POWER ELECTRONICS, MOTOR DRIVES LABORATORY
&
ADVANCED VEHICLE SYSTEMS RESEARCH PROGRAM

ANNUAL REPORT

2005

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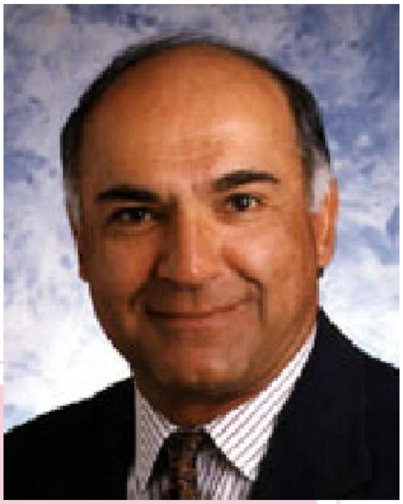

I am very pleased to present this 2005 Annual Report of our Advanced Vehicle Systems Research Program and Power Electronics and Motor Drives Laboratory at Texas A&M. This year we started a new technology development initiative for sustainable energy and transportation. This new initiative, which we have tentatively named the Crop-to-Wheel initiative, combines several component technologies in bio fuel, engine, motor drives, power electronics, and advanced vehicle systems that our group has developed over the past two decades. This is a novel and practical energy and vehicle technology complex for civilian and military use. Several patents have been filed for this new technology complex and several faculty members are actively working to expand and demonstrate the various aspects of this initiative. I invite you to read a summary of this new initiative in this report.

This report also presents a collection of our recent technologies and papers. All of these technologies are available for transfer to industry and numerous patents that are based on them are available for licensing. Last year was our most dynamic and productive year yet. The group is growing, the technologies are proliferating, the industrial base is expanding, and a new energy and transportation technology complex is being developed. In addition, many short courses have been offered and are available to our new and existing affiliates. All of these are listed in the body of this report.

I invite you to contact us and find out more about the details of our work and how you can partake in its results. There are many modes of collaboration that are available, from a general membership in our industrial consortium to a specific contract R&D relationship. Please refer to the enclosed consortium information section or contact me for information.

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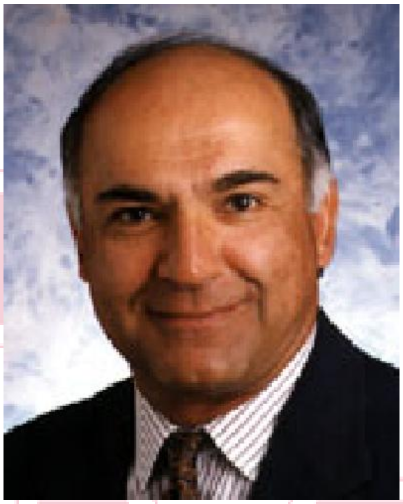

Prof. Ehsani elected SAE Fellow – Prof. Ehsani has been elected a fellow of the Society of Automotive Engineers for his "outstanding accomplishments in the field of hybrid electric vehicles". He was honored in April at the 2005 SAE World Congress in Detroit.

Robert M. Kennedy Endowed Chair – Prof. Ehsani was the inaugural holder of the Robert M. Kennedy '26 Professorship in Electrical Engineering. The Kennedy Professorship is one of two established in 2003 by an estate gift from the late Robert M. Kennedy, Texas A&M Class of 1926. "I was touched and honored to receive this recognition especially since it is in the name of Mr. Robert M. Kennedy, who was one of our own graduates that became so successful in his professional life. I always feel a special sense of pride when our old and new graduates do well and then turn around and remember their alma mater. This makes me redouble my efforts in making this university one of the best in the world, as I have tried to do over the past 23 years. I believe that I have had significant success in this effort," Ehsani said.

2003 IEEE Undergraduate Teaching Award - Prof. Mark Ehsani received the 2003 Undergraduate Teaching Award for "outstanding contributions to advanced curriculum developments and teaching of power electronics and drives" from the Institute of Electrical and Electronics Engineers during the 2003 IEEE Industry Applications Society Annual Meeting in Salt Lake City, UT. This award recognizes "inspirational teaching of undergraduate students" in the fields of electrical and electronics engineering. This award is the recognition of Prof. Ehsani's efforts in creating the nation's first program in power electronics and motor drives. This program has taught more than a thousand undergraduate students, many of whom pursued a successful career in that field.

Spirit of Innovation Award - On Wednesday, May 14th 2003 three members of the Advanced Vehicle Systems Research Group were honored for their inventions by the Texas A&M University Technology Licensing Office. Sébastien E. Gay and Prof. Mark Ehsani received the Spirit of Innovation Award for the "2000th Disclosure" for their invention of the "Electric Hybrid Electric Drive Train". Prof. Mark Holtzapple received the Spirit of Innovation Award for "Ingenuity" for his invention of the StarRotor engine.

Sébastien E. Gay and Prof. Mark Ehsani receive the Spirit of Innovation Award for "2000th disclosure" from Texas A&M University Chancellor Howard D. Graves.

Prof. Mark Holtzapple receives the Spirit of Innovation Award for "Ingenuity" from Texas A&M University Chancellor Howard D. Graves.

2003 Undergraduate Research Award – Hugo Eduardo Mena, an undergraduate research assistant working within the Advanced Vehicle Systems Research Program was one of the recipients of the 2003 Undergraduate Research Awards. The award is granted by the Department of Electrical Engineering at Texas A&M University to undergraduate students as financial assistance and as an incentive to purse research and graduate studies. The research project proposed by Mr. Mena is entitled "Research on Electromechanical System Oscillations" and pertains to the modeling of interactions in electromechanical systems through the use of gyrator theory and equivalent electric circuit modeling.

2001 IEEE VTS Avant Garde Award – Prof. Mark Ehsani was awarded the 2001 IEEE Vehicular Technology Society Avant Garde Award for "Contributions to the theory and design of hybrid electric vehicles". This award is a recognition for Prof. Ehsani's research efforts and accomplishments and that of the Advanced Vehicle Systems Research Group in this field since 1991.

2000-2001 Convergence Fellowship – Mr Jean-Yves Routex, then a Master's student at Texas A&M University and an active member of the Advanced Vehicle Systems Research Program was awarded the 2000-2001 Convergence graduate fellowship with a $12,000 stipend in recognition for his "outstanding accomplishments in the fields of vehicle electronics".

CURRENT RESEARCH PROJECTS

STARROTOR ENGINE

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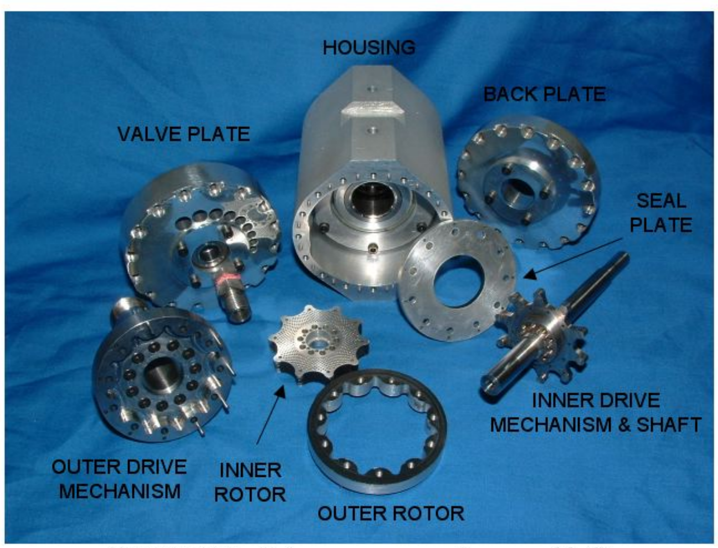
Internal combustion engines are inefficient in converting fuel into mechanical energy. While the theoretical maximum efficiency is about 40%, practical engines reach at most 20 to 25%. Furthermore, this peak efficiency is achieved only for one point and rapidly decreases for changing speed and torque output.

The StarRotor engine is a novel embodiment of the Brayton thermodynamic cycle, otherwise used in gas turbines and jet engines. Axial or centrifugal compressors and expanders are replaced by a novel positive displacement device called a "gerotor", which compresses large volumes of air efficiently at low speed. The other features of the StarRotor engine include quasi-isothermal compression by spraying a fluid in the compressor, the use of a heat exchanger to recuperate the thermal energy of exhaust gases and a variable compression ratio obtained by non-restrictive means. The result is an engine that is very efficient (45-65%) over a broad range of speed and torque output, clean, quiet, vibration-free, low-maintenance, and capable of burning a wide variety of fuels.

The particular design of the gerotor compressor permits the integration of an electric generator within its outer rotor structure. This approach reduces the size and complexity of connecting the engine to a generator, while it allows an intimate integration of the StarRotor engine with hybrid electric drive trains. Hybrid vehicles based on the StarRotor engine and the integrated StarRotor engine-generator are being investigated.



500 Watt StarRotor compressor (unassembled)

CROP-TO-WHEEL INITIATIVE

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Widely available and inexpensive fossil fuels have been the key to the development of the modern civilization by providing cost-effective and convenient transportation, electricity, heating, etc… However, they suffer two major flaws that result from their fossil nature. The amount of fossilized carbon is finite and will eventually be exhausted. The combustion of fossil fuels is an open-cycle process that accumulates carbon dioxide in the atmosphere, which results in global warming due to increased greenhouse effect.

The crop-to-wheel initiative is an integrated approach to the automobile that focuses both on fuel production and vehicle power train technologies. The result is a new automobile industry with the following properties: sustainable fuel supply, no net carbon dioxide emissions and higher efficiency. This approach presents many advantages over hydrogen economy schemes.

The crop-to-wheel initiative is based on biofuels, derived from biomass. Although the combustion of biofuels does release carbon dioxide, photosynthesis removes an equivalent amount from the atmosphere. Carbon dioxide thus follows a closed cycle driven by solar energy, which ensures sustainability. While biomass is an inexpensive feedstock, the conversion process was traditionally where the excessive cost was added. The novel MixAlco process is a cost-effective process that converts the biomass into ketones through lime pre-treatment, digestion by micro-organisms and thermal treatment. The ketones may be converted to alcohols by hydrogenation. The selling price for the alcohol fuel is estimated between $0.40 to $1 per gallon depending on feedstock costs and scale.

The StarRotor engine and StarRotor-based hybrid electric vehicles based are key technologies for the crop-to-wheel initiative. The resulting fuel efficient transportation is beneficial because it limits the requirements for land area. This latter is also reduced by the use of municipal and other biological wastes, which in turn provides a convenient and cost-effective solution to their disposal.

This initiative is based on 20 patents from our group, with many more to follow.

EDDY-CURRENT BRAKES

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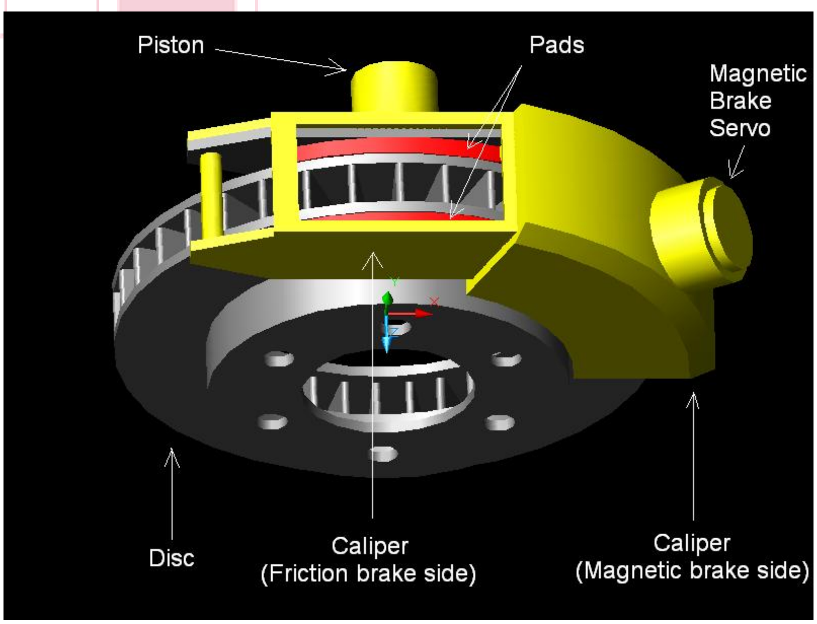
Conventional automotive friction brakes suffer from reduced reliability and safety under varying conditions, such as wear, water, and high temperature. They are also an unsatisfactory tool for anti skid and vehicle dynamic stability enhancement, due to their long hydraulic or pneumatic system time delay. Eddy-current brakes integrated with existing friction disk brakes solve the above problems, in a safe and cost effective way. Eddy current braking is already being used in drilling rigs and some large buses.

Braking is obtained by the rotation of the disc in front of magnetic poles, which results in induced eddy-currents in the disc. The interaction of the currents with the magnetic flux of the poles creates the braking torque. The novelty is the use of rare earth permanent magnets instead of electromagnets to induce the magnetic flux in the disc. The flux is controlled by shunting the magnet using a specially designed magnetic circuit. Shunting is achieved by mechanical or electrical means. The magnetic circuit is designed to preserve the magnets from the heat dissipated in the disc. Eddy-current brakes provide many advantages such as reduced actuation power, immunity to wheel-lock, failure safety, fast response, and compatibility with regenerative braking in hybrid vehicles. While friction brakes are not replaced, they are rendered smaller, cheaper, and safer.

Further refinements of the concept of eddy current braking include a technique for obtaining a constant braking force from critical speed to maximum speed and a novel concept of self-powered wireless-control brake.



INDUCTION MOTORS FOR REGENERATIVE-DISSIPATIVE BRAKING

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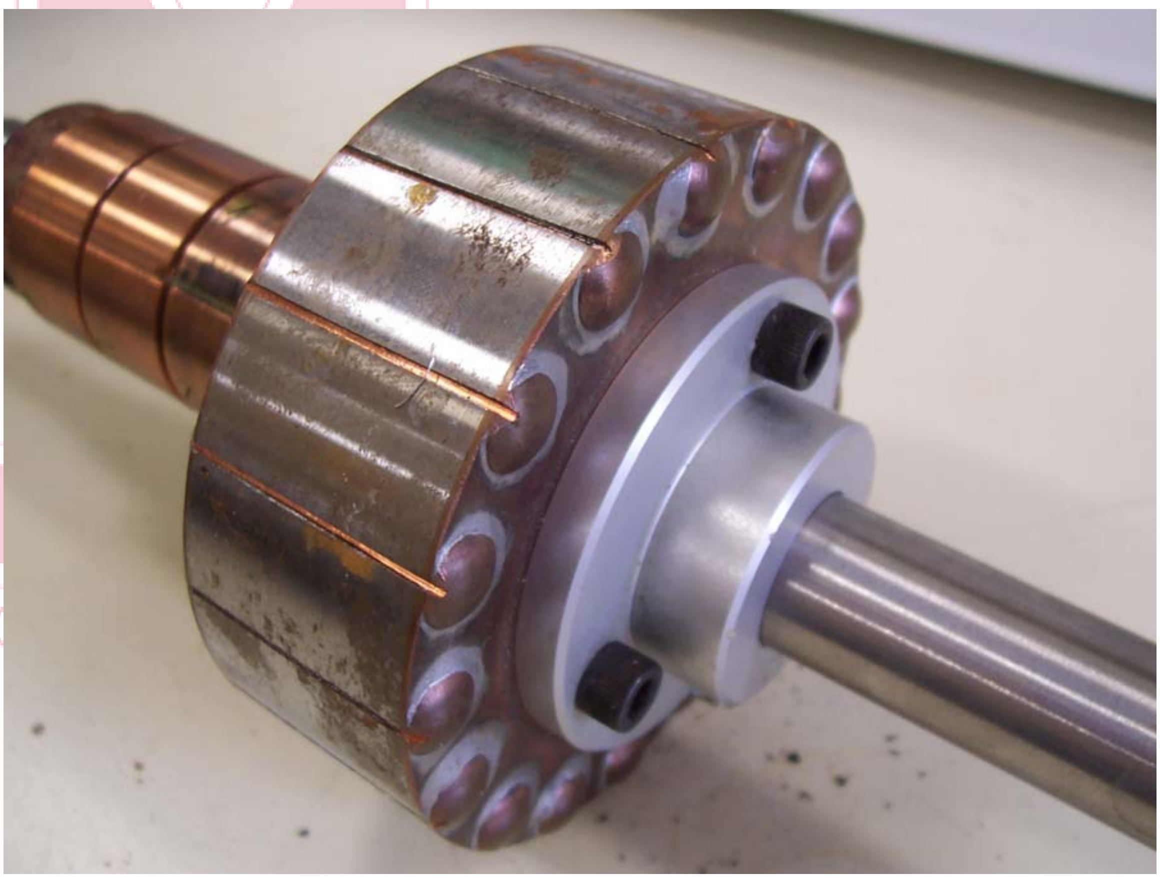
This project is an evolution of the eddy-current brake project. An eddy-current brake and an induction motor are similar machines with very few differences. While an eddy-current brake has a plain rotor and a DC excitation flux, an induction motor has a squirrel cage rotor and AC excitation.

A properly designed induction motor can therefore be operated as a motor-generator, as an eddy-current brake or both at the same time. The application of this machine is in hybrid vehicles, where it would be used for traction, regenerative or dissipative braking. The vehicle's kinetic energy can simultaneously be regenerated or dissipated in proportions that can be varied to optimize the operation of the hybrid drive train. For instance, if the batteries are not fully charged regenerative braking may be used at rated power and while dissipative braking provides additional braking torque to meet the driver's demand. When the batteries are fully charged, dissipative braking alone is used.



OSCILLATING ELECTRIC MACHINES

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Oscillations have been shown to occur naturally in electric machines because of the interaction between the rotor inertia and the armature inductance. While these oscillations are usually unwanted, this research is aimed at obtaining machines that oscillate naturally within a useful range of stroke and frequency. The objective is to develop an oscillating machine that can be fully controlled by its inverter and field winding. The parameters controlled include oscillating frequency, stroke, and nonlinear oscillation profiles. Their applications are in internal combustion engine valve actuation, piston pumps, printing heads, etc…

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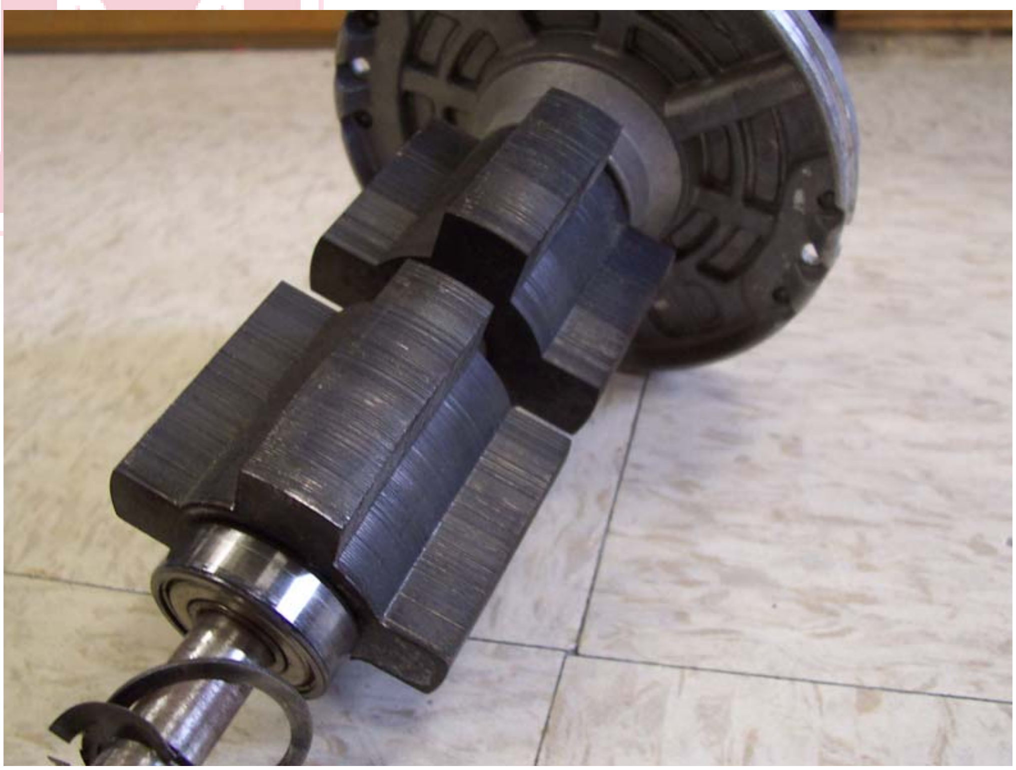
Regenerative breaking is a critical issue in propulsion applications such as electric and hybrid electric vehicles. Switched reluctance machines have been previously shown to provide decisive advantages for traction and regenerative braking, as well as rugged construction, and fault tolerance.

The power output of the switched reluctance generator is controlled by the phase current, which is challenging because of the dominant back-emf that causes the stator currents to increase even after the phase is turned off. This results in incontrollable torque on the shaft and requires an oversized inverter. The inverter rating should be further increased to withstand a worst case scenario due to speed variations in the prime mover. A current control technique has been developed that relies on turning off the phase at a safe angle determined using an online estimation of back-emf variations. At high speed, where the switched reluctance machine is the most efficient, the only control variables are the turn-on and turn-off angles. More power can be obtained from a switched reluctance generator if the phase is turned off in two steps. A control technique is being developed to take advantage of this technique and maximize both efficiency and power output.



ADVANCED 4-QUADRANT BRUSHLESS DC MOTOR-GENERATOR DRIVES

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Proper brushless DC machines operation requires firing the inverter's switches at the appropriate time. In order to determine this appropriate time, knowledge of the rotor position is required. This may be achieved with a shaft position sensor but their reliability is questionable. In many applications, should the sensor fail the drive should still be operable. Sensorless control techniques allow replacing the sensor in case it fails. Conventional sensorless control techniques have two major weaknesses: they do not work well at low speed and during transients. We have developed a control technique that remedies to these problems and allows accurate and robust operation from near zero speed to high speed. It uses a physically insightful, speed-independent function based on a new flux linkage function.

Some applications of brushless DC generators require maximizing the power throughput (mechanical to electrical) for a given size, weight and amount of copper losses. This is particularly true for aerospace, ground vehicle or portable applications. A novel control technique has been developed that maximizes the power throughput of a brushless DC generator by controlling the profile of the current waveforms by the means of an inverter. Improvements over 20% in power throughput have been obtained compared to a brushless DC generator coupled to a diode rectifier. This technique is currently being investigated for motoring operation.

ACTIVE VIBRATION CONTROL BY ELECTRIC MACHINES

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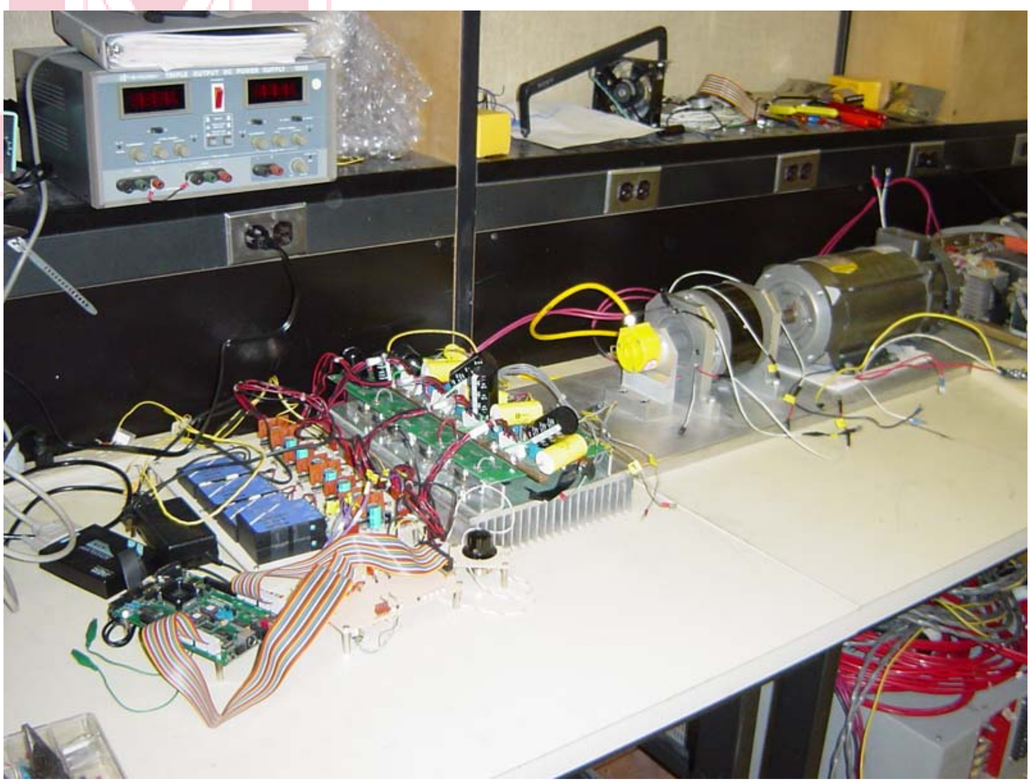
In industrial systems such as robotic manipulators, automotive transmissions, engines, and high-performance electric motor drives, the load torque often rapidly fluctuates and induces vibrations. Such vibrations degrade dynamic control performance, fatigue the motor shaft as well as other system components, and result in audible noise. It is therefore desirable or necessary to suppress the vibration to achieve the required dynamic performance. The objective of this research is to improve the system robustness against load torque fluctuation and system parameter drift.

The conventional approach consists in introducing a disturbance rejection controller that uses a load torque observer. The load torque observer is essentially a differentiator for low-frequency signals. The drawback of this method is the need for accurate motor acceleration information, which is difficult to obtain in practical applications. A novel approach is being developed that uses a feed-forward compensation voltage or current command to reduce the vibration. This approach has the advantage of reducing vibrations during bother steady state and transient operation. The key to this approach is the generation of the compensation signals. They are derived through the analysis of system parameters and operational variables.



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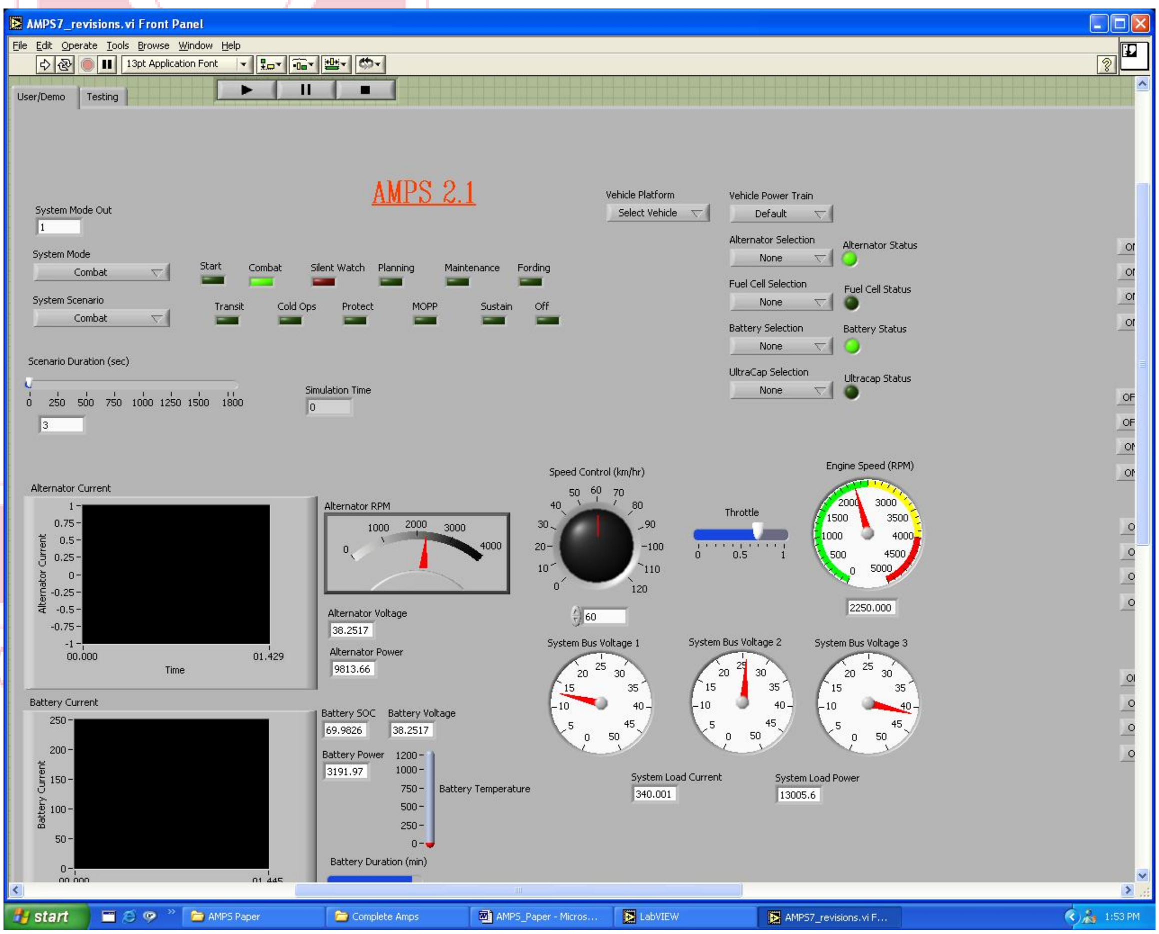
This research decomposes into two projects: modeling and simulation of advanced electrical power systems for military applications and simulation of multi converter power electronic systems for practical constant power loads. The purpose of the first project is to develop a configurable power system capable of handling electrical power requirements of modern multifunction military vehicles. The initial phase involves the development of models for the different subsystems of the aircraft: engines, alternator, integrated starter generator, fuel cell, rectifier, CAN, load and energy storage devices. The strategy is to individually develop and test the different subsystems in Matlab/Simulink, then to proceed to the integration of the overall system. The second project involves the analysis of interactions, dynamics and stability problems caused by the interconnection of power electronics converters in modern power systems.



SURVIVABILITY AND VULNERABILITY OF HYBRID ELECTRIC DRIVE TRAINS

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Hybrid drivetrains are more complex than conventional drivetrains powered by a single engine. This complexity increases the probability of failures at system and component levels, which theoretically lowers the reliability and survivability of the vehicles. However, the presence of two power sources within the drivetrain confers hybrid vehicles a relative immunity to single point failure, i.e. the complete loss of functionality due to the failure of a single component. In most cases, it only results in a degradation of vehicle performance.

The analysis of survivability and performance degradation is based on two levels: system and component (or subsystem). The system level analysis includes control failure, signal transfer failure, energy transfer failure. The component level failure analysis is focused on the insides of the component and the analysis of failure causes and their immediate effects to this components and extended effects to overall drivetrain and vehicle performance.

Survivability is especially crucial to military vehicles. A proper analysis of the drivetrain reveals possible failure points and critical components that influence survivability. The results of this analysis allow the designer to implement specific technical measures to prevent total failure and reduce the degradation of performance in case of partial failure. The prediction of the level of performance degradation may also be used to generate warn the future users of the vehicle, thus allowing them to reach safety or repair. The benefits of this research carryover to civilian vehicles, enhancing their reliability for greater user satisfaction and safety.

ACTIVE COMPOSITE WHEEL

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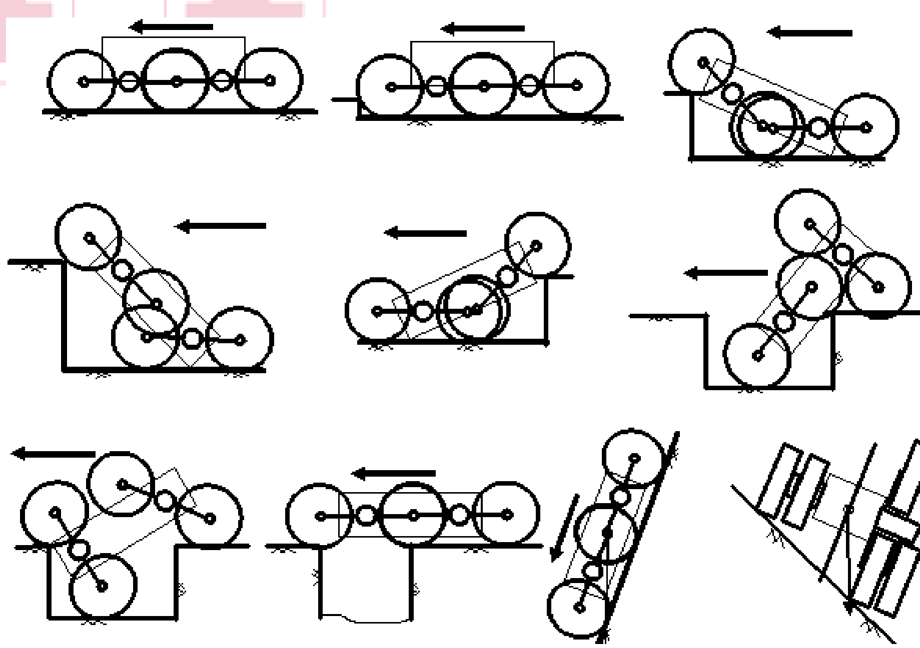
Active-composite wheel vehicles extend the concept of the wheel to climb and jump over large obstacles, and provide active suspension capabilities. Current vehicle systems are very fast and comparatively efficient on flat, paved surfaces. However, both speed and efficiency decrease greatly in off-road or variable terrain applications. To offset these disadvantages, larger wheels would have to be installed. Unfortunately, the larger wheels will be under-utilized in paved road applications, and their extra weight will considerably reduce the average fuel efficiency.

The active composite wheel accommodates a wide variety of terrains, and is able to negotiate both positive and negative obstacles in its path. Essentially, the effective wheel sizes are variable, allowing higher speed while traveling on wheels of smaller radius, and increased maneuverability while traveling on wheels of larger radius. Such a vehicle would be much lighter than a vehicle with equivalent capabilities using larger wheels.

The issues to be investigated include the control system of the vehicle. The increased flexibility of the vehicle requires controls of a high degree of complexity. Even defining the user inputs so as to minimize them yet retain maximum capabilities requires significant research. In addition to forward drive control, steering systems are also researched, as the simple axles of conventional vehicles do not exist on composite-wheel vehicles.



REAL-TIME SIMULATION

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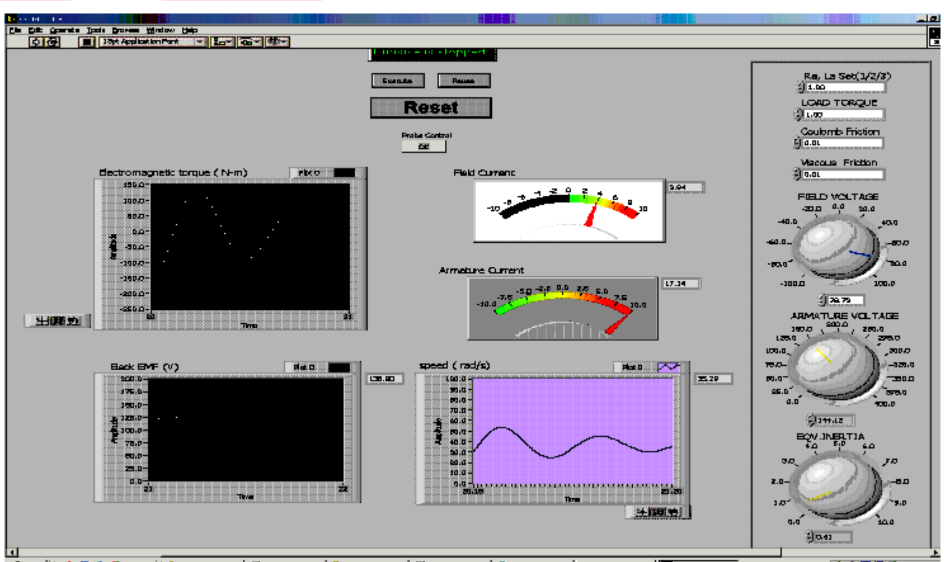
Laboratory experiments are an indispensable part of undergraduate teaching especially in motor drives, where students run motors in the lab and verify their behavior under different conditions as predicted by the theory taught in class. Hardware experiments are important for the students because they provide them with a "feel" of the machine. However, hardware-based experiments suffer inherent disadvantages: cost concerns limit the number and variety of experiments, safety concerns limit the nature and extent of experiments, and there is a limited access to motor parameters. Overall, hardware-based laboratories suffer a lack of flexibility. While offering maximum flexibility, conventional simulation packages do not offer any practical "feel" or sense of time.

The "Actual-Virtual Lab" has been developed to remedy to these shortcomings. It uses real-time simulation techniques and implements the concept of "virtual machine". Students initially perform the experiment on the hardware, and then do the same on a virtual replica of the hardware. The parameters of the virtual machine are adjustable at any time through a graphic interface. The real-time simulation provides the students with a feel for electromechanical time constants and with the possibility to change design parameters such as inertia, friction coefficients, etc… Experiments that would be dangerous or impossible to conduct with hardware are now possible, thus greatly expanding the scope and reach of the laboratory. The possibility to remotely access the virtual laboratory through the internet further enhances the convenience and the quality of the teaching.



HARDWARE-IN-THE-LOOP DEVELOPMENT OF MOTOR DRIVES

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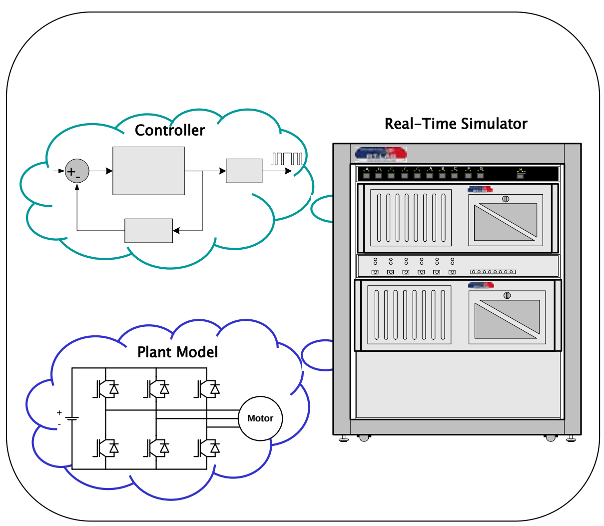
This research focuses on the use of commercially available off-line and real-time simulation packages for the hardware-in-the-loop development of motor drives. The objective is to provide a fully adjustable development tool that allows developing the controls for a motor drive before the drive or a specific load is available. This technique is particularly useful for the fast and low-cost development of short-development cycle drives, high-cost drives, critical mission motor drives, drives and loads not yet developed, such as in automotive traction, manufacturing, military, aerospace, and in research and education. The various aspects of this research include the modeling of DC, induction, brushless DC, and switched reluctance motor drives in Matlab-Simulink™, and the conversion of these models to real-time simulation models using RT-LAB™ with a focus on the issues of real-time sampling rate and high-fidelity.

Fully Digital Real-Time Simulation

Both the controller and the drive circuits are simulated



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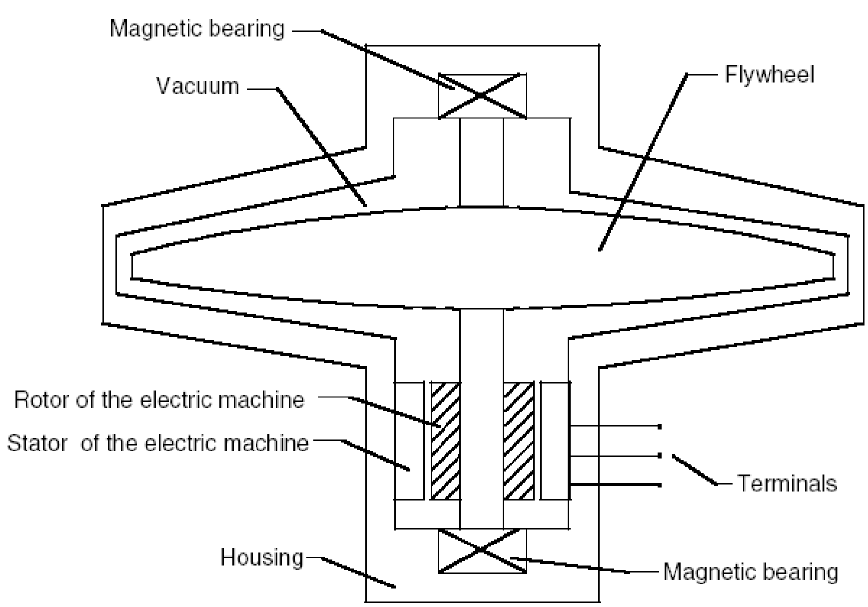
Very high speed flywheel systems are promising energy storage means for hybrid vehicles. They posses many advantages over chemical batteries, including high specific energy, high specific power, long cycle life, high energy efficiency, low maintenance requirements, reduced environmental contamination, reduced sensitivity to temperature and cost effectiveness.

Flywheels store kinetic energy in its high-speed rotor. However, current technology makes it difficult to propel the vehicle directly from the flywheel. The most commonly use approach is to couple the flywheel to an electric machine, a combination often referred to as a mechanical battery. While the amount of energy stored depends solely on the characteristics of the rotor (moment of inertia and speed), the peak power depends only on the electric machine. It is thus critical to design the electric machine so that it matches the characteristics of the flywheel and is capable of delivering rated power all across the operational speed range of the flywheel. This requirement primarily determines the maximum speed to base speed ratio and efficiency contour. It results that the choice of electric machines for flywheel drives is heavily influenced by these characteristics, and that the switched reluctance machine is strongly favored because of its ability to operate at constant power over a broad speed range and at very high speed.



DEVELOPMENT OF THE WIRELESS CAR

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Advances in wireless communication offer the possibility of completely reworking automotive power systems, controls, and communications.

The architecture of the power system for instance is no longer constrained by the necessity to run power-carrying cables from the battery to a distant load via the dashboard. A single power bus may run across the length of the vehicle, easily reaching all electrical loads, with a minimum expense of copper. Controls and data are then provided and collected by wireless means, which greatly simplifies the wiring in the vehicle and offers the possibility of adding components to the vehicle without concerns of routing wires. New vehicle power system topologies are rendered possible as well as new control methods, operational modes, dynamic responses and integration of novel components.

OMNI-DIRECTIONAL DESIGN TOOL

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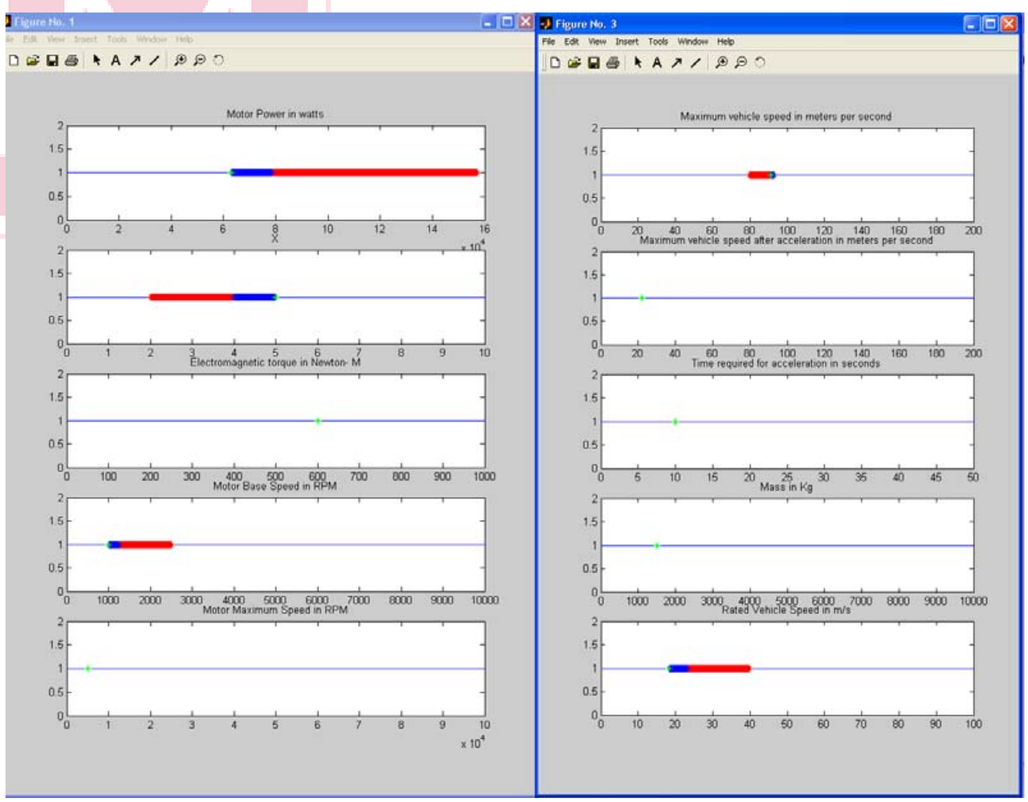
The parametric design of a vehicle drive train involves determining the power/energy ratings, sizes, weights, etc.... of all major functional components in the drive train. These components are sized in order to meet performance requirements such as acceleration performance, grade ability, gas mileage, while simultaneously satisfying constraints like pollution norms, weight and volume restrictions. The conventional design procedure starts with performance requirements and works its way towards the sizing of the components, using the laws of physics relating them.

Omni-directional design is a new approach towards parametric design wherein the designer may start from any and as many of the design parameters of his choice and calculate the possible values for the remaining variables. When this design approach is applied to a complex system like hybrid electric vehicles, scenarios arise such that there are many possible values (ranges of values) for a particular output given the set input parameters as singular values. This interesting phenomenon can be harnessed for better design using multiple iterations with either the designer choosing the inputs following each iteration or having an optimization algorithm in the design algorithm.



SERIES-PARALLEL HYBRID DRIVE TRAINS

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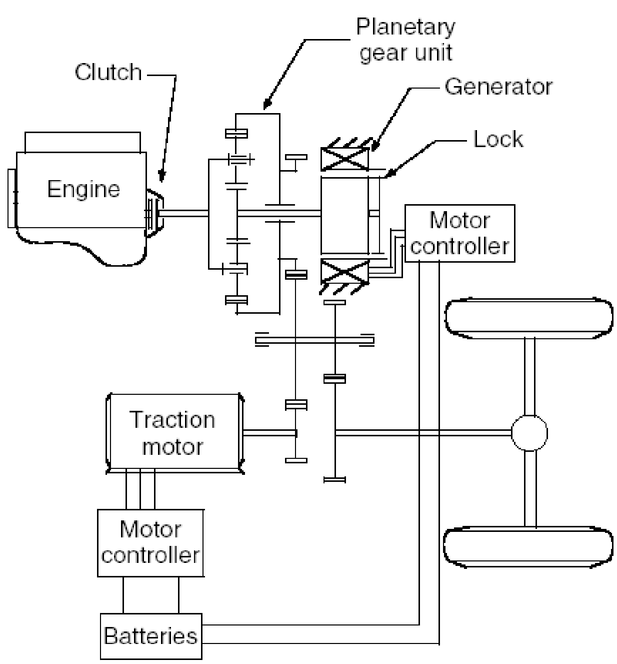
While series and parallel hybrid drive trains are easy to understand and conceptualize, series-parallel hybrid drive trains provide the most opportunities for the optimization of the operation of each component, the minimization of overall drive train losses and the maximization of kinetic energy recovery during regenerative braking.

Series-parallel hybrid drive trains are a hybrid drive train architecture class that combines structural features of series and parallel drive trains. They are sometimes referred to as "power-split" architectures because the power flow is split between a mechanical path and an electrical path by the means of gears and planetary gears. The drive train performs the functions of an electric port for energy input and output and of an electromechanical continuously variable transmission. This later allows operating the engine on a locus of minimum specific fuel consumption.

This research project aims at inventorying all possible configurations for series-parallel hybrid drive trains, conceptualizing them, analyzing their fundamental characteristics and modeling them. Then we will devise design rules and control strategies for these architectures and apply them to a broad variety of vehicles, duties, and drive cycles.



HYBRID ENERGY STORAGE

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Chemical batteries, ultracapacitors and flywheels have different operating characteristics. Chemical battery and flywheel are more like energy sources, which deliver energies with medium power in relative long time period, whereas, ultracapacitor is more like a power source, which delivers large power in a short time period. It is feasible by combining two of these basic energy storages together to constitute a high energy and high power energy storage system-hybrid energy storage system.

The most straightforward approach is to directly connect ultracapacitors to batteries. This configuration has the simplest structure and no control unit needed. The behavior of the ultracapacitors is more like a current filter, so that, high battery peak current is leveled. The first responding for this step current is the ultracapacitors, and then the load current gradually transfers from the ultracapacitors to the batteries due to the voltage drop caused by the storage energy decrease in the ultracapacitors. When the load disappears, the ultracapacitors is charged by the batteries automatically.

In a passively connected pack of ultracapacitors and batteries, the power flows (output and between the components) cannot be managed. A passive combination makes poor use of the high-power density of ultracapacitors. This remedied to by the use of power electronics converters to interconnect the two. Basically, the power conditioning operation can be divided into three different modes, (1) Ultracapacitor peaking operation for high power demand (positive and negative, (2) ultracapacitor charging from batteries, and (3) batteries alone operation. These operation modes are implemented by a central control unit. The central control unit commands the power electronics and receives signals through sensors. The control objectives are: (1) to meet the power requirement, (2) to keep the battery current in a preset region, and (3) to keep the battery SOC in its middle region (0.4 to 0.6 for example), in which the battery efficiency are usually optimized. This system can potentially fully use the high power property of the ultracapacitors, and therefore resulting in a small battery pack. The actively controlled battery current can potentially lead to more efficient battery operation and easier thermal management. electric machine, stable operation and high efficiency. Compared with battery/ultracapacitor hybrid system, flywheel/ultracapacitor system would bear the advantage of extended service life, wide temperature adaptability and less maintenance needed. These advantages are very important to military vehicles.

ACTIVE SUSPENSION

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Most road vehicles still rely on passive suspensions composed of a spring and damper combination. While passive suspensions are simple and cost effective, they do not provide optimal ride comfort and road handling under all circumstance. Their characteristics are fixed by design and favor either performance or comfort. Semi-active suspensions in which damping and springing parameters are electronically adjusted have been introduced during the last decade to remedy to these shortcomings but they still do not provide ideal ride characteristics. Active suspensions provide great comfort and perfect road handling without any compromise. Active suspensions are either hydraulically or electrically actuated. Existing systems typically require large power supplies and consume very significant amounts of energy, which increases the fuel consumption of the vehicle.

Our approach is based on oscillating electric machines, which allows tuning in real time the parameters of the suspension over a seemingly infinite range of frequencies and adjusting the ride height electronically. The use of oscillating electric machines reduces very significantly the energy consumption of the suspension, which is now limited to compensating the losses of the system.

SYSTEM LEVEL CONTROL FOR H_2-FUELLED ENGINES

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Hydrogen is being evaluated as an alternative fuel for internal combustion engines. Hydrogen engines have two major obstacles when competing with gasoline/diesel engines: a poor volumetric efficiency and high NOx emissions under stochiometric conditions. Supercharging, direct injection, and turbo charging lean mixtures, and exhaust after-treatment at stochiometric conditions are the most commonly adopted methods to solve these problems.

The hybridization of the hydrogen engine power train offers a unique alternative to solve these problems. It can result in better fuel economy, lesser intake boost requirement, and low emissions without exhaust after-treatment. The objective of this research, in cooperation with Argonne National Lab is to evaluate the optimum degree of hybridization, along with proper system and engine control, to achieve minimal pollution and maximal performance.

The Center for transportation research at Argonne National Laboratory is building a Mobile Advanced Technology Tested (MATT), which has the capability of hybridizing a hydrogen engine by emulating different sizes and types of motor and battery combinations through a torque source and a voltage source respectively, using hardware in the loop principle. Different degrees of hybridization and system controls will be tested with MATT on a 4 wheel chassis dynamometer to determine an effective degree of hybridization and control strategy.

STARROTOR ENGINE BASED HYBRID VEHICLE

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In this project, we are investigating the integration of the StarRotor engine in hybrid vehicles. The objectives are to achieve minimum fuel consumption with minimum component weight, size and cost.

Rather than optimizing each component separately, the integration study seeks the optimization of the whole system. Two approaches are combined to achieve this goal: system level design and control strategy. In system level design, the parameters investigated include the power rating, operational speed range of the StarRotor engine, drive train gear ratios, energy storage system energy and power ratings, and electric motor rating and extended speed range width. Our previous research work has shown that proper system level design can significantly decrease the size and weight of the components and reduce the overall system losses while allowing maximum recovery of energy during regenerative braking.

The control strategy seeks the harmonious optimization of the overall system. Its design is tightly intertwined with that of the system. The control strategy decides the power flows within the system while taking into account the efficiency maps of each component and system level operational rules.

SIMULATION OF MAGNETIC TRANSIENTS IN SYSTEM APPLICATIONS

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In conventional equivalent electric circuit model of magnetic circuits the reluctance is modeled by a resistance, while the magnetic flux is modeled as a current. This approach is fundamentally flawed and as a result it does not allow understanding and modeling transient phenomena in magnetic circuit such as the in-rush current in transformers.

In a continuation of our previous research work on the equivalent electric circuit modeling of electromechanical systems, we are developing a new approach, based on fundamental physics that remedies to these shortcomings. This approach conserves energy at every instant by considering the storage of magnetic energy in the magnetic circuit due to the orientation of magnetic dipoles. We also seek to represent the effects of magnetic saturation and magnetic hysteresis.

The objective of this project is to design an insightful theory and modeling tool, based on fundamental physics.

RECENTLY COMPLETED PROJECTS

ELECTRIC AND HYBRID ELECTRIC VEHICLES

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For over a century, automobiles have been relying on one single technology: the internal combustion engine fueled with fossil fuels. This technology has benefited from the following advantages that have allowed it to dominate the market:

- Good performance
- Long driving range
- Ease of refueling
- Compact and lightweight power plant
- Well established manufacturing techniques and infrastructure
- Well known technology
- Safety

Because of the ever-increasing number of personal automobiles on our roads, numerous problems have arisen:

- Air pollution due to the emission of pollutants (NO_x, CO, HC_x, SO_x, O_3)
- Global warming due to the emission of huge quantities of carbon dioxide, a greenhouse effect gas
- Exhaustion of fossil fuel reserves
- Dependency of western nations upon foreign oil

As a solution to these problems, the next generations of automobiles must:

- Have a significantly improved fuel economy
- Have cleaner emission characteristics
- While being compatible with existing fuel and trafic infrastructure
- While maintaining today's level of performance, comfort, safety and convenience

Over the last 30 years, western nations have become increasingly aware of the environmental, economical and political problems caused by personal transportation. Consequently, the research for new vehicle technologies and fuel infrastructures has been thriving. Three major technologies have been investigated:

- Electric vehicles (EVs)
- Hybrid electric vehicles (HEVs)
- Fuel cell vehicles (FCVs)

Electric vehicles

Electric vehicles are vehicles that rely on an electric motor connected to the wheels as their unique power plant. In most practical designs, the energy is provided by electrochemical batteries. In some experimental designs, flywheels, ultracapacitors, or solar cells are used for energy storage. The electric vehicle combines several advantages:

- Complete absence of tailpipe emissions
- Fuel infrastructure may be free of fossil fuels
- quiet operation
- Smooth operation

The electric vehicle technology has benefited from concentrated research attention for the last 30 years because of its emission characteristics and the possibility of having a fuel infrastructure that does not rely on fossil fuels at any point. However, the electric vehicle suffers major disadvantages:

- Limited driving range due to the low energy density of electrochemical batteries
- Slow recharge of batteries
- Limited payload due to heavy and bulky batteries
- Reduced energy efficiency of the conversion from fossil fuels to electricity in power plants, thus resulting in increased amounts of carbon dioxide emissions
- High manufacturing cost
- Sluggish performance

The failure of electric vehicles to achieve the objectives of replacement for the future automobiles is mostly due to the failure of their electrochemical batteries to meet the task. Although we now have far better battery energy storage systems, their energy density is still well below that of gasoline and they lack specific power. Our research suggests that fundamental electrochemical limitations prevent batteries from competing with gasoline, even for the most advanced battery technologies.

Hybrid electric vehicles

Hybrid electric vehicles combine a gasoline or diesel engine with an electric motor and an electrical energy storage device (electrochemical batteries, ultracapacitor, flywheel). The engine is controlled to supply the power necessary to overcome the aerodynamic drag, the rolling resistance friction and the losses in the drive train. The electric system (motor and batteries) is used to accelerate the vehicle and to recover its kinetic energy through regenerative braking.

The internal combustion engine and its fuel tank provide for a compact power plant and a long driving range, while the electric system provides high accelerations and regenerative braking. Studies show that most of the urban driving is made up of frequent acceleration and braking phases with a very low average speed. While a conventional vehicle will use an oversized engine, burning fuel inefficiently to accelerate the vehicle and then dissipate the kinetic energy of the vehicle at the next red light, a hybrid vehicle will use the electric motor to efficiently accelerate the vehicle and recover the kinetic energy. Thus, the kinetic energy is not all lost but is considerably increasing the fuel economy of the vehicle. In addition, the engine can be downsized and operated only within its range of maximum efficiency. Finally, the downsized and less used engine is more easily controllable for emissions.

Hybrid electric drive trains may be classified in two major categories: series and parallel:

- Series hybrid electric drive train: The engine drives an electric generator, which recharges the batteries while an electric traction motor alone propels the vehicle and draws its power from the batteries. In series hybrid drive trains, the decoupling between the engine and the vehicle speed allows operating the engine optimally. As a result, the control strategy is simple. However, the weight and volume of the drive train are high because of the presence of the generator and because the traction motor is sized to supply the full traction requirements. In addition, the energy output by the engine is processed twice, which reduces the energy efficiency of the vehicle.

- Parallel hybrid electric drive train: The engine and the electric motor both supply mechanical power to the driven wheels. Because of the mechanical coupling between the engine and the wheel, the energy efficiency is higher than for a series hybrid drive train. A parallel drive train is much more compact and much lighter. However, because of the mechanical coupling between the engine and the wheels, the engine cannot always be operated within its range of maximum efficiency although it can still be operated along its line of minimum fuel consumption if coupled to a continuously variable transmission. The greatest disadvantage of parallel hybrid drive trains is their great complexity of architecture, design and especially control.

Hybrid electric vehicles combine the advantages of both conventional and electric vehicles. Like conventional vehicles, they have a moderate weight, long driving range, are easy to refuel, make use of most of the existing automotive technology infrastructure and fit the existing fuel and road infrastructure. Unlike electric vehicles, they require smaller battery packs, and do not need charging from an external source. However, they suffer a few disadvantages mostly resulting from their complexity. In order to fully exploit their potential, careful design and drive train control are required.

Our vehicle research has been concentrating on new drive train concepts, new traction system components, new system controls and new modeling methods. We are also investigating regenerative braking and its integration in the automobile. Indeed, an effective regenerative braking is the key to achieving a good energy efficient in urban drive cycles, while the flexibility and controllability of the electric motor offers many possibilities in optimizing the vehicle braking dynamics (ABS, stability control).

Our development of electric propulsion systems for EV and HEV is concentrated on the influence of the characteristics of electric motors on the EV and HEV drive trains. The parameters investigated include torque density, converter size, extended speed range, energy efficiency, safety and reliability, cooling, and cost. Among these parameters, the extended speed range and energy efficiency are the two characteristics that are the most influenced by the vehicle dynamics and system architecture. Short circuit events on the traction motor can cause “wheel-locking” on the vehicle and may have an adverse impact on vehicle stability. Several types of electric motors have been investigated for fault-tolerance.

Fuel Cells

Fuel cells are electrochemical devices that convert directly the chemical energy of a fuel into electrical energy without combustion. The energy conversion efficiency is potentially very high, while the conversion process emits virtually no pollutants. A fuel cell can replace an engine-generator couple in a series hybrid drive train, thus providing a high energy conversion efficiency. There are five major fuel cell technologies: proton exchange membrane (PEM), alkaline (AFC), phosphoric acid (PAFC), solid oxide (SOFC), and molten carbonate (MCFC). Because they operate at low temperature and high efficiency, only PEM and AFC are thought of for vehicle applications, because high-temperature fuel cells have fundamental warm-up problems.

Despite their total absence of emissions and high energy conversion efficiency, fuel cells suffer some disadvantages. Cost, volume and weight are being actively researched and constantly improved. However, the major disadvantage is the supply of hydrogen, the preferred fuel for PEM and AFC. To this day there is no source of hydrogen that is practical, safe, efficient and cost effective at the same time. Therefore, fitting fuel cell powered vehicles in the existing fuel infrastructure is difficult.

Hybrid and fuel cell hybrid railway vehicles

Today railway vehicles rely on direct drive trains where a single source of energy supplies the traction power to the electric traction motors on the axles. This single energy source may be either an overhead line (electric traction) or a diesel-generator (diesel-electric traction).

In the case of the diesel-electric traction, there is to this day no possibility to regenerate the kinetic energy of the train. In the case of the electric traction, the regeneration is possible but other problems may affect the use of a direct drive train: high peaks of current during the acceleration phase, large line transformer and converters. The hybrid drive train remedies these problems because only the average drive cycle power is drawn from the primary energy source (overhead line or diesel-generator), while the peaking power (acceleration and regenerative braking) is provided by onboard storage (e.g., batteries). This approach allows regenerative braking for diesel-electric traction, and low and leveled current profiles in overhead lines for electric traction. Finally, the power rating of the primary energy source is greatly reduced.

This last aspect yields the possibility to replace the diesel-generator by a fuel cell, thus considerably increasing the energy efficiency of the vehicle. The reduced power rating required, reduces the impact of the high fuel cell cost, while the unique characteristics of a railway vehicle reduce the impact of the fuel cell size, weight and unique hydrogen fuel requirements. The professional use and maintenance of these vehicles are definitely advantages when dealing with today's complex fuel cell technology.

The hybrid railway vehicle and the fuel cell hybrid railway vehicle may prove economically viable and enhance the competitiveness of rail transportation versus road transportation.

Modeling and Simulation

Simulation software packages are very helpful for the design and evaluation of vehicle propulsion. Software development is based on the knowledge of architecture, control strategies and design methodology. Simulation can give a lot of valuable operating information about the propulsion system, such as engine or fuel cell power rating, electric motor power rating, battery/ultracapacitor power and energy flow. Simulation may also be used to predict the vehicle performance such as maximum speed, acceleration, grade-ability, and fuel economy.

We have developed a new approach for the modeling of hybrid electric vehicles using gyrator theory. The key advantage of this approach is that it results in very simple and unified models under the form of equivalent electrical circuits for both the electrical and the mechanical parts of the system. Therefore, the dynamic characteristics of the vehicle can be fully studied in one unified language.

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More Electric Vehicles

There is a trend towards electrical actuation to replace mechanical, hydraulic actuation in vehicles. This concept is referred to as "More Electric Vehicle", MEC. The functions concerned include power steering, braking, active suspension, air conditioning, engine valve actuation, oil pump, and water pump in automobiles, flaps and landing gear in airplanes. Other functions, in either vehicle hotel loads for the comfort of the passengers or traction loads to improve the fuel economy of the vehicle, can also become electrified.

Electrical actuation offers a much greater flexibility and versatility than hydraulic, pneumatic or mechanical actuation. For instance a hydraulically actuated load needs a pump that is connected to the engine shaft and therefore subject to the speed variations encountered by the engine. However, the load must be able to operate fully even when the engine speed is low. This leads to over sizing of the pump and the actuator, which increases the weight, volume and cost of the system and increases the fuel consumption of the vehicle. MECs decouple the operation of the actuators from the engine, thus diminishing their size and weight while improving the operation of the vehicle and its fuel consumption.

Vehicle power systems

The vehicle power system is the backbone that allows the upgrade to electrical actuation. It is therefore critical and must meet several requirements: enough power to supply all loads in any given condition, stability in all situations, safety for the driver and the passengers, simplicity, low weight, etc. These requirements severely impact the technical choices such as voltage level, frequency, architecture, and control strategy.

42-Volts Electrical Power System

The electric load in the automobiles is continuously increasing, with more and more electronic and electric controls and actuators. Furthermore, hybrid electric propulsion will eventually be introduced into the automotive traction system. Thus, it is clear that the conventional 14V electric power system should be replaced by a higher voltage electric system, such as 42V. The 42V electric system can not only enhance the efficiency of conventional systems, but also provide the opportunity for the development of low voltage hybrid traction. However, 42V is low, compared to traditional electric drives. With a 42V power system, a moderate amount of hybridization is possible.

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Traction motor drives

Traction motor drives are essential for the performance of the electric and hybrid electric vehicles. Many traction motor drive technologies have been investigated and evaluated for electric and hybrid electric vehicles. The most commonly used motor drive technologies are the induction motor drive, the permanent magnet motor drive, and the switched reluctance motor drive.

The induction motor drive is a classic motor drive technology. The advantage of this technology is the low cost of the motor. However, possibility of mechanical failure, complexity in control, and heating problem at high power or low voltage applications, are some of the disadvantages of this technology.

The permanent magnet motor drive is proposed by several automobile manufactures, such as Honda and Toyota, for electric and hybrid electric vehicle applications. The permanent magnet motor offers the maximum power density and energy efficiency compared to its counterparts. Simplicity of control is also a preferred feature of permanent magnet Brushless DC motor drive. However, the permanent magnet motor drives have high cost and are difficult for field-weakening operation, which is required in vehicle applications.

The switched reluctance motor drive is a relatively new technology for variable speed drive applications. The switched reluctance motor drive has a low cost motor structure, reliable motor drive inverter, simple control strategy, and high efficiency over a wide speed range. In particular, the switched reluctance motor drive can have an extended constant power range by proper design and control. This feature makes this motor drive an interesting candidate for electric and hybrid electric vehicle applications.

Sensorless Control of SRM Drives

Switched Reluctance Motor (SRM) drives have some advantages over other conventional variable speed drives. For example, simple motor structure and absence of permanent magnets and windings on the rotor make very high speed SRM operation possible. It is now well known that SRM drives are suitable for aircraft starter/generator systems, automotive applications, power steering applications in vehicles, washing machines, compressors, pumps, electric and hybrid vehicles, and others.

The control electronics of SRM drives are simple. However, accurate control of the SRM drive needs rotor position information. The rotor position information is usually obtained by employing rotor position sensors. The presence of discrete position sensors not only add complexity and cost to the system, but also tend to reduce the reliability of the drive system. Therefore, there are some applications, such as in the compressor, where the conditions do not allow the use of external position sensors.

Several sensorless control methods have been developed in our research group. These methods can be broadly classified into the following: hardware intensive methods, which required external circuitry for signal injection, data intensive methods such as flux integration technique, which demand large look up tables to store magnetic characteristics of the SRM, and MIPs intensive methods that are model based methods, such as, the state observer method, signal power measurement method, and inductance model based techniques. We have perfected our inductance model based sensorless SRM controls as shown in references.

Self-turning Control of SRM Drives

One advantage of the SRM is in its simple and rugged structure. Though it has a simple structure, its precise control is complicated by the highly nonlinear characteristics of the machine. Digital Signal Processors (DSPs) can be used for advanced digital controllers, which can handle complicated SRM control strategies. Several control strategies have been developed to improve the performance of the SRM drives, under parameter variation. The performance indices that are usually considered are maximizing torque, minimizing torque ripple and maximizing drive efficiency. Previous work on optimization of SRM drive performance consists mainly of off-line calculation to find the excitation instances for optimizing the performance indices, such as, efficiency and torque output. These control strategies are based on the assumption that there are no parameter variations that can change the electrical characteristics of the machine. However, significant SRM parameter variations occur in its mass production or with motor aging. Control techniques with self-tuning capability are essential to maintain optimal performance in the SRM drive, in presence of parameters variations. It has been shown that parameter variations can alter the inductance profile to a significant extant. Since the control of SRM is essentially based on the inductance profile, an inductance model based on-line self-tuning control strategy for optimal performance can be developed.

We have developed a self-tuning control method, which takes into account the variations in the inductance profile due to parameter variations. Furthermore, we have developed a novel method, which combines an Adaptive Artificial Neural

Network based control with a heuristic search method, which periodically updates the weights of the NN in accordance with the parameter variations. The NN is trained with the experimental data obtained from the heuristic search based self-tuning setup. Hence, it includes the effect of saturation and has a very good accuracy. In addition, it offers a good dynamic response and has an excellent self-tuning capability.

Power Factor Control of AC Motor for Low Cost Application

AC motor drives are popularly used in industry. However, variable speed control of AC motor is complex and very costly. The conventional control system of a variable speed AC motor usually consists of two steps: rectifier and PWM inverter. The rectifier converts fixed-frequency AC power into DC power, and then PWM inverter converts DC power into three phase, frequency and voltage adjustable AC power. Although this technology has been well established for many applications, there are some drawbacks for this configuration, such as restricted drive operating range and high input harmonic distortion. A new drive system configuration has been developed to try to overcome these drawbacks and further reduce the parts count. No extra inductor or switches are required. The operation and control strategy for this new drive system are presented. Simulation and experimental results with a high speed DSP based induction motor drive has been achieved and the impact of the converter operation on the machine performance has been addressed.

Advanced Brushless DC Motor Drives

Brushless DC motors are permanent-magnet motors that use electronic switches instead of brushes and a commutator. BLDC motors offer quiet and high-speed operation. They are easily adapted to programmable controls in appliance applications where variable speed, reversibility, and braking are required. The safe, low-voltage, arc-less operation of the brushless DC motors also makes them suitable for hazardous. Brushless DC motors have some advantages over induction motors, such as, high power density, low mass and small volume, high torque, high efficiency, and easy operation as a generator. We are presently working on novel sensorless controls for the brushless DC motors at all speeds, including very low speeds.

Power Electronics

Power electronics and power converters play an increasing role in the control of electric power. However, as the complexity of the power system, that includes power converters, grows, new problems surface. We are working on modeling and the study of the dynamics of multi-converter power systems.

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The overall research objective of this project was to design and develop an automated catastrophic failure identification and intelligent reconfiguration/ restoration system for shipboard electric power systems (SPS).

The project was divided into three main tasks: develop a catastrophic failure identification subsystem; develop an intelligent reconfiguration / restoration subsystem; and conduct simulation and modeling where appropriate.

A complex AC radial system based on a surface combatant ship was devised, which served as the test electrical system during the development and verification of the failure identification and reconfiguration techniques. This system was modeled and simulated extensively in Alternative Transients Program (ATP) and Professional Simulation Program with Integrated Circuit Emphasis (PSpice) for use in the development of the catastrophic failure identification and reconfiguration and restoration subsystems.

The catastrophic failure identification subsystem was implemented as an expert system with rules containing the logic for detecting and locating failures and affected loads in a SPS. The failure identification system was verified using the ATP computer model of a surface combatant ship. The intelligent reconfiguration system was implemented as three modules: reconfiguration for restoration using optimization technique, reconfiguration for restoration using expert system, and general reconfiguration using heuristic rules. The reconfiguration for restoration using optimization technique was developed to gain an understanding of the problem formulation and to understand the combinatorial nature of the solution approach. The reconfiguration for restoration using expert system incorporated the knowledge gained from the optimization-based technique and the ATP fault studies performed on the computer model. The general reconfiguration method included rules for performing system reconfiguration for operational reasons other than restoration.

Catastrophic Failure Identification

Electric power failures in ships are generally as a result of widespread system fault due to battle damage and material casualties of individual loads. Such a fault may be catastrophic which may jeopardize the ship's survivability and its ability to defend against the enemy. Depending on the magnitude of the damage, these catastrophic failures may be very complex in nature and lead to simultaneous and/or multiple faults in the power system. The goal of protective devices is to remove just the faulted portion or system, keeping power supplied to as much of the system as practical. This must be accomplished while maintaining the likelihood of cascading faults causing loss of more of the distribution system than is actually necessary due to the specific fault.

Depending upon the type of system/load fault occurring, one or more of the following techniques are used to manage and control the fault: circuit breakers and fuses to remove faulted loads, generators, or distribution systems from unfaulted portions of the system; bus transfer switches to connect loads to alternate power sources when normal power sources are faulted and removed from service; and load shedding schemes to reduce power demand to match generation capacity due to faulted generator capacity. The existing protection systems used in ships are not always effective in isolating a minimal portion of the system. A catastrophic failure identification subsystem was developed that detects a failure and determines what has been affected (for example, circuit breakers opened, loads that lost power, etc.). A rule-based expert system methodology was used.

Intelligent Reconfiguration

When a fault occurs in distribution systems, relays detect fault areas and disconnect the network by opening circuit breakers. Some loads become unavailable during the fault and should be re-energized as quickly as possible. The re-energizing procedure is called service restoration.

In Navy ship power systems, the automated reconfiguration for service restoration is a new area of research focus. The main objective of the reconfiguration/restoration scheme is to restore as much out-of-service load as possible by reconfiguration with priority attached to some loads. Service restoration is a complex combinatorial optimization problem due to the large number of candidate switches in the distribution system. The optimization problem may take a long time to reach a feasible restoration plan that satisfies operational requirements.

Before restoration is performed the fault must be located and the faulted zone must be isolated which is performed by the catastrophic failure identification subsystem. A methodology was developed and implemented for performing reconfiguration for service restoration using an optimization technique. Also a methodology was developed and implemented for performing reconfiguration for service restoration using an Expert System approach.

On other occasions, the operator may wish to reconfigure the system for operational reasons such as change in operation mode (cruise to battle), taking out equipment for maintenance, etc. This function has been addressed through the development of a general reconfiguration methodology using heuristic rules. The method has not been developed using the expert system shell at this time.

Modeling and Simulation

Ungrounded delta type system configuration is widely used in U.S. Navy shipboard electric power distribution systems with the objective of providing continuity of power supply. To conduct system analysis such as fault analysis, system reconfiguration/restoration, etc., for Shipboard Power Systems (SPSs), an effective simulation tool is needed. In the literature, there is little public information discussing the appropriate simulation tool for simulating SPSs. ATP, PSpice, and Saber are popular simulation tools used for electrical power systems, power electronics, and analog/digital circuits.

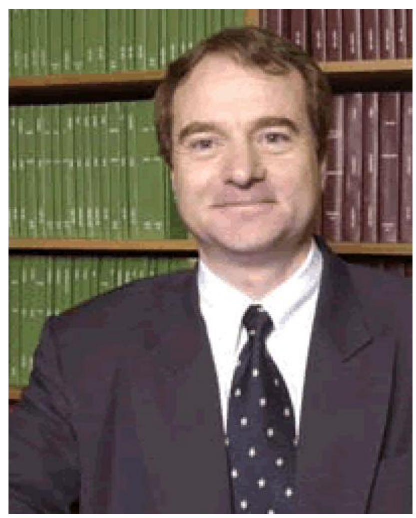
In the present work, these tools were explored to determine their suitability to simulate SPS. These tools were used to simulate a sample test system that includes components common to SPS. The simulations obtained were used to illustrate the performance of each tool (package) for conducting steady state and transient system studies for SPSs.

PERSONEL

Dr. Karen L. Buttler-Purry, Associate Professor, Assistant Dean of Engineering

Dr. Karen L. Butler received a B.S. degree from Southern University - Baton Rouge in 1985, a M.S. degree from the University of Texas at Austin in 1987, and a Ph.D. degree from Howard University in 1994, all in electrical engineering. In 1988-1989, Dr. Butler was a Member of Technical Staff at Hughes Aircraft Co. in Culver City, California. She was a recipient of a 1996 Faculty Early Career Award and a 1999 Office of Naval Research Young Investigator Award. She is also a 1998-99 Center for Teaching Excellence Montague Scholar. Her research focuses on the areas of computer and intelligent systems applications in power distribution automation, and modeling and simulation of vehicles and power systems. She is an author of several publications in the areas of power system protection and intelligent systems and has made invited presentations in Nigeria and India. She is the Assistant Director of the Power System Automation Laboratory at Texas A&M University. She is a registered professional engineer in the States of Louisiana, Texas, and Mississippi.

Dr. Mark T. Holtzapple, Professor



Dr. Holtzapple received the PhD from the University of Pennsylvania in 1981 and the BS from Cornell University in 1978, both in chemical engineering. He is now at Texas A&M University in the chemical engineering department. His research interests include biomass conversion for fuel and chemical manufacturing, environment-friendly air conditioning systems, and advanced heat engines. He is the inventor of the MixAlco biomass conversion process and the inventor of the StarRotor engine. Dr Holtzapple has received many awards, including the Presidential Green Chemistry Challenge Award in 1996, McGraw-Hill Environmental Champion Award in 1997, and the Spirit of Innovation Award for Ingenuity in 2003. He has been honored by Texas A& M University as a Halliburton Professor. Prof. Holtzapple has also created a company to develop and market the StarRotor engine. He is a member of the American Institute of Chemical Engineers, the American Society of Mechanical Engineers, the American Chemical Society and the American Society for Engineering Education.

Dr. Reza Langari, Associate Professor

Dr. Reza Langari received his PhD, MS and BS degrees in mechanical engineering from the University of California at Berkeley in 1991, 1983 and 1980 respectively. He is an associate professor in the Department of Mechanical Engineering at Texas A&M University and Associate Director of the Center for Fuzzy Logic, Robotics and Intelligent Systems Research. Dr Langari is the co-author of the textbook Fuzzy Logic: Intelligence, Control and Information, and co-editor of Fuzzy Control: Synthesis and Analysis. He serves as associate editor of IEEE Transactions on Fuzzy Systems as well as ASME Journal of Dynamic Systems, Measurement and Control. His current research interests include dynamic systems and control, intelligent control systems, vehicle dynamics and control. real-time control systems and mechatronics.

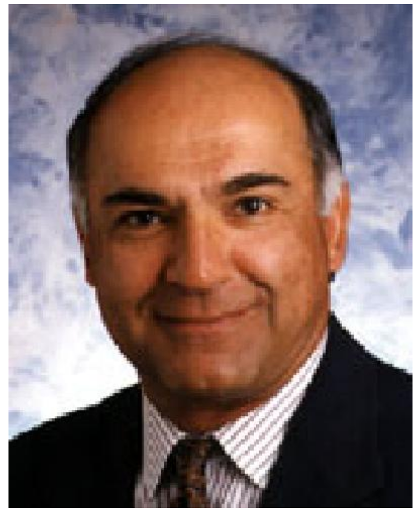
Dr Thomas Lalk, Associate Professor

Dr. Lalk received his PhD, MS and BS from the University of Wisconsin at Madison in 1972, 1967, 1964 respectively. He joined Texas A&M University in 1976 after having worked as a research engineer for McDonnell-Douglas and DuPont, and as an Assistant Professor at The Cooper Union, NYC. During the early portion of his academic career he was primarily involved with teaching courses in thermal sciences (thermodynamics-undergraduate and graduate, heat transfer, internal combustion engines, graduate combustion, fluid dynamics, instrumentation and measurement, and experimentation). Since 1987 he has become extensively involved with the senior capstone design courses teaching the lecture and design studios, and contributing to the development of the system engineering approach to teaching design. As a Ford Fellow he serves on a Committee to integrate design throughout the engineering curriculum. He has advised numerous graduate students conducting research in energy conversion systems (combustion, engines, hybrid vehicles, fuel cells, design and Alkali Metal Thermal to Electric Conversion). He has done considerable consulting with industry, government and law firms in the areas of engineering design, fire research, combustion, internal combustion engines, heat transfer and fluid mechanics, and automotive engineering. At the College and University level he has served on numerous committees and served six years on the faculty senate.

Dr. John M. Miller, Adjunct Professor

John M. Miller received the BS from the University of Arkansas, the MSEE degree from Southern Methodist University, TX, and the PhD from Michigan State University in 1976, 1979 and 1983 respectively, all in electrical engineering. He was a member of the technical staff at Texas Instruments from 1976 to 1980 and joined Ford Motor Company Research Laboratory in 1983 to work on electric vehicle programs and vehicle electrical systems and simulation. He was technical project leader for 42V Integrated Starter Alternator product development program and later technical leader of hybrid technology governance at Ford before his retirement. He is a charter member of the MIT/Industry Consortium on Advanced Automotive Electrical and Electronic Systems and Components. He became an Adjunct Professor of Electrical and Computer Engineering at Michigan State University in 1998 and an Adjunct Professor of Electrical and Computer Engineering at Texas A&M University in 2002. He is the holder of 44 US patents, has authored or co-authored 106 publications and 3 books. Dr Miller retired from Ford Motor Co. in August of 2002 to start up a private enterprise consulting in AC drives, alternative energy, energy storage systems and propulsion systems for transportation, J-N-J Miller design services, P.L.C. He is a member of SAE, and a Fellow of IEEE. He is the recipient of the Henry Ford Technology Award for the development of the starter-alternator system for Hybrid Electric Vehicles and is recipient of the Ford Directors Team Achievement Award.

Dr. Mark Ehsani, Professor, Director

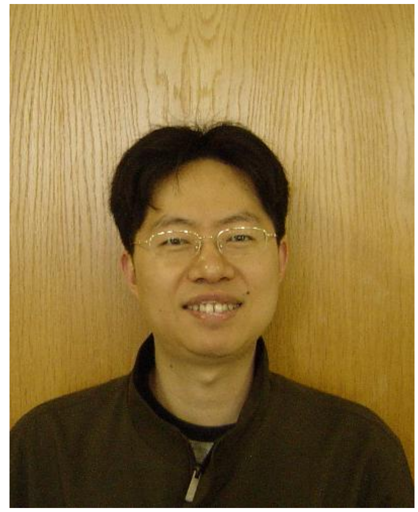


Dr. Mark Ehsani received his PhD in electrical engineering from the University of Wisconsin-Madison in 1981. Since 1981, he has been at Texas A&M University where he founded the power electronics program. He is the co-author of more than 300 technical papers, 3 books, an IEEE standards book, and 20 patents. Three of these papers have received prize paper awards in IEEE-IAS. He has also been honored by numerous organizations, including IEEE awards and Texas A&M University as Halliburton Professor and Dresser Industries Professor. His current research work is in power electronics, motor drives, hybrid electric vehicles and systems. He has served on the Ad Com of Power Electronics Society, Executive Council of Industry Applications Society, elected member of the Board of Governors of Vehicular Technology Society, and as chairman and member of several technical committees, in several societies. He is a Fellow of IEEE, a Distinguished Speaker of Industrial Electronics Society, Power Engineering Society, and past Distinguished Lecturer of Industry Application Society and a registered Professional engineer in the state of Texas.

Dr. Yimin Gao, Research Associate

Dr. Yimin Gao received his BS, MS and PhD degrees in mechanical engineering in 1982, 1986 and 1991 respectively, all from Jilin University of Technology, PR of China. He specialized in the development, design and manufacturing of automobiles. From 1991 to 1995, he was an associate professor and automotive design engineer in the Automotive Engineering College of Jilin University of Technology. He joined the Advanced Vehicle Systems Research Program at Texas A&M University in 1995 as a visiting professor. Since then, he has been working in this program as a research associate on the research and development of electric and hybrid electric vehicles. His research interests include the fundamentals, architecture, control, modeling, and systematic design of electric and hybrid electric vehicles.

Dr. Taehyung Kim, Research Associate

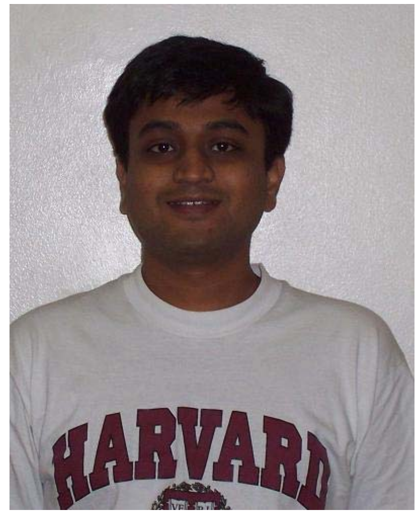


Dr. Taehyung Kim received his PhD from Texas A&M University in May 2003 and his BS and MS degrees from Korea University, Seoul in 1994 and 1998 respectively, all in electrical engineering. He then worked for Samsung in Korea before joining the Advanced Vehicle Systems Research Group as a Research Associate in October 2003. His research interests include sensorless control of BLDC motor drives, power conversion system of BLDC generators, inverter topology for AC motor drives, and application of DSP controllers for motor drives.

Dr. Sébastien Gay, Research Assistant, Lab Manager

Sébastien E. Gay received his PhD and MS in electrical engineering from Texas A&M University in 2001. Beforehand, he obtained his "Diplôme d'Ingénieur" from the "Institut National Polytechnique de Grenoble", France in 2000, and bachelor's degrees in mechanical and electrical engineering from the "Institut Universitaire de Technologie", Grenoble, France in 1996 and 1997 respectively. His research interests include eddy-current brakes, hybrid electric and electric road and rail vehicles, vehicle systems advanced components, fuel cells, and oscillating electric machines. He is the co-author of one book on hybrid vehicles and one published book on DSP-based control of electromechanical motion devices.

Ravish Ailinani, Research Assistant

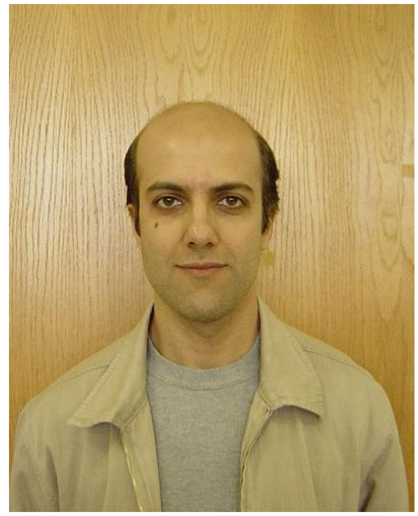


Ravish Ailinani, Research Assistant Ravish Ailinani received his BTech in Electrical Engineering from Indian Institute of Technology - Madras in Aug 2003. He has been actively involved with the research group since Fall 2004 and is currently working towards his Master of Science. His research interests include hybrid electric vehicles, advanced vehicle technology, and electric motor drives. His primary research topic is the Design of an Optimized Low-Cost and Low-Weight Energy Storage Unit.

Peyman Asadi, Research Assistant

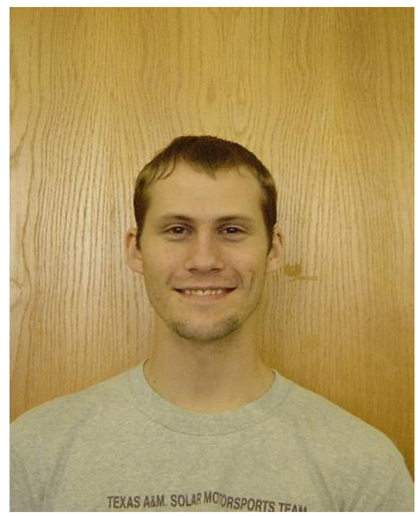
Peyman Asadi received his MS degree from University of Tehran, Tehran, Iran in 1999 and his B.S. degree from Iran University of Science and Technology, Tehran in 1996, both in Electrical Engineering. He has been doing research on the control of motor drives since 1997. Since September 2001, he has been working towards a Ph.D. degree at Texas A&M University. His research interests are mainly advanced control methods in motor drives, intelligent and robust control systems, and industrial electronics.

Mahmood Azadpour, Research Assistant



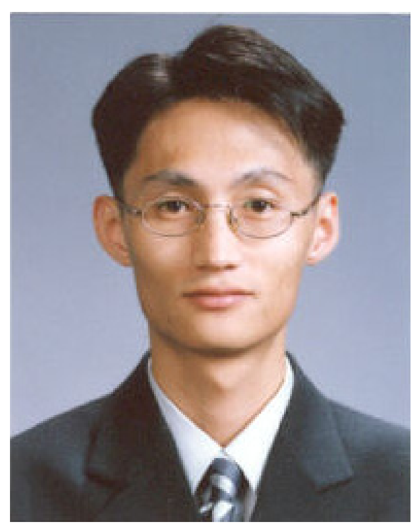
Mahmood Azadpour received his BS in electrical engineering from Sharif University of Technology, Iran in 1993 and MS in socioeconomics system engineering from the Institute of Research in Planning and Development, Iran in 1996. From 1996 to 2001, he worked as an engineer with Kerman-Tablo and OIEC in Iran. He is currently working towards his PhD at Texas A&M University. His research interests are in hybrid vehicles and StarRotor engine-based vehicles.

David Hoelscher, Research Assistant



David Hoelscher received his BS in electrical engineering from Texas A&M University in May 2003. He is currently working towards his Master of Science. His research interests include hybrid electric vehicles, advanced vehicle technology, and electric motor drives. His primary research topic is the modeling and control of active-composite wheel vehicles. He has been actively involved with the research group since Fall 2001. He is also an active member of the Texas A&M Solar Motorsports Team, and was manager of the organization for the 2002-2003 racing season.

Dr. Hyung-Woo Lee, Research Assistant



Dr. Hyung Woo Lee received his PhD from Texas A&M University in December 2003 and his BS and MS degrees from Hanyang University, Seoul, Korea in 1998 and 2000 respectively, all in electrical engineering. His research interests include the maximization of the power throughput of brushless DC generator drives.

Melissa Lipscomb, Research Assistant-

Melissa Lipscomb received her BS in electrical engineering from Texas A&M University in 2000. She joined the Bettis Atomic Power Laboratory, where she studied alternative energy storage techniques for Navy submarines. She was also the lead engineer for the development and operation of the rod control system on the Virginia-class submarine. Since September 2003, she has been working towards her MS degree at Texas A&M University. Her research focuses on the modeling of combat vehicle power systems.

Behrooz Nikbakhtian, Research Assistant-

Behrooz Nikbakhtian obtained his Bachelor's Degree in Electrical Engineering and a Master of Science from the K.N. Toosi University of Technology, Tehran, Iran in 1994 and 1998 respectively. His Master's thesis dealt with the applications of non linear optimal control techniques in spark-ignited engines. His current research interests include active vibration control and active suspension control.

Neeraj Shidore, Research Assistant

Neeraj Shidore received his MS degree from Texas A&M University in December 2003 and his BS Electrical Engineering from the Government College of Engineering, Pune, India, both in Electrical Engineering. He is currently pursuing his PhD at Texas A & M University. His research interests include real time remote access motor drives laboratory, multi-variable design of Hybrid Vehicles and oscillating electric machines.

Steven Welch, Research Assistant

Steven Welch received his BS in Computer Engineering in 2002 from Texas A&M University. In 2001, he became the Membership Officer of the Texas A&M IEEE chapter, which he transformed into the 6th largest IEEE student chapter in the world. He was elected president of the chapter in 2002. He is currently working towards his MS in electrical engineering with the Advanced Vehicle Systems Research Group. His research focuses on the sensorless control of switched reluctance machines.

Hugo Eduardo Mena,
Undergraduate research assistant

Hugo Eduardo Mena was born in the Dominican Republic. He moved to the United States to pursue a higher education. He received recipient of an undergraduate research award. He plans on pursuing a master's degree after his bachelor in electrical engineering. His current interests are in power electronics, motor drives and electromechanical interactions.

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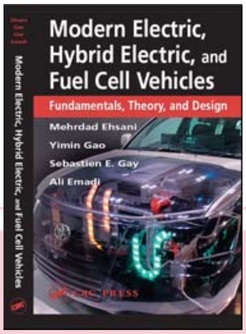

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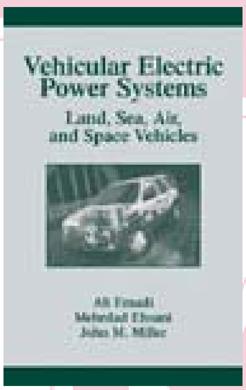

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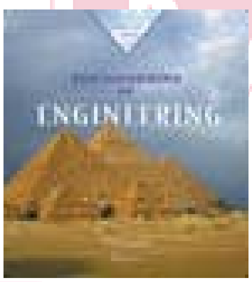

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“Network Reconfiguration for Service Restoration in Shipboard Power Distribution Systems”
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"Kinetic Studies of Ketone Hydrogenation over Raney Nickel Catalyst"
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"Using Lime Pretreatment to Facilitate the Enzymic Hydrolysis of Corn Stover"
W.E. Kaar and M.T. Holtzapple
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Vol. 18, pp 189-199

"Fundamental Factors Affecting Biomass Enzymatic Reactivity"
V.S. Chang and M.T. Holtzapple
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"An Investigation of Electric Motor Drive Characteristics for EV and HEV Propulsion Systems"
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"Effect of Extended-Speed, Constant-Power Operation of Electric Drives on the Design and Performance of EV-HEV Propulsion System"
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“Dynamic Modeling of Brushless DC Motor Drives”
Lee. B. K., Fahimi, B., and Ehsani, M.

“Dynamic Modeling of Brushless DC Motor Drives”
Lee. B. K., Fahimi, B., and Ehsani, M.

“Review of Sensorless Control Method in Switched Reluctance Motor Drives”
Fahimi, B., Suresh, G., and Ehsani, M.
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vol. 3, pp. 1850-1857

“Spatial Distribution of Acoustic Noise Caused by Radial Vibration in Switched Reluctance Motor Drives”
Fahimi, B., and Ehsani, M.
IEEE 2000 Industry Applications Conference
vol. 1, pp. 114-118

“Fault Studies of a U.S. Naval Shipboard Power System”
Adediran, A., Xiao, H., Butler, K.
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October 2000
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“Modeling of Hybrid Electric Vehicles Using Gyrator Theory: Application to Design”
Routex, J. Y., Gay-Desharnais, S., and Ehsani, M.
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vol. 5, pp. 2090-2094

<u>"A Comparison Study Between Two Parallel Hybrid Control Concepts"</u>
Rahman, Z., Butler, K. L., and Ehsani, M.
2000 SAE World Congress, Detroit, MI
March 6-9, 2000
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1999 PUBLICATIONS

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"The Use of Computer Simulated Experimentation to Investigate Fuel Cell Systems with Large Numbers of Parameters"
Lee, J.H. and Lalk, T.R.
Proceedings of the Renewable and Advanced Energy Systems for the 21st Century Conference, Lahaina, HI
Paper No. RAES99-7612

"Biomass Conversion to Mixed Alcohol Fuels Using the MixAlco Process"
M.T. Holtzapple, R.R. Davison, K. Ross, S. Aldrett-Lee, M. Nagwani, C.M. Lee, C. Lee, S. Adelson, W. Karr, D. Gaskin, H. Shiraga, N.S. Chang, S. Chang, and M. Loescher
Applied Biochemistry and Biotechnology
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"Conversion of Waste Biomass to Animal Feed, Chemicals, and Fuels"
M.T. Holtzapple
Texas Animal Manure Management Conference
Ellen Jordan Ed., Austin TX

"More Electric Aircraft"
Emadi, A. and Ehsani, M.

"Advanced Silicon Rich Automotive Electrical Power Systems"
Emadi, A., Ehsani, M., and Miller, J. M.
1999 IEEE 18th Digital Avionics Conference
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"Current Status and Future Trends of More Electric Cars' Power Systems"
Emadi, A., Rajarathnam, A. V., and Ehsani, M.

"Current Status and Future Trends of More Electric Cars' Power Systems"
Miller, J. M., Emadi, A, Rajarathnam, A. V., and Ehsani, M.
1999 IEEE-VTS Fall Vehicular Technology Conference
vol. 2, pp. 1380-1384

“A Simplified Functional Simulation Model for 3-Phase Voltage-Source Inverter Using Switching Function Concept”
Lee, B. K., and Ehsani, M.
IEEE 1999 IECON
vol. 1, pp. 462-467

"A New Method of Network Reconfiguration for Service Restoration in Shipboard Power Systems"
K. Butler, NDR Sarma, V. R. Prasad
IEEE Transmission and Distribution Conference, New Orleans
April 1999
Proceedings pp. 658-662

SHORT COURSES

SHORT-COURSES

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"Real-Time Simulation of Vehicle Power and Propulsion Systems Using Opal-RT Real-Time Tools"
M. Ehsani and S. E. Gay
Short-course to US Army Tank Automotive Command (TACOM)
Detroit, MI, January 11th, 2005

"Control of BLDC Machines with Improved Performance"
M. Ehsani
Short-course to US Army Tank Automotive Command (TACOM)
US Army Vetronics Institute 3rd Annual Winter Workshop
Detroit, MI, January 13th, 2004

"Vehicular Power Systems: Architectures, Dynamics, Control, and Stability Assessment"
M. Ehsani and A. Emadi
Short-course to US Army Tank Automotive Command (TACOM)
Detroit, MI, September 4th 2003

Vehicular power systems increasingly make use of power electronics for added capabilities, greater flexibility in accomplishing the vehicle's mission and improved functionality. However, the connection of several power electronics converters within a system presents particular challenges. This course presents modern vehicular power system architectures, their dynamics as well as control methods for robust and stable operation.

"Control of BLDC Machines with Improved Performance"
M. Ehsani
Short-course to US Army Tank Automotive Command (TACOM)
Detroit, MI, September 4th 2003

This short course is an introduction to three advanced BLDC motor drive technologies being developed by the Advanced Vehicle Systems Research Group: maximization of power throughput control techniques, reduced part converters, and advanced sensorless techniques.

"Design, Analysis and Control of Electrical Motor Drives using Hardware-in-the-loop Simulation"
M. Ehsani and C. Dufour
Short-course to Applied Power Electronics Conference (APEC)
Miami, FL, February 9-13, 2003

This short course presents a novel simulation technique for electric motor drive analysis and controls design. The concept involves the real-time simulation of motor drives and controllers. The theory and technology of real-time simulation are introduced as well as the theory of motor drives and controls. The concept is demonstrated with practical examples.

"Vehicular Power Electronics: Automotive and Aerospace Applications of Power Electronic Converters and Motor Drives"
M. Ehsani and A. Emadi
Short-course to Applied Power Electronics Conference (APEC)
Miami, FL, February 9-13, 2003

This short course presents multi-converter vehicular power systems with a particular emphasis on automotive and aerospace applications. Special attention is brought to stability issues.

"Advanced Military Vehicle Power and Propulsion Systems Survivability and Reliability"
M. Ehsani
Short-course to Army Research Laboratory (ARL)
September 2003

This short course is a presentation of advanced silicon-rich vehicular power systems and their reliability and survivability in military applications. Vehicular power systems are analyzed for systemic, control or component failure modes, preventive solutions are presented at design and control stages. Novel tools for power systems vulnerability research, evaluation and training are presented.

"Real-Time Simulation of Electrical Drives (Control & Firing)"
S. Abourida
Detroit, MI, November 2003

This short course is an introduction to the theory and technology of real-time simulation specifically applied to electric motor drives. The technological issues associated with the real-time simulation of electric motor drives are presented.

PATENTS

PATENTS

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"Advanced Sensorless Drive Techniques for Brushless DC Motors"
Inventor: M. Ehsani and T.H. Kim
US Patent Pending

"Advanced Embodiments of Biomass Fermentors"
M. Holtzapple, C. Granda, R. Davison, E. Darlington, G. Noyes
Disclosed

"Highly Improved Embodiments for Quasi-Isothermal Brayton Cycle"
M. Holtzapple, A. Rabroker, K. Ross, S. Atmur
Disclosed

"Improved Embodiments for Quasi-Isothermal Brayton Cycle"
M. Holtzapple, A. Rabroker, K. Ross
Disclosed

"Advanced Vapor-Compression Evaporator and Heat Exchanger Systems"
M. Holtzapple, G. Noyes
Disclosed

"Position Sensor Elimination Technique for the Switched Reluctance Motor Drive"
Inventor: M. Ehsani
US Patent No. 5,072,166

"Inverse Dual Converter for High-Power Applications"
Inventor: M. Ehsani
US Patent No. 5,208,740

"Power Conversion Using Zero Current Soft Switching"
Inventor: M. Ehsani
US Patent No. 5,287,261

"Phase and Amplitude Modulation Techniques for Rotor Position Sensing in Switched Reluctance Motors"
Inventor: M. Ehsani
US Patent No. 5,291,115

“Method and Apparatus for Sensing the Rotor Position of a Switched Reluctance Motor”
Inventor: M. Ehsani
US Patent No. 5,410,235

“Indirect Rotor Position Sensor for A Sinusoidal Synchronous Reluctance Machine”
Inventors: M. Ehsani, M. S. Arefeen, and T. A. Lipo
US Patent No. 5,448,149

“The Electrically Peaking Hybrid System and Method”
Inventor: M. Ehsani
US Patent No. 5,586,613

“Capacitive Power Circuit”
Inventor: M. Ehsani
US Patent No. 5,852,358

“Switched Reluctance Motor Drive System”
US Patent Pending

“Method and Apparatus for Sensing the Rotor Position of a Switched Reluctance Motor without a Shaft Position Sensor”
Inventor: M. Ehsani
European Patent No. 93923117.1

“Self-Tuning Control of Switched Reluctance Motor Drives System”
Inventor: M. Ehsani
US Patent No. 6,472,842

“Method and Apparatus of Indirect Torque Estimation in Switched Reluctance Motor Drives”
US Patent Pending

“An Efficient Power Circuit for Capacitor Charging and Discharging”
US Patent Pending

“Sensing of Rotor Position of a Switched Reluctance Motor without a Shaft Position Sensor”
European Patent No. EP0662265

“Self-Tuning Control of Switched Reluctance Motor Drive System”
US Patent Pending

“Inductance Model based Indirect Rotor Position Sensing Scheme for Switched Reluctance Motor (SRM) Drive”
US Patent Pending

“Method and Apparatus for Reducing Noise and Vibration in Switched Reluctance Motor Drives”
US patent pending

“Application of Active Composite Wheels to All Terrain Vehicle”
US patent pending

“The Series-Parallel HEV with a Transmotor”
US patent pending

“Fuel Cell Powered Hybrid Drive Train and its Control Strategy”
US patent pending

“A New type of Transmission for Hybrid Vehicle with Speed and Torque Summation”
US patent pending
“Method and Apparatus for Self Tuning Control of Switched Reluctance Motor Drives”
US Patent No. 6,472,842

“Recovery of Fermentation Salts from Dilute Aqueous Solutions”
M.T. Holtzapple, R.R. Davison. T. Luettich
US Patent No. 6,478,965

“Vapor-Compression Evaporative Air Conditioning Systems and Components”
M.T. Holtzapple, R.R. Davison, G.A. Rabroker
US Patent No. 6,427,453

“Process for Recovering Low-Boiling Acids”
M.T. Holtzapple, R.R. Davison
US Patent No. 6,395,926

“Quasi-isothermal Brayton Cycle Engine”
M.T. Holtzapple, G.A. Rabroker
US Patent No. 6,336,317

"Methods of Biomass Pretreatment"
M.T. Holtzapple, R.R. Davison, M. Nagwani
Singapore Patent No. 49186

"Thermal Conversion of Fatty Acid Salts to Ketones"
M.T. Holtzapple, R.R. Davison
US Patent No. 6,262,313

"Method for Conversion of Biomass to Chemicals and Fuels"
M.T. Holtzapple, R.R. Davison
US Patent No. 6,043,392

"Methods of Biomass Pretreatment"
M.T. Holtzapple, R.R. Davison, M. Nagwani
Chinese Patent ZL 93109499.2

"Recovery of Fermentation Salts from Dilute Aqueous Solutions"
M.T. Holtzapple, R.R. Davison, T. Luettisch
US Patent No. 5,986,133

"Thermal Conversion of Volatile Fatty Acid Salts to Ketones"
M.T. Holtzapple, R.R. Davison
US Patent No. 5,969,189

"Apparatus for Producing Organic Acids"
M.T. Holtzapple, R.R. Davison, M.K. Ross, M. Loescher
US Patent No. 5,962,307

"Method and Apparatus for Producing Organic Acids"
M.T. Holtzapple, R.R. Davison, M.K. Ross, M. Loescher
US Patent No. 5,874,263

"Methods of Biomass Pretreatment"
M.T. Holtzapple, R.R. Davison, M. Nagwani
US Patent No. 5,865,898

"Methods of Biomass Pretreatment"
M.T. Holtzapple, R.R. Davison, M. Nagwani
Guatemala Patent No. 415-97

"Calcium Hydroxide Pretreatment of Biomass"
M.T. Holtzapple, R.R. Davison, M. Nagwani
U.S. Patent No. 5,693,296

"Methods of Biomass Pretreatment"
M.T. Holtzapple, R.R. Davison, M. Nagwani
Indian Patent No. 179192/93

"Methods of Biomass Treatment and Products Therefrom"
M.T. Holtzapple, R.R. Davison, M. Nagwani
Taiwan Patent NI-071403

"Biomass Refining Process"
M.T.Holtzapple, Richard Davison, Earnest Stuart
U.S. Patent No. 5,171,592

"Hermetic Compressor"
M. T. Holtzapple
US Patent No. 5,106,274

"Method and Apparatus for Vapor Compression Refrigeration and Air Conditioning Using Liquid Recycle"
M.T. Holtzapple
U.S. Patent No. 5,097,677

"High-Efficiency, Orientation-Insensitive Evaporator"
M.T.Holtzapple, and D. Ernst
US Patent No. 4,825,661

"Torque Monitor"
M.T. Holtzapple, R. L. Wehe, C. G. Myer
US Patent No. 4,176,522

"Stationary Excitation Synchronous Machine (SESM)"
S. Gay and M. Ehsani
Disclosed

"Electric Hybrid Electric Drive Train or Onboard Peaking Electric Drive Train"
S. Gay and M. Ehsani
Disclosed

"Four-Quadrant Brushless ECM Drive with Integrated Current Regulation"
Disclosed

"Integrated Reactive Components & Networks in Power Electronic Circuits (Integrated Inductor-Capacitor-Transformer LCT Technology)"
Disclosed

“New Techniques for Position Sensing in Switched Reluctance Motors”
Disclosed

“Indirect Rotor Position Sensing Technique in Variable Reluctance Motor (VRM) Drives”
Disclosed

“Capacitive Coupled Converter (C3) for High Power DC-DC Conversion”
Disclosed

“ELPH Car”
Disclosed

“An Efficient Power Circuit for Capacitor Charging and Discharging”
Disclosed
“Optimizing Torque Controller for a Parallel Hybrid Vehicle”
Disclosed

“A New Type of Drive Train for Hybrid Electric Vehicle”
Disclosed

“Misalignment Detection / Correction Technique of Sensorless Control for Brushless DC Machine”
Disclosed

“Improved Accuracy and Speed Range in Indirect Rotor Position Sensing Scheme for Switched Reluctance Motor (SRM) Drive”
Disclosed

“Improved Interface between the Indirect Positron Encoder and the Digital Controller in Switched Reluctance Motor Drives”
Disclosed

“Inductance Model Based Indirect Rotor Position Sensing Scheme For Switch Reluctance Motor (SRM) Drive”
Disclosed

“Simplified High Resolution Indirect Rotor Position Sensing Scheme for Switched Reluctance Motor (SRM) Drive”
Disclosed

“Method for Improving the Dynamics and Robustness of Self-Tuning Control of SRM Drives”
Disclosed

“Interface Between DSP and External Analog Circuit with Optical Isolation”
Disclosed

“Indirect Rotor Position Sensing for High Speed Operation of Switched Reluctance Motor”
Disclosed

“Method and Apparatus for Reducing Noise and Vibration in Switched Reluctance Motor Drives”
Disclosed

“Control Algorithm for Extended Constant Power Operation of Switched Reluctance Motor (SRM) Drives”
Disclosed

“Inductance Model Based Indirect Rotor Position Sensing Scheme for Switched Reluctance Motor (SRM) Drive”
Disclosed

“Inductance Model Based Torque Estimation in Switched Reluctance Motor (SRM) Drives”
Disclosed

“A Novel Switched Reluctance Motor Drive with Radially Uniform Flux”
Disclosed

“Auto-Calibration of Switched Reluctance Motor Drives without Position Sensor”
Disclosed

“High Bandwidth Estimation of Torque in Switched Reluctance Motor Drives”
Disclosed

“Torque Ripple Minimization in Switched Reluctance Motor Drives”
Disclosed

“Control of Switched Reluctance Generators”
Disclosed

“Sensorless Control of Switched Reluctance Motor Drives at Super High Speeds”
Disclosed

"Sensorless Control of Switched Reluctance Motor Drives in Constant Power Region"
Disclosed

"Sensorless Control of Switched Reluctance Motor Drives in Constant Torque Region"
Disclosed

"Sensorless Control of Switched Reluctance Motor Drives at Near Zero Speeds"
Disclosed
"Sensorless Control of Switched Reluctance Motor Drives at Standstill"
Disclosed

"Fixed Point Implementation of Inductance Based Sensorless Algorithms"
Disclosed

"AC Motor Drive Circuits with Integrated Power Factor Correction and Motor Controls for Low Cost Applications"
Disclosed

"Direct Current Control Scheme for Four-Switch Brushless DC Motor Drive"
Disclosed

"Fuel Cell Powered Hybrid Drive Train and its Control Strategy"
Disclosed

"Advanced Sensorless Drive Technique for Brushless DC Motors"
Disclosed

"Sensorless Control of the Switched Reluctance Motor Drive From Standstill to Ultra-High Speed"
Disclosed

"Additional Novel Embodiments of Quasi-Isothermal Brayton Cycle"
Disclosed

"Advanced Control for Power Density Maximization of the Brushless DC Generator"
Disclosed

"Contactless Magnetic Automotive Disk Brake"
Disclosed

“Optimal Power Tracking Control Scheme for Wind Turbine Systems”
Disclosed

“Field-Weakening Control of the Brushless DC Generator in the High-Speed Operation”
Disclosed

“A New Method of Conducting Undergraduate Teaching Laboratories Using Real Time Simulation and Remote Access Facility”
Provisional

“New Control Strategies for Switched Reluctance Motor (1995)”
Disclosed

“HEV Battery pack balancing, Thermal Management, and Modeling”
Disclosed

“Torque Estimation in Switched Reluctance Motor Drive Using Artificial Neural Networks”
Disclosed

“A Hybrid Electric Vehicle Drive Train with Ultracapacitor as the Peak Power Source”
Disclosed

“Electromechanical Gearing for Hybrid Electric Vehicle Applications”
Disclosed

“Torque-Speed Summing Transmission for Hybrid Electric Vehicle Drive Trains”
Disclosed

“Low Cost Sensorless Speed Control for Induction Motor Drives”
Disclosed

“Contactless Magnetic Disk Brake”
Disclosed

“Development and Simulating Demonstration of High Efficiency Series/parallel hybrid electric vehicle that use Internal Combustion engine, transmotor, traction motor, batteries and ultrapacitors as the power source”
Disclosed

<u>"Some More Novel Embodiments for Quasi-Isothermal Brayton Cycle"</u>
A. Rabroker, M. Holtzapple
Disclosed

<u>"More Novel Embodiments for Quasi-Isothermal Brayton Cycle"</u>
K. Ross, A. Rabroker, M. Holtzapple
Disclosed

<u>"Additional Novel Embodiments of Quasi-Isothermal Brayton Cycle"</u>
M. Holtzapple, G. Noyes, A. Rabroker, K. Ross, M. Whiteacre, M. Ehsani
Disclosed

<u>"High-Efficiency Jet Ejector and Propulsive Jet"</u>
M. Holtzapple, O. Rediniotis
Disclosed

<u>"Heat Exchanger for an Evaporator"</u>
M. Holtzapple
Disclosed

<u>"Process to Solubilize Protein"</u>
M. Holtzapple, R. Davison, G. Coward-Kelly
Disclosed

<u>"Long-Term Pretreatment of Lignocellulose"</u>
M. Holtzapple, R. Davison, and C. Granda
Disclosed

<u>"More Novel Embodiments of Quasi-Isothermal Brayton Cycle"</u>
M. Holtzapple, A. Rabroker, K. Ross, G. Noyes
Disclosed

<u>"Drive Mechanisms for Quasi-Isothermal Brayton Cycle"</u>
M. Holtzapple, A. Rabroker, K. Ross
Disclosed

<u>"Yet Even More Embodiments for Quasi-Isothermal Brayton Cycle"</u>
A. Rabroker, M. Holtzapple, T. Beck
Disclosed

<u>"Even More Embodiments for Quasi-Isothermal Brayton Cycle"</u>
M. Holtzapple, A. Rabroker
Disclosed

"Some More Embodiments for Quasi-Isothermal Brayton Cycle"
M. Holtzapple, A. Rabroker
Disclosed

"More Embodiments for Quasi-Isothermal Brayton Cycle"
M. Holtzapple, K. Ross
Disclosed

"New Embodiments for Quasi-Isothermal Brayton Cycle"
M. Holtzapple, A. Rabroker, K. Ross
Disclosed

"Additional Embodiments for Quasi-Isothermal Brayton Cycle"
M. Holtzapple, A. Rabroker, T. Beck
Disclosed

"Alternate Embodiments for Quasi-Isothermal Brayton Cycle"
M. Holtzapple, A. Rabroker, K. Ross
Disclosed

"Plasma Expander/Compressor"
M. Holtzapple, J. Holste
Disclosed

"Cracked Gas Heat Exchanger"
M. Holtzapple, K. Hall
Disclosed

"High-Efficiency Jet Ejector"
M. Holtzapple
Disclosed

"Seals, Insulation, and Compression Controller for Quasi-Isothermal Brayton Cycle"
M. Holtzapple, A. Rabroker, L. Archer
Disclosed

"Novel Jet Engines and Aircraft"
M.T. Holtzapple and O. Rediniotis
Disclosed

"Electricity Production from a Natural-Gas-to-Liquids Process"
M.T. Holtzapple
Disclosed

“Vertical-Lift Aircraft”
M.T. Holtzapple and O. Rediniotis
Disclosed

“Integrated Fermentation System”
M.T. Holtzapple
Disclosed

“Vertical-Lift Platform”
M.T. Holtzapple and O. Rediniotis
Disclosed

“Vertical-Lift Aircraft - Alternate Embodiment”
M.T. Holtzapple
Disclosed

“High-Efficiency Evaporator - Alternate Embodiment”
M.T. Holtzapple
Disclosed

“High-Efficiency Evaporator”
M.T. Holtzapple
Disclosed

“Vertical-Lift Aircraft”
M.T. Holtzapple
Disclosed

“Improved Isbell Oxygenator”
M.T. Holtzapple, S. Aldrett, A. Isbell
Disclosed

“Integrated Biomass and Sugar Production”
M.T. Holtzapple, R. R. Davison
Disclosed

“Noncantilevered Compressor and Expander for Quasi-Isothermal Brayton Cycle”
M.T. Holtzapple, Andrew Rabroker
Disclosed

“High-Conversion Biomass Process”
M.T. Holtzapple, R.R. Davison, and M.K. Ross
Disclosed

“Treatment to Increase the Enzymatic Digestibility of Feathers”
M.T. Holtzapple, R.R. Davison, S. Aldrett
Disclosed

“Method for Concentrating Sugar Solutions”
M.T. Holtzapple, R.R. Davison, W. Adorno-Gomez
Disclosed

“Compressor and Expander for Quasi-Isothermal Brayton Cycle”
M.T. Holtzapple, Andrew Rabroker
Disclosed

“Improved System for Removing Noncondensibles from Vapor-Compression Evaporative Cooler”
M. T. Holtzapple, R.R. Davison, Mike Bennett, Edward Pinkerton
Disclosed

“Improved Fermentation Broth Dewatering System”
M. T. Holtzapple, R.R. Davison
Disclosed

“Gerotor Compressor for Vapor-Compression Evaporative Cooler - Noncantilevered Embodiment”
M.T. Holtzapple, R.R. Davison, A. Rabroker
Disclosed

“Gerotor Compressor and Aspirator for Vapor-Compression Evaporative Cooler”
M.T. Holtzapple, R.R. Davison, A. Rabroker
Disclosed

“Gerotor Compressor for Vapor-Compression Evaporative Cooler”
M.T. Holtzapple, R.R. Davison, A. Rabroker
Disclosed

“Actuated Flap Compressor for Vapor-Compression Evaporative Cooler -Alternate Embodiment”
M.T. Holtzapple, R.R. Davison, A. Rabroker, S. Ruhmann
Disclosed

"Scroll Compressor for Vapor-Compression Evaporative Cooler"
M.T. Holtzapple, R.R. Davison, A. Rabroker
Disclosed

"Upflow Fermentor, Extractor, and Solids Handling System for Producing Volatile Fatty Acids from Biomass"
M. Holtzapple, R. Davison
Disclosed

"Plug-flow Fermentor and Extractor for Producing Volatile Fatty Acids from Biomass"
M. Holtzapple
Disclosed

"Energy-Efficient Dewatering System"
M. Holtzapple, R. Davison
Disclosed

"Mixer/Decanter"
M. Holtzapple, T. Lüttich
Disclosed

"Large-Scale Fermentor for Producing Volatile Fatty Acids from Biomass – Alternate Embodiment"
M. Holtzapple, R. Davison, M. Ross, M. Loescher
Disclosed

"Noncondensible Vacuum Pump"
M. Holtzapple
Disclosed

"Multistage Vapor-Compression Evaporative Cooler"
M. Holtzapple and R.R. Davison
Disclosed

"Acutated Sliding Vane Compressor for Vapor-Compression Evaporative Cooler"
M. Holtzapple and R.R. Davison
Disclosed

"Sliding Vane Compressor for Vapor-Compression Evaporative Cooler"
M. Holtzapple and R.R. Davison
Disclosed

“Rotary Compressor for Vapor-Compression Evaporative Cooler”
M. Holtzapple and R.R. Davison
Disclosed
“Method for Thermally Converting Volatile Fatty Acid Salts to Ketones”
M. Holtzapple and R.R. Davison
Disclosed

“Integrated System for Biologically Treating Air Pollution”
M. Holtzapple and R.R. Davison
Disclosed

“Vapor-Compression Evaporative Cooler”
M. Holtzapple and R.R. Davison
Disclosed

“Quasi-Isothermal Brayton Engine”
M. Holtzapple
Disclosed

“Erickson Open Cycle Heat Engine”
M.T. Holtzapple
Disclosed

“Process for Disposing of Biodegradable Wastes”
D. Carrabba, M.T. Holtzapple, and R.R. Davison
Disclosed

“Lime Pretreatment of Biomass-Alternate Embodiment”
M.T. Holtapple and R.R. Davison
Disclosed

“Compressed-Air Powered Automobile - Alternate Embodiment”
M.T. Holtzapple
Disclosed

“Compressed-Air Powered Automobile”
M.T. Holtzapple and R.R. Davison
Disclosed

“Direct Contact Process for Lime Pretreatment of Biomass”
M.T. Holtzapple and R.R. Davison
Disclosed

“Home Energy System”
M.T. Holtzapple
Disclosed

“Alkaline Oxidative Pretreatment of High-Lignin Biomass”
M.T. Holtzapple, R.R. Davison
Disclosed

“Indirect Hydrogenation of Organic Acids to Alcohols”
M.T. Holtzapple, R.R. Davison
Disclosed

“Electrochemical Regeneration of ADP to ATP”
M. Holtzapple, K. Nam, D. Struck
Disclosed

“Vapor-Compression Evaporative Cooler”
R.R. Davison, M.T. Holtzapple
Disclosed

“Production of Chemicals and Fuels from Biomass”
M.T. Holtzapple, R.R. Davison
Disclosed

“Receptor-Based Biosensor”
L. Ellis, M.T. Holtzapple
Disclosed

"Lime Pretreatment of Biomass"
M. Holtzapple, R. Davison, M. Nagwani
Disclosed

“Steam Drying of Paper”
K.R. Hall, M. Holtzapple, R.R. Davison
Disclosed

“The Activated Biomass (Actimass) Process”
M. Holtzapple, R. Davison
Disclosed

“Oscillating Gassing Tube Bioreactor”
M. Holtzapple, P. Monahan
Disclosed

“Method and Apparatus for Recovering Dilute Solvents”
M.T. Holtzapple
Disclosed

“Stirling Engine/Hydraulic Motor”
M.T. Holtzapple
Disclosed

“Stirling Engine/Stirling Heat Pump”
M.T. Holtzapple
Disclosed

“High Pressure Hermetic Compressor”
M.T. Holtzapple
Disclosed

“Apparatus, Method, and Composition for Concentrating Dilute Aqueous Ethanol Solutions by Adsorption Using Bound Hydrophobic Molecular Sieve”
M.T. Holtzapple
Disclosed

“Immobilization of Biologically Active Molecules in an Artificial Membrane”
M.T. Holtzapple, T.V. Nguyen
Disclosed

“Method and Apparatus for Vapor Compression Refrigeration and Air Conditioning Using Liquid Recycle”
M.T. Holtzapple
Disclosed

TEXAS APPLIED POWER ELECTRONICS CONSORTIUM

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The Texas Applied Power Electronics Center has been established for interdisciplinary research and development in advanced systems in which power electronics is the enabling technology.

At the present, this center is developing advanced power converters, advanced motor drives, new electric traction systems, hybrid electric propulsion systems, and other vehicle power and propulsion components, for commercial and military applications. This work encompasses all aspects, such as theoretical studies, design, numerical simulation and computer modeling, and experimental evaluations.

The center has several stationary test beds for power electronics, motor drives, controls, vehicle power and propulsion systems, and a mobile test bed for evaluation of traction motor drives and internal combustion engines for traction applications. Furthermore, it has developed flexible off line and real time computer simulation packages for design and evaluation of any type of motor drive and automobile drive train. In addition, the center has access to several research laboratories of its member faculty, such as engine tests, dynamometer, biofuels, advanced engines, and others.

The facilities and expertise of the center can be used for any R&D project related to its past activities and present interests. These include studies of silicon driven power systems, such as aerospace power systems, vehicle, ship and military power systems, and other advanced specialty power systems.

Funding for the above activities come from individual projects and donations from industrial companies that are interested in the results of this center's research. Interested companies are invited to join this research consortium by a typical contribution of $20k per year. More specific projects can also be defined for individual companies, as separate research contracts.

The contributions of the member companies may be used to support all aspects of research and professional activities of the center, such as salaries of the research and support staff, purchases of hardware, domestic and international travel for meeting present and prospective member companies and presenting technical papers at conferences, and similar activities.

LETTER OF INTENT

Our company: ____

Is interested in supporting the current activities of TAPC and in receiving the results of these activities as the y become available.

We intend to contribute $ ____________ for a year of cooperation with this center, starting from the date _______________.

Authorized signature: _______________________________________

Name and title: ____

Approved: ____
M. Ehsani, Director, TAPC