Control of Renewable Integrated Systems Targeting Advanced Landmarks CRISTAL

Project Summary

The Coordination Action aims to contribute to the **integration and strengthening** of European research on Renewable Energy Sources and associated power converters, controllers and combined use. The proposal is a step forward in securing a leading role for Europe in **sustainable energy systems**, strategically important to some EC Programme objectives: large scale implementation of **Distributed Energy Resources (DER)**, **energy storage technologies** and **systems for grid connected applications.** It is focused on the **development of key enabling technologies** for **distributed / smart energy networks,** with high power quality and service security. The technical issues to be coordinated are concerned with solar, wind and micro-hydro systems control in conjunction with compensatory energy storage systems (fuel cells, hydrogen) and connection to the grid. The activities achieve the exchange of expertise through visits, longer studies and meetings, enabling the coordination of the DER modeling, simulation and system integration work, leading to the identification of controllers that enable high efficiency operation and solutions to grid connection issues. First year's visits and longer study findings will be reported at a general meeting. Further visits are scheduled for the second year. Open access events will be organized to raise public awareness on sustainability and renewable energy. A final general meeting will collate the exchange of expertise into conclusive reports. Intellectual property protection, the dissemination of knowledge beyond the consortium through publications, conference participation, public events and websites will also be tackled. The foreseen benefits include: increased awareness and enhanced knowledge on sustainable energy systems, both for participants and general public, correlated European research in DER and the identification of niche areas for further coordinated research, to comply with EC/national policies. An European expert group will be implicitly set up.

Renewable Energy based Embedded Generators provide a significant and growing contribution to the grid as well as being used as stand-alone generators for relatively small power networks, for example those associated with isolated locations, island systems and industrial complexes applications. However, their output power fluctuations constitute a concern that needs to be addressed. Systems combining renewable energy sources such as Photovoltaic (PV– solar energy), wind energy and hydro-energy, with compensatory more stable sources such as fuel-cells, hydrogen energy storage systems or electric batteries are the key to minimizing the disadvantages of renewable sources and extending their applicability in the future. Most of the system components are connected to the shared electric grid by means of Power Electronic Converters. The converters are individually controlled, but they also have to be supervised by a general holistic control system, facilitated by rapid progress of Electronic Design Automation techniques, which in recent years has created the opportunity for the modeling and development of complex integrated systems. The advances in VLSI technology enable the development, design and implementation of compact high performance intelligent controllers for power systems.

Wind energy. Onshore wind power generation is now considered cost competitive with most other forms of generation. The costs are more favorable for large-scale installations. Offshore wind power is still considerably more expensive but costs are falling with the deployment of more effective specialized resources for installing the turbines and cables. For reasons of output power quality and to avoid excessive operational stresses, large wind turbines usually include frequency conversion systems to permit variable-speed operation. The major disadvantage of wind energy is its intermittency leading to costs associated with spinning reserve elsewhere on the utility grid or to the need for energy storage which is at present not developed on a sufficient scale. If these costs are included then wind power can appear rather more expensive.

Solar energy, as a base energy source for all other energy forms, has nevertheless the lowest conversion rate (10 – 20 % for present photo voltaic cells) in power system applications. The photo voltaic (PV) cells, as fundamental elements, convert the solar light into electrical energy, having about 1W peak power for an output voltage of about 0.5V. They are together connected into solar panels (modules, units) to provide higher power and to facilitate their marketing. A complete solar power system includes the solar panels setup, power-electronic devices, auxiliary equipment, cable set, etc. and has quite expensive cost (about 4 – 8 Euro / W power during the year 2002). For an efficient cost recovery for such a system, all the exploitation conditions (light brightness, light range, efficiency, lighting exposed time / year) must be considered and a long lifetime (20 – 30 years). A complex problem is the energy storage.

Hydro energy: Where there is the hydrological potential, hydropower is usually the lowest cost form of renewable energy. Modern technologies provide relatively low-cost solutions using an induction generator – compensating inverter control system to meet variable loads. In addition, the mechanical systems are robust and have relatively high efficiencies even for small power. Pico-hydropower (<5 kW) can have potential if standardized equipment is used with appropriate control systems, and could provide flexible power for a network. Such schemes would be beneficial when operated alongside wind and PV generators and would require very little additional infrastructure. However, they would require intelligent control strategies in order to integrate them with the grid network.

Regenerative cells. Energy Storage is always an issue with renewable energy systems, as it is extremely unlikely that the variations of supply and demand will match. A further problem is that electrical energy is particularly difficult to store efficiently. Regenerative fuel cells are a possible way of storing large quantities of energy. The conventional hydrogen fuel cell can be used in this way, as it can also be used as an electrolyser for water; the Proton Exchange Membrane (PEM) fuel cell is a well-established example. A PEM based electrolyser can be run at high pressure, so that the generated hydrogen can be stored in high-pressure cylinders without the use of a pump. The stored hydrogen can then be run back through the cell to produce electricity as needed. Such devices have reached a state of development where their performance can be reasonably well modeled – future progress will mainly be in the area of reducing cost. The benefits and losses of incorporating such systems into a renewable energy based generator can thus be reasonably securely modeled. The losses would be considerable, as although much is made of the efficiency of fuel cells, it is considerably lower that that of conventional secondary batteries. System modeling may show that these are a better solution. An important part of the work would also be to evaluate other possible regenerative technologies, such as those based on sodium sulfide, for which a trial plant is being built in Cambridgeshire, England. A complication with the modeling of electrical energy storage is that the cost/benefit balance is highly dependent on the pricing mechanism used for electricity. For example, for countries such as the UK using the NETA system, unpredictable supplies of electricity to the grid, such as a renewable system without storage would provide, are particularly unrewarding. However, the ability to supply electricity at set times, for short periods, is highly commercially advantageous. In such circumstances, battery or regenerative fuel cell storage systems could well be very important. This makes it even more important to be able to accurately model the likely behavior of systems under different conditions.

Hydrogen Energy Storage Systems. The vision of the Hydrogen Economy anticipates an energy industry that will have eliminated the hazards of greenhouse gases. In a system where all the primary energy will come from renewables (and, some argue, nuclear power), whose output cannot be controlled to match the fluctuating electrical load on the grid, it is necessary to have some form of energy storage. Hydrogen presents both a means of storing grid power and of providing transport fuel. Vehicles will then be able to run emission-free, but with the range and performance we have come to expect from conventional engines – something that batteries have never been able to match. Combining the needs of balancing supply and demand on the electricity grid with providing fuel for fuel cell powered vehicles, hydrogen (produced using renewable energy) is the energy medium that promises a pollution-free energy system for the future. In a stand-alone renewable energy system, it is inevitable that the electrical supply rarely matches the loads, since the primary energy sources are entirely dependent upon the weather. Batteries are able to overcome this mismatch over short periods, but beyond about four days of storage capacity, they become expensive, bulky and inefficient. Hydrogen, on the other hand, offers a method of longer-term or large-scale energy storage, achievable at a lower cost and with a smaller footprint. When there is a surplus of electricity from the renewable sources, hydrogen can be produced by electrolysis of water and stored for later use. At times when there is a shortfall of power from the renewables, the stored hydrogen can be converted back to water via fuel cells, releasing electricity to feed the loads. The production and consumption of hydrogen is thus used as a load balancing mechanism. (Rupert Gammon, Bryte Energy Ltd., UK) There are many variables that come into play when designing an embedded generation system based on renewable sources, such as: climate, equipment costs, equipment performance, economic conditions, electricity pricing regimes, fuel prices and user demand profile. The above solutions / alternatives and various parameters are to be carefully considered and coordinated as part of the activities within this Coordination Action project.

Warsaw University of Technology is represented by Institute of Control and Industrial Electronics, with expertise in energy conversion and power conditioning, digital control in power systems and drives. The development of mathematical models of wind turbines combined with power conditioning systems for power quality, that represent their steady state and dynamic electrical behavior is an essential part of the ongoing work. This contribution of Institute of Control and industrial Electronics will be coordinated within WP1 and WP3 of this Coordination Action. A power conditioning system, meant to assure the stability of a grid to which the wild nature renewable energy source is connected, will also be considered.

Prof. Wlodzimierz Koczara is Head of Electrical Drives Division (since 1981) on Warsaw University of Technology, expert in power electronics conversion, drives and power generation. Prof. Koczara's extensive research expertise in power systems is very valuable, therefore he is a member of the project's Scientific Management Board.
The WUT team also includes:
Prof. Lech Grzesiak, (MSc 1976, PhD 1985, DSc 2002) - specialist on power electronics, hybrid energy systems and intelligent control drives,
Dr Bartlomiej Kaminski (MSc 1999, PhD 2006) - specialist on power electronics, DSP and programmable devices
Dr Grzegorz Iwanski (MSc 2003, PhD 2005) – specialist on power electronics and variable speed power generation.

List of Participants

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3	Politecnico di Torino	PUT	Italy
4	Environment Park S.P.A.	ENV	Italy
5	Transilvania University of Brasov	TUB	Romania
6	Warsaw University of Technology	WUT	Poland
7	EM Renewables Ltd.	EMR	UK
8	University Politehnica of Bucharest	UPB	Romania
9	Technological and Educational Institute of Patras	TEI	Greece
10	Newage AVK SEG	NAS	UK
11	Sustainable Technology Solutions	STS	UK
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