40th INTERNATIONAL UNIVERSITIES POWER ENGINEERING CONFERENCE (UPEC 2005)#

7-9 September 2005, University College Cork, Cork, Ireland

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The 40th International Universities Power Engineering Conference (UPEC 2005) was held 7-9 September 2005 at University College Cork, Cork, Ireland. It excelled earlier conferences by the exceedingly high quality of the presentations, the technical content of the papers, and the number of delegates attending. As in the past, it had a broad theme, covering all aspects of electrical power engineering, and was attended by academics, research workers, and members of the power service and manufacturing organizations. During the sessions, 253 papers selected from an unprecedented 388 uploads from 29 countries were debated. There were 3 plenary session, 33 technical paper sessions, 2 poster sessions, and a closing session. All papers in the technical paper sessions were presented orally in five groups of parallel sessions with 15 minutes allowed for each presentation. The high standard of the papers, presentations, and technical discussions was particularly gratifying.

Held annually, UPEC provides a forum for the exchange of ideas among practicing engineers from the universities, consultants, and in the manufacturing and supply industries. The first full conference was held at the University of Glasgow, UK, in 1967, following an inaugural meeting in Newcastle. Last year the conference was held at University of West England, UK and the previous year at Aristotle University of Thessaloniki, Greece. The 41st (2006) conference will be hosted by the University of Northumbria, Newcastle-upon-Tyne, UK. Future venues under consideration by the International Steering Committee include the University of Sussex (Brighton), UK (2007), Università degli Studi di Padova (University of Padova), Padova, Italy (2008), Strathclyde University, Scotland (2009), Cardiff University, Wales (2010 tentative), and South Westphalia University of Applied Science, Germany (2011 tentative). The working language at all meetings is English.

This year the technical co-sponsors included IEEE/PES/PELS, IEE, CIGRE, and IEI (the Irish body). Industrial co-sponsors included ESBI, University College Cork, and Cork Institute of Technology

The conference was hosted in the historical campus of University College Cork. It provided engineers and academia with the opportunity to explore recent developments, current practices and future trends in power engineering. Young engineers and research students were particularly invited to contribute. It was residential lasting 3 full days with both en-suite and standard accommodation provided in the University Halls of Residence on the campus.

1. OPENING SESSION

Dr Noel Barry, Chairman of the Organizing Committee, welcomed delegates and accompanying persons to the conference, Cork, and Ireland. He outlined the aims of the conference, summarized the detailed organization of the meeting, and reviewed the program. He said that 388 abstracts were received from all five continents and following a thorough review process by the International Steering Committee papers from 28 countries had been included in the Conference Proceedings (ISBN 0-9502440-4-X). 253 papers would be presented orally in five parallel groups of sessions. The full conference papers (1259 pages) were published in the two volumes of the Conference Proceedings hard copy and on CD-ROM.

He said the International Universities Power Engineering Conference or UPEC as it is more commonly known, with a history of close on 40 years, has provided and still provides engineers and academia with an

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opportunity to find and explore the newest trends in the development of Power Engineering and scientific methodology that is connected with it.

After a review carried out by the International Steering Committee and the local Organizing Committee, papers reflecting the effort and knowledge of engineers and allied scientists from 29 countries have been published in the Proceedings. All these papers, after being judged for their affinity to the subject of the conference in abstract form, were then reviewed in full form by a committee of competent scientists. Further, all the papers would be presented by their authors and discussed in the sessions.

He then said that as is the custom of all the UPECs, besides being a scientific event helping engineers and allied scientists to get acquainted with state of the art in Power Engineering, UPEC has also a considerable social dimension not only in allowing personal contact and discussions with colleagues from various countries but also in helping them to know things about the country that hosts the conference. For this reason social events and technical visits had been organized.

Dr Barry then thanked the institutions and the companies supporting the conference. The contributions of members of the International Steering Committee and the Local Organizing Committee, the reviewers, and the session chairpersons were highly appreciated.

Both the Vice President of Research Peter Kennedy of University College Cork and Dr. Brendan Murphy of Cork Institute of Technology spoke at the opening and represented the sponsoring institutes. ESB International Managing Director, Don Moore also addressed the audience. The formal opening was undertaken by Minister for State Mr. Batt O'Keeffe.

He also expressed personal thanks to members of the Local Organizing Committee, the staff of the Department, and especially to Robert Yacamini (Conference Organizer and Conference Co-Chair from University College Cork) , Paul Sliney (Conference Co-Chair , from Cork Institute of Technology), and to Gordon Lightbody and Tom O'Mahony (Programme Co-Chairs), without whose selfless dedication the conference would not have been able to take place.

Thomas G. Habetler, Georgia Institute of Technology (USA) and Dean Paterson, Nebraska University Lincoln (USA) then presented the first two Plenary Addresses.

2. PLENARY SESSIONS

These followed the Opening Remarks and on the second day of the conference. The first Plenary Lecture was given by Thomas G. Habetler, School of Electrical and Computer Engineering, Georgia Institute of Technology, USA. It was entitled On-Line Condition Monitoring and Diagnostics of Electric Machines. Dean Paterson, Nebraska University Lincoln, USA, who talked on Renewable Energy Engineering—Sustainable-Alternative Energy Engineering, followed this. On the second day Charles Elachi, Director of the NASA Jet Propulsion Laboratory at Pasadena, California Institute of Technology, USA discussed the future of the electrical industry in space exploration (the full presentations can be accessed at http://pei.ucc.ie/UPEC2005/index.htm)

2.1 On-Line Condition Monitoring and Diagnostics of Electric Machines

The first Plenary Lecture was entitled: On-Line Condition Monitoring and Diagnostics of Electric Machines. It was delivered by Thomas G. Habetler, School of Electrical and Computer Engineering, Georgia Institute of Technology, USA. The Address is summarized below:

Induction motor performance at a level not often enough considered can be greatly enhanced through the use of condition monitoring and diagnostics. These are becoming very important issues in power and power electronic systems since they can greatly improve reliability, availability and maintainability in a wide range of sensitive applications. Furthermore, the addition of condition monitoring functions to existing systems need not be expensive or complicated. Existing sensors and hardware can provide a vast array of system information that has traditionally not been used.

Traditional monitoring of motors has consisted only of protection. This means that typically, a motor is protected from an overload condition (i.e., misuse) by an overload relay that monitors the current and estimates, usually in a very crude way, the temperature of the machine windings. It is only in expensive, or sensitive load applications that condition monitoring is extended to include fault prediction. Traditionally, sensors are added to motors to detect specific faults. These include thermal and proximity sensors for bearing faults, accelerometers for vibrations, etc. Fault prediction implies that an impending failure is sensed in the monitored device prior to shutdown, so that maintenance can be performed without incurring unscheduled downtime. Protection and fault prediction, therefore, are philosophically quite different. When both are used with sensible preventative maintenance, low operating costs AND high availability rates can both be achieved.

The lecture then presented methods for the protection and condition monitoring of electric machines using only the quantities typically available in a motor control center; the terminal voltage and current. Examples of such work in the literature include the detection of broken rotor bars, worn bearings, and rotating unbalances and misalignments. Diagnostics and failure prediction are accomplished in these cases by monitoring very small spectral components in the stator current arising from the fault condition. Examples were given for condition monitoring of both induction motors and PM synchronous machines. In addition, the issues involving monitoring of drive-connected machines were presented. The early detection of insulation deterioration in low voltage motors can be done using the negative sequence currents. An overview of each of these methods for complete motor monitoring and protection were presented.

The work done at Georgia Institute of Technology, and many other research laboratories, has led to monitoring schemes that greatly increase the availability rate of system components without requiring changes to the system configuration or hardware. Such incipient fault detection devices will no doubt become common in the industrial marketplace.

2.2 Renewable Energy Engineering—Sustainable-Alternative Energy Engineering.

The second plenary lecture, given also on the first day, was entitled: Renewable Energy Engineering—Sustainable-Alternative Energy Engineering. Dean Paterson, Nebraska University Lincoln, USA, gave it. It discussed many of the issues of renewable-sustainable energy use in light of the second law of thermodynamics. The paradigm reinforced some issues and highlighted others. The proposition was put that no energy is renewable, and budget was presented for energy use in the globe. Several technologies currently experiencing substantial research attention were discussed. The case was made that efficiency of use is a fundamental part of energy considerations, and several topical issues in energy efficiency were discussed. The issue of matching entropy of the load to entropy of the source was introduced.

The presentation is summarized below.

He introduced his presentation by saying there is both good news and bad news.

The good news is that the law of conservation of energy holds, that is, there is a finite and unchangeable amount of energy in the Universe, and while it can be changed from one form to another, energy can neither be created nor destroyed

The bad news is that the second law of thermodynamics also holds. Whilst in its simplest form it states that heat flows from a hot body to a cold one, in its more complex formulation it discusses the level of disorder, or entropy in the universe, which is continually increasing. Energy in its most organised form continuously and uni-directionally is changing into its least ordered form, that of low grade heat, where the energy exists as random molecular or atomic motion.

In simple terms, if there is heat in the sun and the dark side of the moon is cold, sooner or later they will both be at the same temperature. At the end of time the universe will be a cold, still, quiet place, with all matter and all energy uniformly distributed. We already know the final temperature, it's the background radiation of space, a chilling 2.3 K. The reality is that all energy, on average, is on this downhill run. Whatever we do to organise or structure our energy must in the broadest terms lead to an increase in average disorder.

Tom Stoppard in his play "Arcadia", made the same point with a little more whimsy. The play is a *tour de force* concerning mathematics and science, set at the beginning of both the 18th and the 19th centuries. The heroine is a brilliant thirteen year old woman, Thomasina, and her tutor, no slouch at 21, Septimus.

When Thomasina explains the second law to Septimus he says:

"So the improved Newtonian Universe must cease and grow cold. Dear me".

To which Thomasina replies,

"Yes, we must hurry if we are going to dance."

The whimsy is in the sense of time scale. General opinion is that our solar system is about 5 billion years old and has about another 5 billion years to go, so it seems reasonable to consider a "half time report" on our management of the globe and its resources. Rather than try and estimate the life of the universe, contracting our view to the much shorter "life of the solar system" will still provide a challenge, with some worthwhile insights.

The significant and important reality of the second law discussion above is that no energy is renewable. It is all being continuously degraded from its low entropy highly ordered form to its most disordered form, as low grade heat. Strictly any conscious or unconscious human activity, "degrades the universe" and thus by the strict argument, nothing is even sustainable. The concept of sustainability is however introduced in a very broad and general sense. We will need to invoke some of the time scale arguments, and take into account one of the fundamental properties of life forms, that they inherently organise and structure, that they "rage against the second law". The case will be made that against very long time scales our actions should produce managed and understood impacts, while understanding and accommodating those actions fundamental to human nature of organising, structuring, and building. We will use this word "sustainable" to indicate actions that attempt to take this broader view of energy "husbandry" into account.

The Current Concerns

Our current concerns result from the use, over one or two centuries, of solar energy stored over aeons via photosynthesis. This pattern of use has produced very short term urgent concerns, such as the 70's threats of shortages and the 80's urban air pollution, (and whilst we are aware of the Los Angeles problem and the California mandate, a list of heavily polluted cities would include the largest population centres of the world, New Delhi, Jakarta, Bangkok, Mexico City and Cairo). Finally in the 90's green-house gas emission concerns have become significant.

The next concern which might surface if we do indeed find much larger sources of energy such as nuclear fusion, is that of the total thermal load on the globe. It is estimated that our increased use of energy over the last two centuries has raised the temperature of the globe by only 0.01 degrees Celsius. So the effect is very small compared to the heating predicted by the green-house gas models. However localised thermal pollution, in for example, the cooling water streams used for large scale thermal electric power plants, is not insignificant.

2.2.1 AN ENERGY BUDGET MODEL

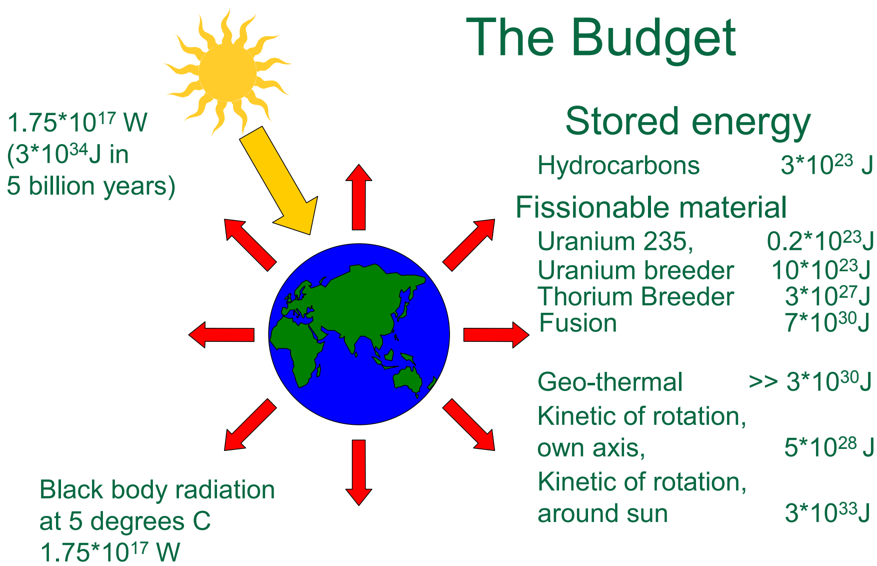

Figure 1. An Energy Budget Model for the Globe

Paterson then viewed the problem in this light. It leads to the following model for an energy budget for the globe. This budget is based on income, expenditure, and capital accumulation, or energy stored "In the bank", as shown in Fig. 1. It is worth noting however that this particular bank pays no interest.

The energy in the bank is shown on the right, and includes energy stored chemically in hydrocarbons, that obtainable through nuclear fission and fusion, and the thermal energy in the core of the earth. The figure of $3*10^{30}$ J is based on existing temperature profiles and estimated specific heats, and thus does not consider the source of the heat, the ongoing nuclear reaction in the core. Then there are two aspects of the kinetic energy of the globe. Of course these KE storages imply some relative motion, and whilst the KE of rotation of the earth around the sun is included, it is not a source which we have any access to, and strictly is an energy relating to the earth – sun couple, or the complete solar system, rather than the earth alone.

The income and expenditure statement however are particularly interesting seen against this "bank balance". Note that incomes and expenditures are in rates, i.e., joules per second or watts, rather than in absolute joules. The figure for insolation over the notional 5 billion years is however instructive. Further, the incoming energy in some 20 days is equal to the total stored in hydrocarbon form.

The expenditure shown is simply that resulting from the application of standard black body radiation,

$$W = k\,T^4 \text{ watts }/m^2,$$

where k is the Stefan-Boltzmann constant, and the formula is applied to the surface area of the globe.

The balance shown occurs for an average temperature of 5 degrees Celsius. Whilst this may not be the actual average temperature of the globe, and the formula should ideally be integrated over the global temperature distribution, the delicacy of the balance is clearly revealed. Also the reason why any kind of heat trapping due to green house gas accumulations is so significant, is demonstrated.

With the above budget in mind let us now approach the issue of sustainability, which we might define in simple terms as making expenditure equal income, without using any accumulated capital.

This is the general brief of research into energy balance.

In this light, we see that solar energy is our only continuing input. Solar energy falls on vegetation, and is stored by photosynthesis; it falls on oceans causing evaporation resulting in rain used for hydro power; it falls on land masses producing air convection, which together with the rotational kinetic energy via coriolis forces produces winds which we again access. The issue is that apart from photosynthesis, and storage of water in elevated lakes, the solar energy all ends up as low grade heat in a very short time frame, and our primary aim is to get it to do useful work on its way there, knowing that the result of useful work is the low grade heat that would have eventuated anyway.

Storage

The budget model highlights the issue of adding to the bank balance, or storing energy in some way. Since many of our alternative sources such as wind and solar are highly variable, high levels of penetration imply storage to match the unrelated demand profiles of consumers. Thermal storage is under consideration, however storage at very high temperatures and hence high entropy becomes progressively more difficult. Unfortunately electrochemical storage on a large scale is currently a long way from being viable. Potential energy storage via pumped hydro is used where available. The work on Ammonia dissociation is perhaps the most promising of the technologies being researched today to store e.g., solar energy directly.

2.2.2 "RENEWABLE ENERGY" SOURCES

In the central part of his presentation he reviewed renewable energy sources.

Photovoltaics

Figure 2. Photovoltaic array as part of a Hybrid Remote Area Power Supply at Jilkminggan in the Northern Territory of Australia. - Designed Constructed and Operated by the NT Power and Water Authority

He said that Photovoltaics are indeed a sustainable source of energy, however from mono and poly-crystalline solar cells the cost is high, and much of this cost is representative of the very high levels of embodied energy in the pure crystalline silicon, indeed a very low entropy state for silicon atoms. While the future may reveal a range of less expensive photovoltaic generators, whether by concentration - focussing techniques or a range of variations on crystalline and amorphous structures, or indeed other materials, the reality is that the niche markets will grow, particularly for remote area power supplies, but large scale adoption in the short term is unlikely. Fig. 2 shows a remote community power supply in the Northern Territory.

Solar Thermal

This is perhaps the only way in which large scale energy needs can be supplied from direct sunlight. The technology exists today in close to economic form. Very serious attention should be paid to this in the absence of any other conversion techniques or new technologies. The 400 square metre aperture dish at the Australian National University, Canberra is shown in Fig 3.

Wind Power

The commercial viability of wind power has altered dramatically in the last decade, primarily because of the application of solid engineering development, and the rewards of economies of scale. The resource is however limited to certain geographic locations, and has a high degree of variability and unpredictability. There are also concerns for visual and acoustic pollution as wind farms proliferate. Fig. 4 shows the ENERCON E112 to indicate the state of the art, at a rating of 4.5 MW.

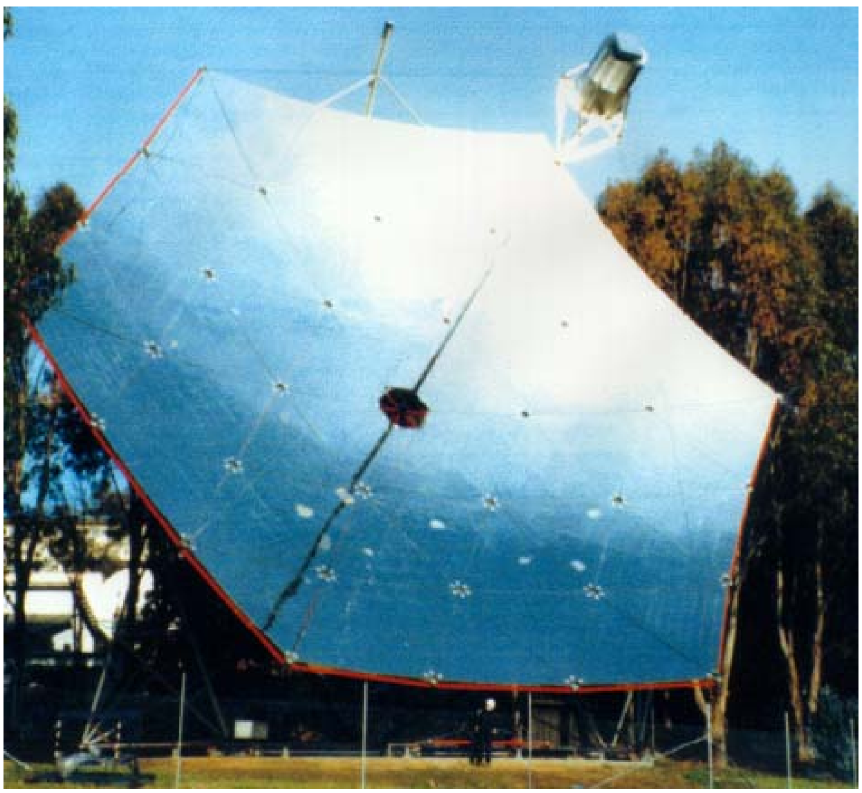

Figure 3. The 400 m^2 Parabolic Solar Collector at the Australian National University, Canberra

Figure 4. The ENERCON E112, a 114 metre diameter wind Turbine, hub height 124 metre, with a direct drive variable speed generator rated at 4.5 MW.

Tidal Power

It should be clear that this is not renewable, nor even sustainable. All we do when using tidal power is use the kinetic energy of the moon and the kinetic energy of rotation of the earth, hastening the departure of the moon from orbit, and slowing down the globe's rotation rate. A few calculations however are revealing if one looks for some time scale arguments. The friction of tides flowing over the ocean floor and against land masses naturally absorbs some of this kinetic energy. It has been estimated that this effect has retarded the rotation of the earth so that a solar year is about one second longer than it was a century ago.

The kinetic energy of rotation of the earth is as shown in the budget $5.3 * 10^{28}$ joules. An estimate of all the tidal power units of the earth both existing and proposed (including La Rance at 240 MW, and the proposed Severn development in the UK at 8 GW) might result in a total capacity of some 30 GW. Converting energy at this rate, it would take 200,000 years to make a solar year one second longer. Thus this again illustrates the difficulty of sustainability or renewability arguments, and indicates the need to take time scale into account.

Thus it is believed that there is a future for tidal power, both in its large scale potential energy form, and also the free flowing kinetic energy conversion for application in very small systems for remote communities. Fig. 5 shows the Northern Territory University – NT Power and Water Authority Kinetic tidal energy converter, with the "outboard leg" raised for maintenance, on shore. When deployed, the propeller is lowered in exactly the same way that an outboard motor would be angled into the water. The pontoon is tethered, and at a water flow rate of 2 metres per second, the 2 metre diameter turbine produces 2 kW. of electrical power.

Figure5 The NTU – NT PAWA Kinetic tidal energy converter, on shore for maintenance

Geothermal

Very similar arguments apply to Geothermal energy as do to tidal power. The resource is neither renewable nor sustainable, however the resource is in current terms, vast. Also as it makes its way to the surface and contributes to black body radiation, attempting to get it to do useful work on its way there should be seen in the light of sustainability.

Biomass

This is perhaps the most sustainable of all. Photosynthesis and the carbon cycle provides solar energy conversion, and short term storage. The overall efficiency of conversion of the sun's energy has been estimated to be around 3%. The balance of the world's forest reserves, and their depletion in some developing countries, are serious concerns. However in the long run Biomass can substantially contribute to our energy management strategies.

2.2.3 NEED FOR EFFICIENCY

Paterson then viewed energy balance in the light of the above discussion. He said it focuses the mind on delicacy of the balance. The inevitability of the second law drives us to an issue deeply intertwined with all discussions of renewability and sustainability, that of the efficiency of energy use as we pass it from its stored or received form, heading inevitably toward low grade heat. The level of waste involved when viewed under the second law paradigm, becomes perhaps the most important issue of all.

We have not as a people been used to viewing our energy use in this light, however a study of the efficiency of use of our existing technologies is sobering.

Various estimates of the level of wastage exist, one estimate is that the overall efficiency of energy use in the USA is 41%, implying that 59% is wasted directly. Much of this of course results from the thermodynamic limitations again driven by the second law. However estimates that some 30% of our energy use could be saved by applying currently available technology abound.

A very few representative energy uses and their inefficiencies are now discussed.

Transport – The Automobile

About one third of energy used in the USA is used for vehicular motion. The time is close when the heat engine will no longer be used as a direct source of tractive effort in the automobile, and the reasons are very clear when one considers the efficiency issues. In a well operated automobile in urban traffic, in the order of 12-14 % of the energy in the gasoline gets to the road, an extraordinary waste of our precious resources.

The battery EV can, when operated from electricity produced from natural gas, reduce the net emissions of greenhouse gases by 2/3, as well as increasing the efficiency by about a factor of two. Battery vehicles do however have range problems, and are unlikely to make a substantial impact on the market. Hybrid vehicles combine the best of both worlds, with a small internal combustion engine which runs only under tightly controlled conditions or is shut down. Under these circumstances efficiencies of between 35 and 40% (direct injection diesel) result, and it is not difficult to fabricate an electric power train with an efficiency above 90% Much effort has been directed to the Proton Exchange Membrane Fuel Cell (PEMFC) fuel cell vehicle, using on board reformation of methanol to produce hydrogen, for the fuel cell, and finally an electric traction system. Ongoing cost issues with the PEMFC, and catalyst poisoning issues are however restraining progress to some extent

The efficiency rewards are however substantial: over 60 per cent of the energy in the fuel can be converted to electricity.

Vehicles with electric traction systems have the further advantage that, by using regenerative braking, up to 20% of the energy provided to the wheels can be re-used.

Electric Motors

The proportion of electricity generated which ends up in motors is estimated to be as high as 65% in the USA. The number is a little higher than in Europe, since there are higher levels of natural gas usage in the USA for process heat. Much of this is used in small motors, below 3 kW, where the machine design has been dominated by production costs rather than running costs. Efficiencies of less than 50% abound below 1 kW. This “window of opportunity” for dramatic improvement has been enhanced by very recent developments in rare earth permanent magnets and power electronics. For a small premium, low power electric motors can be made with very high efficiencies. They also automatically provide the extra benefit for efficiency of energy use, of simple speed control.

There is major work to be done in this area in the near future.

Lighting

It has been understood for many years that operating fluorescent light from a high frequency power source (e.g., 25 kHz instead of 50 Hz) can raise the light output by 20% for the same energy input. What is not so well known is that once an electronic inverter is used to provide the high frequency, far more detailed and automatic management of building light levels becomes a simple matter. Dimming lights by say 20% when the fixtures are new, dimming them by imperceptible amounts when there are no people detected, and dimming them when sunlight is available can all save energy. With the reduced cost of managing the building heat load from the lamps and traditional ballasts if excess heat is a problem, and the increased maintenance interval gained by operating the lamps at less than 100 %, total savings can be as much as 50% of existing building lighting costs.

As in so many of these possibilities for energy efficiency the actual trade is between a higher installation cost and a lower running cost. Education is a crucial issue in gaining adoption of these existing technologies, reliant on a clearer understanding of whole of life costing. The adoption of such technologies is further hindered if different groups are involved in the construction, owning and operation of a building. Considering such efficiencies in the light of the entropy discussions above is part of that education process.

Air-conditioning

The issue is again one of capital cost versus running costs. Large scale screw compressors for commercial buildings can operate with a coefficient of performance (COP), the ratio of energy pumped to the energy required to do the pumping, of around 6. Domestic split level systems have COPs of close to three, and smaller units nearer two. There are huge gains to be made in this area, and the issue of the motor efficiency, and the value of variable speed drives is closely intertwined, particularly in the smaller systems

Domestic Refrigeration

Domestic refrigeration is according to a recent Australian study the second largest source of greenhouse gas emissions from the domestic sector, after water heating. Early analysis indicates that the motor in a small compressor is unlikely to be more than 65% efficient, and when the heat injected by the inefficiency into the refrigerant is taken into account, that replacing the compressor motor with a small modern permanent magnet machine could halve the energy use. The increased initial cost with the use of such a small motor would have to be less than AUD $100. The problem is growing with the proliferation of vending machines.

2.2.4 MATCHING THE SOURCE TO THE LOAD

This is another area of research highlighted by studying energy use via the paradigm of the second law of thermodynamics.

The issue is that of matching the quality of the energy source to the required quality of the energy to be used, where high quality implies low entropy. For example using electricity (energy in its highest quality form) to heat water for domestic purposes at say 50 degrees Celsius (energy in its lowest grade form) has been described as thermodynamic folly. Much more research is necessary in this area.

2.2.5 CONCLUSIONS

He concluded by stating his presentation had presented a broader view of energy use than that commonly considered by researchers in the "Renewable Energy Engineering" area. By invoking the second law of thermodynamics, a rather different paradigm results, and some rather different goals emerge. It is proposed that this model be considered alongside other models in the general debate about renewability, sustainability, energy use, and our responsibility for the globe and its precious and scarce energy resources.

2.2.6 ACKNOWLEDGMENTS

The presenter expressed his gratitude and sincere appreciation to the Northern Territory Power and Water Authority for their support, both financial and in kind for the work of the Northern Territory Centre for Energy Research, and to the Australian CRC for Renewable Energy, who funded wind turbine and small motors work. He also thanked the *International Journal of Renewable Energy Engineering* where in April 1999 earlier material presented in this presentation was originally published.

2.3 Space Exploration to 2020

Dr. Charles Elachi, Professor of Electrical Engineering and Planetary Science at California Institute of Technology and Director of the Jet Propulsion Laboratory (JPL), the National Aeronautics and Space Administration (NASA), USA gave a very interesting plenary talk on Space Exploration for 2020 on the morning of the second day of the conference. The audience consisted of the UPEC delegates, and invited people from the astronomical and planetary societies in the Cork area. Elachi explained NASA and JPL plans for robotic space exploration for the next two decades, and emphasized how power engineering technology developments have enabled past space exploration and how they will continue to do so in the future.

The first part of his talk consisted in reviewing where we are at this time regarding space and its exploration and our knowledge to date of the solar systems. He summarized forty-seven years of JPL robotic space exploration of the inner planets, the outer gas giants and their moons, comets and asteroids, planets around other stars, and distant stars and galaxies out to the edge of the known universe, which began in 1958 with the formation of NASA and its assignment of the robotic space exploration mission to JPL. He said that this exploration seeks to answer NASA's three fundamental questions:

- How did we get here,
- Where are we going, and
- Are we alone?

One of the criteria used is to "follow the water", on Mars, in that if we look for life to be sustained on another planet, then water must be there or have been there for life to have existed.

Having set the tone Charles Elachi then brought us to the planet Mars and showed us photographs of its surface as taken by the robot rovers *Spirit and Opportunity*. These robots are in essence geologists and performed all the functions that a trained geologist performs on rocks in a laboratory. We were also treated to how *Opportunity* got down into Endurance Crater via the Karatepe slope followed by what findings it made there. Next he spoke about the Cassine-Huygens voyage to Saturn. This made fascinating listening as he went through all the details of how to reach such a place, so far away. Pictures of Saturn's Moon Titan were shown to us. The probes there detected methane as a gas in the atmosphere. Next he spoke about the comets in our solar system and how NASA and JPL are trying to find out more about them by flying spacecraft close to them. One such comet is Tempel 1. They made a device to collide with and to study the impact. Other techniques that NASA depends upon are spectroscopic analysis from on-board sensors in space to find evidence of water and other constituents.

He continued and said in more detail that JPL seeks to answer the above questions by developing exploration programs in five themes:

1) Mars exploration. "Follow the water" to find previous or extant life on the red planet.
2) Study other potentially life-friendly sites in our solar system such as the moons of the gas giants Jupiter and Saturn (moons such as Saturn's Titan and Jupiter's Europa), comets, and asteroids.

3) Search for planetary systems around other stars.
4) Investigate the origins of our solar system 4,500 million years ago and of the universe 13,700 million years ago.
5) Characterize the atmosphere, oceans, and solid lithosphere of our own Earth.

Elachi described in some detail spacecraft projects that carry out studies in each of these themes. For instance:

- The Mars Exploration Rovers Spirit and Opportunity have been exceptionally successful in finding incontrovertible evidence for past very wet periods on Mars by traveling several kilometers over the surface of the red planet for over seventeen months. Launched in 2003, and arriving in January 2004, the rovers were to travel up to one kilometer and to survive for three months, but they have far surpassed these minimum requirements.
- Cassini-Huygens has been an extraordinarily successful joint U.S.-European Space Agency (ESA) mission studying Saturn and its moons, most importantly Titan, on which ESA landed the Huygens probe to study the moon's nitrogen atmosphere, ethane lakes, and water ice "rocks." The U.S. Cassini Saturn orbiter, which carried the Huygens probe into orbit around Saturn, continues to study the planet, its rings, and its many other moons.
- JPL missions to comets also support the theme of studying life-friendly sites in the solar system. The Stardust mission, launched in 1999, flew through the coma of comet Wild-2 in 2004, and will return to Earth in January 2006 carrying samples of comet dust so scientists can have hands-on experience analyzing its properties. Similarly, the Deep Impact spacecraft sent an impactor on a collision course with comet Tempel 1 in July 2005 to analyze the debris from the impact spectroscopically from a spacecraft flying by the comet at the same time as the impact.
- NASA's Origins program includes a continuing series of missions to study planets around other stars, starting with the Spitzer Space Telescope's recent discovery of a reduction in a star's light output as a planet passes in front of the star. The Kepler mission will study the transit of Earth-sized planets across other stars; in the next decade the Space Interferometer Mission (SIM) Planet Quest mission will perform astrometry on extra-solar planets; and the Terrestrial Planet Finder will have sufficient resolution and starlight-blocking capability to make spectroscopic analyses of extra-solar planets.
- The Origins program also studies distant galaxies, and looks deep into the past toward the beginning of the universe. For example, the Spitzer Space Telescope has observed potentially life-forming polycyclic aromatic hydrocarbons, including some containing nitrogen, in extragalactic clouds.
- A major portion of NASA's and JPL's projects are devoted to studying our own planet Earth. NASA's Aura spacecraft carries JPL's Microwave Limb Sounder (MLS) and Tropospheric Emission Spectrometer (TES) to characterize Earth's atmosphere; JPL's QuickScat, Topex/Poseidon and Jason 1 spacecraft study the winds and surface elevations of Earth's oceans, and interferometric synthetic aperture radars monitor small changes in Earth's solid surface.

Elachi explained that NASA communicates with its deep space robotic spacecraft through the JPL-managed Deep Space Network (DSN), a 24-7 operation that commands and listens to both engineering and science data from dozens of missions from large antennas in California, Spain and

Australia. Plans are being made to upgrade this forty-year-old system that is crucial to the successful operation of both Earth-orbiting and deep space missions.

Finally, Elachi explained how power engineering is critical to the success of all robotic space missions, from primary power sources, through energy storage mechanisms, to power electronics and controllers. He summarized these important technologies in several categories:

- Primary power sources include: solar cell arrays; radioisotope thermal power (in which a radioisotope heats one junction of a thermocouple while the other junction radiates to the cold of space so that the temperature difference generates a usable voltage); and in the future perhaps a space fission nuclear reactor to generate large amounts of power for both propulsion and powering spacecraft systems. Nuclear primary power, either in the form of radioisotope or fission sources, is required for spacecraft traveling beyond the orbit of Mars because the sun's energy falls off inversely as the square of the distance from the sun, so that the area of solar panels required beyond that distance becomes much too large and heavy for any useful mission.
- Energy storage is used in the form of primary, non-rechargeable batteries for short duration missions; advanced high energy density rechargeable batteries; and fuel cells.
- Power electronics monitor and control all operations of the complete power systems.

All these power components face severe challenges in the hostile environments of deep space, including:

- Extreme temperatures from -230 degrees C in lunar shadows, to +480 degrees C temperature on the surface of Venus;
- High radiation levels, such as the 20 megarads of Jupiter's radiation belts;
- Multi-year voyages to traverse the distances of deep space, such as the Voyagers' 28-year and 8000 million mile journey to become an interstellar (instead of an interplanetary) mission;
- Minimum mass and volume while withstanding these rigors, to reduce costs and required launch vehicle energies.

Current technology developments are directed toward improving the operating characteristics of all spacecraft power components, such as:

- Increasing the power output of solar panels from a present level of less than 25kW to a range of between 40kW and 100kW, while at the same time improving their mass efficiency from 60 W/kg to greater than 200 W/kg, their power efficiency from about 20% to as much as 40%, and reducing their cost from about $1.0US/kW to $0.4US/kW.
- Improving the mass efficiency performance of rechargeable batteries from 30 Wh/kg to as much as 150 Wh/kg, while extending their life from ten to more than fifteen years, and expanding their operating temperature range from -10 degrees C to +30 degrees C to a much larger range of -100 degrees C to +400 degrees C.

He spoke of the engineering problems facing them in producing power for such far away locations from the Sun. NASA concluded, having presented all the arguments that nuclear sources will be the key to deep space exploration in the future. However other problems, which the hardware will have to risk are temperature extremes up to +480 degrees C.

Following his talk, a question and answer session followed, where numerous questions were asked and responded to on various aspects, including whether there is “life out there”!

A presentation was then made to Charles Elachi of a specially engraved Cork crystal vase by Professor Peter Kennedy, Vice President of Research, University College Cork.

Elachi's slides can be viewed at: http://pei.ucc.ie/UPEC2005/index..htm

3 TECHNICAL PAPER SESSIONS

Topics debated in the five parallel groups of technical paper sessions on the first day included:

Power quality and harmonics, transmission and distribution, power system operation and control, fault protection, renewable energy systems, electrical machines and drives, power generation, system integrity and protection, power system operation and control, and renewable energy systems.

On the second day, there were further parallel groups of sessions on system integrity and protection and on renewable energy systems, and on power utilization, high voltage engineering, electrical machines and drives, power conversion, high voltage engineering, and power system simulation and analysis,

Topics debated in parallel groups of technical paper sessions on the third day included topics debated on the first two days together with power system simulation and analysis, generation, power engineering education, and power system simulation and analysis.

4. OTHER CONFERENCE HIGHLIGHTS

These included:

- Welcome Buffet Refreshments at the Main University Campus on the Tuesday before the Conference in the historical Aula Maxima
- The Civic Reception on the Wednesday evening at the Millennium Hall, City Hall, at which Councilor Deirdre Clune, the Lord Mayor hosted delegates and guests at the Conference. Coaches took participants and guests to the Reception. Mr Paul Sliney thanked the Lord Mayor for the reception.
- Four Cultural Excursions on the Thursday afternoon to Blarney, a Distillery, Cobh, and West Cork, where attendees were taken in coaches.
- Conference Banquet on the Thursday evening at Clarion Hotel in Cork, where attendees were taken in coaches.
- Awards Luncheon at Kampus Kitchen on the Friday at the conclusion of the Conference

5. CONFERENCE BANQUET

This took place on the Thursday evening at the Clarion Hotel in Cork.

Besides the Irish food, there was an after dinner speech by Prof. Ger Hurely, Vice President of University College Galway and an old friend of UPEC who himself ran a UPEC conference in Galway in 1988. Then Dr. Charles Elachi, Director of the NASA Jet Propulsion Laboratory, California Institute of Technology. USA showed a video of the landing of space vehicles and robots on Mars. Prof. Robert Yacamini also spoke on the future of power systems.

Towards the end of the Banquet, Ghanim A. Putrus (UPEC 2006 Conference Organizer, School of Engineering and Technology, Northumberland University, UK highlighted the main events and proposed program for the 2006 Conference in England. Irish dancing followed with many of the delegates participating

6. AWARDS

Prizes were awarded by UPEC for the Best Paper and for the Best Oral Presentation by a Young Engineer under the age of 30. The recipient of the UPEC Best Paper Prize was:

Tom Canning and Dara Connoly, for a paper entitled “Desulphurisation of Flue Gas in a Large Peat-Fired CFB Bolier. This paper was presented in a Session on Power Generation. The recipient of the UPEC Best Oral Presentation by a Young Engineer under the Age of 30 was Ciara Doyle for a paper entitled "Using Load Research Data to assess Demand Side Management Interventions" (her co-authors were Cliton C. Gaunt and Ron Herman. This paper was presented in a Session on Transmission and Distribution.

7. CONFERENCE PROCEEDINGS

All technical papers were incorporated in the UPEC 2005 1259-page Proceedings in Hard Copy and CD-ROM (with 251-page book of conference abstracts) that was distributed to delegates at the conference. UPEC 2005 Proceedings may be purchased (Hard Copy and CD-ROM) for 200 Euro (Hardcopy) (plus postage) and 40 Euro (CD ROM) plus postage, until supplies are exhausted, from Dr Noel Barry, UPEC 2005 Conference Organizer, School of Electrical and Electronic Engineering, Cork Institute of Technology, Bishopstown, Cork, Ireland, Tel: +353 21 432 6384, Fax: +353 21 432 6625, E-mail: nbarry@cit.ie

8. UPEC 2006

In closing the conference, Dr Barry stated that the 41st International Universities Power Engineering Conference (UPEC 2006) will be held September 6-8 2006 at Northumberland University, Newcastle-upon-Tyne, England and will be hosted by the School of Computing Engineering and Information Sciences. It will be co-sponsored by IEEE, IEE, and CIGRE.

Its aim will be to provide professional engineers from the universities, consultants, and in the manufacturing and supply industries opportunities to explore recent developments, current practices and future trends in Power Engineering. Young engineers and research students are especially invited to attend. The conference will cover all aspects of power engineering. It will be residential for three nights. The working language will be English. Accepted papers will be presented in oral and poster sessions.

For more information on UPEC 2006, contact: UPEC 2006 Secretariat, School of Computing Engineering and Information Sciences, Northumbria University, Ellison Building, Newcastle-upon-Tyne NE1 8ST, UK, E-mail upec2006@northumbria.ac.uk, Tel: +44 191 227 3603, Fax: +44 191 227 3598, or the Conference Organizer, Dr Ghanim A. Putrus, E-mail: ghanim.putrus@northumbria.ac.uk Tel: +44 191 227 3107, Fax: +44 191 227 3598.

Abstracts are to be submitted by February 10, 2006; notification of acceptance of papers will be by March 24 2006; and receipt of full papers for review will be required by May 19, 2006.

9 CONFERENCE WRAP-UP

Papers were well thought out and benefited from the 15 minutes allowed for presentation and discussion of each paper. The general level of the discussions was extraordinarily high and stimulating. Of particular note was the high standard of the presentations by the younger members of the profession. The pleasure the participants experienced in meeting colleagues with similar interests from so many countries should be particularly noted

Gratitude is expressed to Dr Noel Barry, UPEC 2005 Conference Organizer, Members of UPEC Steering Committee, and colleagues at University College Cork for the detailed organization of the meeting.

The conference closed with a unanimous vote of thanks to Noel Barry for organizing one of the most successful events ever.

T. J. Hammons
October 18, 2005

41ST INTERNATIONAL UNIVERSITIES POWER ENGINEERING CONFERENCE (UPEC 2006)

NORTHUMBRIA UNIVERSITY, NEWCASTLE-UPON-TYNE, UK

SEPTEMBER 6-8, 2006

Call for Papers

Abstract Deadline: February 10, 2006

The 41st International Universities Power Engineering Conference (UPEC 2006) will be organized by the School of Computing Engineering and Information Sciences, Northumbria University, Newcastle-upon-Tyne, September 6-8, 2006. It will be based at the main University campus that is located at the heart of Newcastle. It will be co-sponsored by IEEE, IEE, and CIGRE. Its aim will be to provide professional engineers from the universities, consultants, and in the manufacturing and supply industries opportunities to explore recent developments, current practices and future trends in Power Engineering and related fields. Young engineers and research students are especially invited to attend. The conference will cover all aspects of power engineering. It will be residential for three nights. The working language will be English. Accepted papers will be presented in oral and in interactive sessions.

UPEC 2006 seeks papers in all aspects of power engineering, including the following topics:

1) Power Generation
2) Renewable Energy Systems
3) Distributed Generation
4) Transmission and Distribution
5) Future Power Networks
6) Power System Operation and Control
7) Power Conversion
8) Power Electronics and Devices
9) Electrical Machines and Drives
10) FACTS: Power Electronic Applications
11) System Integrity and Protection
12) High Voltage Engineering
13) Power Utilization
14) Power Quality
15) Expert Systems
16) Power Engineering Education

Prospective Authors are invited to submit an abstract (max 2 A4 pages) in the relevant subject area to the UPEC 2006 Secretariat or to the Program Chair (Dr Ghanim Putrus), School of Computing Engineering and Information Sciences, Northumbria University, Ellison Building, Newcastle-upon-Tyne NE1 8ST, UK, E-mail eb.upec@northumbria.ac.uk, Tel: +44 191 227 3603, Fax: +44 191 227 3598 before February 10 2006. On the front page they should give the full name, address, affiliation, and e-mail of the author to communicate with, the number of the area the paper is from taken from the list above, the preference for presentation (oral or interactive), and title of the paper, Notification of acceptance will be by 24 March 2006. Final camera-ready papers are to be received by May 19, 2006 for final review. Style of submission is available on the conference web site (http://www.upec2006.org/) One of the authors will be required to register and attend the conference. Registration will be available at: http://www.upec2006.org/

For more information on UPEC 2006, contact: UPEC 2006 Secretariat, School of Computing Engineering and Information Sciences, Northumbria University, Ellison Building, Newcastle-upon-Tyne NE1 8ST, UK, E-mail eb.upec@northumbria.ac.uk, Tel: +44 191 227 3603, Fax: +44 191 227 3598, or the Conference Organizer, Dr Ghanim A. Putrus, E-mail: ghanim.putrus@northumbria.ac.uk Tel: +44 191 227 3107, Fax: +44 191 227 3598.