School of Electrical and Electronic Engineering
Faculty of Engineering and Physical Sciences

The 2nd Annual School PGR Poster Conference, 25th November 2009

School of EEE
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1. Oskar Vivero

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*Long Range Dependence Estimation*

There is significant interest in long-range dependent or 1/f processes since they appear to be ubiquitous in a wide range of phenomena across different areas of study. Long range dependence is a measure on the variability of a system and it has been observed in phenomena pertaining to electronics, econometrics, hydrology and biomedical sciences, particularly in heart rate variability, ocular accommodation, dynamics of human gait and the rate of insulin uptake among others. Several of these biomedical studies suggest that many of the systems within the human body behave as long range dependent processes, hence proper estimation techniques should be employed when trying to fit experimental data to a model in order to obtain a useful representation of the phenomena observed. System identification techniques can be extended in order to estimate parameters that properly represent the long range dependence characteristic of a phenomenon within a model. We have developed a computationally efficient approximate Maximum Likelihood estimation algorithm that quantifies the long-range dependence characteristic from a data set under certain conditions.

2. Zhouyue Song

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*Stabilization of Uncertain Negative-Imaginary Systems*

The controller synthesis problem of uncertain negative-imaginary systems has important engineering applications in, for example, lightly damped flexible structures with collocated position sensors and force actuators. This paper provides a systematic controller synthesis procedure via an LMI approach to construct a state-feedback internally stabilizing controller such that the nominal closed-loop system satisfies negative-imaginary properties and a DC gain condition. As a result of this, the closed-loop system can then be guaranteed to be robustly stable against uncertainties that are stable strictly negative-imaginary (e.g. unmodeled spill-over dynamics in a lightly damped flexible structure). An numerical example is given to show the usefulness of the proposed results.
3. Xuejiao Yang

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Wide-Area Supervisory LQG Control for Multimachine Power Systems

Power system stability has been an important problem for many decades. As the modern electric power systems are becoming ever more complex, with longer-distance transmission lines and more complex interconnections, the advanced control concepts are required to be employed to coordinate various elements of these power systems. However, the communication time delays are omnipresent in such wide-area interconnected systems and may deteriorate their overall dynamic stability. This poster presents a supervisory LQG controller that is designed for rotor angle stability of multi-machine power system with communication time delays. The supervisory LQG control strategy is applied to a 4-machine, 8-bus power system simulation. Results show the effectiveness of the supervisory LQG controller in maintaining rotor angle stability when subjected to communication time delays.

4. Faisal Alhasawi

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Optimal Allocation of FACTS Devices

Contemporary power systems utilize Flexible AC Transmission Systems (FACTS) devices due, primarily, to their multifunctional capabilities. The optimal allocation of FACTS devices vary greatly depending on the objectivity of such placement. In this study, four types of FACTS devices: Static Var Compensator (SVC), Thyristor-Controlled Series Capacitor (TCSC), Thyristor-Controlled Voltage Regulator (TCVR), and Thyristor-Controlled Phase Shifting Transformer are considered for optimal allocation in a multi-machine power system to reduce the overall operation-al cost. The placement methodology accounts for the cost of generating real and reactive powers as well as the cost of the installed FACTS devices for a range of operating conditions selected from the annual Load Duration Curve, LDC. The use of LDC eliminates any bias in the device selection process while assuring that the proposed allocation is beneficial throughout the year.
5. Uzoamaka Anombem

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IEC61850 Process Bus Architecture for National Grid AS3 Project

The National Grid Architecture of Substation Secondary System (AS3) project was started in order to address the issues hindering long term system availability. The aims of this project are to:

- form a new policy for substation light current systems aimed at maintaining high availability and reliability of the transmission network by balancing the whole life-cycle risk, performance and cost of assets and

- develop a new architecture for substation secondary system targeting a quicker, safer and easier approach for the installation and replacement of protection and control equipment beyond 2011.

IEC61850 standards have been developed for substation communication networks and systems. If implemented, Generic Object Oriented Substation Event (GOOSE) messages can be broadcast to Intelligent Electronic Devices (IEDs) in order to control circuit breakers. Analogue signals from Current Transformers (CTs) and Voltage Transformers (VTs) can be digitised into sampled values, and then transmitted to IEDs connected to a local area network over an Ethernet-based fibre-optic link called the process bus. This bus can replace existing complex CT and VT copper wire connections. Overall, IEC61850 could produce significant benefits for National Grid, Scottish Power and Scottish Southern Electric by reducing outage duration and requirements for secondary system access for maintenance/replacement.

6. Brian Azzopardi

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Multi-objective Framework for Optimal Integration of Grid-Connected PV Systems using Emerging PV Technologies

Developments in photovoltaic (PV) technologies may lead to cheaper PV micro-generation systems at the likely expense of life expectancy and efficiency. With decreasing costs of PV technologies, the cost of electricity from PV systems will move towards grid parity prices. At the same time electric power systems are evolving into smart grids. The poster presents a framework for optimal integration of grid-connected PV systems using emerging PV technologies. Under the proposed methodology, PV systems are modeled as active and pro-active participants within the smart electricity grid from the design stage to system life cycle performance. For a thorough techno-economic analysis, the objectives are to minimise the annual energy cost and maximise the PV contribution to the on-site load. Using this multi-objective approach, an investigation is conducted on the characteristics of emerging PV technologies that may need to be met to penetrate the market without subsidies or direct monetary support schemes.
7. Xiaolei Cai

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Environmentally Acceptable Alternatives to SF6 in Substation

The reduction and elimination of SF6 used at high voltage levels of up to 400kV in gas insulated substations (GIS) is desirable considering the high global warming potential of the gas. This paper examines a number of radical options to replace SF6 gas. This includes the use of gas mixtures, the relatively new CF3I and c-C4F8 gases, high pressure dry air, vegetable oil and vacuum. In this poster, the limiting field strength of the various forms of insulation was used as a tool to compare the relative sizes of GIS enclosures designed for use of 400kV. Consideration must be given to the dielectric strength of the gas under AC and transient voltage conditions as well as the impact of the working pressure and its relationship with the working temperature. The analysis has shown that it appears feasible to replace SF6 gas with a gas mixture of CF3I. It would also be possible to replace SF6 with vegetable oil although this would have a significant impact on the weight of the GIS. The paper also discusses potential installation and maintenance considerations.

8. Ilias Christou

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Optimization Of High Voltage Wire Systems For Aerospace Applications

The aim of this work is to find the optimum voltage for an aircraft electrical system (from generation to transmission, distribution and utilization of electrical energy). By optimum we mean that which achieves the maximum power to weight ratio within a confined space while not compromising aircraft reliability and safety. This work is driven by the move to a more electric architecture. An increase in power can be achieved by either increasing the current or voltage rating of a system. The former would cause an increase in conductor weight, something which is likely to be unacceptable. Increasing the voltage would enable the use of even smaller conductor sizes but would require increased levels of insulation in order to avoid partial discharges and dielectric breakdown. This poster describes the optimum voltage calculation methodology and presents numeric results obtained for specific cable systems in a duct.
9. Nofri Yenita Dahlan

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*Investment Evaluation and Decision Technique For Generating Company in Deregulated Electricity Industry*

A decision to build a new plant by a generating company in a deregulated industry supply is more complex to make than in a traditional industry. Since there is no central decision, generating company has to evaluate its own investments anticipating what will happen to the system in the future. This paper presents a new framework to assist a generating company to perform new plant investment evaluation and makes selection over the choice of plant technologies. The framework consists of i) forecast future load demand and plant technologies’ fuel cost; ii) anticipate competitors' future expansion scenario using dynamic programming; iii) generate future cash-flow of the new plant from the electricity market with respect to the anticipated system in (i and ii) each year over the plant's life time; iv) compute the plant's rate of return and overall profit of the generating company; and finally v) select the most profitable plant for expansion.

10. Qiang Liu

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*Assessment of Ageing Conditions through Paper Tensile Strength Analysis of Scrapped Transformers*

With the increasing population of transformers whose service ages are approaching or in excess of their designed lifetimes, it is of critical importance for asset managers to evaluate these transformers' ageing conditions, to determine reasonable end-of-life criteria and to make medium/long term replacement plan. In order to support the above tasks, numerous laboratory-ageing studies have been conducted. Still, forensic examinations of scrapped old transformers would be of increasing importance to provide the ultimate 'under-service' ageing information. Paper tensile strength (TS) results of three scrapped transformers have been analyzed in this paper. Paper TS data were mapped vertically to give an indication of overall ageing condition of the winding, and they were also mapped horizontally across phases and windings, to examine thermal balances. The results demonstrated that there are various dominant ageing/degradation processes at both winding locations and layers of paper of the same conductor.
11. Yi Liu

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Knowledge Extraction within a Distribution Substation using Rough Sets and Genetic Algorithms

Intelligent Electronic Devices (IEDs) are now being introduced into substations that during a major disturbance capture large quantities of data and communicate it back to the control centre. Power system operators are expected to analyze the data from numerous substations and decide how to respond to the disturbance. The reality is “data overload”, stress and a risk to the decision process. This project describes a soft computing technique based on rough sets and a genetic algorithm that enhances substation informatics and ensure greater insight into the useful information contained in the data sets associated with IEDs. A rough set is based on the notion of indiscernibility and the inability to distinguish between objects. It provides an approximation of sets or concepts and the outcome is described as the reduct and the core, which contains the most important information in the data set. This information will help the control and the management of the power system, and help the decision making of the operators during emergency.

12. Kang Ma

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Risk Assessment under Corrective Control Paradigm

This project focuses on the impact of corrective control on the operating risk of power systems. The risk level is assessed through the Expected Energy Not Served (EENS) and the Expected Interruption Cost (EIC). The goal is to find the most cost effective option for enhancing the ability of the transmission system to deliver projected demand by comparing various corrective control scenarios with traditional reinforcement schemes. This is undertaken for different levels of corrective control and reliability profiles of control devices. In this paper the Static Var Compensator (SVC) is used as the primary corrective control device. A simple method for optimal placement of the SVCs around the network is proposed. Annualized risk indices are calculated through Chronological Monte Carlo Simulation (CMCS). Reliability worth assessment is then carried out based on net present value (NPV) which accounts for the Expected Interruption Cost as well as investment and operating costs. The scenario with the minimum overall cost is selected as the best one. The methodology is tested on the RBTS 6 bus composite system.
13. Gary Preston

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*Settings-Free Numerical Algorithm for Power Systems Protection*

This poster presents a novel numerical algorithm for the location of faults on overhead transmission lines. The proposed algorithm does not require the parameters of the line in order to locate the fault; it is a settings-free fault locator. Existing fault location algorithms need prior knowledge of the line's parameters and length in order to locate the fault. However, line parameters do not remain constant; they vary with differing loading and weather conditions, and this can affect the accuracy of the fault locator. Therefore, an algorithm that does not use line parameter information would be more accurate, flexible, robust and cost effective. This poster presents the derivation of the algorithm and the results of rigorous testing using ATP-EMTP software.

14. Rui Rui

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*Multi-Stress Ageing Of High Temperature Insulation*

Introduction:-- in a number of applications such as aircraft starter generators, fuel cells and high power density machines, higher operating temperatures are being sought of insulation. High temperature insulations in use are normally under more than one ageing stress during the life of insulation, either simultaneously or sequentially. This poster describes tests that have been carried out to examine the impact of some specific parameters including voltage, temperature and pressure on the long term behaviour of various forms of insulation including a ceramic insulation specifically designed for use at such temperatures.
15. Xin Wang

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Particle Effect on Breakdown Voltage of Transformer Oil

Easter based oil has been used more and more popular in large transformers recently. Compared to traditional mineral oil, these oils are non-toxic, less flammable, and more biodegradable. Previous research on ac breakdown strength, carried out at Manchester University laboratories, were based on ‘as-received’ oil, which concluded that ester-based oils have comparable dielectric characteristics to mineral oil. Worldwide research has also been conducted to investigate the breakdown voltages of new and used transformer oil in terms of different water contents. However, there is a lack of discussion on breakdown voltages of ‘processed’ transformer oil; especially ‘processed’ ester-based transformer oil. Note that the ‘processed’ oil refers to the oil processed using industrial standard through degassing, dehydrating and filtering. This paper used a GE insulating oil purification plant to process oil samples, i.e. 10GBN as mineral oil and FR3 as vegetable based oil, and their ac breakdown strengths were comparatively studied and analysed. The highest and lowest breakdown voltage values, as well as the mean, are discussed. It can be clearly seen from the results that ‘processed’ oil has a distinctly different breakdown characteristic from ‘as-received’ oil in terms of the effect of water contents.

16. Samila Mat Zali

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Dynamic Equivalent Model of Distribution Network Cell Using Prony Analysis and Nonlinear Least Square Optimization

The poster presents initial results in development of dynamic equivalent model of Distributed Network Cell (DNC) comprising various types of loads and distributed energy resources. The method used for development of the model is based on Prony analysis and Nonlinear least square optimization. The dynamic equivalent model is developed in MATLAB based on simulated measurement data of DNC. The model is given in the form of an equivalent second order transfer function that can be used in dynamic stability studies. The model estimation procedure is evaluated on a case study and the initial simulation results show very good performance of the proposed dynamic equivalent model.
17. Xin Zhang

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Accelerated Ageing of Insulation Surfaces Through Dry-Band Arcing

The occurrence of dry-band arcs on outdoor composite insulators can degrade the materials' surface and ultimately may lead to insulator failure. If a stable dry-band arc is physically compressed in length by external forces, the arcing activities will become more severe. This in turn, may accelerate the degradation into a short time-frame hazard. A series of experiments are carried out to investigate the electrical characteristics of the arcs as they become compressed. Based on the experiments, a 'Double Sinusoidal Model' is developed to simulate the current-voltage characteristics of dry-band arcing during its compression. Both experimental and simulation work show that dry-band arc compression reduces the length of the dry-band, and increases the energy of the arc. As a result, processes controlling insulation lifetime may not be continual and gradual, but are determined by rare events such as the occurrence of dry-band arc compression.

18. Qi Zhong

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Ageing Transformer Management: Statistical Approach and Physical Ageing Process

Power Transformers are generally designed to operate for 40 years. The transformer assets owned by National Grid in the UK were mostly installed between 1955 and 1975. Consequently the prediction of the remaining life of an ageing transformer is important to National Grid.

A statistical analysis is firstly carried out based on transformer installation and failure records. The curve of hazard against service age is produced; Normal and Weibull Distribution are used to fit that curve. Results indicate that the predicted ageing failure is unreliable, because the actual failure data appear random.

The degree of polymerisation (DP) indicates the paper insulation quality related to the physical ageing process. The lowest DP obtained from a particular scrapped transformer is used to evaluate the unit's thermal life. The thermal life of an active transformer is also suggested by the lowest DP from the same type or design of scrapped transformers.

Transformer condition priority help determine the replacement decision, based on the transformer overall physical assessment. The transformer short- to mid-term replacement hazard is developed according to the condition priority.
19. Maksims Abalenkovs

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**Huygens Subgridding with Filtering for Finite-Difference Time-Domain Method**

Building prototypes to verify electromagnetic (EM) characteristics of a device is expensive. Nowadays modern engineers simulate EM wave propagation on computers. Maxwell’s equations (ME) specify EM wave properties in theory. Numerical methods are used to approximate ME and obtain a practical solution. Finite-Difference Time-Domain (FDTD) is one of widely applied numerical approximation methods, but it is inefficient for complex electrically-large problems with fine geometric details. Subgridding (SG) is one of the ways to increase computational efficiency of FDTD.

This work (i) describes the main constituents of a generic SG method, (ii) presents unique features of Huygens Subgridding (HSG), (iii) explains one-dimensional (1D) and three-dimensional (3D) filtering needed to suppress late-time instabilities in HSG, and (iv) illustrates performance gains of HSG applied to Frequency Dependent--FDTD (FD--FDTD) over classical FDTD.

20. Junaid Ahmed

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**Lifetime Analysis of Cooperative Ad-hoc Sensor Networks**

This paper presents a new joint node selection and power allocation strategy that increases lifetime of an ad hoc sensor network when nodes cooperate to enable diversity in transmission. Lifetime of a network can be increased if both channel condition and residual energy are used to determine the power distribution. Our method outperforms the existing strategies in all conditions of initial battery energy, receiver distance, number of nodes and probability of transmission.
21. Saswata Bhaumik

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*pHEMT and mHEMT considerations for ultra Low Noise Amplifiers for the Square Kilometer Array*

This poster concentrates on the power efficiency of three advanced High Mobility Electron Transistor (HEMT) technologies used in Low Noise Amplifiers (LNA) for Square Kilometer Array. The three technologies studied are 150nm gate length GaAs pHEMT, 150nm InP pHEMT and 70nm GaAs mHEMT. The study shows that the 70nm GaAs mHEMT displays the highest normalized gm of more than 1.4S/mm at 0.1W/mm power consumption. The 150nm InP pHEMT and GaAs pHEMT shows normalized gm of more than 1S/mm and 0.5S/mm with 0.3 W and 0.15W power consumptions respectively. The bias GaAs mHEMT shows a promise of better noise performance compared to both InP and GaAs pHEMT processes. But the associated power consumption at room temperature with all three foundries to display minimum noise is close to 0.05W/mm. The InP and GaAs pHEMTs display an increase of gm by more than 80 S/mm and 40 S/mm respectively from 600°C to -500°C physical temperature. The mHEMTs exhibit a distinct shift in the gm curves by 0.6 V in the Vgs scale over the same temperature scale.

22. Ahmed El Kalagy

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*A Polyphase CDMA User Pairing Algorithm Based On Constructive Interference And Code Allocation*

The poster proposes and analyses a novel cooperative MIMO diversity technique with an efficient user-pairing strategy for uplink CDMA systems. The proposed can enable the support of K active users using only K/2 spreading codes while providing excellent BER performance even under asynchronous Rayleigh fading channels. It also considers the use of orthogonal polyphase (OPP) spreading sequences in the synchronous and asynchronous uplink scenarios, and presents a dynamic sequence allocation criterion for optimising the potential gains of the proposed system. For fairness-sake, the performance of this new diversity technique is compared with a conventional pairing diversity one as well as with the maximum gain combined (MGC) time diversity technique. The results show that the new algorithm outperforms the conventional pairing technique, and, when combined with the proposed dynamic code allocation criterion, it is also able to outperform time diversity even in uncorrelated fading channels.
23. Lina Jin

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Low Complexity Scheduling Algorithm for Multiuser Multiple-Input Multiple-Output Downlink System

A new low complexity scheduling algorithm is proposed for a multiuser multiple-input and multiple-output (MU-MIMO) downlink system based on block diagonalization (BD) precoding. The algorithm provides equivalent system performance evaluated as sum-rate capacity in comparison with other user selection algorithms, such as semi-orthogonal user selection (SUS) and capacity-based user selection algorithms. The proposed algorithm has the advantage of reduced computational complexity achieved by using a new volume-based user selection method that uses the product of the diagonal elements in the upper-triangular matrix obtained via Householder reduction procedure of QR factorization to the selected users channel matrix. The computational effort of the proposed algorithm is reduced by 1/3 compared with SUS algorithm. Compared with the capacity-based algorithm, the proposed algorithm does not need to perform the singular value decomposition (SVD) operation and water filling algorithm during each user selection step and hence significantly reduces the computational time.

24. Shokrollah Karimian

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Application of Metamaterial Resonator in Filter Design

A novel microstrip $\lambda_g/4$-type Stepped Impedance Resonator (SIR) based on Composite Right/Left-Handed (CRLH) transmission line is presented to resonate at frequencies assigned to Wireless Local Area Network (WLAN) applications. Supported by theory and full-wave simulations, a comparison is made between this design and its conventional counterpart. This is followed by fabrication and measurement of the SIR. The presented CRLH SIR design is not only 48% smaller in length than its conventional counterpart, but also benefits from a much better performance. In addition, an attempt is made to further develop this resonator and use it to form a filter as a subsystem of the WLAN front-end receiver building block.
25. Asim Khan

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Small Array Pattern Optimization using Particle Swarm Optimizer

In this work Particle Swarm Optimizer (PSO) is used to synthesis linear and planar array patterns. The study is focused on small uniformly spaced arrays with non uniform taper (weights). For linear array Schelkunoff’s unit circle approach is used to find out the optimum weights for low sidelobe patterns. The technique is extended to sum and difference patterns. The PCO performance is compared with conventional Taylor distribution, Elliott’s root matching and the Bayliss distribution. This approach is then used to investigate wideband arrays in the presence of mutual coupling for scanning applications. The PSO is further modified for the planar array pattern synthesis. The two-dimensional convolution model is used to control the weights.

26. Mina Panahi

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SKADS Low Noise Amplifier Design

A Low Noise Amplifier was designed to meet the required criteria of the 2-PAD (Dual-Polarization All Digital phased array) programme in the Square Kilometre Array project. The operation frequency range of this LNA is 0.3 to 1 GHz. A model was designed and built to measure the noise of this LNA which consists of differential input and single ended output.
27. Sarinya Pasakawee

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Left-handed Microstrip Delay Line Using Complementary Split Ring Resonators

A new design of a pass band filter implemented by means of complementary split-ring resonators (CSRRs) is presented using stubs. The use of stubs has been shown that they can significantly improve group delay of such resonators whereas the bandwidth could be maintained. Moreover, the size of the novel band pass filter is small as well as the conventional design. Two cells of CSRRs initially were designed and fabricated on a low loss substrate and the simulation and measured results show that the group delay can be doubled from 1 to 2 ns for 2 cells of CSRRs. Finally, the number of CSRR cell has been increased and the results show that the delay can be proportionally increased.

28. Ying Peng

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60GHz wideband folded dipole antenna in high impedance electromagnetic surfaces cavity

As the 60GHz frequency range was permitted taken to be commercial usage, wireless communication with large data capacity has been further developed. Recently those advances developments are mainly focused on compatibility and efficiency. Besides the metamaterial of GaAs and SiGe, silicon is chosen to build into CMOS structure because of the simple integrated circuit and low cost in fabrication. Different types of antennas were built based on the CMOS substrate, a folded dipole antenna was presented in this paper. The bandwidth of the antenna structure investigated gave a bandwidth of 7GHz around the centre frequency of 75GHz, which could provide enough bandwidth for high definite media data transferring. Furthermore, the gain, directivity and bandwidth can also be improved by placing metal bars on the substrate surface to decrease the edge current effusing or arranging a high impedance metalmaterial structure under the substrate.
29. Imran Rashid

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*Multiple HARQ Processes for MIMO Multi-hop Systems*

Multi-input multi-output (MIMO) wireless systems promise significant improvements in terms of spectral efficiency, link reliability, increase in capacity and data rates. Use of Automatic-Repeat-reQuest (ARQ) mechanisms for multi-hop wireless links has found little attention so far. Hybrid Automatic-Repeat-reQuest (HARQ) improves the throughput performance of ARQ by combining retransmitted packets with the soft values of previous erroneous transmission of same packet. This arrangement is known as MIMO Single-stream ARQ (MSARQ). In case of MIMO Multiple-stream ARQ (MMARQ), per antenna encoders are used, separate HARQ processes are maintained in parallel with regards to each transmit antenna. This concept has been extended to Multi-hop MIMO systems and throughput results show significant improvement in the system throughput. To compensate the delay introduced due to the relay node, it has been proposed to use higher modulation scheme for multi-hop system as compared to single-hop system. Elaborate delay analysis show that improvement in the throughput can be maintained while using higher modulation scheme in case the value of path loss exponent is greater than 2.3 or no of total ARQ transmissions are greater than 2.

30. Hasan Rouf

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*3-D Crank Nicolson FDTD scheme for frequency-dispersive media*

Finite Difference Time Domain (FDTD) method is a straightforward and robust numerical technique for solving electromagnetic problems. However conventional explicit FDTD method has limitations in computational efficiency and modeling capabilities. Media parameters are fixed in conventional FDTD while many current and emerging technological applications involve electromagnetic wave interactions with materials having frequency-dispersive dielectric properties. Explicit FDTD has to satisfy Courant-Friedrich-Levy (CFL) condition to make the computation stable. Because of this when small spatial resolution is used to accurately model fine geometries an unnecessarily small temporal resolution is enforced which increases the total CPU time. In this work a novel three-dimensional frequency dispersive Crank Nicolson FDTD (FD-CN-FDTD) method has been developed. First order Debye model is used to introduce frequency-dispersive media in the Crank Nicolson scheme. Numerical results show that the scheme is unconditionally stable and can maintain high accuracy with the time-step size much higher than the CFL limit. As the scheme results in a system of linear equations works have also been done to identify the most efficient solver for the proposed scheme. Future works include using the scheme in applications like interaction of electromagnetic waves with frequency-dispersive human body model.
31. Rashid Saleem

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**Multiband OFDM (Ultra Wideband) Performance in a Field of Generic Interferers**

This work will present a generalized analysis of Multiband OFDM (MB-OFDM) Ultra Wideband (UWB) communication in the presence of generic or non-specific interference sources. The interference sources are assumed to be distributed in a two-dimensional space according to a Poisson field. An aggregate interference is formed by the asynchronous operation of these sources. To provide a generalized analysis, the conventional Gaussian approximation is replaced by a method involving the moment generating function (MGF) of the signal-to-interference-plus-noise ratio (SINR) and Laplace transform to derive the exact expression for the probability density function (pdf) of the interference power. From this, overall expression for the bit error rate, BER, is derived based on the cases where band limited interference is present and otherwise. This resulting expression is valid equally for the first and next generation devices.

32. Chithambaram Anand Veerappan

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**Development of Automated Condition Monitoring Robots for High Voltage Equipment**

Detailed inspection of high voltage equipment is difficult because the high voltage and high fields prevent people getting physically close; this also creates a challenging environment for electronic equipment. Through the development of a robot as a technology demonstrator, this project aims to determine the effects of high field strengths on complex electronic systems. If these systems are shown to be viable under these conditions, knowledge obtained can be transferred to the design of other complex systems for monitoring other high voltage equipment.

This robot is being designed to assist in research involving the aging mechanisms of polymeric insulators; it will additionally be useful in the live line monitoring of glass and porcelain insulators, conductors and associated fittings. Current inspection methods include aerial and ground photography and ground-based infrared analysis – neither provides the clarity of photography obtainable at close range.
33. John Wilson

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A long range bi-directional HF modem

Abstract: The aim of this project is to develop a battery powered high-frequency (HF) band modem for long distance communications (hundreds or thousands of kilometres). The link is to be bidirectional, but it is assumed that the link from the modem to the mains-powered base station (primary link) will require the highest throughput. The link from the base station to the device will be used for simple commands and acknowledges (ACKs). HF links are generally poor channels with unique challenges and necessitate designing for very low signal-to-noise ratio (SNR). This poster describes the main areas of research focus in the project.

34. Fasir Amir

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Development of High Power THz sources for Imaging Applications

This paper presents continuing work on the development of an advanced step-graded Gunn diode using joint modeling-experimental approach. These devices are realized to test GaAs based Gunn oscillators at sub-millimetre wave for use as a high power (multi mW) Terahertz source in conjunction with a multiplier. The mm-wave multiplier, with novel Schottky diodes and Schottky varactors for Terahertz imaging applications will be presented. Concerning the two semiconductor components in a Varactor, the epitaxial growth of both the Gunn diode and Schottky diode wafers are performed at the University of Manchester using an industrial scale Molecular Beam Epitaxy (V100+) reactor. The Gunn diodes are then packaged by e2v Technologies (UK) Plc.

The Gunn diode model has been developed in SILVACO. The model was used to perform predictive modelling for the high frequency and high power devices that will be discussed in detail and presented with measured results. Further work will then be presented on novel self-aligned non-alloyed contact Schottky diodes that will be utilised in the multiplier to generate multi-mW terahertz frequency sources.
35. Ahmad Al-Adsani

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*HPM Generator for a Series Hybrid-Electric Vehicle*

In the UK, road transportation accounts for approximately 30% of all energy consumed, additionally vehicles are a major source of airborne emissions. Electric vehicles are a transportation technology that has the potential to address some of the energy and pollution issues within the UK and globally. However, there are some drawbacks related to pure electric vehicles, for example, limited driving range, excessive battery volume and battery charging times. Hybrid electric vehicles can address the driving range problem while having fuel and emission levels lower than for conventional combustion engined vehicles, specifically when in urban driving. Brushless permanent magnet generators having a secondary source of excitation are an interesting topology for implementation in series hybrid electric vehicles. Because of their duel excitation, these machines are referred to as hybrid permanent magnet (HPM). This poster reports on the control of HPM generators to maintain constant power output during vehicle load transients. Traction system DC-link voltage regulation via three operating scenarios has been investigated.

36. Peter James

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*Prognostics and health monitoring in power converters*

The use of IGBT power modules in the automotive industry is becoming more and more common due to the increase in hybrid and all electric vehicles. But, unlike industrial applications the duty cycle or usage of such devices due to the environment or operating requirement is very random and not well defined. This makes predicting when the device will fail very difficult as the life of the device is dependant on it’s use and temperature environment. This poster describes work being done on a real time, on line prognostic algorithm which uses the operating history of the device to calculate and predict the time of failure of the device.
37. Meliksah Ozakturk

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Power Quality for Wind Farms

Wind power today has an increasing importance in power production. Investments in wind energy technologies have been continuously made to generate clean and environment friendly energy. Apart from construction and decommissioning, these systems never emit CO2 to the atmosphere. However, one of the disadvantages of using wind power is that the wind speed is unpredictable and very changeable. To reduce the effect of this handicap, Doubly Fed Induction Generators (DFIGs), which can operate at variable speeds, are widely used in wind conversion applications to maximise power generating and to reduce converter costs and mechanical loads. Hence, DFIG wind turbines currently dominate the market due to their cost-effective provision of variable-speed operation. DFIG systems consist of back-to-back converters, namely rotor-side and grid-side converter, and a DC link capacitor placed between these two converters. In this project, the controls of rotor-side and grid-side converters of the DFIG model were designed and simulated in PSCAD/EMTDC, along with coordination to the wider connection system and its control.

38. Renee Chin

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3D Tomographic Imaging Using Ad Hoc Arrays of Mobile Sensors

Tomograms obtained in Electrical Impedance Tomography (EIT) often misrepresent the conductivity or permittivity distribution imaged due to the lack of spatial resolution limited by the information provided for inverse solving. This work explores utilising ad hoc and mobile arrays of sensors with conventional EIT, increasing the amount of information, to improve the quality of reconstructed images. Two strategies are explored – the ‘Augmented Electrical Tomography’ (AET) and the ‘Extended Electrical Tomography’ (EET). A simulation-based feasibility study has been carried out and shows that both approaches are viable. The AET approach, while easier to implement, is limited by factors related to inverse solving. The implementation of the EET approach provides the main challenge as the measurement system for the ad hoc sensors needs to mimic one that is used for the ad hoc sensors, where the earth is locally rather than globally referenced.
39. Xuan-Tien Doan

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Estimating the losses in quality of perishable produce subjected to changing temperatures

Significant postharvest loss during transport of perishable produce provides an economic incentive to improve quality control in chilled supply chains. Monitoring of temperature, the most important environmental factor, is possible using data-loggers or RFID tags. A method to estimate the postharvest loss using logged temperature is therefore desired.

The most common technique to model postharvest loss is kinetic modelling. This technique is popular because it is often based on kinetic principles, which govern all chemical processes occurring within the produce. However, the most significant disadvantage of this method is that it is a complicated modelling technique. Research has been undertaken to develop a novel method that overcomes the disadvantages of the kinetic modelling approach. The new method that has been developed is called “Kinetic Linear System” (KLS), and this has been derived from kinetic modelling principles, but does not require any knowledge of the (bio-)chemical systems involved.

The results of simulation studies have all confirmed that the KLS method is simpler and easier to implement, and can reproduce the performance of the kinetic modelling technique.

40. Nsikak Ekpenyong

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Characterization of a hyperspectral imaging system

Hyperspectral images are acquired by capturing monochromatic images over a range of wavelengths. They provide an important source of information in applications in agriculture, medicine, surveillance, and fundamental scientific research. An accurate characterization of any hyperspectral imaging system is crucial to its successful use. In this presentation, I shall identify the main sources of random and systematic errors in a hyperspectral imaging system operating over the visible range. These errors include internal and external noise, spatial non-uniformities in the optical system and sensor response, wavelength-dependent magnification effects, and scatter from stray light. I shall then show how these errors can be largely compensated for by careful calibration.
41. Liam Marsh
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*Future Walkthrough Metal Detectors*

In the modern world there is a continued threat of terrorism and threats to life in environments such as the aviation industry. There is a constant need to ensure that all passengers are checked for any weapons, explosive materials or other prohibited items in order to protect the many other passengers whilst they are in an environment as potentially hostile as that on board an aircraft. However, in addition to this there is a further need to allow thousands of innocent passengers through airport terminals in order to prevent the build-up of large crowds, and to ensure that everybody can safely board their airplane on time. The EMBODY project is seeking to increase the throughput of passengers at airport terminals whilst ensuring that security checkpoints are capable of increased detection sensitivity using highly discriminative detection techniques.

42. Mark Pottinger
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*Wireless Sensor Networks for Industrial Processes*

The interest in wireless sensor networks for industrial processes stems primarily from the chemical industry for monitoring of mixing processes in vessels. Current technology such as tomography is limited to determining object's positions within a vessel via material properties of the object; these technologies do not have the ability to map temperature, pressure or pH through the vessel all of which are desirable when monitoring a process. The delivery of a buoyancy controlled flow follower for use in industrial process vessels allows monitoring, with the ability to take extensive readings of chemical and physical parameters from within the environment in real time. The use of acoustic signals allows the location of the devices to be obtained, onboard sensors take readings of the surrounding environments and this is then transmitted to an external interface for display and interpretation.
43. Zhi Wei Sim

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*Investigation of PCB Microstrip Patch Receiving Antenna for Outdoor RF Energy Harvesting in Wireless Sensor Networks*

In this poster, the suitability of using a printed circuit board (PCB) microstrip patch receiving antenna for a novel application - RF energy harvesting to power a wireless soil sensor network deployed in an outdoor environment - is investigated. The performance of a conventional circular microstrip patch antenna using different microwave laminate substrates are evaluated in terms of return loss, radiation efficiency, and gain. Based on a chosen PCB material as the antenna substrate, an enhanced gain circular patch with a ring shaped parasitic radiator is presented. Simulations have been carried out using CST Microwave Studio to examine the antenna's performance both in free air and in the presence of different soil conditions.

44. Mayasha Mohammed Ali

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*Linearity Analysis & Modelling of Compact Microwave Components*

In Monolithic microwave integrated circuits (MMICs) both active and passive devices are integrated on the same chip. Passive components have larger dimensions than active devices and most of the area of the chip occupied by the passive devices. However multilayer MMICs not only allow two separate technologies to be integrated providing flexible design but also provides compact design with multifunctional capability and affordable cost.

Linear MMICs are highly desirable for future communication systems. However the explosion of wireless infrastructure hammered by the lack of components with sufficient linear RF characteristics. This study concerns with the understanding of non-linearity of microwave components. In this study a variety components are investigated for their linearity including: high electron mobility transistors (HEMTs) with single and multiple channels and passive multilayer circuits. A two-tone intermodulation distortion (IMD) measurement system has been used where two sinusoidal signals with very close input frequencies are fed into the device under test. The output products will be a combination of frequencies including the fundamental signal. The aims are to design devices and circuits with linear characteristics using device design and circuit optimizations.
Long Range Dependence

When the past events of a phenomenon have a high order of relevance to its present and future events, then it is said that the phenomenon exhibits long-range dependence.

Long-range dependence allows us to quantify the extent of a phenomenon’s memory, and in general, it is represented by a power-law decay on its spectral density function. In other words, the spectral density function resembles a decreasing straight line when plotted in a log-log chart.

Relevance

Long-range dependence can assess the variability of an event. It has been observed in a wide range of phenomena:

- Electronics, e.g. voltage or currents of diodes, transistors and vacuum tubes, semiconductors resistance, the frequency of quartz oscillators.
- Econometrics
- Hydrology, e.g. flow of the Nile river.
- Biomedical sciences, e.g. heart rate variability, ocular accommodation, dynamics of human gait and the rate of insulin uptake by diabetics.

Maximum Likelihood

Maximum likelihood is an estimation method with attractive statistical properties such as its consistency and asymptotical efficiency. On different studies it was found to be among the most accurate estimators for long-range dependent processes. Nevertheless, its computational cost makes it impractical for implementation when the data set length is large.

We propose an asymptotically equivalent approximation to the maximum likelihood estimate (MLE) that is computationally efficient and accurate.

Current and Future Directions

- Extend the proposed approximate MLE such that it covers more flexible models; for instance, ARFIMA and Heavy tail distributions.
- We are working with C. Leahy and L. Diaz-Santana as they have observed long-range dependence in ocular accommodation.

Reference

Stabilization of uncertain negative-imaginary systems

Zhuoyue Song

Negative-Imaginary systems

➢ Stable systems with a positive-frequency branch of the Nyquist plot below/on the real axis
➢ Similar to positive-real systems, phase-constrained

Engineering Applications

➢ Large space structures, multi-link robots, etc.
➢ These structures with position sensors and force actuators typically give rise to negative-imaginary systems.
➢ Unmodelled dynamics give rise to spill-over dynamics that can easily destabilize the systems.

Robust Stabilization

We propose a systematic controller synthesis method via LMI approach such that the nominal closed-loop system
➢ satisfies negative-imaginary properties
➢ satisfies DC condition
As a result of this the above system in the face of strictly negative-imaginary uncertainties is robust stable.

Simulations

Recent stability analysis result

Notice spill-over dynamics satisfy strictly negative-imaginary (J-) property, the analysis results of NI systems is underpinning to controller synthesis for this class of systems.

Conclusion

The state feedback controller synthesis method can robust stabilize systems in the face of strictly NI uncertainties, which arises for example unmodelled spill-over dynamics in lightly damped structures.

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Wide-Area Supervisory LQG Control for Multimachine Power Systems

Xuejiao Yang

Introduction
As a result of modern power systems being large nonlinear systems, with an increasing size and complexity, the conventional stabilizers or regulators are not always able to provide satisfactory performance. This is particularly the case when the operating conditions change and severe disturbances, for example a three-phase fault on a transmission line, occur. Therefore, the advanced supervisory LQG controller is designed in order to improve rotor angle stability of multi-machine power system and perform wide-area system management.

Control Problems
➢ Rotor angle stability control – Maintain generators in synchronism, stabilize the overall power system, when the system is subjected to a three-phase fault.
➢ Robust control – Robustness to communication delay.

Supervisory LQG Control on Power System
Figure 1 shows the supervisory LQG control scheme applied on the power system, when the system is subjected to a three-phase fault. The inputs of the controller is terminal voltage, electrical power and rotor speed. The outputs is the rotor speed deviation of generators.

Test Power System
The project is tested on a multimachine power system, which is a 2-area, 4-machine, 8-bus power system, figure 2 is the single line diagram of the test power system.

Communication Time Delay
To realize a supervisory control strategy for wide-area power system stability, satellites, cables, microwaves and fiber optics are used to deliver different signals and measurements of voltages, currents and phase angles from local areas to a central controller and the control signals are also need to be sent to the local controllers. Therefore, time delay has significant effects on wide-area power system stability. Figure 3 is the pictorial of time delay in power system.

Simulation Results
Rotor angle stability control – The comparison of speed deviations of four generators between the conventional Power System Stabilizer (PSS) and PSS with supervisory LQG controller illustrates the improvement of the stability control in figure 4.

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Optimal Allocation of FACTS Devices
Mr. Faisal Alhasawi

Introduction
The steady growth of power demand, the sensitivity to environmental impact along with the ever rising cost of energy impose new challenges to minimize losses while maximizing the capacity of existing power transmission lines. Flexible AC Transmission Systems (FACTS) technology enhances the capacity of existing transmission lines and grants the opportunity to control their power flow. Optimally allocated, FACTS devices can, in addition to improving system functionality, have high return on investment.

Investment Cost
Unlike SVCs and TCSCs, the cost functions of TCPSTs and TCVRs are more related to the current and voltage rating of the circuit of interest and thus are normally fixed; they are set at 100 $/kVA.

Reduction of Operating Costs By Use of FACTS Devices
Assuring the proposed allocation is beneficial throughout the year, a range of operating conditions are selected from the annual Load Duration Curve.

Conclusion
The addition of Flexible AC Transmission Systems (FACTS) technology allowed a reduction in operational cost while enhancing the capacity of the transmission lines to which it was attached. Though, in this study case, the investment returns profit in the first year of operation, this should not be taken as the norm for all power systems. The applications of FACTS technology is not limited to available transfer capability and power flow control, they cover other areas of interest in power systems such as transient and small signal stability, voltage stability and reactive power compensation.
IEC61850 Process Bus Architecture for National Grid
AS³ Project
Miss Uzoamaka Anombem

Scope of Architecture of Substation Secondary System (AS³) project
- To form a new policy for substation light current systems aimed at maintaining high availability and reliability of the transmission network by balancing the whole life-cycle risk, performance and cost of assets
- To develop a new architecture for substation secondary system targeting a quicker, safer and easier approach for the installation and replacement of protection and control equipment beyond 2011

Existing Arrangement

![Existing Arrangement Diagram](image)

- PU - Protection Unit
- CU - Control Unit
- C/P - Control/Protection Unit

Issues with Existing Arrangement
- Short asset life span/ replacement cycle <15 yrs. This is due to fast technological changes / product obsolescence / backward compatibility
- Hardwired I/O interface resulting in long outages, high cost / replacement risk
- Long outages for new product installation and commissioning

Way Forward – New Architecture
Based on IEC 61850 - Substation Communication Standards. IEC 61850 addresses digital substation configuration and communications

Major Benefits
- Fixed I/O interface modules enabling longer asset life
- “Plug & play” functions enabling IEDs/relays with short asset life
- Quicker/safer/cheaper to replace with fewer or no outages
- Inter-operability/changeability reducing the requirements for spares
- Optical fibre cabling reducing EMC requirements

IEC61850 Concept

Digital substation world

- Logical device (IED)
- Analog quantities

Future Arrangement

![Future Arrangement Diagram](image)

Conclusion
An adoption of an IEC 61850 process bus architecture will be a positive factor in the successful completion of the National Grid AS³ project.
Multi-objective Framework for Optimal Integration of Grid-Connected PV Systems using emerging PV Technologies

Eur Ing. Brian Azzopardi

Introduction

Developments in photovoltaic (PV) technologies may lead to cheaper PV micro-generation systems at the likely expense of life expectancy and efficiency [1, 2]. With decreasing costs of PV technologies, the cost of electricity from PV systems will move towards grid parity prices. At the same time electric power systems are evolving into smart grids [3, 4]. This work presents a framework for optimal integration of grid-connected PV systems using emerging PV technologies [5]. Under the proposed methodology, PV systems are modeled as active and pro-active participants within the smart electricity grid from the design stage to system life cycle performance. For a thorough techno-economic analysis, the objectives are to minimise the annual energy cost and maximise the PV contribution to the on-site load. Using this multi-objective approach, an investigation is conducted on the characteristics of emerging PV technologies that may need to be met to penetrate the market without subsidies or direct monetary support schemes.

The Multi-Objective Formulation

The Multi-Objective Function using the Weighting Method

\[ Z_1 = \min \left( \frac{Cost_{\text{annual}}}{\eta_{\text{PV}}} + Cost_{\text{BOM}} + Cost_{\text{storage}} - Revenue_{\text{annual}} \right) \]

Fig. 2: Energy Flow Management Diagram

Results

Fig. 5: Trade-Off Relations

Fig. 6: Optimal Values

Conclusion

The trade-off relationship between the economics and PV contribution on the micro-level (domestic) has been clarified. There are particular optimal technical specifications to be met for the optimal integration of emerging PV technologies. These may result in prioritising markets by geographical location or market segments.

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References


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Environmental Acceptable Alternatives to SF₆ in Substation
Xiaolei Cai

Introduction:
SF₆ is widely used as an insulating gas and interruption medium in gas insulated substations (GIS) and in circuit breakers. However, SF₆ is a greenhouse gas and reducing the reliance of the electricity supply industry on this gas would be ideal from an environmental perspective. The gas has excellent performance and arc quenching capability of those substations should show a similar performance to SF₆ and allow no increase in size of the equipment it is used in.

Environmental Concerns Over SF₆:
According to the Kyoto Protocol, SF₆ is a greenhouse gas that is chemically stable. It therefore remains in the atmosphere for a prolonged duration up to 3,200 years, and in comparison to the same quantity of CO₂ contributes considerably more to global warming. In the press release from G8 summit, HFC emissions are predicted to be up to 45% of CO₂ emissions by 2050 under a 2°C scenario to stabilize CO₂ at 450 ppm. Further, according to statistical report, a pound of SF₆ emission is equal to 24,900 pounds carbon dioxide, which will be severe pollution to the environment. Another concern on SF₆ is that the production of SF₆ involves the production of fluorine gas, which will be severe pollution to the environment. Another concern on minimizing the SF₆ leakage rate has been raised for a long time.

Vacuum Circuit Breaker:
The work is looking at the ability of vacuum circuit breakers to replace SF₆ breakers at transmission voltage levels. Already, 168kV/40kA double break are being commercialized in Japan and six 12kV interrupters have been connected in series to build 750kV vacuum circuit breakers in China. Vacuum circuit breakers behave safely and are low maintenance and long life, compared to oil and SF₆. To increase current interrupting capability, the interruption contacts were designed to produce AMF (Axial Magnetic Field) contact and axial magnetic field (AMF) contact (left and right) [3].

Conclusion:
Initial studies have shown that the replacement of SF₆ with CF₃I gas is possible. However, either the boiling point of the gas moves closer to the operating temperature (by virtue of a required change in working pressure) or the radius of the system will increase. However, the changes are not significant and could be tolerated. Further work will look at the role that vacuum circuit breakers could play on the high voltage transmission system.

Reference:

Environmental Acceptable Alternatives to SF₆ in Substation
Xiaolei Cai

Introduction:
SF₆ is widely used as an insulating and interruption medium in gas insulated substations (GIS) and in circuit breakers. However, SF₆ is a greenhouse gas and reducing the reliance of the electricity supply industry on this gas would be ideal from an environmental perspective. The higher the gas pressure, the more likely the gas is to liquify in working conditions. This is something must be avoided so a low boiling point is demanded.

Potential Substitutes For SF₆
Within GIS Equipment:
Current research papers discuss the use of a low concentration of SF₆ in N₂ as a possible alternative. This gas mix has similar properties to SF₆. However, SF₆ usage still exists. Gases such as N₂O, CO₂ and N₂ cannot be used alone unless very high pressures of around 1MPa are introduced. More recently, another electronegative gas CF₃I (Trifluoriodomethane) which is colourless, non-flammable, non-toxic and much lower global warming potential (less than 5), has been introduced as a potential substitute, for its better dielectric strength.

Analysis Of Use Of CF₃I In GIS:
Data describing the dielectric strength of this gas is available as limiting (E/N) values. This work provides a figure for the maximum electric field strength that a gas can operate at for a given concentration (usually measured as a function of pressure). The higher the gas pressure, the higher the dielectric strength of the gas.

In this work, a typical 400kV GIS enclosure has been taken and an analysis of the ability of the replacement the SF₆ with CF₃I has been undertaken. At the same time, the calculation for c-CF₃I gas mixture was included after considering other suggestion from literatures. This study has examined the enclosure size / gas pressure required to provide sufficient strength for the GIS. The sizing has been based on a 1425kV lightning impulse voltage withstand requirement.
Optimisation Of High Voltage Wire Systems
For Aerospace Applications
(Mr. Ilias Christou)

Introduction
The aircraft industry is moving to more advanced electrical systems to reduce the aircraft’s weight by increasing the power to the drive, eliminating heavy mechanical & pneumatic systems. This will minimize fuel consumption & operational costs. The increase in electrical power can be achieved by increasing the current or the voltage. Increasing the current will result in bigger conductor weights. Aerospace wires greatly influence aircraft weight & the increase in conductor weight might counterbalance the weight decrease due to the removal of mechanical & pneumatics systems. On the contrary, a voltage increase will allow the use of smaller conductors. However thicker insulation will be required to avoid partial discharges (PD) & disruptive discharges. This is an issue if the available space for wires is restricted and if the increase in insulation weight compensates the reduction in conductor weight. Another concern is that PD ignites at lower voltages at low pressure & high temperature environments.

Fig. 1. Partial discharges - occurring around an unscreened insulated thin wire

This work is devoted in optimising space confined electrical wire systems, functioning at a voltage level achieving maximum power to weight ratio and without compromising aircraft reliability & safety.

Designing a wire system free of PD
If the insulation capability is proved satisfactory by BS EN 60243-1 (testing standard for disruptive discharges), the voltages required to cause PD are lower than the ones causing disruptive discharges. Thus designing for a free PD system will ensure reliable operation of the insulation system. Identifying possible PD locations in wire systems (Fig.3.), enables safe operating voltage (SOV) evaluation.

Fig. 2. Disruptive discharges - Catastrophic effect on insulated unscreened wires

Aircraft wires are relatively small in size & the air-gap between them is also small. As a result the related electric fields can be assumed to be uniform & Paschen’s Law (Fig.4.) can be used for computing PD inception voltages (or SOV), for the cases of void, wire to ground & wire to wire discharges. By using equations defining the fraction of the voltage $V_{air/gap}$ across the air-gap for all three cases, SOV can be computed by dividing the $V_{air/gap}$ curve from Paschen’s curve for each case.

Fig. 3. Locations that PD could occur

Fig. 4. Paschen’s Law, Fraction of the voltage across air-gap & calculated SOV curve

Types of wire systems examined

Using a fixed duct size of 30 mm, equations have been derived for the calculation of maximum cable size possible, taking into consideration a minimum clearance between cables & duct. For a list of AWG conductor sizes the insulation thickness has been calculated.

System Optimisation-Methoodology

<table>
<thead>
<tr>
<th>Calculation optimal cable size</th>
<th>Insulation thickness for fixed cable size</th>
<th>RMS partial discharge inception voltage (the highest of the 2 values)</th>
<th>Volume per metre for all insulation &amp; copper conductors</th>
<th>Total cable weight per metre</th>
<th>Pick Lowest Insulation Voltage</th>
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</tr>
</tbody>
</table>

| Calculation optimal cable size | Insulation thickness for fixed cable size | RMS partial discharge inception voltage (the highest of the 2 values) | Volume per metre for all insulation & copper conductors | Total cable weight per metre | Pick Lowest Insulation Voltage |
| Determination of power to weight ratio curves and determination of optimal cable system

Calculation Results

Conclusions
The higher the no. of cables in a fixed sized duct & the larger the conductor, the less thick the insulation & thus the lower the voltage rating. (Note: doubling the insulation thickness does not imply doubling of the operating voltage). Maximum power transfer increases with increasing insulation thickness up to a certain voltage. Beyond this voltage, because conductor size gets smaller, the decrease in current rating dominates & power transfer capability falls. The 2 +ve DC & 2 –ve DC system, offers the best solution giving higher power to weight ratios at higher voltages. In DC systems the insulation is utilized at its peak rating, thus giving a high power transfer. However in AC systems the power transfer is determined by the RMS voltage rating, this being $\sqrt{2}$ lower than the maximum operating voltage.

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**Investment Evaluation and Decision Technique for Generating Company in Deregulated Electricity Industry**

Nofri Yenita Dahan

**Introduction**

A decision to build a new plant by a generating company in a deregulated industry is more complex to make than in a traditional industry. Since there is no central decision, generating company has to evaluate its own investments anticipating what will happen to the system in the future. This paper presents a new framework to assist a generating company to perform new plant investment evaluation and makes selection over the choice of plant technologies. The framework consists of:

1. forecast future load demand and plant technologies’ fuel cost;
2. anticipate competitors’ future expansion scenario using dynamic programming;
3. generate future cash-flow of the new plant from the electricity market with respect to the anticipated system in (iii) each year over the plant’s life time;
4. compute the plant’s rate of return and overall profit of the generating company; and finally
5. select the most profitable plant for expansion.

---

**Overall Structure of the Investment Decision:***

**Load Curve, Demand and Fuel Cost Forecast:**

*Long Term Load Forecasting*

\[
D_t = D_{ref}(1+r)^t
\]

*Long Term Fuel Cost Forecasting*

\[
f_C = f_{C,ref} + C_t
\]

*Five segments of LDC*

---

**Market Design:**

*Objective function:*

\[
\min \left( \sum \left( M C b_i, p_i, d_i \right) \right)
\]

*Subject to:*

\[
\delta_{i, p, d}^m \leq p_i \leq \delta_{i, p, d}^n
\]

**Profit Calculation:**

\[
P_{C,ref} = \max \left( \sum (ER_i + SR_i - PC_i) \right)
\]

*Plan’s Worth:*

- Plan’s cash-flow is computed from the market clearing process over its life time
- The Future Worth Value (FWV) and Internal Rate of Return (IRR) of the plan are then calculated

Which plan is feasible? \( \text{IRR} > \text{MARR} \) and \( \text{FWV} > 0 \)

Which plan is the best option?

Plan that give the max (incremental profit) to the company

---

**Conclusion and Future Work:**

- This technique able to assist generating company to make investment decision in deregulated electricity industry by considering the future expansion from its competitors
- Uncertainty, risk evaluation and probabilistic study will be considered in the model in future work

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**Supervisor(s):** Prof. Daniel S. Kirschen

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**Test System:**

- IEEE Test System omitting hydro
- Three generating company are in the system
- Plans PGC1, PGC2,PGC3 are belong to GenCo1, GenCo2 and GenCo3 respectively
- In this example, GenCo2 is evaluating PGC2_01 (155MW coal power plant) for investment

Possible future plants for DP:

- Possible future plants for DP:

**Result-Future Investment Using DP:**

**Result-IRR, Forecasted price, system reserve, share:**

- **IRR = 12.42% which is greater than MARR=12%**
- **FWV = 1.83266e-006 which is greater then zero**
- **Plan PGC2_01 is economically feasible for investment**

---

**Electrical Energy and Power Systems (EEPS)**
Group, School of Electrical and Electronic Engineering
Assessment of Ageing Conditions through Paper Tensile Strength Analysis of Scrapped Transformers

Mr Qiang Liu

Introduction

With the increasing population of transformers whose service ages are approaching or in excess of their designed lifetime, it is of critical importance for asset managers to evaluate these transformers’ ageing conditions, to determine reasonable end-of-life criteria and to make medium/long term replacement plan. In order to support the above tasks, numerous laboratory-ageing studies have been conducted. However, interests in forensic examinations of scrapped transformers have increased in recent years since it provides the ultimate ‘under-service’ ageing information. Paper tensile strength results of three scrapped transformers were analyzed in this paper.

Ageing of Transformer Insulation

Ageing and degradation of the oil-paper insulation system is a complex chemical and physical process under thermal, electrical, mechanical and chemical stresses. Hydrolysis and oxidation reactions usually exist in cellulose ageing process; at high temperature pyrolysis may also occur.

Tensile Strength Test

Tensile Index (TI) was chosen to indicate the paper tensile strength, measured by Instron 5564 universal testing machine according to BS EN ISO 1924-2:1995.

\[ TI(N\ m^{-1}) = \frac{TS}{g} = \frac{F/w}{g} \]

where:
- g is grammage, g/m²
- F is maximum tensile force, N
- w is initial width of test piece, m

Transformers investigated

<table>
<thead>
<tr>
<th>Transformer</th>
<th>Service age (years)</th>
<th>Voltage level (kV)</th>
<th>Rated power (MVA)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>37</td>
<td>275/66</td>
<td>180</td>
<td>Substation</td>
</tr>
<tr>
<td>B</td>
<td>45</td>
<td>275/132</td>
<td>120</td>
<td>Substation</td>
</tr>
<tr>
<td>C</td>
<td>41</td>
<td>275/132</td>
<td>240</td>
<td>Substation</td>
</tr>
</tbody>
</table>

Multiple Layer Effect

The degradation rate of the paper layer in contact with oil is greater than that in contact with copper conductor. The decreasing trends from the middle to the outer and to the inner sides are probably controlled by different mechanisms, i.e. chemical impact and thermal impact. A ‘filter’ effect of paper layer might exist in the chemical degradation control region, which means less chemicals generated by oil oxidation can go through the layers. Colour appearance of paper pieces from different layers is also a supplemental evidence.

Cross Comparison

<table>
<thead>
<tr>
<th>Phase</th>
<th>Transformer B, LV winding</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>33.4</td>
</tr>
<tr>
<td>B</td>
<td>38.3</td>
</tr>
<tr>
<td>C</td>
<td>37.4</td>
</tr>
</tbody>
</table>

The lowest value observed in this transformer is: 25.3

<table>
<thead>
<tr>
<th>Phase</th>
<th>Transformer C, B phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV</td>
<td>39.8</td>
</tr>
<tr>
<td>LV</td>
<td>36.7</td>
</tr>
<tr>
<td>HV</td>
<td>33.7</td>
</tr>
<tr>
<td>Tap</td>
<td>31.6</td>
</tr>
<tr>
<td>Mean</td>
<td>35.4</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>3.6</td>
</tr>
<tr>
<td>Coefficient of variance</td>
<td>0.10</td>
</tr>
</tbody>
</table>

The lowest value observed in this transformer is: 27.4

Conclusion

Examinations on scrapped transformers can provide ‘under service’ ageing data of transformer insulation. These data are useful to verify/modify the end-of-life prediction model, which is largely based on laboratory accelerated ageing. Paper tensile index results of three scrapped transformers have been analysed in this paper. It is concluded that there is obviously multiple layer effect on variation of paper TI, due to different dominating ageing/degradation processes. Overall, we are endeavouring in closing the gap between ”lab ageing” & "under service ageing". Ongoing study attempts to use the forensic examination results for transformer asset management and end-of-life prediction.
Abstract

The growth in substation data generated by microprocessor-based IEDs has far outstripped our capability for interpretation. To consider moving beyond data acquisition to knowledge discovery, a new computational intelligence approach based on Rough Set and a Genetic Algorithm can be used to group objects of interest into classes indiscernible with respect to some or all of their features.

A Solution

This project uses “Rough Set” and a Genetic algorithm to solve the data overload. A rough set is based on the notion of indiscernibility and the inability to distinguish between objects. It provides an approximation of sets or concepts and the outcome is described as the reduct and the core. These contain the most important information in the data set. A genetic algorithm is used to find the minimal solution of the rough set, which is regarded as a “N-P hard” problem.

Introduction

In the Past:

- electromechanical relays & no communications:
- minimal data
- difficult to know what happened during a fault
- how the system should be restored if maintenance required.

And Now

- Processor based IEDs & digital technology can solve the problem
- Engineers are now suffering from data overload.
- Same data in multiple IEDs
- Superfluous information can be a major problem

We need to design a POWERFUL tool to handle these problems

Information Overwhelm In IEDS

Figure 1: Different types of data from a distribution network

Knowledge can assist the operator’s decision, but raw data without an adequate analysis tool will overwhelm the control centre --- this is especially dangerous when a fault happens, and a wrong decision may result in unexpected damage to the power system.

Results

An example simulation involves an A-B solid fault in the outgoing feeder of transformer 2 in a 33/11 kV substation. This result indicates: IED6 and IED8 are regarded as the main source of this fault event during the simulation. This table contains the core information. This information describing this will be sent to the control room, and it will help the operator to make right decision during abnormal events.

Conclusions

- Rough Set and Genetic Algorithm can automatically process a large volume of data from a substation. It identifies the most significant and meaningful data patterns and presents this information in an appropriate form to the end users.
- The approach is considered as a white box rather than a black box e.g., neural network, because it offers us both the opportunity to learn about the data and to validate the extracted knowledge.

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Supervisor: Prof. Peter Crossley
Dr. Haiyu Li
Risk Assessment under Corrective Control Paradigm

Kang Ma, Dr Joseph Mutale

Introduction

With the increasing demand for electrical energy coupled with concerns about environmental issues, the traditional way of reinforcing power systems by installing new lines and generation facilities is facing more constraints than ever. The alternative is to implement corrective control. By further utilizing existing system margin, the prohibitive cost of new generation and transmission facilities are replaced by the relatively low cost of corrective control.

Aim

This project addresses the following questions arising from the adoption of corrective control:
1) how do different penetration levels of corrective control affect risk of power systems?
2) under what circumstances is corrective control more cost effective than network reinforcement?

Means of Corrective Control

Corrective Control may include Flexible AC Transmission Systems (FACTS), Energy Storage, Demand Response and Corrective Switching. FACTS have been modelled up till now and the modelling of Demand Response is an ongoing work.

Key features of Corrective Control:
1 - Potentially more cost effective
2 - Few environmental issues
3 - Challenges the “N-1” rule

Means of Corrective Control

Three SVCs at bus 3, 4 and 5
Two SVCs at bus 3 and 4
One SVC at bus 3
Base Case

Methodology

Three approaches that are most used are: State Enumeration, Monte Carlo Simulation and Genetic Algorithm.

In this work Chronological Monte Carlo Simulation (CMCS) has been applied to assess risk. Optimisation based on AC load flow is performed to minimise the cost of load shedding. Optimal SVC set points are determined in this process.

Reliability Assessment- System scenarios are convolved with SVC reliability profiles. Expected Energy Not Served (EENS) and Expected Interruption Cost (EIC) are calculated.

Economic Assessment- Three types of cost are taken into account: investment cost, operation cost (cost of transmission losses) and Expected Interruption Cost. Present Value approach is applied.

Conclusion

The optimal scenario of corrective control is determined through overall economic assessment accounting for Investment Cost, Operation Cost and Expected Interruption Cost.

Two factors affect the viability of corrective control:
1 - The number of SVCs and 2 - Reliability profile of SVC. An optimal point exists where marginal benefit of corrective control matches the marginal cost. In the test case the optimum scenario is scenario 2). For scenario 3) and 4), the marginal cost outweighs the marginal benefit.

Test Case

Roy Billington Test Case with 6 buses.

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Settings-Free Numerical Algorithm for Power System Protection  
Gary Preston

Introduction.

Reliable algorithms for the analysis of faults on overhead transmission lines have become an essential part of modern transmission line protection schemes. An integral part of such algorithms is the fault locator which determines the distance to the fault from the local line terminal. Numerous methods of fault location have been developed in the past, some of which use data from one line terminal and some of which use data from two or more line terminals. FLAs using data from multiple line terminals are more complex than their single-terminal counterparts but are more accurate. A common factor between all of the existing fault location algorithms is that they need the line parameters (resistance and inductance per unit length) and the length of the line to determine the fault distance. However, the line parameters are not always known exactly and they can vary with differing weather and loading conditions. The aim of this project is to develop a new numerical algorithm that can determine the distance to the fault on a line without any knowledge of the line parameters.

Algorithm Derivation.

The new algorithm can be used for both asymmetrical and three-phase faults; here the solution for asymmetrical faults will be given. An asymmetrical fault occurs transmission line at distance $f$ from the left line terminal as shown in Fig. 1. $F$ is the fault point, $f$ the fault distance, $D$ the length $f$ the line and $S$ and $R$ denote the sending and receiving ends of the line, respectively.

![Transmission line with asymmetrical fault](image1)

Fig. 1: Transmission line with asymmetrical fault

The voltages and currents are sampled at each end of the line and their phasors are obtained using the Discrete Fourier Transform. Using these phasors and the symmetrical components technique, the positive-sequence and negative-sequence can be found, as shown in Fig. 2.

![Equivalent p- and n-sequence circuits](image2)

Fig. 2: Equivalent p- and n-sequence circuits

For the equivalent circuits in Fig. 2, the following equations hold:

$$
V_p^f - zDp^f = V_n^f - z(D-f)n^f
$$

(1)

$$
V_n^f - zDn^f = V_p^f - z(D-f)p^f
$$

(2)

The fault distance can be expressed as percentage of the line length, and thus as a function of the line impedance:

$$
\%f = \frac{f}{D} = \frac{z\ell}{z\ell + z(D-\ell)}\times 100
$$

(3)

By rearranging equations (1) and (2) to find $zt$ and $z(D-t)$ and putting them in equation (3), the fault distance can be found as:

$$
\%f = \frac{100}{1 + \frac{\ell}{D}} \left( \frac{V_n^f - zDn^f}{V_p^f - zDp^f} \right)
$$

(4)

From equation (4) it can be seen that the fault location can be determined using only voltage and current phasors from each line terminal and without any line parameters. This solution is specifically for asymmetrical faults. The solution assumes that the data sampling at the line terminals is synchronised; this is discussed below.

Synchronised Measurement Technology

Synchronised measurement technology (SMT) is based on the Global Positioning System (GPS) and synchronises different Intelligent Electronic Devices (IEDs) in large power networks. SMT gives fast and reliable communications links between remote line terminals. In Fig. 3 two synchronised measuring units take voltage and current samples at each line terminal and send them to a Data Concentrator to be processed by the new algorithm.

![Synchronized sampling arrangement](image3)

Fig. 3: Synchronized sampling arrangement (CT – current transformer, VT – voltage transformer, CB – circuit breaker, SMU – synchronised measurement unit, DC – data concentrator

Algorithm Testing

In order to test the accuracy of the new algorithm, asymmetrical faults were simulated over a range of distances along a 100 km long 400 kV transmission line and the voltage and current phasors from each line terminal were used as inputs to the algorithm. The results are presented in Fig. 4; it can be seen that the algorithm accurately determined the location of each fault as a percentage of the total line length.

![Algorithm results](image4)

Fig. 4: Algorithm results

Conclusions

A new efficient settings-free numerical algorithm for fault location on overhead transmission lines is presented. The algorithm is based on synchronously measured voltages and currents sampled at both line terminals. The algorithm is derived in the spectral domain and based on the processing of voltage and current phasors. Through algorithm testing it was proved that the algorithm efficiently and accurately determines the fault location.
Multi-Stress Ageing Of High Temperature Insulation

Rui Rui

Introduction: in a number of applications such as aircraft starter generators, fuel cells and high power density machines, higher operating temperatures are being sought of insulation. High temperature insulations in use are normally under more than one ageing stress during the life of insulation, either simultaneously or sequentially. This work includes tests that have been carried out to examine the impact of some specific parameters including voltage, temperature and pressure on the long term behaviour of various forms of insulation including a ceramic insulation specifically designed for use at such temperatures.

Insulation Ageing Tests

Ageing from more one ageing factor, either gradually or at the same time, is denoted as multi-stress ageing. Under most circumstances, insulation degradation in windings is not dominated by one single stress. In this work, the following stresses have been investigated: thermal, electrical, ambient, mechanical stresses, the so called TEAM stress.

Aerospace Engine Environment

Figure 1: Engine electrical system. (The more electric engine, Mike Hirst, Rolls-Royce)

Figure 2: Engine harsh environment. (The more electric engine, Mike Hirst, Rolls-Royce)

Given the application of the insulation being tested, that of a More Electric Aircraft, the temperatures that have been used to carry out the testing are extremely harsh (as shown in Figure 1&2). The peak high pressure compressor air temperature used to cool an embedded machine within the high pressure spool would be at around 400°C. Therefore experiments will be conducted from room temperature to 500 °C to allow for the winding temperatures that will be higher than the ambient. Conventional windings would fail at this temperature and the Arrhenius rule would indicate a very short lifetime being available. Therefore, multi-stress tests are conducted on newly developed high temperature insulation.

Conclusion

It is the combination of different stress factors that affects the insulation ageing process. The impact of aerospace environment on machine insulation needs to be investigated through long term ageing tests. More results will be gained in future experiments.
Particle Effect on Breakdown Voltage of Transformer Oil

Xin Wang

Introduction

AC breakdown voltage tests are usually used for transformer oil quality check during routine operation. The oil quality, such as particle and moisture content, should be clarified when breakdown voltage test are applied. It found that the particle content sometimes has dominant effects on ac breakdown voltages, and the clean oil has relatively high breakdown voltage than oil contains more particle content in terms of different water content. This paper comparatively studied the breakdown characteristic of 3 types of transformer oil - mineral, synthetic ester and natural ester oil - in the forms of clean and relatively dirty ‘unfiltered’ oil.

Oil Sample Preparation

- Unfiltered oil: use oil from transportation
- Clean oil sample: filter oil through 0.2 μm membrane filter
- Dehydrate: <3% relative moisture content
- Degas: under vacuum condition overnight

Results

Clean and unfiltered mineral oil showed a significant difference in the breakdown voltage with different moisture content. The breakdown voltage distribution of ester oil indicated the similarity of mean breakdown voltage for all the oil. The comparison of oil's breakdown voltage should be made provided similar particle and moisture content.

Discussion

- The dielectric strength of both mineral and ester based oil increased significantly after particle removal.
- The ester based oil have comparable breakdown voltage with mineral oil but high deviation, indicating its unpredictability and probably higher change of breakdown at lower voltage.
- The breakdown voltage of unfiltered mineral oil drop sharply with the increase of relative moisture content, while the breakdown voltage of clean mineral kept almost steady within about 40 percents of relative moisture content. This indicates the necessity of a effective filtering in transformer oil filling process, in order to achieve a better oil breakdown performance with different relative moisture content.
Dynamic Equivalent Model of Distribution Network Cell Using Prony Analysis and Nonlinear Least Square Optimization

Samila Mat Zali and J. V. Milanović

Introduction

The aim of the project is to develop simple dynamic equivalent model of Distribution Network Cell (DNC) comprising various types of loads and distributed energy resources. The method used for model development is based on Prony analysis and Nonlinear Least Square Optimization using MATLAB software. The equivalent dynamic models of DNC are highly needed so that power system operators can estimate DNC impact on power system dynamic behaviour. The model should be able to account appropriately for the DNC dynamics seen by the external system through DNC interconnection. The main goal of dynamic equivalent model is to eliminate a part of distribution network to replace it by simple equivalent model which has the same dynamic characteristics. The detailed modeling of the whole DNC is not practical due to the size of the system and computational time constrain associated with dynamic simulations of large power networks.

The Estimation Procedure

The purpose of this proposed method is to represent the model of the response \( y(t) \) as a sum of an initial step, \( K \) and a damped sinusoid response. Therefore, the DNC responses are represented as follows:

\[
y(t) = [K + Ae^{\alpha t}\sin(\omega t + \phi)]u(t) \tag{1}
\]

where \( y(t) \) is active power response, \( K \) is the initial step, \( A \) is amplitude, \( \alpha \) is damping factor, \( \omega \) is frequency (in radian) and \( \phi \) is phase angle (in radians). The equation (1) is presented in MATLAB/Simulink as shown in Fig. 1.

![Fig. 1. MATLAB/Simulink representation of equation (1)](Image)

Initially, the PowerFactory DiGILENT software is used to simulate dynamic response of the network and the appropriate active power responses are recorded. A Prony analysis algorithm is written in MATLAB software and the active power responses are imported into MATLAB in order to obtain the parameters of (1). Once the parameters are derived, they are used as the initial values for the nonlinear least square optimization algorithm.

The estimation of parameters is performed using Simulink Parameter Estimation. The Simulink model shown in Fig. 1 is then used to obtain model responses with estimated parameters and to compare those with actual DNC responses. The accuracy of the estimation procedure is checked by calculating the Root Mean Square Error (RMSE) values. Once the parameters of the model are tuned the model is converted into transfer function form using the Laplace transformation.

DNC Structure

The DNC study system shown in Fig. 2 is broadly based on the UK 11 kV distribution network. In this system, the total installed local generation, i.e., generation connected at Bus 1 (see Fig 2) is equal to total load in DNC.

![Fig. 2 Single line diagram of the test network](Image)

The generation mix consisted of 85% of synchronous generators and 15% of renewable generation. The renewable generation included fixed speed wind turbines (modeled as conventional induction generators) and converter connected, photovoltaic, generation. The load mix consisted of 50% of static load (modeled as constant power load) and 50% of dynamic load (modeled as a mix of conventional small and large induction motors).

Case Study and Result of Simulations

The responses of active power to various small disturbances are measured at the point of connection (Bus 1). Only two types of disturbances are considered at this stage, namely small increase in DNC load and torque reduction of synchronous generator.

![Fig. 3. The comparison between the actual DNC response and response obtained with the equivalent model using estimated parameters](Image)

![Fig. 4. The equivalent model response (thick dashed line) with average value of parameters with all individual responses.](Image)

The generation mix consisted of 85% of synchronous generators and 15% of renewable generation. The renewable generation included fixed speed wind turbines (modeled as conventional induction generators) and converter connected, photovoltaic, generation. The load mix consisted of 50% of static load (modeled as constant power load) and 50% of dynamic load (modeled as a mix of conventional small and large induction motors).

Conclusion

Initial stages of development of the dynamic equivalent model of distribution network cell using Prony analysis and Nonlinear least square optimization are described in this paper. The model is intended primarily for the use in small disturbance stability studies of large distribution and transmission networks. The paper is primarily concerned with the estimation method to establish the deterministic model of reasonably complex DNC in a simple transfer function form. The results obtained so far are promising and they gave a significant confidence in applicability of the method for determining the dynamic equivalent of the DNC. The equivalent model developed is measurement-based rather than component-based as the exact composition and structure of DNC is generally not known.

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Accelerated Ageing of Insulation Surfaces Through Dry-Band Arcing

Mr. Xin Zhang

Introduction

The use of polymeric materials as replacements for ceramic outdoor insulation has become standard. If hydrophobicity is lost, substantial currents of the order of mA can result over the insulation surface, and this can lead to dry-band arcs and even flashover. The standard view is of gradual deterioration due to surface discharges with periods of dry-band arcing accelerating damage to the material surface. An alternative view is presented here, in which the dynamic nature of arcs between water droplets and between regions of wet insulator, leads to variation in arc length. It is shown that high mobility of surface water can lead to transient ‘arc-compression’ events which rapidly deteriorate the surface.

Experimental

- Dry-band arc is physically compressed in length following by the inclination of sample rod.
- The more inclined sample, the shorter arc length.

Simulation

A novel double sinusoidal model is used to simulate I-V curves during the dry-band arc compression.

- Pre-arching period (0 < t < t₁)
  \[ u_i(t) = \sqrt{2} U \sin(\omega t) \quad i_j(t) = 0 \]

- Arcing period (t₁ < t < t₂)
  \[ u_i(t) = U_0, \quad i_j(t) = \sqrt{2} I \sin(\frac{\pi}{t_0 + t_j}) ]\]

- Post-arching period (t₂ < t < 10 ms)
  \[ u_i(t) = \sqrt{2} U \sin(\omega t) \quad i_j(t) = 0 \]

Based on the estimated parameters applying on the double sinusoidal model, the I-V curves for dry-band arc compression with variable arc lengths can be simulated by:

- \[ i(t) = 1.095 \sin(0.408(t-1.12)) \]
- \[ i(t) = 1.095 \sin(0.408(t-1.12)) + 1.095 \sin(0.408(t-2.25)) + 4.35 \sin(0.408(t-3.88)) + 4.35 \sin(0.408(t-3.88)) \]

Energy Calculation:

The simulation result agrees with the experimental result that the more compressed arc with shorter length will generate more arc energy in every half cycle.

Conclusion

Both experimental and simulation work show that dry-band arc compression reduces the length of the dry-band, and increases the energy of the arc. As a result, processes controlling insulation lifetime may not be continual and gradual, but are determined by rare events such as the occurrence of dry-band arc compression.
Ageing Transformer Management: Statistical Approach and Physical Ageing Process

Miss Qi Zhong

Introduction

Majority of National Grid’s transformer assets are approaching their designed end-of-life. Accurate prediction of the remaining life is of major importance for replacement policy. Traditionally-employed statistical approach requests to be enhanced with physical ageing process models, in order to compensate the lack of ageing related failure data.

- Statistical analysis are made on National Grid’s transformer installation and failure records.
- The lowest DP (degree of polymerisation) value of paper obtained from scrapped transformers is used to evaluate its thermal life.
- This information is then used to predict the thermal end-of-life of any identical transformers still in service.

National Grid Statistical Analysis

- Many transformers are approaching their designed end-of-life.
- Recorded failure data only indicate historical random failures.

End-of-life Prediction based on Understanding of Ageing Process

- Degree of polymerization (DP) indicates cellulose molecular chain scission due to ageing, DP reduction against age is given as
  \[
  \frac{1}{DP} - \frac{1}{DP_0} = kt
  \]
  where \( k \) is the ageing rate, new paper \( DP_0 = 1000 \), and 200 represents the exhausted paper.
- Scrapped transformer thermal end-of-life is evaluated by its obtained lowest DP.

Table 1: Transformer Predicted Thermal Lifetime and Standard Deviation

<table>
<thead>
<tr>
<th></th>
<th>Weibull</th>
<th>Lognormal</th>
<th>Gamma</th>
<th>Skew normal</th>
<th>Arithmetic</th>
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<tr>
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<td>116</td>
<td>108</td>
<td>117</td>
<td>110</td>
<td>119</td>
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<td>Std</td>
<td>87</td>
<td>83.31</td>
<td>83.2</td>
<td>84.208</td>
<td>86.79</td>
</tr>
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</table>

- Table 1 shows large discreteness of the predicted thermal life.
- Discreteness reflects the variance of hot-spot factors and operating conditions in the scrapped transformer population.
- Lifetimes of active transformers can be suggested by the scrapped transformers with identical design, and only 19% of active transformers’ lifetimes are able to be predicted in such a way.

Conclusions

- Traditional statistical analysis of the transformers failures cannot be used to predict the age related transformer end-of-life.
- Scrapped units represent 19% of active transformers in design. Hence the lifetime of 81% of active transformers need to be predicted by other approaches.
- Other failure modes need to be considered, besides thermal end-of-life.
Huygens Subgridding with Filtering for Finite-Difference Time-Domain Method

Maksims Abalenkovs

Introduction
- Building prototypes to verify electromagnetic (EM) characteristics of an object is expensive.
- Engineers use numerical methods to simulate EM wave propagation on computers.
- Finite-Difference Time-Domain (FDTD) is one of widely applied numerical schemes to approximate Maxwell’s Equations.

Motivation
- Current electromagnetic problems are characterised by:
  - large problem size
  - fine geometry
  - variety of dielectric materials.

Research Objective and Focus
- Provide an efficient Maxwell’s Equations Solver capable of incorporating dielectric material properties and fine object geometry.
- This project focuses on:
  - Huygens Subgridding (HSG) application to increase computational efficiency of FDTD
  - Filtering to suppress late-time instabilities of HSG.

Huygens Subgridding Principles
Huygens Subgridding is a novel algorithm with the following unique properties [1]:
- Interface is implemented via Huygens Surfaces and produces little reflection.
- Influence from coarse to fine (a → b) and fine to coarse (b → a) grid is passed with equivalent currents.
- Temporal advancement scheme is the synchronised multistep: $x_{a} = x_{b} + \Delta x_{b}$.
- Subgridding ratios for spatial and temporal domains are equal: $r = \frac{\Delta x_{a}}{\Delta x_{b}}$.

Filtering
- All HSG simulations suffer from instabilities [2].
- Frequency of instability equals to transition frequency of travelling to evanescent waves:
  \[ \frac{1}{2 \pi} \text{Im} \left( \frac{1}{\text{freq}_{\text{inst}}} \right) \]  
- Filters absorb unstable frequencies of $k_{\text{abs}}$ and preserve the frequencies of interest $f$.
- Filters work as averaging functions and are applied to equivalent currents in IS:
  \[ F_{\text{filter}}(k_{b}) = \frac{\text{exp} \left( \frac{\text{freq}_{\text{inst}} \Delta t}{2} \right)}{\text{exp} \left( \frac{\text{freq}_{\text{inst}} \Delta t}{2} \right) + 1} \]

Algorithm 1: HSG Pseudocode. Algorithm consists of two symmetric parts. Electric and magnetic fields are denoted as $E, H$ and polarisation currents as $q$. Supervisor: Dr. Costen.

Verification Results
- Materials absorb part of the signal and delay the instability occurrence.
- HSG with $r = 3$ executes 8 times faster than any fine grid FDTD.
- Since filtering is done at every time step, it increases the computation time by 4.2% (Filter 15) and 20.5% (Filter 35).
- HSG uses approximately 5.5 times less memory than FDTD.

Summary
- HSG was successfully applied to FDTD and extended to three dimensions.
- HSG provides an efficient Maxwell’s Equations solver capable of fine geometry representation.
- Filtering was implemented to suppress late-time instabilities of HSG.
- Filter 33 shows the best instability suppression properties:
  \[ T_{\text{total,inst}} = 5200 \]  
  \[ T_{\text{total,inst}} = 1500 \]  
- Future work will focus on HSG parallelisation and further improvement of HSG stability.

Bibliography
Lifetime Analysis of Cooperative Ad-hoc Sensor Networks
Junaid Ahmed

Introduction

In ad-hoc sensor networks cooperative diversity refers to the diversity that is achieved by nodes by helping each other in their transmissions. This method of transmission has shown to display lower probability of error, higher data rate and larger coverage area. In ad-hoc sensor networks power consumption is an important topic as in most cases it determines the lifetime of a network itself. In cooperative ad-hoc networks the power at which the source and relay nodes transmit can be dynamically calculated and adjusted to increase battery lifetime and hence the lifetime of the whole network. We shall analyse three different ways of calculating this power and compare them with the non cooperative system.

Ad hoc Sensor Networks

Ad hoc networks are the networks that do not have a specific structure. They are made up of nodes that happen to be in the vicinity of each other without any pre planning or organization for either a short period of time or permanently. Nodes communicate with each other and help each other to communicate outside their immediate neighbourhood.

Applications

Disaster Recovery
Battlefield Surveillance
Assistance for Elderly
Traffic Avoidance
Environmental Monitoring

Cooperative Networks

In cooperative communication multiple single antenna entities work together to transmit/receive the data from/to one entity; in other words a single antenna entity tries to use the antennas of its surrounding entities to emulate a single multiple antenna system for both transmission and reception. In a cooperative network the power at which a source node and a relay node transmit can be variable depending on the channel condition and residual energy in the node.

Lifetime Analysis

Lifetime of a network is the time at which the first node within the network drains out of power. We study lifetime with three different power allocation strategies and compare it to non-cooperative networks. The three strategies are:
- Both channel and residual energy are considered
- Only channel condition is considered
- Only residual energy is considered

Conclusion

The lifetime of an ad hoc sensor network can be increased by nodes cooperating with each other to transmit data. The cooperation should be controlled such that both the channel condition of the node as well as the residual battery life of that node should be considered in deciding the power allocation.
pHEMT and mHEMT considerations for ultra Low Noise Amplifiers for the Square Kilometer Array

Mr Saswata Bhaumik

Introduction

SKA, to be the largest telescope in the world, will investigate the evolution of black holes as well as the basic properties, birth and death of the universe. The telescope plans the installation of close to 1 million Low Noise Amplifiers with power budget of maximum 50mW per LNA. The power efficiency of state-of-the-art 150nm gate length GaAs pHEMT, 150nm InP phEMT and 70nm GaAs mHEMT for LNA to be used in SKA have been studied. The study shows that the 70nm GaAs mHEMT displays the highest normalized gm of more than 1.4S/mm at 0.1W/mm power consumption and also the potential of delivering superior noise figure. Since the physical temperature of both proposed sites of SKA in Australia and South Africa [1] is expected to vary over a wide range a temperature dependent analysis has been done.

LNA Power Consumption for minimum noise and maximum gain

In a multistage LNA design, the primary focus of stage 1 is to achieve minimum noise figure in accordance with Friss’ noise equation. The main objective of the subsequent stages is to maximize the gain and stabilize Friss’ noise equation. The main objective of the LNA. The minimum noise bias for a HEMT has been presented after normalization to millimeter. The drain current bias of the three foundries have been chosen to be 0.75 V, 0.75 V and 0.4 V respectively to ensure that the rate of change of peak gm of the transistor saturates beyond these chosen Vd and the bias points are in the saturation region of the I-V characteristics.

Temperature dependency of the HEMTs

A comprehensive picture of the temperature dependence of transistor biases to achieve peak gm has also been shown. The physical temperature of the devices has been varied between -50°C and 60°C to carry out the experiments. Figure 4 shows the change in the response of the transistors of foundries 1 and 2. The normalized Id has been kept constant at 43mA for 0.75V drain bias voltage. The normalized g_m of both the foundries increases with lower temperatures. The gradient of g_m of foundry 2 is greater than that of foundry 1. The transistors of foundry 3 have shown a very distinct shift of transconductance curves towards positive values on the Vgs scale with temperature. Figure 4 conclusively shows that, at peak gm and constant Vds, Vgs of the transistors increases when the devices are cooled down. But the drain also current changes significantly.

Conclusion

Foundry 3 displays the potential to deliver best noise and gain performance at a much lower power consumption. Table 1 summarizes estimates for a single LNA for SKA. The temperature dependence of device performance concludes that at lower temperature better performance is obtainable. As a part of future work, more investigation must be done into the trend of behavior of the 70nm mHEMTs with temperature. Adaptive LNA designs, dependent on temperature, should be investigated to avoid the change in performance on time frame.

References


**Introduction**

As the demand for higher data rates and improved capacities in future wireless systems increases, the research has moved into the direction of MIMO systems to exploit the spatial diversity aspects offered by them. Unfortunately due to size and complexity limitations on the mobile units, equipping them with multiple transmit/receive antennas is practically unrealistic. The idea of uplink user cooperation/pairing has led to much improved performance and overcoming the limitations of the mobile units.

**Conventional User Pairing**

- Active users are paired together for cooperation.
- One unique spreading code/user.
- Users detect their partners symbols.
- Detected Symbols are forwarded to base station.

**Proposed Pairing Technique:**

- One spreading code/pair.
- Users are divided into two groups and then are paired.
- Pairs communicate on unlicensed frequency channels.
- Uplink transmission using a QPSK like constellation table.
- Constructive interference at base station.

**Code Allocation**

- Orthogonal polyphase spreading codes exhibit very good asynchronous cross-correlation properties.

\[ CC_q(i) = \sum_{j=1}^{Q} c_j^*[q]c_j[N+i] \]

- The first allocated code is the one least correlating with all the available codes.
- From their on allocation is based on the code that least correlates with the codes which are already in use.

**Results**

- Performances in a 3 path fading asynchronous channel before (top) and after (bottom) code allocation.
- Double Capacity performance in a synchronous flat fading channel (top) and a synchronous 3 path channel.
Low Complexity Scheduling Algorithm for Multiuser Multiple-Input Multiple-Output Downlink System

Lina Jin

Introduction

Multiuser MIMO (MU-MIMO) has a potential to meet the demand of serving multiple users simultaneously in a wireless system with a large number of users. However, a highly complex combination of precoding, feedback, scheduling scheme would be needed to cancel the inter-user interference and achieve high system sum-rate capacity. A new scheduling algorithm with low complexity for user selection is proposed for a MU-MIMO downlink system based on block diagonalization (BD) precoding. The algorithm is a suboptimal scheduling strategy which can significantly reduce the computational effort in comparison with optimal scheduling algorithm, such as Dirty Paper Coding (DPC), although the suboptimal scheduling strategy undergoes a few bps/Hz penalty of the system throughput.

System Model

Fig. 1 shows a typical MU-MIMO downlink system. The assumption for a MIMO system with K users are:

- One base station with M antennas and K receivers with each receiver equipped with N_k antennas.
- Perfect channel state information at the transmitter and the receiver.
- Block Diagonalization (BD) precoding is applied.
- Number of users K is greater than or equal to number of transmitter antennas
- The channel matrix H_k for user k with each entry following an i.i.d. complex Gaussian distribution CN (0,1).

Low complexity volume-based user selection algorithm

The details of the novel algorithm are as follows:

- Defines the channel volume as the product of diagonal elements of an upper-triangular matrix R by performing QR factorization to a channel matrix.
- The volume metric is used for user selection.
- The rule of the algorithm is to select a subset of users whose channel matrix provides maximum volume in a subspace spanned by the row vectors of the channel matrix.

Conclusion

Fig. 2 presents the simulation result for a MIMO 4x2 system.

The benefits of the proposed algorithm are:

- Offering very good sum-rate in comparison with the optimal DPC scheduling algorithm.
- Achieving an equivalent performance provided by other suboptimal scheduling algorithms, such as the capacity-based algorithm and the SUS algorithm.
- Having the lowest computational complexity in the category of the suboptimal scheduling algorithm.
Application of Metamaterial Resonator in Filter Design

Shokrollah Karimian

Introduction

It has been revealed that one of the main advantages of employing Left-handed (LH) transmission line (TL) is that it can significantly reduce the size of passive components due to its dispersive phase properties. It has also been known that amongst the existing TL resonators (TLRs), stepped impedance resonator (SIR) has proven to be very suitable candidate for reducing resonator size, while capable of controlling spurious frequencies by design.

Combining the distinctive characteristics of SIRs and the unique properties of LH MTMs, a novel resonator is designed and presented for the first time to be employed in Wireless Local Area Network (WLAN) applications. The architecture of WLAN is depicted in Figure 1.

Configuration of the $\lambda_g/4$-type SIR

The SIR can be designed by cascading two transmission lines of different impedances $(Z_i)$ and electrical lengths $(\theta_i)$ terminated by either short or open circuit load. Figure 3 shows the fundamental element of short circuited SIR (i.e. a $\lambda_g/4$-type).

$$Z_n = jZ_i \tan \theta_i + Z_i \tan \theta_i \tan \theta_i$$

Aims and Objectives

The main objective of this research work is to design and develop a WLAN front-end receiver subsystem utilising LH Metamaterials for miniaturisation and performance enhancement purposes. In doing so, a LH $\lambda_g/4$-type SIR is designed, to resonate at 2.1 GHz, based on periodically loading TLs using series capacitance and shunt shorted inductance.

The novel LH SIR will then be developed to form a filter as a subsystem of the WLAN front-end receiver building block, seen in Figure 2.

SIR Layout & Simulation Results

The $\lambda_g/4$-type SIR is fabricated on Rogers RT/duroid 5880 substrate with dielectric constant $\varepsilon_r = 2.2$ and thickness $h = 1.57$ mm (loss tangent = 0.0009). Its layout and simulation results are shown in Figure 4.

Conclusion

A microstrip $\lambda_g/4$-type LH SIR is presented to resonate at 2.1 GHz for WLAN applications. This novel SIR is not only 48% smaller in length than its conventional counterpart, but also benefits from a much better performance.
Small Array Pattern Optimization using Particle Swarm Optimizer

Asim Ali Khan

Introduction

In antenna array systems pattern synthesis has vital importance. The term pattern synthesis is widely used for pattern shaping (includes sidelobe level control), pattern null position control etc. The study is focused on small uniformly spaced arrays with non uniform taper (weights) particularly for sidelobe level (SLL) optimization. For linear array Schelkunoff’s unit circle approach is used to find out the optimum weights for low sidelobe patterns. The technique is extended to sum and difference patterns. The PSO performance is compared with conventional Taylor distribution, Elliott’s root matching and the Bayliss distribution. This approach is then used to investigate wideband arrays in the presence of mutual coupling for scanning applications.

Particle Swarm Optimizer (PSO)

The PSO is now very widely used optimization algorithm. This algorithm is based on the intelligence of the swarm. Consider a swarm of bees. Their objective in a field is to find a place with highest concentration of flowers. Swarm is considered to have no prior knowledge of the field. Each member of the swarm is capable of remembering the location found with abundance of flower. The swarm can also share the locations found by other members. Now each bee in the swarm has its own best location and the best location found by the group. This information effects the acceleration of a bee in a particular direction. Each bee adjusts its velocity to achieve the best location. This process continues until they achieve their objective

Methodology

Pattern nulls across the unit circle have been manipulated by using PSO to obtain the desired results

Results

Results have been presented for wideband operation in the presence of mutual coupling

Wideband array pattern after compensating for coupling scanned to -30° and SLL constrained to -30dB

Wideband performance comparison for -30°

Conclusion

It is shown in this work that PSO can be used as an efficient and robust tool to improve the wideband performance of the linear array system without any a priori knowledge of coupling properties. The low SLLs were obtained in the presence of mutual coupling while scanning the main beam over a range of frequencies with in +2dB tolerance. It was shown that the optimized complex weights show better bandwidth performance as compared to the Taylor current distribution in the presence of mutual coupling.

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Supervisor(s): Prof. A. K. Brown
SKADS Low Noise Amplifier Design

Mina Panahi

Introduction
Square Kilometre Array Design Studies, “SKADS”, is an international project under investigation and development of building a radio telescope with a collecting area of a million square meter and cost constraint of 1.5 billion Euros.

One of the various undergoing verification programmes in SKADS is 2-PAD (Dual-Polarization All Digital phased array) which covers the frequency range of 0.3-1GHz.

2-PAD system consists of two fully operational tiles and another ten dummy tiles for effective system tests. Fully functional tile would enable the testing of several important aspect of SKA [1]. Fig. 1. shows a block diagram of a differential input and single ended low noise amplifier which was designed for the front end of the 2-PAD project.

Differential Input and Single -Ended Amplifier Design
A Low Noise Amplifier (LNA) with two stages was designed in Advanced Design System (ADS). This LNA operates in the frequency range of 0.5 to 1 GHz. This LNA has a 150 ohm differential input to match the antenna impedance before the LNA and a 50 ohm single ended output. Simulated S-parameters of the designed differential LNA is illustrated in Fig. 2.

According to the simulated S-parameter responses for this amplifier (Fig.2), the input return loss is less than -10dB between 0.5 to 0.8 GHz. Gain produced by this amplifier varies between 32.5dB to 26dB over the frequency range of 0.5-1GHz. NF is less than 1dB up to 0.9GHz.

Noise Measurement
Characterizing the differential input and single ended LNA is a challenging process for 2-PAD project. S-parameter responses characterizing of the designed LNA can be measured by a four port VNA but the noise measurement is more complicated due to the lack of well established method.

Therefore, a model in HFSS has been designed as shown in Fig.4 and Fig.5 [2]. It consists of stainless steel cylinder filled in with Teflon and two copper wires. The 50 ohm impedance of the system is defined by the separation between the copper wires using the equation of:

$$Z_0 = \frac{\eta}{\pi} \left[ \ln \left( \frac{1 + q^2}{1 - q^2} \right) - \frac{1 + 4q^2}{16q^2} \left( 1 - 4q^2 \right) \right]$$

The prototype of the noise measurement model has been built as shown in Fig.6.

The ratio of the hot and cold power is defined as Y-factor. Then noise can be measured by the hot and cold load method from the Y-factor.

$$T_e = \frac{T_{\text{hot}} - T_{\text{cold}} Y}{Y - 1} \quad Y = \frac{P_{\text{hot}}}{P_{\text{cold}}}$$

Noise tests would be carried out by using the manufactured noise measurement model which is shown in Fig.6. One of the differential end of this model would be connected to the differential input of the designed and manufactured LNA by using the hot and cold load method explained above.

Conclusion
An amplifier design with differential input and single ended output has been described and the simulated RF performance is shown. A method for measuring the noise of differential amplifiers was explained.

References
Left-handed Microstrip Delay Line using Complementary Split Ring Resonators

S.Pasakawee and Z.Hu

Introduction

The use of left-handed metamaterials (MTMs) which provides negative values of permittivity and permeability can increase the time delay of a popular media such as a microstrip line, resulting in planar circuitry simple and compatible in many new microwave circuit applications. This can be achieved by including Complementary Split Ring Resonators (CSRRs) in such circuits, i.e., CSRR left-handed microstrip transmission line [1]. In this paper we demonstrate that a CSRR left-handed microstrip line can provide significantly more time delay than that of a conventional microstrip line for the same length. In other words, for the same time delay, CSRR left-handed microstrip line will be much shorter than that of a conventional one.

Experimental Results

• The lower and higher cutoff frequencies of the CSRR transmission line are approximately 2.3 and 2.6 GHz.

CSRR Model and Equivalent Circuit

• A CSRR can be modelled as a lump elements of L and C
• C’g and L represent the microstrip line with a gap.
• C’c and L’c are the model of the Split ring.

6 and 12 cells of CSRRs

Front View

Back View

Conclusion

• Left-handed microstrip delay line implemented by CSRRs has been designed, fabricated and tested.
• The left-handed microstrip CSRRs can realize much longer delay in time as compared with a conventional transmission lines for the same length.
• 12-cell using CSRRs provide the highest delay of 16 ns while a conventional line can only offer the delay at only 6 ns.
• The much needed delay properties with compact size of the line will lead to application of phase array radar systems.

References

60GHz wideband folded dipole antenna in high impedance electromagnetic surfaces cavity

Miss Ying Peng

Abstract- In this paper, a 60GHz half wavelength folded dipole antenna in high impedance electromagnetic surfaces surrounding cavity based on standard CMOS technology is proposed. With the use of this high impedance electromagnetic surfaces made cavity, the antenna bandwidth obtained a 2GHz enhancement. At the same time, the antenna gain was increased 1dB and the back lobe was well eliminated.

Introduction

In 2001, the Federal Communications Commission (FCC) allocated 7 GHz in the 57–64 GHz band for unlicensed use. Substantial knowledge on 60-GHz millimeter-wave (MMW) channel has been accumulated for commercial applications. In order to make full use of this frequency range on the wireless communication network, recent antennas are designed mainly focus on wideband, compatibility and efficiency. Due to its fast speed and low noise implements, dielectric materials like GaAs, SiGe and InP are widely used in design. Whereas, an easier integratable and cheaper technology is CMOS.

A folded dipole antenna is easily assembled for its planar structure. It also has wide bandwidth due to the folded element at its both ends. Investigation is made by putting the folded dipole antenna into a metal cavity and a high impedance electromagnetic surfaces surrounding cavity. Comparison of bandwidth, gain and radiation pattern directivity was made out in this paper as well.

High Impedance Electromagnetic Surfaces

This type of metallic electromagnetic structure forms a character of high surface impedance. Fig 1-(a) shows the top view of a hexagonal metal plate. A lattice of metal plates are connected to a metal sheet via vertical metal columns through the center of each unit.

This structure has a high impedance surface so that it prevents the wave from flowing along the metal structure.

Design and Result Comparison

Fig.2 shows three design structures, (a) a simple folded dipole antenna lying on the CMOS substrate, (b) a folded dipole antenna lying below the substrate and suspending inside a metal cavity, (c) a folded dipole antenna lying below the CMOS substrate and suspending inside a cavity building with high impedance electromagnetic surfaces.

(a) (b) (c) Fig.2

Here Fig.3 shows the bandwidth of two different cavities. In 3-(a) the bandwidth is 6GHz (VSWR<-2dB), while in the high impedance electromagnetic surface cavity where 3-(b) shows, the bandwidth is increased up to 8GHz from 58GHz to 66GHz.

Fig.3

(a) (b) (c) Fig.4

Fig.4 gives the radiation pattern results of antenna gain. It clearly presents that in (a) simple antenna with substrate, antenna has poor gain. Gain is increased to 6dB in (b) with metal cavity. However in (c), the high impedance electromagnetic surfaces cavity, the antenna gain exceeds 7dB and the radiation pattern is more directivity.

Conclusion

The high impedance electromagnetic surface cavity is investigated to apply into the 60GHz antenna design and give a better performance in bandwidth, gain and radiation efficiency. It also reduce the interaction between the antenna and its back surrounding devices.
Multiple HARQ Processes for MIMO Multi-hop Systems
Mr Imran Rashid

Abstract
• MIMO (multiple-input multiple-output) systems use multiple transmit and receive antennas to achieve higher data rates by transmitting multiple, independent data streams.
• To improve the coverage multi-hop relay systems can be used in conjunction with MIMO.
• Transmission errors can be reduced by using Hybrid Automatic-Repeat-reQuest (HARQ) which requests for retransmission of erroneous packets and combine it with the erroneous packet.
• Combining the HARQ techniques with MIMO Multi-hop systems have been investigated in this research and significant improvement in the data throughput as compared to a single-hop system is achieved.
• MIMO Transmission

Multiple HARQ Processes
• Multiple transmit and receive antennas are used with Layered Space time architecture.
• As data is sent through multiple streams, errors could occur in some of the sub-streams, while other are correct.
• Instead of having error checking for each packet, MIMO Multiple-stream ARQ (MMARQ) has independent error checking for each individual sub-stream.
• Only erroneous sub-streams are considered for a retransmission.
• This scheme provides an advantage of better throughput because un-necessary re-transmissions of correct sub-streams are not carried out.

Multiple HARQ Processes for MIMO Multi-hop Systems
• Combining the HARQ techniques with MIMO Multi-hop systems have been investigated in this research and significant improvement in the data throughput as compared to a single-hop system is achieved.

Multi-hop MIMO Systems
• A relay node is introduced in the system to improve throughput.
• Sub-streams are only forwarded to the next hop, if they are correctly received at the relay station.

Conclusion
• The throughput results indicate performance improvement in the throughput of Multi-hop MMARQ as compared to Single-stream and single-hop systems.
• Delay Analysis highlight that by using higher modulation scheme, delay of Multi-hop MMARQ can be reduced and it becomes even smaller than single-hop as the value of path loss index becomes higher.

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Supervisor: Dr D. K. So
Introduction

A new three-dimensional frequency dependent Crank Nicolson Finite Difference Time Domain (FD-CN-FDTD) scheme has been proposed. Frequency dependence of single-pole Debye materials has been incorporated into CN-FDTD by means of an auxiliary differential formulation. The scheme can maintain its stability beyond Courant-Friedrich-Lewy (CFL) limit which restricts the computational efficiency of conventional explicit FDTD.

FD-CN-FDTD Scheme

Maxwell’s equations:

\[ \nabla \times E = -\frac{\partial H}{\partial t} \quad \nabla \times H = \frac{\partial D}{\partial t} \quad B = \mu_0 H \]

For dispersive media according to single-pole Debye model

\[ D = \varepsilon_0 (\varepsilon_{\infty} + \frac{\varepsilon_s - \varepsilon_{\infty}}{1 + j\omega\tau_D} - \frac{j\sigma}{\omega\varepsilon_0}) E \]

\[ \varepsilon_s = \text{static permittivity}, \quad \varepsilon_{\infty} = \text{optical permittivity}, \quad \tau_D = \text{relaxation time}, \quad \sigma = \text{conductivity} \]

By mapping \((\omega\tau_D)^n\) (in frequency domain) into \(\frac{\partial\varepsilon}{\partial t}\) (in time domain) the above equation yields

\[ \frac{\partial^2 D}{\partial t^2} + \frac{\partial D}{\partial t} = \varepsilon_0 \varepsilon_s \tau_D \frac{\partial^2 E}{\partial t^2} + (\varepsilon_0 \varepsilon_s + \sigma \tau_D) \frac{\partial E}{\partial t} + \sigma E \]

Applying Crank Nicolson method and manipulation of the resultant discretised equations gives

\[ E_{x,n+1} = \xi_1 E_{x,n} + \xi_2 E_{x,n+1} + \xi_3 D_y \frac{\partial E_y}{\partial x} + \xi_4 D_z \frac{\partial E_z}{\partial x} \]

\[ E_{y,n+1} = \xi_1 E_{y,n} + \xi_2 E_{y,n+1} + \xi_3 D_x \frac{\partial E_x}{\partial y} + \xi_4 D_z \frac{\partial E_z}{\partial y} \]

\[ E_{z,n+1} = \xi_1 E_{z,n} + \xi_2 E_{z,n+1} + \xi_3 D_y \frac{\partial E_y}{\partial z} + \xi_4 D_x \frac{\partial E_x}{\partial z} \]

where \(\xi_1, \xi_2, \xi_3, \xi_4, \xi_5, \xi_6\) are space dependent

Permutation of \(x, y\) and \(z\) gives the remaining two E-Field equations which result in a system of linear equations \(Au=b\) with \(A\) being extremely large and highly sparse. All the remaining field quantities are found in an explicit manner from the electric field. Mur first order boundary conditions were used in FD-CN-FDTD

Numerical Results

To validate the scheme a computational space as shown below was considered in which the source was a z-directed dipole with a modulated Gaussian pulse centred at 3GHz. Spatial sampling was uniform: \(10^{-3}\)m. As a reference observation was taken using standard frequency dependent FDTD. Time step was varied based on \(CFLN = \Delta t_{CFL}\) where \(\Delta t_{CFL}\) is the maximum time step allowed by CFL condition.

Memory and CPU time requirements: A direct algorithm was used to solve the sparse system. CPU time required for LU decomposition was 633 minutes and average CPU time per iteration was 6.489 seconds when \(CFLN=1\) on dual AMD Opteron 280 with 8 GB of memory. When homogeneous material of only media 1 was used or when \(CFLN>1\) there were no significant differences in these values. 2.4 GB of memory was required.

Conclusion

Although results from Gaussian elimination based sparse direct solver is shown here application of different iterative solvers to identify the most efficient solver has also been performed. Bi-conjugate gradient stabilized (Bi-CGStab) is found to be the opt-solver for FD-CN-FDTD. Future works include using the scheme in applications like interaction of electromagnetic waves with frequency-dispersive human body model.

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Supervisor(s): Dr F. Costen
Multiband OFDM (Ultra Wideband) Performance in a Field of Generic Interferers

Rashid Saleem

Introduction

Ultra Wideband has enabled the revolutionary concept of a high speed Wireless Personal Area Network (WPAN) and Wireless USB. It employs either MB-OFDM or DS-CDMA radio, with MB-OFDM being more accepted. The MB-OFDM operation spectrum is conventionally divided in 14 sub-bands, each having a bandwidth of 528 MHz and can achieve data rates starting at 110 Mb/s at a radius of 10 m and going as high as 480 Mb/s at a radius of 2 m (typical of WPAN).

The performance of Multiband OFDM link in the presence of generic interference is investigated. Sources of technology specific potential interference include WiMax and Wireless LAN apart from ubiquitous cellular systems. Interference is assumed to be produced by a field of generic interferers located spatially according to Poisson distribution. We derive its overall probability density function, PDF, to find the exact Bit Error Rate (BER).

Interference PDF

As the Moment Generating Function \( \phi(t) \) is the Laplace Transform of interference plus noise PDF, \( f(x) \)

\[
\phi(t) = \int_0^\infty e^{-tx} f(x) dx
\]

We derive the MGF through rigorous mathematics as

\[
\phi(t) = \frac{1}{\sqrt{1+4t/(\lambda^2\pi)}}, \quad \lambda^2 = \frac{\lambda^2}{\pi}
\]

Inverse Laplace Transform yields the required PDF as

\[
f(x) = \frac{\lambda^2}{2\pi x} e^{-\frac{\lambda^2}{2\pi} x^2}
\]

This PDF falls into the category of heavy-tailed distributions.

General Bit Error Rate

BER for MB-OFDM carrier under interference is therefore,

\[
P_{\text{BER}} = 1 - e^{-\lambda A}
\]

BER under noise only is

\[
P_{\text{BER}} = 1 - 2\text{erfc}\left(\frac{\sqrt{\lambda}}{2}\right)
\]

MB-OFDM systems operate in different sub-bands such that a sub-carrier group may be inside interference plus noise or noise only sub-bands. Therefore for a system with total \( N \) bands, experiencing interference in \( n \leq N \), the final general BER expression from equations 1 and 2 is

\[
P_{\text{BER}} = \frac{n}{N} P_{\text{BER},1} + \frac{N-n}{N} P_{\text{BER},2}
\]

Error Performance Comparison of MB-ODM under the affect of varying spatial density of DS UWB and Generic Interference

Conclusion

Performance of Multiband OFDM under the influence of generic or non-specific interference has been demonstrated. Bit Error Rate as a function of source spatial density has been derived keeping in view the band hopping characteristics. According to the simulated results, for certain spatial density conditions, the performance of the link is more realistic than that shown under previously published correlation based models.
Development of Automated Condition Monitoring Robots for High Voltage Equipment

Mr Chithambaram A. Veerappan

Introduction
In today’s society there is an increasing demand for electrical energy. To avoid unnecessary power cuts, it is important that equipment in the network is regularly monitored for early signs of potential failure. Monitoring can take a number of forms, requiring either low data rate or high data rates. Short term, this involves the streaming video and data to an operator working at a safe distance. Longer term, data will be stored over time and collected periodically wirelessly.

Mechanisms of Interference
High field strengths should not affect radio transmissions directly. Even if the antenna is exposed to a high field, the data signal is superimposed so should still be recoverable. Partial discharges are more complex however, as it is a known that they produce radio energy at varying frequencies. Moore, Portugues & Glover [1] have shown that the RF energy generated by partial discharges can be used to locate faults in electricity substations; although it is indicated that radio frequency energy decreases as the frequency approaches 1 GHz.

Target Application
One part of the electricity supply system is the transmission network. One task is to examine the insulators (left) for damage. Currently performed from ground level or helicopter, neither provides the quality of visual assessment from a distance of a few centimetres. The aim: to develop a robot, which can
  • traverse a live insulator string
  • send live video of the insulator

Operating Problems
When operating near high voltage equipment, high field strengths and partial discharges need to be considered. High field strengths can cause large potential differences to develop across parts of electronic circuits, creating unintentional spark gaps. Measuring apparatus and mechanical components in the field can increase the localised field, possibly causing further breakdown and corona discharge.

Future Development: Extended Measurements
While the 500 kbps data rate assessed can be used for low resolution video, higher bandwidths are needed to offer a more realistic solution. A link of this type will be formed using an ARM based mini-computer with a consumer wireless LAN adaptor as the transmitter and a laptop as the receiver. An application, such as Kismet will be used to collate statistics about the link under high voltage conditions.

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A Long-Range Bi-directional HF Modem

John Wilson

Introduction

The aim of this project is to develop a battery powered high-frequency (HF) band modem for long distance communications (hundreds or thousands of kilometres). The link is to be bidirectional, but it is assumed that the link from the modem to the mains-powered base station (primary link) will require the highest throughput. The link from the base station to the device will be used for simple commands and acknowledges (ACKs). HF links are generally poor channels with unique challenges and necessitate designing for very low SNR. This poster describes the main areas of research focus in the project.

Forward Error Correction

To protect against errors at the receiver from noise and interference caused by the channel, redundancy is added to the signal by encoding the outgoing data. This is referred to as forward error correction (FEC). The effect is to spread the energy of a source bit widely throughout the transmitted signal, which also helps to protect against fades and erasures from the channel.

Low density parity check (LDPC) codes are high performance FEC codes based on sparse bipartite graphs (fig. 1). They are used in the forthcoming DVB-2 and WiMax standards. Decoding is performed at the receiver by an iterative maximum likelihood (ML) algorithm. LDPC will be used in the proposed modem for FEC in the primary link.

Fountain codes are also based on sparse graphs and are similar to LDPC codes. An individual code word can be an arbitrary number of bits down to one and decoding requires the collection of enough code words at the receiver to rebuild the original information. These codes were designed for the erasure channel, but we are investigating them as extra data for the receiver’s LDPC decoder as a HARQ technique.

Automated Repeat Request

Automatic repeat-request (ARQ) is a method of error control where a request is made for the transmitter to resend any corrupt received data. They range from simple ACK/NAK techniques to more sophisticated techniques where only portions of a received packet are requested. ARQ is commonly used in TCP/IP to ensure integrity of received data. The combination of ARQ and FEC is referred to as Hybrid-ARQ (HARQ).

We are investigating the performance of sending Fountain coded data in place of conventional repeats in an LDPC coded system. Performance is, at this early stage, looking promising. Fig. 2 compares throughput performance of reliability-based RB-HARQ and our Fountain coded FC-HARQ.

Channel Equalization

Channel equalization seeks to correct changes to the signal induced by the HF channel model, including in phase, frequency and reduction of multipath interference. Often the channel is represented within an equalizer as an FIR filter, and the algorithm convolves its inverse with the received data.

We are researching the possibility of using blind turbo equalization in the primary link, a recently developed technique which iteratively estimates and equalizes the channel based on the output of a soft output decoder, such as an LDPC decoder.

Modulation

Modulation is the act of representing data as a real-world signal. In general this is achieved by mapping data to different traits of a carrier wave, such as phase, amplitude or frequency. The mapping of data to phase and amplitude is accomplished using constellation mapping, which maps groups of data to complex phasors representative of the state the carrier will be in to transmit them. The choice of equalizer can have an effect on these mappings.

Channel

HF Channel

Beyond-horizon communications are possible at the HF band due to the refractive properties of the ionosphere which acts to bend the radio waves back towards earth (fig. 4). The ionosphere is composed of layers at different altitudes which are each capable of refracting a portion of the energy. This leads to a channel which exhibits:

- Rayleigh fading due to atmospheric scattering.
- Multipath (with path delays in the order of milliseconds) from reflections from different ionospheric layers.
- Doppler spread from the altitude shifts of the ionosphere.
- Long term variations of maximum- and lowest-useable frequencies from daily/seasonal changes.

The ITU recommends HF channel simulator parameters for standard channels, fig. 3 shows the amplitude response.

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Development of High Power THz sources for Imaging Applications
Faisal Amir and Mohamed Missous

Introduction
An advanced step-graded Gunn diode is presented, which has been developed through joint modelling-experimental work. The novel higher frequency devices have been realized to test GaAs based Gunn oscillators at sub-millimetre wave for use as a high power (multi mW) Terahertz source in conjunction with a mm-wave multiplier, with novel Schottky diodes.

DC IV Characteristics
The simulated forward and reverse bias IV characteristics of the 77 GHz model are shown in figure 5 and match extremely well with measured data thus validating the choice of the physical models and material parameters used. The doping spike analysis provided 1×10¹⁸ cm⁻³ as optimized value. The model was then used to predict and develop higher frequency devices.

Harmonic generation
The THz frequencies considered (up to 600 GHz) are to be generated in a two-stage module. The initial frequency source is to be provided by the novel high frequency Gunn diodes. The output from these diodes is then to be coupled into a multiplier module shown in figure 7.

Higher Frequency Gunn
The doping spike carrier concentration optimized value was used during higher frequency model development and instead the transit region length was reduced. The measured and simulated forward and reverse-bias IV characteristics of the ~100 GHz fundamental model are shown in figure 8 and match extremely well with measured data. The manufactured device yielded a maximum fundamental power of ~22 mW at 94 GHz, the highest ever reported for a GaAs Gunn device.

Conclusion
A novel 2D physical model for an advanced step-graded AlGaAs hot electron injector Gunn diode was successfully extended to higher frequency (> 100GHz). Future work includes the development of a full functional multiplier as a high power terahertz source.

Microelectronics and Nanostructures (M&N) Group, School of Electrical and Electronic Engineering

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Introduction

Hybrid electric vehicles (HEVs) have been introduced to alleviate some of the electric vehicles drawbacks and provide an intermediate power-train concept in the move from conventional to an all-electric rational. These drawbacks are due mainly to the limited driving range, excessive battery volume and long battery charging times. As for the transportation systems pollution problems, the series HEVs, as in Fig. 1, offers the best solution in terms of engine reduction and operational optimisation (emission and fuel conversion efficiency). Hybrid permanent magnet (HPM) machine topology, with a passive rectification stage, will be considered for an engine mounted generator as an alternative to a PM machine with an active rectification stage.

Target of the Analysis

The aim of the analysis is to operate the internal combustion engine (ICE) and HPM generator over their most efficient regions while accounting for the nonlinear behaviour in the vehicle peak and average power requirements, which presents a critical issue in HEVs operational philosophy.

ICE/HPM Output Power Control

Decoupling the ICE from peak power requirements in HEVs by controlling the HPM generator excitation field current to match the dc-link voltage variation while maintaining a constant ICE/HPM output power, will reduce the engine size and make it operate in its maximum efficiency region. A simple adaptive control technique is used to control the HPM generator excitation field current by utilising a negative feedback loop, as in Fig. 2.

Results and Conclusions

Improvement in vehicle driving range, with optimal ICE efficiency over repetitive new European driving cycle (NEDC) has been numerically achieved, as in Fig. 4. This was accomplished by levelling of the HPM generator output voltage while maintaining a constant output power by controlling the excitation field current to match the dc-link voltage. The third scenario presents the best HPM operating scenario because it produced the highest efficiency, as in Fig. 5. Furthermore, if the generator excitation field is lost, there will not be any risk to the vehicle power-train system.

HPM Operating Scenarios

For the HPM generator, several operating scenarios are investigated to obtain the best operating scenario, which leads to the most efficient and safe power-train system operation. According to the three battery terminal voltage characteristic curve levels, as in Fig. 3, a decision has to be made, as to whether the HPM generator, with zero dc excitation, is to be operated as in scenario 1, 2, or 3. This can subsequently be regulated by the wound field excitation current to match the dc-link voltage variation with a constant output power.

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Prognostics and health monitoring in power converters

Pete James

Introduction

The use of IGBT power modules in the automotive industry is becoming more and more common owing to the increase in hybrid and all electric vehicles. In such a market the reliability of a component is critical and vehicle manufacturers have put a lot of effort in to diagnostic and prognostic systems that run in real time. These prognostic systems are commonplace on vehicles today but power electronic components do not have similar prognostics available. The traditional use of power electronic modules has been in applications where their life or duty cycle is well defined. A mean time to failure is then used to signal when a power module is at the end of its life and requires replacement.

This type of prognostics is not appropriate for the automotive industry because the operating cycle of the vehicle varies greatly, both in driving style, duty cycle and environment. A prognostics system is required that will calculate the age of the power module in real time as the device and vehicle is being used.

Power module failure modes

The most common failure mode for IGBT modules used in power converters of the power and voltage associated with this project is bond wire lift off and stress cracks in the solder that joins the various parts of the IGBT modules. Both the bond wires lift off and stress cracks are caused by the dissimilar coefficients of expansion of the materials that make up the modules.

Life calculation

As the device undergoes a temperature change, parts expand or contract, and because of the different rates at which this happens, stresses build up in the solder which joins the parts together. After a number of cycles have occurred the solder breaks and therefore the device fails. This number of cycles to failure can be determined using the modified Coffin-Manson equation.

\[
N_f = C \frac{f^\alpha}{\Delta T^\beta} G_{T_{max}}
\]

Where:
- \(N_f\) is the number of cycles to failure
- \(C\) is a characteristic of the material
- \(f\) is the frequency of the cycles
- \(\alpha\) is the frequency exponent
- \(\Delta T\) is the change in temperature
- \(\beta\) is the change in temperature exponent
- \(G_{T_{max}}\) is a constant for the system

Real time health monitoring

In order to calculate the age of the device in real time, a DSP (Digital signal processor) is used to estimate the junction temperature of the power device, using gate time and current.

The junction temperature is then processed in real time to calculate \(\Delta T\) and frequency for each temperature cycle.

Life cycle history

Due to solder being a eutectic metal, the Linear Damage Accumulation Hypothesis can be used, resulting in the equation for percentage age.

\[
P_{age} = \left[ \sum_{\Delta T=0}^{\Delta T=150} \frac{N_{max}}{C \frac{f^\alpha}{\Delta T^\beta} G_{T_{max}}} \right] \times 100
\]

Conclusion

In order to determine the time of failure or age of an IGBT power module in random usage applications, knowledge of the operating history of the device is required. This research describes a method where the operating history can be recorded and processed in real time to obtain the age or predict the failure of the device.
Power Quality for Wind Farms

Mr Meliksah Ozakturk

Introduction

Wind power today has an increasing importance in power production. Investments in wind energy technologies have been continuously made to generate clean and environment friendly energy. Apart from construction and decommissioning, these systems never emit carbon dioxide to the atmosphere. However, one of the disadvantages of using wind power is that the wind speed is unpredictable and very changeable. To reduce the effect of this handicap, Doubly Fed Induction Generators (DFIGs), which can operate at variable speeds, are widely used in wind conversion applications to maximise power generation and to reduce converter costs and mechanical loads. Hence, DFIG wind turbines currently dominate the market due to their cost-effective provision of variable-speed operation.

DFIG-based Wind Turbines

As seen in Fig.1, DFIG systems consist of back-to-back converters, namely rotor-side and grid-side converter, a DC link capacitor placed between these two converters, and protection of power electronic components. In this project, the controls of rotor-side and grid-side converters of the DFIG model are designed and simulated in PSCAD/EMTDC, along with coordination to the wider connection system and its control.

Rotor-side Converter Control

The equation of the rotor voltage in the excitation frame are derived in order to design current controller loops in dq reference frame (see Fig.2).

The PI loops are tuned by considering damping ratio ζ=1, and natural frequency ω_n=450 Hz, which is ideally 10 times smaller than the switching frequency of 4500 Hz.

Simulation Results

a. Rotor-side Converter

The simulation set up in PSCAD/EMTDC is run with an over-synchronous speed of 1.02pu to see the rotor-side converter and its control work properly. After the curves become steady-state, first the set value of the d-component of the rotor current is increased to 1kA while the q-component is constant at effectively 0. A little while later, the set value of the q-component of the rotor current is increased to 1kA while the d-component is fixed at 1kA. The effects of changing in rotor current on active and reactive power and stator currents are shown in Fig.3.

b. Grid-side Converter

The simulation is re-run to clarify that the control of grid-side converter of the DFIG model works reasonably. Once the system reaches steady-state, the set value of the q-component of the current flowing from the grid side into the converter is increased to 0.4kA while the DC-link is constant at 1kV. The traces are presented in Fig.4.

Conclusion

The controls of both rotor- and grid-side converters of the DFIG are established. The stator active power can be controlled by the q-component of the rotor current, while the d-component of the rotor current is used to control stator reactive power where the stator voltage vector and the stator flux linkage are constant.

The active power and reactive power dissipated in the grid side converter are proportional to i_{q,r} and i_{q,g} respectively.
Introduction

Aim: Explore utilising ad hoc and mobile arrays of sensors with conventional tomographic techniques to determine the conductivity or permittivity distribution of materials in a process vessel through 3D tomograms

Motivation: To improve the lack of spatial resolution in tomographic images, often found lacking using conventional set-ups

This project is part of a larger project – Wireless Sensor Network for Industrial Processes (WSN4IP). The aim of the WSN4IP project is to utilise an array of ad hoc sensors, which is given the freedom of mobility to assume any position within a process vessel, to acquire information of interest of its vicinity, which provide information for control and monitoring purposes.

This project utilises these measurements and incorporate the measurements into conventional electrical tomography (ET) set-ups. By increasing the number of measurements, theoretically, this provides more information for image reconstruction.

Two novel approaches are devised to utilise the measurements acquired using the ad hoc sensor “pills” in conventional electrical tomography (ET) systems:

- Augmented electrical tomography (AET)
- Extended electrical tomography (EET)

Augmented Electrical Tomography

Measurements acquired from the ad hoc sensors are localised conductivity measurements. Conductivities are assumed to occupy the space of the corresponding elements in a Finite-Element Method (FEM) model. The ‘known conductivity measurements’ translate into ‘known solutions’ for the corresponding elements, reducing the number of unknowns to be solved for the inverse problem.

Preliminary study:
- The ‘known conductivity’ occupies 1 finite-element – only 1 ‘known conductivity’ is used

Extended Electrical Tomography

The ad hoc sensors on the ‘pills’ are used as part of the ET electrodes system, measuring the voltage difference between a pair of electrodes on the same ‘pill’.

Preliminary studies done include efforts to determine a suitable design for the internal electrodes pair (separation between electrodes, electrodes size) and effect of different orientation and position of internal electrodes pair in a process vessel.

Every pair of internal electrodes with a single plane of 16 electrodes system provide an extra 16 measurements for the adjacent strategy and 8 for opposite strategy. SVD plots (Fig. 2) reveal that the extra voltage measurements provide unique information. Only 1 out of 16 measurements for the adjacent strategy is deemed unusable.

Discussion & Conclusion

AET vs. EET: Feasibility studies show that both approaches are possible. Both approaches pose different challenges. AET is limited by inverse solving algorithm and parameters. EET requires a floating voltage measurement system, which mimics the system contained in the ‘wireless pill’. It is essential that the grounding is isolated from the common earth of the main power source when performing laboratory experiments in order to obtain realistic comparison with simulated results. EET shows more encouraging signs and preliminary studies indicate that this approach provides more directions to explore.

The EET approach forms the main focus for the remainder of the project. Laboratory experiments will be carried out to verify the simulated results. The number of internal electrode pairs will be increased and its effect will be studied. The possibility of using other current-injection strategies will also be explored.
Estimating the losses in quality of perishable produce subjected to changing temperatures

Xuan-Tien Doan

Introduction

Significant quality loss incurred during transport of perishable produce including fruits, vegetables and cut flowers provides an economic incentive to improve quality control in chilled supply chains. Monitoring of temperature, an important environmental factor, is possible using data-loggers or RFID tags. A method to estimate the postharvest loss using logged temperature is therefore desired.

Post-harvest loss in perishable produce

- 2008 UK production: £2.4b (vegetables, fruits, and flowers)
- Quantitatively: ~12% are lost between production and consumption sites for developed countries
- Qualitative loss is more significant.

Post-harvest temperature is important

- Temperature speeds up all metabolic reactions and subsequently the deterioration of the produce.
- Providing optimal temperature (and humidity) is considered the most important tool in maintaining quality of perishable produce. (Cantwell and Reid, 1993; Gross et al., 2002; Kader, 2002a; Nell and Reid, 2000; Thompson et al., 1998; www.fao.org/inpho).

Kinetic modelling technique

- The most common technique to model quality loss.
- It is based on kinetic principles, which govern all chemical processes occurring within the produce.
- However, its most significant disadvantages is that it requires (some) first principle knowledge of the product, which is not always available, and that multiple kinetic models are needed when multiple attributes are considered.

Kinetic Linear System (KLS) technique

KLS was developed to overcome the limitations of kinetic modelling technique. It is:
- Based on kinetic principles
- Data-driven i.e. no first principle knowledge is required
- One KLS model for multiple quality attributes.

Tomato simulation study

- 117 temperature profiles were used.
- Simulated shelf life was assessed based on tomato colour (Figure 4) or colour and firmness (Figure 5), which were modelled kinetically.
- Leave-one-out strategy: 116 temperature profiles and their corresponding simulated shelf life were used to obtain a KLS model which produced predicted shelf life for the 117th temperature profile.
- This strategy was repeated 117 times and subsequently statistics including coefficient of determination ($R^2$), root mean squared error in prediction (RMSEP), slope and intercept of best fit line were evaluated.

Additional results

- Other simulations including mushroom (colour), seasoned soybean sprout (bacterial counts), and various seafood products showed similar KLS performance.
- Real supply chain data for cut roses is being analysed.

Conclusion

- KLS was developed to estimate the quality loss in perishable produce due to post-harvest temperature.
- Simulation studies showed that it could reproduce the performance of kinetic modelling while being data-driven and simpler to implement.
- These additional advantages enable KLS application in perishable produce such as cut roses the models of which do not normally exist.

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Characterization of a Hyperspectral Imaging System

Nsikak Ekpenyong

Introduction

Hyperspectral Images are acquired by recording monochromatic images over a range of wavelengths. Hyperspectral imaging (HSI) combines conventional imaging and spectroscopy to obtain spatial and spectral information for an object. This technology is used in various applications in remote sensing, agriculture, medicine, surveillance and scientific research. A major advantage over RGB imaging is the availability of spectral information (Figure 1) which can be used to identify and segment materials using their unique spectral signatures. The characterization of the hyperspectral imaging system to identify random and systematic errors is crucial to obtaining accurate radiance and reflectance data.

Sources of error and their correction

Temporal and spatial CCD Noise. Temporal noise can be corrected by frame averaging. Dark noise, on the other hand, can be compensated for by frame subtraction. An image (Figure 3a) with the entrance aperture of the camera completely obscured is captured and subtracted from the scene image.

Spatial non-uniformities in the sensor and optical system. The sensitivity of the CCD sensor varies from pixel to pixel owing to different quantum efficiencies and the illumination over the field appears to vary mainly to vignetting in the optics. Both are corrected using a technique known as flat fielding. An image (Figure 3b) of a smooth, matt, white card is captured and is used for pixel-by-pixel division of the scene image.

Stray light. Stray light is that light in the optical path that is imaged on the sensor but does not originate directly from the captured scene. It was modelled here as a combination of image signals over the field, with empirically determined coefficients, obtained by calibration against a scene of known radiance.

The corrected image is thus given by the following quotient:

\[
\text{Corrected image} = \frac{\text{Scene image} - \text{Dark image}}{\text{Flat-field image} - \text{Dark image}}
\]

Aims

The initial aim of this research was to identify the main sources of error in hyperspectral imaging, to compensate for these errors, and to recover accurate spectral radiance and reflectance data.

HSI System

The HSI system (Figure 2) used for this work was made up of a low-noise Peltier-cooled monochrome CCD camera and liquid crystal tuneable filter (LCTF). It was mounted in front of the camera lens and the wavelength of its peak transmission was varied over the visible spectrum (400-720 nm) in 10-nm intervals.

Before acquisition, exposure time at each wavelength was determined by an automatic routine so that the maximum output at any pixel was within 85-90% of the CCD saturation value.

Spectral Reflectance

The spectral reflectance for each pixel is obtained by normalizing the corrected image at each pixel against internal standards placed within the scene with known reflectance spectra. Figure 4 shows HSI spectral-reflectance data for “purple” and “yellow-green” Gretag-Macbeth ColorChecker patches in a test scene compared with their spectra measured with a Shimadzu spectroradiometer.

Conclusions

With careful calibration, accurate radiance and reflectance data can be recovered from raw HSI data. The next step is to apply the calibrated system to more demanding, natural, test scenes.

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Future Walkthrough Metal Detectors

Mr Liam Marsh

Overview

Walkthrough metal detection (WTMD) is used extensively at security checkpoints in locations such as airports, prisons, large public gatherings, embassies and financial reserves all over the world. Whilst it does a good job of locating contraband items such as knives, guns and precious metals it has some large drawbacks. The most significant of these is that it is not currently possible to identify the location of detected metals with any great accuracy, meaning that it can require a significant amount of human intervention to find items even once detected. In addition to this there are frequent false positive classifications which also require time and personnel to investigate.

Better Sensitivity and Discrimination

Typical WTMDs use a series of between 8 and 16 parallel transmit-receive coil pairs as channels for metal detection purposes. This PhD project seeks to improve on existing technology by combining contributions from multiple transmit-receive pairs. By using a greater number of detection channels it is possible to increase the accuracy with which potential threat objects are located. Coupling this with the increased signal quality allows for discrimination between threatening and innocuous objects according to shape and metallic composition.

New Detector Concepts

The research also seeks to design walkthrough metal detection technologies which can be implemented without the need for a conventional portal. This allows new scanning possibilities in locations such as shopping centres and sports arenas.

Integrated Vision and EM detection

Combining electromagnetic detection techniques with visual feedback allows for greater detection methods to be developed. As well as providing a real-time visual display which can be integrated with surveillance systems it will also be possible to locate a threat object on an image of the person allowing for reduced search times. This system will help to limit the number of false positive classifications by knowing both when a candidate is inside the detector and their position once inside.

Wave Technology

Using ultra-wideband (UWB) technology it is possible to make greater use of other areas of the EM spectrum to scan for non-metallic threat objects through clothing without any loss of scanning efficiency. Combining this with standard metal detection allows for a fully-integrated security checkpoint.

Real-time Data Analysis

Windows-based software allows for real-time plotting and storage of data in a familiar environment. This allows for detailed, quantifiable testing results whilst minimising the hardware requirements of the electronics unit for advanced operations such as characterising a threat object.

System Electronics

The current system uses a fully digital system for generation and demodulation of signals. Consequently there are fewer sources of noise when compared to other walkthrough metal detectors. All bespoke hardware is integrated onto a single multi-layer PCB, which can be connected to any PC using a standard RJ45 ethernet link.

Conclusion

At present there is a working prototype system which is capable of cross-coupled channel walkthrough metal detection. The system exhibits fully functional demodulation and filtering techniques, as well as detection and calibration algorithms which are currently being refined and tested. It has been shown that it is possible to have a fully digitised solution for the synthesis, processing and analysis of signals which has led to more reliable and readily modifiable detection techniques which are less prone to external noise. Once the final modifications have been made to the prototype system it is expected to enter a phase of field trials.
Wireless Sensor Networks for Industrial Processes

Mark Pottinger

Aims

The aim is to deliver a cluster of small, wireless, low cost, buoyancy controlled pills for use in industrial process vessels. Each individual pill will be able to position itself within the vessel and record readings of the surrounding environment. Ultrasonic signals transmitted between the pill and receivers mounted to the vessel, determine the pill’s position through time difference of arrival (TDOA).

Motivation

Motivation behind a network of wireless sensors in industry stems from the interest in monitoring the process environment. Current technology such as tomography is limited to determining object’s positions within a vessel via material properties of the object; these technologies do not have the ability to map temperature, pressure or pH through the vessel all of which are desirable when monitoring a process.

Challenges

- The use of small low cost transducers to create an array of small transmitters to mimic the beam pattern of a more expensive omnidirectional transmitter
- How does the transmitter and receiver layout effect the positional accuracy of the TDOA strategy
- Investigation of strategy to overcome reflection issues present in small vessels

Results

Example pill transmitter layouts using multiple small low cost transducers are suggested. Ray trace modelling demonstrating the amplitude superposition properties of the vessel surface are shown along with comparisons between experimental and theoretical range data when direct transmission signals can be correctly identified in the presence of reflections.

Conclusion

The use of multiple low cost transmitters is a viable option to create a pill able to provide wide beam coverage to multiple receivers. Modifications to standard TDOA methodology and careful placement of transmitters on the pill allow positional accuracy to be maintained within the system even with spatially separated transmitters. Results have shown that the effect on positional accuracy of errors in TDOA measurements can be greatly reduced with careful receiver placement.

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Investigation of PCB Microstrip Patch Receiving Antenna for Outdoor RF Energy Harvesting in Wireless Sensor Networks

Zhi Wei Sim

Introduction

In recent years, there has been a growing interest for the deployment of wireless sensor networks (WSN) in many sectors. One emerging WSN application is in agriculture sector, where the sensor nodes are deployed in outdoor fields to monitor humidity, temperature and soil moisture of the crops. Energy supply has been a limiting factor to the lifetime of these agriculture sensors as they are typically powered by conventional batteries, which have limited lifespan. The cost could be prohibitive when replacing the exhausted batteries since the sensor devices need to be unearthed. A promising solution is by using radio frequency (RF) energy harvesting, which relates the concept of wireless energy transmission, to power the sensors. The envisaged application of this research is a wireless soil sensor network, used for pest monitoring and control.

RF energy transfer mechanism between transmitter and sensor receivers.

Receiving antenna is a key element of a RF energy harvesting system as it is responsible to capture the radiated energy from the ambient. In this poster, the suitability of using a printed circuit board (PCB) microstrip patch receiving antenna (MPRA) for the intended application was investigated. The performance of a conventional circular MPRA using different microwave laminate substrates, was evaluated. Based on a chosen material, an enhanced gain circular MPRA was studied. Simulations were carried out using CST Microwave Studio to examine the antenna’s performance both in free air and in the presence of different soil conditions.

Antenna Design Requirements

- **Operating Frequency** – An unlicensed band, 867MHz was chosen due to its lower free space attenuation (compared to 2.4GHz) and higher radiated power permitted by regulations.
- **Size** – The antenna must be small so that it can be mounted easily upon the sensor node. Its maximum allowable volume is 120mm × 120mm × 20mm.
- **Impedance Bandwidth** – The antenna should resonate from 865.6-867.6 MHz, with an impedance bandwidth (S11<10 dB) covering that band.
- **Directivity** – The antenna must be directed so that its maximum gain lobe is pointed towards the transmitter, in order to optimise the received energy.
- **Gain** – An arbitrary antenna gain of 3dB was set.

Conventional Circular MPRA

The performance of a conventional circular MPRA (in free space) using five PCB materials – RT5880, FR4, RO3003, RO3006, and RO3010, was evaluated using CST Microwave Studio.

<table>
<thead>
<tr>
<th>Material</th>
<th>Dielectric constant, ε</th>
<th>Loss tangent, tan δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT5880</td>
<td>2.2</td>
<td>0.0009</td>
</tr>
<tr>
<td>RO3003</td>
<td>3.0</td>
<td>0.0013</td>
</tr>
<tr>
<td>FR4</td>
<td>4.4</td>
<td>0.007</td>
</tr>
<tr>
<td>RO3006</td>
<td>6.5</td>
<td>0.002</td>
</tr>
<tr>
<td>RO3010</td>
<td>10.2</td>
<td>0.0022</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Feed position (x,y) (mm)</th>
<th>Return Loss (dB)</th>
<th>Bandwidth (MHz)</th>
<th>Simulated radiation efficiency (%)</th>
<th>Simulated realized gain (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT5880</td>
<td>(120,0)</td>
<td>28.40</td>
<td>9.8</td>
<td>76.2%</td>
<td>5.72</td>
</tr>
<tr>
<td>RO3003</td>
<td>(15,0)</td>
<td>25.65</td>
<td>6.2</td>
<td>73.1%</td>
<td>5.29</td>
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<tr>
<td>FR4</td>
<td>(25,0)</td>
<td>18.55</td>
<td>17.9</td>
<td>25.3%</td>
<td>0.38</td>
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<tr>
<td>RO3006</td>
<td>(100,0)</td>
<td>25.75</td>
<td>5.5</td>
<td>57.9%</td>
<td>3.80</td>
</tr>
<tr>
<td>RO3010</td>
<td>(80,0)</td>
<td>20.65</td>
<td>5.2</td>
<td>50.1%</td>
<td>2.98</td>
</tr>
</tbody>
</table>

Enhanced Gain Circular MPRA

(A) Antenna Simulation in Free Space

<table>
<thead>
<tr>
<th>Parameter</th>
<th>r</th>
<th>a</th>
<th>b</th>
<th>F (x,y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mm)</td>
<td>56.9</td>
<td>56.9</td>
<td>35.5</td>
<td>(15,0)</td>
</tr>
</tbody>
</table>

(B) Antenna Simulation on a Soil Surface

Radiation patterns of the enhanced gain antenna in the presence of soil surfaces are almost identical to that of free space. The main radiation beam of each antenna is in its broadside direction with its maximum gain changes marginally for different types of soil due to varying electrical conductivity and dielectric constant of the soil. A moderate gain can still be achieved without tilting the enhanced gain antenna.

Conclusion

An enhanced gain circular patch antenna stacked with a ring shaped parasitic radiator using RO3003 could meet the antenna design requirements of the intended application, but with the need of slight tilt to ensure correct directivity and also with the expenses of higher material and fabrication cost. We are currently investigating a cheaper alternative – an air-substrate-based, folded, MPRA with tilted beam capability. Findings on this antenna will be presented in the future.

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Linearity Analysis & Modelling of Compact Microwave Components

Mayahsa M Ali

Introduction

In Monolithic microwave integrated circuits (MMICs) both active and passive devices are integrated on the same chip. Passive components have larger dimensions than active devices and occupy most of the area of the chip. However, multilayer MMICs not only allow two separate technologies to be integrated providing flexible design route for exploitations but it provides compact design with multifunctional capability and affordable cost.

Linear MMICs are highly desirable for future communication systems. Study of linearity of these components allows circuits and sub-systems to be produced with efficient performance. The better the linearity, the less power consumption.

Single & Multiple Channel HEMTs

Conventional HEMTs have only one channel in which the 2DEG phenomena occurs. This active layer (2DEG) is formed because of one layer of wide band gap semiconductor (n-AlGaAs) and the other of narrow band gap material (undoped GaAs).

Multiple-channel HEMTs have multiple active sheets of 2DEGs. The linearity of multiple-channel HEMT is very good because of the transconductance ($g_m$) wide profile over wide range of input voltages ($V_{gs}$).

Characteristics Comparison

Two Tone Inter-modulation Distortion

If two sinusoidal signals with very close input frequencies are combined from two signal generators and fed to the device, the output products will be a combination of frequencies including the fundamental signal. This accounts for the non linear behaviour of the DUT.

Conclusions & Future Work

The linearity of the transconductance in HEMTs provides insight information on how to produce linear microwave components. Multiple-channel pHEMTs provides a better linearity than single channel ones due to their flatter transfer properties over wider range of input signals. The two-tone intermodulation distortion provides knowledge of the nonlinearity of the DUT. Future work will involve understanding the nonlinear characteristics of the devices and circuits used in multilayer MMICs.

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