authors develop a flux switching PM motor with the use of both NdFeB PMs and AlNiCo magnets. The authors claim the proposed motor achieves high power density, potentially with reduced RE material. The AlNiCo magnets are used for online magnetization and demagnetization and to achieve flux control. However, the machine in [2] is not experimentally validated and is a simulation based conceptualization. In [3] the authors design PM motors using combinations of NdFeB magnets and either ferrite or AlNiCo magnets. In contrast, the proposed research project will incorporate the magnetic material in the motor such that the magnetization can be dynamically controlled, thereby achieving enhanced performance.

It is expected that an experimental machine be fabricated based on this research project with the use of the manufacturing facilities of the RMIT Advanced Manufacturing Precinct. The machine will be used to validate the proposed concept of dynamic control of magnetization of magnetic material and torque/speed range extension.

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Online Monitoring and Fault Diagnosis for Electrical Machines for Renewable Energy Applications

Electrical and Biomedical Engineering

Project Description

This research proposal focuses on condition monitoring and fault diagnosis of electrical machines by the integration of field effect sensors within the machine. Electric machines applied in renewable energy applications operate in harsh environments and may undergo degradation leading to faults [1,2]. It is essential to continuously monitor these machines and determine maintenance requirements to avoid loss of power generation. Fault analysis and condition monitoring of electrical machines has been the subject of interest and can be divided into two main classes, namely electrical and mechanical faults. Electrical faults mainly include stator and rotor winding faults whereas mechanical faults include bearing faults, delamination, failure of magnet retention, rotor bar retention failure and eccentricity.

State-of-the art techniques include sensing of leakage currents, magnetic flux, temperature, vibrations and partial discharge [3]. The motor current signature analysis employing small signal processing is used for fault analysis in harsh industrial environment where signal to noise ratio is quite high [4]. The use of Soft material based magnetic field sensors have been developed over the past decade and offer the opportunity to be applied in condition monitoring of electrical machines.

It is expected that an experimental machine be fabricated based on this research project with the use of the manufacturing facilities of the RMIT Advanced Manufacturing Precinct. The prototype machine will be fabricated with integrated soft magnetic field sensors. The most appropriate placement of the sensing elements will be investigated with simulation and experimental studies. Signal processing algorithms and fault signatures will be investigated with the prototype machine for the above mentioned fault conditions. A framework for electrical machine field sensor placement and fault diagnosis will be developed and validated using the prototype machine. The developed electrical machine prototype will be subjected to rigorous testing and will lead to furthering of the fundamental understanding of the use of advanced sensors for condition monitoring and fault diagnosis in electrical machines.

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Real Time Medicine

Electrical & Biomedical Engineering, City

Project Description

This PhD project represents a joining of two areas of strength, the Internet of Things (IoT) area in Computer & Network engineering, and the Biomedical Engineering research area under Professor Dinesh Kumar. Patient Reported Outcome (PRO) systems have become wide spread in the management of cancer [1]. These systems allow patients to report symptoms in real time, or for data to be collected in real time. The data is typically processed by back end systems and alerts sent to medical staff as required.

The penetration into other areas of medicine other than cancer treatment is not so wide spread. For example the well published research into diabetic foot problems from Professor Kumar [2] [3] could be enhanced by developing a PRO based system.

The economic, large scale implementation of PRO systems requires clever data capture at the patient end and clever processing by backend servers. This project aims to identify the most promising treatment areas for Australia and then work with specialists in that area to develop information capture methods and backend processing. Telcos such as Telstra will also have a strong interest in providing the backend services. The ideal outcome is a system that not only results in better medical outcomes but also helps reduce costs for Australia's health system.

Applicants should have a strong background in networking, software and embedded systems development. Challenges will include data collection hardware and methodologies, machine learning, knowledge management, human factors analysis, secure networking, and data management. A strong interest and experience in medical matters would be a distinct advantage.

This project will require ethics approval and candidates will be required to understand and work through this process at an early stage as the system design will be heavily influenced by these issues. Other constraints to be addressed include government regulations, privacy regulations, and current medical protocols.

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IoT Self Identification

Electrical & Biomedical Engineering, City

Project Description

The Internet of Things (IoT) name covers a vast area of research [1]. IoT is a new and dynamic area with a great deal of ongoing research. IoT based solutions can provide new services and streamline existing services [2].

The topic of this project is how IoT devices can securely join a network and show any authorized device such as a mobile phone how to display the status and capabilities of the IoT device, and control that device. The challenge is to achieve this when the authorized device has no prior knowledge of the IoT device. If these capabilities can be developed then IoT devices will find it much easier to penetrate the consumer market, and become easier to use and manage in the enterprise and industrial market. Our group has already developed secure joining protocols and device discovery protocols [3][4][5]. This work needs to be extended to develop status, display, and control methodologies. There are challenges in terms of knowledge representation, network protocol design, network robustness analysis, and user interface design. Success in developing such a system should lead to an open standard on IoT interfacing that will have significant market effects in the area of smart homes and smart buildings.

Applicants should have a strong background in networking and software development. A strong knowledge of embedded systems would be a distinct advantage.

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Analysis of the Dynamics of Neurological Signals

Electrical & Biomedical Engineering, Biosignals Lab, City

Project Description

Many neurological recordings produce large quantities of data which consist of mixtures of different sources with significant spatial and temporal correlation. In order to produce clinically relevant parameters it is crucial to have a greater understanding of the underlying signal generation mechanisms and their dynamics. This project will develop signal processing and information theoretic approaches to the analysis of neurological signals in order to quantify and track information processing in the brain.

The aim of this project will be to investigate the dynamics of interactions within the brain from large scale recordings. Specifically, this project will use bioelectrical data recordings: electroencephalograms and electroretinograms. Such non-invasive recording techniques are often contaminated by noise and also exhibit a wide range of both inter- and intra-subject variability meaning analysis is not a straightforward task. The analysis methods in this project will include the temporal, time-frequency and information theory based methods with the goal of extracting reliable clinically relevant information.

In particular, the project will investigate two primary aspects of neural information processing with a focus on developing methods which address the dynamic non-stationary nature of such data. The first relates to how information is transferred across the brain and causal interactions within the brain [1]. The second relates to how, having established a causal interaction, do connections within the brain adapt with time [2]. This research will be performed with a focus on understanding how these processes are impacted with the progression of disease.

Current ongoing projects are seeking to support the development of early stage diagnostics for neuromuscular disorders such as Parkinson’s disease. The team has active partnerships with Neurological centers, Eye clinics and Victoria Parkinson’s disease Foundation. The research in the project will contribute to these ongoing and future partnerships through the analysis of data provided from the clinics and by providing a theoretic foundation from which new medical device technologies can be developed.

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Fault-Ride-Through Response of Microgrids with Inverter Based Distributed Generation Sources

Electrical and Biomedical Engineering, City

Project Description

As the world moves further into the 21st century, it is becoming increasingly clear that the conventional electrical grid that is presently used to supply electrical energy cannot accommodate the proliferation of distributed generation sources based on renewable solar and wind energy that are being installed in response to the emerging global warming crisis. A major emerging paradigm change in response to this challenge is the microgrid concept, where localized distribution generation sources in concert with "smart" demand side appliances and localised energy storage deliver electrical energy to consumers using dynamic bi-directional power flow within a distribution feeder, with greatly reduced dependency on the overarching transmission network. However, while the inverter technologies of these distributed generation and smart load systems are now reasonably well established, as yet there has been only limited consideration as to how they should be operated in concert – do they require overarching centralised control, can they operate only with un-coordinated localised response algorithms, what standards are required to manage these issues?

One particular area of concern is the response of a microgrid system to faults on the local electrical network. Such faults are an inevitable part of electrical grid operation, and the way an electrical supply system responds to these faults significantly influences its reliability and operational effectiveness. The fault response of a conventional electrical network has been refined by over 100 years of operational experience, and is extremely well quantified and defined. However, microgrids, with their plethora of power electronic converter based generation and load technologies, behave quite differently under fault conditions, often with quite unexpected outcomes that can significantly degrade their reliability and effectiveness.

The aim of this project is to research how best to arrange the response of converter based distributed generation sources to electrical faults on a microgrid network system, to maximize the reliability of electrical supply delivered by the microgrid. The project will require the fundamental responses of electrical convertor systems to fault events to be quantified, and then advanced to increase the fault ride-through capacity of these converters so as to maximize the microgrid reliability. The work will involve fundamental control concepts, extensive simulation investigations, and experimental validation using the advanced 50 kW microgrid system available within the power electronics research laboratory.

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Integrating Energy Storage Systems into a Renewable Energy Based MicroGrid Network

Electrical and Biomedical Engineering, City

Project Description

With increasing world awareness of the impact of greenhouse gas emissions on global warming, the production of electrical energy is currently undergoing a major paradigm change from large scale fossil fuel based generators, to localized small scale renewable generation sources using PV solar, wind and (potentially) wave energy technologies that are clustered within microgrids. On average, it is becoming accepted that these alternative energy sources have the potential to essentially replace conventional fossil generation within a few decades. However, one critical challenge with this changeover process is the intermittent nature of electricity that is generated from renewable energy sources. This makes it very difficult to balance generation against load on an instant by instant basis without the continuous smooth flow of energy that can be delivered by fossil fuel generation.

To address this issue, a variety of electrical energy storage technologies are presently emerging, such as lithium-ion battery banks, hydrogen and compressed air storage systems and innovative pump storage hydro systems. All of these systems have one theme in common – they store electrical energy in a series of small scale systems that can be readily placed within a local microgrid network to best meet local demand needs. However, since these systems invariably use a power electronic converter to interface to the electrical network, they have quite different response characteristics compared to conventional fossil generators, and so require new innovative control and operation concepts if they are to be effectively integrated into a power system. Fault response is also a critical issue, with energy storage systems likely to become a major factor in maintaining reliability during transient events for the microgrid of the future.

The aim of this project is to research how best to manage the integration of such distributed energy storage systems into a localized electrical microgrid network. The work will explore the fundamental principles and operating characteristics of energy storage technologies (and their associated power electronic interface converters) and extend these concepts to develop strategies that can combine the operation of these systems with the established operating principles of a conventional power system network. It will involve fundamental power system network theory, extensive simulation investigations, and experimental validation using the advanced 50 kW microgrid system and its associated hydrogen storage system, available within the power electronics research laboratory.

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Creating Virtual Inertia for a Power System Network using Inverter Based Renewable Generation Systems

Electrical and Biomedical Engineering, City

Project Description

Following the recent South Australian blackout in 2016, the contribution of renewable generation to this network collapse has been hotly debated in recent months in the media, with arguments for and against their role discussed on a regular basis. From a technical perspective, the contribution of inertia to the stability of a conventional power system network is well understood – rotating machine inertia slows down the rate of frequency change caused by load fluctuations and fault events, giving the generator governor systems time to react and compensate. The argument then goes that since renewable generation systems do not have rotating mass, they do not contribute to system inertia and so compromise the electrical grid stability as their penetration levels increase.

However, the process by which a rotating machine helps stabilize an electrical grid during a transient event is actually the energy transferred from its rotating mass as its speed changes in response to the frequency variation. "Inertia" is just the measure of the amount of energy that is available to transfer. So it follows that if another source of energy can be used to inject energy into the network during the transient, it will have the same effect as a rotating machine. This concept is called "virtual inertia", and is becoming an important research topic as renewable generation penetration levels continue to rise. Generally, since most renewable generation systems interface to the power network through power electronic converters, this is the technology that is used to create virtual inertia. And in fact they are much better at this task than conventional generation since they can respond to transient events much more rapidly. Indeed proper usage of a power converter based generation source creates the opportunity to develop completely new ways of managing transient events for a power grid which could well improve its stability, reliability and robustness compared to today's grid systems.

The aim of this project is to address some fundamental challenges that need to be overcome before virtual inertia can become a viable alternative to conventional rotating mass based inertia. Primarily these challenges are control issues – how to regulate the converter to inject the required amount of energy during the transient to improve ride-through stability (and not degrade it), how to extract transient energy from the renewable energy source, and how to co-ordinate the response of large numbers of distributed generation systems located throughout the network. The work will involve advanced control concepts, extensive simulation investigations, and experimental validation using the advanced 50 kW microgrid system available within the power electronics research laboratory.

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Speech Recognition Using Image Processing Methods

Electrical and Biomedical Engineering, Signal Processing and Artificial Intelligence Research Group, City

Project Description

To support the DSTG Grant RE-02761 and the AOARD/ONR-Global Grant RE-02756. This is a project for students interested in speech and image processing using deep learning networks. Strong programming skills and knowledge of signal processing is essential.

State-of-the-art methods of linguistic (words) and para-linguistic (emotions, intentions) speech classification apply deep neural networks (DNNs) [2][3][4] trained on arrays of acoustic parameters estimated from speech recordings. To achieve high accuracy, complex DNN structures must be trained on a very large number of representative features. This methodology is computationally complex and unless extensively trained, performs relatively poorly for simultaneous recognition of multiple acoustic classes. On the other hand, many types of image classification tasks, including emotion recognition from facial images [5], have been shown to perform very well, even for very large numbers of classes, in many cases achieving accuracy above 90% [1].

Aim: The aim of this project is to research how both linguistic (words) and non-linguistic (emotions and intentions) speech classification tasks can be solved using image classification methods.

Method: The project will re-formulate the speech recognition task as an image recognition task, and solve it using efficient DNN image classification methods. Different data visualization techniques such as heat maps [1] or parameter images [2] will be investigated. The advantages of using images in audio processing are consistent with physiological evidence indicating that the human peripheral auditory system transforms mechanical time waveforms of sound into time-evolving, image-like, 2-dimentional arrays of neural impulses (neurograms) representing time-frequency analysis of audio signals [5]. The process of transduction of acoustic signals into neural activity spikes takes place in the cochlea (inner ear). Mechanical displacement of inner hair cells (IHC) located along the Basilar membrane (BM) leads to changes in the IHC potentials, which triggers the generation of neural spikes in Auditory Nerve (AN) fibers connected to the IHCs. The AN fibers preserve the tonotopic frequency structure. This means that the sound information is transmitted by the AN to the Auditory Cortex in the form of a time-evolving, 2-dimensional, time-frequency array.

Novelty: In contrast to existing speech classification techniques, the proposed approach will have much lower training and data requirements. Fast calculation of image features will enable real-time (online) implementation of speech recognition tasks.

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DR220 (PhD)/ MR220(Masters)
Electrical and Biomedical Engineering

Modelling and Understanding of Emotional Interactions in Conversations

Electrical and Biomedical Engineering, Signal Processing and Artificial Intelligence Research Group, City Campus

Project Description

To support the DSTG Grant RE-02761 and the AOARD/ONR-Global Grant RE-02756. This is a project for students interested in social interaction analysis, audio-visual (speech and image) signal processing, statistical modelling, time series prediction and deep learning techniques. Strong programming skills and knowledge of signal processing is essential.

The project will provide an analytical tool for scientists to determine:

- What kinds of emotional state transitions are taking place during conversation?
- What is the degree to which speakers influence each other emotionally?
- How do the emotional influences and transitions change during the conversation?

This knowledge will aid the design of diagnostic methods and efficient therapies for mental health problems, and create education programs and strategies for the reduction and prevention of aggressive behaviour in family and work environments.

Aim: This project will research and develop a new computational technique for speech-based modelling and analysis of emotional interactions between speakers in conversations. Specifically, we aim to develop:
1) A speech processing methodology for an integrated conversation modelling and analysis system that can automatically recognize and label speech emotions and perform a quantitative analysis of emotional interactions between speakers;
2) A method of representing the quantitative outcomes of conversation modelling in a descriptive and meaningful (qualitative) form that can be easily interpreted from the perspective of social analysis and behavioral psychology.

Method: Our previous Dynamic Influence Model DIM [1] was based on the 1st order Markov process, and thus it assumed that the current states of the speakers (at time t) are only dependent on the previous states (at time t-1). The combined effects of states occurring between t and t-1 (where 1 denotes an arbitrary time unit) were not taken into account; therefore, the model accuracy was limited. To overcome this issue, the new modelling process will be extended to a full memory Higher Order Emotional Influence Model (HOEIM), taking into account a longer memory of previous states. The proposed HOEIM assumes that the current state of a speaker at time t depends on their previous N states and the other speaker's previous N states at t-1, t-2, … and t-N, where N is the model order.
Novelty: The most important novelty of this project is that in contrast to existing approaches [2]-[6], the proposed method will move from an independent analysis of individual speakers to an integrated model that couples speakers through intra- and inter-speaker dependency coefficients.

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Creating Autonomous Thinking Machines: Multi-Stage Data Classification with Intermediate Learning

Signal Processing and Artificial Intelligence Research Group,
City Campus

Project Description

To support the DSTG Grant RE-02761 and the AOARD/ONR-Global Grant RE-02756. This is a project for students interested in speech and image processing using deep learning networks. Strong programming skills and knowledge of signal processing is essential. Learning and reasoning are two essential abilities associated with intelligent autonomous machines. While the nature of machine learning is now well understood, the nature of machine reasoning is still an important issue to investigate.

The aim is to take a first step towards creating an autonomous machine reasoning system for basic data recognition and analysis. This aim will be achieved by designing a simple multiple-stage classification system with intermediate learning (MSIL). If successful, the MSIL could provide a basis for creating more complex structures of algebraically connected MSIL units, where the flow of external data and intermediate information generated by the structure elements would infer the problem-solving outputs.

The project will research a machine reasoning process regarded as a sequence of multi-stage algebraic manipulations of information, where information acquired by the previous stage is modified by the next stage [1]. The aim is to solve a complex problem by answering a sequence of simpler questions presented by each stage. This procedure is known as first-order logical or probabilistic inference [2]. More complex reasoning structures can be built by creating algebraic connections between basic inference units. The solution is then derived by the flow of information between these interconnected units. The first stage of the MSIL will perform classical learning and inference based on features calculated directly from the data. The second stage learns and infers the final diagnosis using data related information generated at the first stage. Since both stages will be trained independently, the learning results of the second stage will not alter the learning results accomplished at the first stage. This important property will enable the generation of more complex, multi-channel and/or multi-level machine reasoning systems consisting of algebraically connected basic two-stage units.

In contrast to existing multi-channel and multi-modal classification systems [4], the proposed system will completely exclude all “human designed” decision making units usually incorporating table look-up rules of conjunction, disjunction or implication [3]. The inference of the new “thinking” classification structure will be based purely on information flow through algebraically interconnected classifiers. This is to ensure pure “machine thinking” rather than following a human-designed set of rules.

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Investigation into the non-linearities of Pulse-Width Modulation and their effects on current control of switching converters

Electrical and Biomedical Engineering, Electrical Power Systems
RMIT City

Project Description

Pulse-width modulation (PWM) is fundamental to power electronics and has been studied since the 1950's [2]. PWM is used in many industrial and commercial products, ranging from motor drives to home theatre audio amplifiers. The inherent non-linearities for sinusoidal PWM (SPWM) has been studied for single-edge [1] as well as double-edge modulation [2] and ultimately affect the stability and efficiency of control loops in PWM-based converters.

Recent work has demonstrated that it is possible to optimize naturally sampled PWM control loop design for switching converters using exact analytical solutions of the system and control loop differential equations [3]. This work still needs to be expanded for the symmetrical and asymmetrical regular sampling cases. A small-signal analysis method has recently been introduced to analyze the stability of the continuous-time PWM feedback loop. This method was demonstrated for the naturally-sampled single-edge PWM case [4].

The primary aim of this PhD project is to investigate the theoretical and practical implications of the non-linearities of the PWM process and to derive practical design methodologies that compensate for these non-linearities. The project will be conducted at RMIT Power Electronics Laboratory Facility using a single-phase three-level full-bridge converter prototype.

References

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[2] H. d. T. Mouton, B. McGrath, D. G. Holmes and R. H. Wilkinson, "One-Dimensional Spectral Analysis of Complex PWM Waveforms Using Superposition," in IEEE Transactions on Power Electronics, vol. 29, no. 12, pp. 6762-6778, Dec. 2014.
[3] T. Mouton and S. Cox, "Fast and accurate simulation of bifurcations in naturally sampled PWM control loops," 2016 IEEE 17th Workshop on Control and Modeling for Power Electronics (COMPEL), Trondheim, 2016, pp. 1-6.
[4] T. Mouton; S. Cox; B. McGrath; L. Risbo; B. Putzeys, "Small-signal analysis of naturally-sampled single-edge PWM control loops," in IEEE Transactions on Power Electronics, *in press*.

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