August 16, 2004

PANEL SESSION: EUROPE: TRANSMISSION SYSTEM DEVELOPMENTS, INTERCONNECTIONS, ELECTRICITY EXCHANGES, DEREGULATION, AND IMPLEMENTING TECHNOLOGY IN POWER GENERATION WITH RESPECT TO THE KYOTO PROTOCOL

IEEE 2004 General Meeting, Denver, 6-12 June 2004
Monday, June 7, 2004, Room Silver, 2:00 p.m.

EXTENDED PANEL SESSION SUMMARIES

Sponsored by: International Practices for Energy Development and Power Generation Subcommittee

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Track 1: Active Load Participation and Its Impact on Markets
Track 2: Environmental Dimensions

This Panel Session was on Transmission System Developments, Interconnections, Electricity Exchanges, Deregulation, and Implementing Technology in Power Generation in Europe with Respect to the Kyoto Protocol

Presented was the current and future status of transmission system developments, interconnections, electricity exchanges, deregulation, and implementing technology in power generation in Europe with respect to the Kyoto Protocol. The survey included the adjacent countries and regions. A special view was given on the progress made in the in the integration of renewable energies into the production and transmission system.

The Session presented some results of studies in this area to date.

The Authors and Titles of their Presentations were:

1) W. Leonhard and M. Grobe, Technical University Braunschweig, Germany: Sustainable Electrical Energy Supply with Wind and Pumped Storage—A Realistic Long-Term Strategy or Utopia?
2) J. Feist, Co-convenor of the UCTE Executive Team for Reconnection of the 2nd UCTE Zone, CEPS, Czech Republic. Status of Resynchronization of the Two UCTE Synchronous Zones
3) B. Cova, CESI, Italy: Progress of the Mediterranean Ring and the Interconnection with Europe
4) L. Salvaderi, Consultant, Rome, Italy: The Italian Power System: Recent Evolution
5) Y. Kucherov, Head of Department of R&D Policy and International Cooperation, Federal Grid Company of the UES (FGC), Russia, L. A. Koscheev, Deputy Director General, NIIPT, Russia, and Yuri Tikhonove, Head of Division, VNIIE, Russia: Technical Rules and Standards Harmonization is a Key Issue for Realization of UCTE, NORDEL and IPS/UPS Synchronous Operation.
6) Bernd Buchholz, Dietmar Retzmann, Siemens, Germany. Stability Analysis for Large Power System Interconnections" (Invited Discussion)

Each Presenter spoke for approximately 20 minutes. Each presentation was discussed immediately following the respective presentation. There was a further opportunity for discussion of the presentations following the final presentation.

The Panel Session was organized by Juergen Schwarz (Consultant, Heidelberg, Germany) and Tom Hammons, Chair of International Practices for Energy Development and Power Generation (University of Glasgow, UK).

Tom Hammons and Juergen Schwarz moderated the Panel Session.

1). The first presentation was on sustainable electrical energy supply with wind and pumped storage and discussed whether it is a realistic long-term strategy. Werner Leonhard and Marcus Grobe, Technical University of Braunschweig, Germany prepared it. Juergen Schwarz, Consultant, Heidelberg, Germany and Tom Hammons, Glasgow University, UK presented it.

Sustainability of future energy supply based on renewable resources is a long-term strategic objective in view of limited fossil resources and the avoidance of emissions and toxic waste. Of the various resources, available now or in future, wind is presently considered in Europe to hold most promise for contributing in the next few decades a sizeable part of the electrical energy. Generating electricity from wind is state of the art and feeding large amounts of wind power to the electrical grid is believed by many to pose no problems.

The presenters evaluated recent data from one of the four control areas in Germany and discussed how a sustainable electrical energy supply based on off-shore wind power and pumped storage, called a "wind and water"-model, might look. It turns out that such an energy scheme, while being feasible in principle, would require an immense storage capacity that is impossible to realize, hence thermal generation continues to be needed; and the addition of biomass as a regenerative source will not substantially change the picture.

Werner Leonhard is a Life Fellow IEEE. He is Professor. Emeritus at the Technical University of Braunschweig, Germany. He was born in Weiden (Germany), was appointed Professor of Control Engineering at the Technical. University of Braunschweig in 1963, and in 1974 and 1977 he was Chairman of the first two IFAC- Symposia on Control in Power Electronics and Electrical Drives, Düsseldorf. In 1982 he was Chairman of VDE Conference on Microelectronics in Power-Electronics and Electrical Drives, Darmstadt; and in 1986 he was Advisory Professor at Shanghai University of Technology. He also received the Dr. Eugene Mittelmann Award of the IEEE-Industrial Electronics Society and was elected Fellow of IEEE in 1987. He was Chairman of the European Power Electronics Conference (EPE), Aachen in 1989. In 1993 he became Professor Emeritus, and President of the European Power Electronics Association, Brussels. He is Author of 8 textbooks, among them Control of Electrical Drives, and has published numerous papers and given numerous invited lectures. He has been Advisor to about 600 Dipl.-Ing. and 85 Dr.-Ing. students.

Marcus Grobe is an Assistant Professor at the Technical University of Braunschweig, Germany. He was born in Born at Braunschweig (Germany), studied Electrical Engineering at the Technical University, Braunschweig. In 1999, he gained his Dipl.-Ing. Degree at the Institute of Control Engineering, Technical University Braunschweig.

Jürgen Schwarz has been Managing Director of the Deutsche Verbundgesellschaft (DVG), Heidelberg, Germany for more than 12 years; he retired just recently. In this function he was responsible for the close technical cooperation of the German TSO's in the national and the European grid as well as for the realization of deregulation. He represented the German TSO's in the respective international organizations like UCTE, ETSO, and others. He has strongly been engaged in the integration and the extension of the European interconnected system, and published several papers on that matter in CIGRE and IEEE.

Jürgen Schwarz received a Ph.D. degree in electrical engineering from the Technical University Darmstadt, Germany in 1973. He was president and still is a member of the German National Committee of CIGRE.

2). The second presentation was entitled: *Status of Re-synchronization of the Two UCTE Synchronous Zones* and was prepared by J. Feist, Co-convener of the UCTE Executive Team for Reconnection of the 2nd UCTE Zone, CEPS, Czech Republic.

On September 26, 1991, all connections between the Eastern and Western parts of the electric power system of former Yugoslavia broke (the last disconnection being the 400 kV transmission line Ernestinovo – Tumbri) and the UCTE synchronous zone was split into two synchronous zones. Since then, the electric power systems (EPSs) of Yugoslavia, FYROM, Greece, part of Bosnia-Herzegovina and Albania have been operated separately (as the 2nd UCTE zone) from the main part of the UCTE system (1st UCTE zone).

In April 1994, the EPS of Romania, and in April 1996 the EPS of Bulgaria started parallel operation with the power systems of Serbia, FYROM and Greece, and this is in fact the state of interconnection in the Balkans at the present time. The presentation discussed the status of the reconnection. Juergen Schwarz, Consultant, Heidelberg, Germany and Tom Hammons, Glasgow University, UK presented it.

Jiri Feist (born 1962), is Director, Strategy&Development, CEPS, a.s., **and** graduated from the Czech Technical University′s Faculty of Electrical Engineering in Prague. In 1986 he joined the Czechoslovak Control Center, where he worked in the Operation Planning Department. Later he worked at ČEZ – from 1990 in its Network Development Department and from 1992 as Head of the System Analyses Department. From 1993 he worked in ČEZ s Transmission System Division as Director of the Transmission System Development and Investment Unit. From 1996 he worked as Director of the National Control Center (formerly part of ČEZ and since 1999 part of ČEPS – Czech TSO company). Since 2002 he has been Director for Strategy& Development of CEPS.

From 1993 to 1996 he was project manager for the interconnection of the Czech power system to the UCTE system. He was a member of the Technical Committees for the interconnection of the CENTREL systems, the western part of the Ukrainian power system and the Balkans power systems to the UCTE system. He is a member of the Council and Steering Committee of UCTE and CENTREL. Since 2002 he has been Vice-president of CENTREL and Co-convener of the UCTE Executive Team for the North-South. Re-synchronization

3). The third presentation was concerned with Progress of the Mediterranean Ring and the Interconnection with Europe and was presented by Sandro CORSI on behalf of B. Cova, CESI, Italy: The presentation was prepared by Bruno Cova.

The presentation first addressed the status of the Mediterranean interconnections and the evolution of demand and power exchanges in the area. Thereafter, the main driving forces prompting full integration of the power systems was discussed. These referred mainly to different load patterns in the various countries, imbalance in generation availability and the introduction of market rules that are going to eliminate custom barriers for energy trading.

From the technical point of view, the closure of the MedRing sets challenging problems that should be investigated and suitably solved before starting system operation. These are essentially related to the capability of reacting to small and large disturbances keeping the system stability. The presentation highlighted the potentially critical dynamic phenomena that might occur and the most appropriate countermeasures to be undertaken. Due to the very stretched structure of the grid in the Southeastern area, even a single contingency can cause heavy repercussions on cross-border cut-sets thousands of km away from the disturbance's location. A study project completed in June 2003, supported by the European Commission and with the objective of defining a framework for coherent development of interconnections between the power systems of the Mediterranean Basin was discussed. Finally, the perspectives for a further extension of interconnections towards the South, the Gulf Countries and Northeast of the MedRing were presented.

Bruno Cova graduated in Electric Engineering at the University of Pavia (Italy) in 1985. In 1985 he joined Network Study Department at CESI where he has been involved in power system modeling, studies and simulations. In 1997 he was made responsible for power system studies within CESI System Department, and since February 2003 he has been Scientific Manager within B.U. T&D Networks at CESI.

From 2001 to 2003 he was appointed Project Manager of the Mediterranean Electrical Ring (MedRing) project, aimed at investigating the expected behavior in static and dynamic conditions of the synchronously interconnected Mediterranean system.

4). The next presentation was on recent evolution of the Italian Power System: Also discussed was the power blackout in Italy in the fall of 2003 where power supplies to most of the country failed. Luigi Salvaderi, Consultant, Rome, Italy prepared it. Sandro Corsi of Italy presented it

Luigi Salvaderi was born in Ancona, Italy, in June 1938. He received his PhD. Degree in Electro-technical Engineering from the University of Genoa, Italy in March 1962.

After an initial experience in the automatic control field, he joined ENEL, the Italian Electricity Board, in 1965, where he held many positions and had numerous responsibilities:

On behalf of ENEL Spa Dr. Salvaderi has also acted as a Senior Consultant Engineer in various countries, and since 1968 he has been a very active member of various International Bodies.

Dr. Salvaderi has co-authored more than 120 technical papers published in international reviews on power system planning, reliability evaluation, and energy issues. He has given lectures and tutorials in Institutions, Associations and Universities in various countries of Europe and North America.

He is co-editor of the IEEE book on "Applied Reliability Assessment in Electric Power Systems" used by Consultants, Utilities, and Universities. He was Panelist and Special Reporter at many IEEE and CIGRE sessions on various issues related to planning and new unbundled structure of the electric utilities.

Dr. Salvaderi received in 1996 the "CIGRE Technical Committee Award", in recognition of his outstanding contribution to the work of the Study Committee "Power System Planning and Development".

5). The penultimate presentation discussed harmonization of technical rules and standards and whether it is a Key Issue for realization of UCTE, NORDEL and IPS/UPS synchronous operation. Y. Kucherov, Head of Department of R&D Policy and International Cooperation, Federal Grid Company of the UES (FGC), Russia, L. A. Koscheev, Deputy Director General, NIIPT, Russia, and Yuri Tikhonove, Head of Division, VNIIE, Russia: prepared it. Nikolai Voropai, Director, Energy Systems Institute, Irkutsk, Russia presented it.

Yuri Kucherov was born in the Leningrad Region, Russia in January 1951. He graduated from the Novosibirsk Electro technical Institute in 1973.

After a post-graduated course –1976-1979 - he received his PhD Degree in 1980. In 1986 – 93 he worked in the Siberian Power Institute- Siberian Division of Russian Academy of Science- as a senior researcher, a leading researcher, head of laboratory on security and reliability of large power systems. From 1993 to 1997 he headed the International Power Laboratory in Budapest/Hungary. He received his Degree of Doctor of Technology in 1998.

In 1997 he joined Russian Joint Stock Company of Power and Electrification – RAO "EES Rossii" where he headed Department of Development and Scientific&Technical Policy.

From November 2002, when due to liberalization processes in the Russian Electricity Industry the Federal Grid Company of the Unified Power System – was formed, now he holds the position and responsibility as Head of Department of Research & Development and International Co-operation.

Y. Kucherov is an author of more than 140 technical papers, including six monographs (in the co-authorship).

Lev A. Koscheev was born in Tashkent, USSR, in April 1932. He graduated from Leningrad Electro technical Institute in 1955. He received his first scientific degree in 1967 and doctor of science degree in 1987. He joined Leningrad Power Transmission Research Institute (NIIPT) in 1955, where he held the following positions:

- 1955 to 1972 – Engineering and Scientific Positions,
- 1972 to 1986 – head of the Power System Department,
- 1987 to present -- Scientific Director, Deputy Director General.

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His main fields of his scientific activity are:

- AC and DC long distance power transmission lines,
- stability and reliability of large power systems,
- emergency control systems.

Professor Koscheev is author and co-author of more than 100 technical papers published in magazines and reviews including CIGRE reports. In 1985 he received the "USSR State Award". He has participated in many international working groups, including: (i) East-West High Power Electricity Transmission System – Baltic Rout; (ii) Baltic Ring; and (iii) System Committee on Russian-Finland power connection between RAO UES of Russia and Fingrid.

Yuri Tikhonov was born in Baku/Azerbaijan, in 1937. He graduated from Moscow Power Engineering Institute in 1961. From 1961 to present he has been working at the Moscow Electric Power Research Institute (VNIIE), where he has held the following positions:

- 1961 to 1976 – Engineering and Scientific Positions,
- 1976 to present – Head of Power Systems Stability Laboratory, Head of Power System Regimes Department.

He received his PhD Degree in 1975. His main field of activities is reliability, stability and emergency control of power systems. Dr. Tikhonov contributed a lot in the development of Russian power system emergency control, national rules and standards on the UPS operation.

Dr. Tikhonov is author and co-author of more than 40 technical papers published in Russian and international magazines and reviews on power system modeling, transient stability, reliability evaluation, emergency control of the turbine power etc. He is as a lecturer in the Institution of upgrading professional education of electrical engineers.

Nikolai I. Voropai is Director of Energy Systems Institute, Irkutsk, Russia. He was born in Belarus in 1943. He graduated from Leningrad Polytechnic Institute in 1966. N.I. Voropai received degree of Candidate of Technical Sciences in 1974 and Doctor of Technical Sciences in 1990. His research interests include: modeling power systems; operation and dynamic performance of large interconnections; reliability, security and restoration of power systems; development of national, international and intercontinental interconnections. N.I. Voropai is a Member of CIGRE, a Senior Member of IEEE and a Member of PES.

6). The final presentation was an invited discussion on stability analysis for large power system interconnections. Bernd Buchholz and Dietmar Retzmann, Siemens, Germany presented it

There is a worldwide trend in the development of power systems is to build interconnections with the goal to achieve economical benefits. Such large interconnected systems can cover many countries or even wide continental areas. Interconnections of power systems may offer significant technical, economical and environmental advantages

Evaluation of the best solution for large system interconnections requires detailed system models for stability analysis. In the presentation, examples of very large power system simulations for Europe were shown. The models in use were explained and simulation results given. There are practically no limits for the size of the systems that can be handled by modern computer simulation tools, e.g., the advanced NETOMAC simulation program. Benefits of HVDC and FACTS synchronous and asynchronous solutions for system expansions were also demonstrated and preferences were explained. The challenges of further system interconnections in Europe were considered on the base of existing experience in stability analysis.

Bernd Michael Buchholz is Vice President, Siemens AG, Erlangen, Germany and **Dietmar Retzmann** is Director, Siemens AG, Erlangen, Germany.

Dietmar Retzmann (1947), CIGRÉ, VDE, graduated in Electrical Engineering (Dipl.-Ing.) at Technische Hochschule Darmstadt/Germany in 1974. He received Dr.-Ing. degree in 1983 from the University of Erlangen-Nuremberg. Dr. Retzmann has been with Siemens Erlangen, Germany since 1982. His area of expertise covers Computer and Real-time Simulation; Design & Development and Testing for more than 40 large FACTS & HVDC projects with advanced controls & protections; R&D works; Design & Development and Testing of Analogue, Hybrid and Fully Digital Real-Time Simulators. Currently, he is technical director for Project Development in High Voltage Division, Power Transmission Solutions.

Bernd Michael Buchholz (1948) received his MS and PhD at the Power Engineering Institute in Moscow in 1973 and 1976 respectively. After that he was assigned project manager and later director of R&D at the Institute of Energy Supply in Dresden. In 1990 he joined the Siemens AG and took over the head oft the R&D department of the division "Protection and Substation Control Systems" in Berlin and Nuremberg. Since February 2000 he has been president of the business unit "Network Analysis and Consulting" in the "Service" division of the Power Transmission and Distribution group in Erlangen. He is member of the SC C6 of CIGRE "Dispersed generation in distribution systems".

The final EXTENDED PANEL SESSION SUMMARIES follow:

FINAL EXTENDED SUMMARIES

Rec'd 18 June 2004

1. SUSTAINABLE ELECTRICAL ENERGY SUPPLY WITH WIND, BIOMASS AND PUMPED HYDRO STORAGE – A REALISTIC LONG-TERM STRATEGY OR UTOPIA?

W. Leonhard, Life Fellow IEEE, Prof. Emeritus
M. Grobe, Assistant Professor, Technical University Braunschweig, Germany

Abstract: Sustainability of the future energy supply based on renewable resources is a long-term strategic objective [1] in view of limited fossil resources and the avoidance of emissions and toxic waste. Of the various resources, available now or in future, wind is presently considered in Europe to hold most promise for contributing in the next few decades a sizeable part of the electrical energy; generating electricity from wind is state of the art and feeding large amounts of wind power to the electrical grid is believed by many to pose no problems.

Evaluating recent data from one of the four control areas in Germany it is discussed how a sustainable electrical energy supply based on off-shore wind power and pumped storage, called a "wind and water"-model, might look. It turns out that such an energy scheme, while being feasible in principle, would require an immense storage capacity that is impossible to realize, hence thermal generation continues to be needed; the addition of biomass as a regenerative source is not substantially changing the picture.

Keywords: Sustainable energy supply, Fluctuating wind power, Control power, Pumped Storage, Biomass.

Introduction

The acquisition of wind energy is politically encouraged by strong financial incentives in different European countries, where about 24 GW of generating capacity are presently installed, among them 13 GW in Germany alone; assuming an average of 1 500 full-load-hours per annum, this corresponds to 20 TWh/a or about 4 % of generation in Germany, comparable to the electricity produced from hydro sources.

With favorable wind sites in the coastal regions becoming scarce and the rise of public opposition to additional wind farms in the neighborhood, the interest is now turning to the sea, where the wind is stronger and blowing steadier, and where the off-shore wind farms would be out of sight. Early installations have been built in Denmark and Sweden, close to the shore and in shallow waters of about 10 m depth; off-shore wind projects are also discussed in USA.

Due to the regulations in international waters, dense shipping lines and protected Natural Reserves the German off-shore wind farms would have to be sited more distant from the coast; water depths to 40 m are being considered and building generating equipment on pontoons is also discussed. Large windmills up to 4.5 MW are under development and are being tested on-shore [2, 3]. Should it be technically feasible to install such large equipment at high sea and maintain it through many years at tolerable cost, this could indeed turn into an inexhaustible source of natural energy, offering little cause for ecological controversy. There are hopes that, given adequate public support, 35 GW offshore wind farm capacity might be built in the North and Baltic Seas in the coming 20 to 30 years.

Control Energy

However, after various legal barriers are overcome and the protected National Shoal zone is crossed with AC- or DC-cables, only part of the problem has been solved when the power is finally coming onshore, because it must now be transmitted with the existing grid and new high voltage lines to the industrial and commercial centers. Since wind power and grid load are not correlated in time, this requires large amounts of balancing power for frequency control and stabilization [4, 5]:

Supplementary or **positive control power** (which may be thermally generated) is required during periods of low wind. As seen during last summer's heat wave, the calm could last days and weeks; if it extends over the whole control area, the available generating capacity must cover the full grid load. On the other hand, **negative control power** is needed during periods of high wind when the grid cannot absorb the excessive power and energy should be stored and preserved for later intervals with insufficient wind. This is possible with pumped hydro or with compressed air energy storage, CAES, plants [14,15,16]. **Energy storage is a precondition of any sustainable energy policy.**

Some recent records from a large German control area during a week are shown in Figures 1. The wind power collected with priority and at a subsidized rate by thousands of (presently on-shore) turbines depends on existing meteorological and atmospheric conditions and clearly follows a pattern that is entirely different than the grid load resulting from the economic activities and living habits of millions of consumers in the control area. Altering the load would call for demand-side-management but the easily deferred domestic power consumption (washing, cooking, cooling etc) is only a small part of the total load, while the larger industrial consumption is subject to cost optimization; deferring is often not possible at all, for instance with linked factory production or railway schedules. During the Californian energy crisis, the Independent System Operator had to resort to unselective "rotating blackouts" to preclude general breakdowns during periods of insufficient supply [6].

The mismatch of wind power and grid load will not improve when extending the acquisition to the sea, as the wind power is already averaged over thousands of distant sites in a large area.

In grids with a sizeable content of hydro generation such as in Norway (99%), hydro plants with storage reservoirs (without or with pumping) could provide the necessary control power, but not in Germany with its minimal hydro generation, where the control power comes mainly from thermal (fossil and nuclear) stations. The efficiency of a fossil plant is reduced at part load so that fuel consumption and emissions per MWh are rising and some of the environmental relief by wind energy is lost, while the cost increases [7, 8].

The wind power usually changes with a limited gradient according to regional aerodynamics, but occasionally it may also decay quite rapidly. This happened in March 2002 during a high wind regime, when many rotors reached in short succession their power limits, often set at a wind velocity of 25 m/s, and the equipment was protectively shut down. This led in the control area to a loss of injected wind power of up to 2 500 MW for several hours, changing the power flow in the European grid and affecting neighboring areas [9]. Such events cannot be ruled out even with the improved prognostic tools presently under development [10].

When many more GW of uncontrolled off-shore wind power will in future be fed to the electrical grid with its short-term balancing need, large storage facilities on a GWh scale will be required.

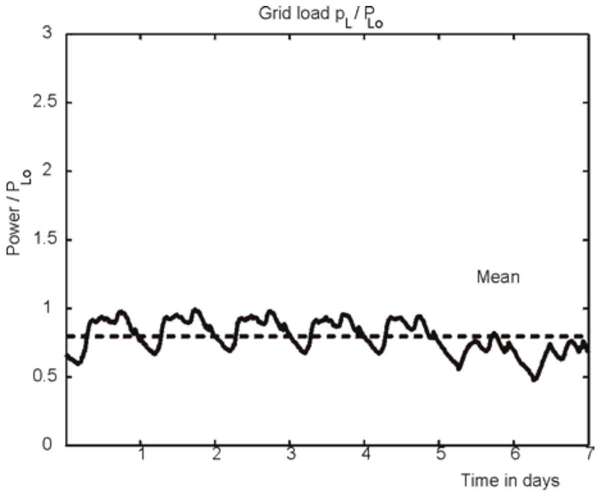

Figure 1a Grid load during the week

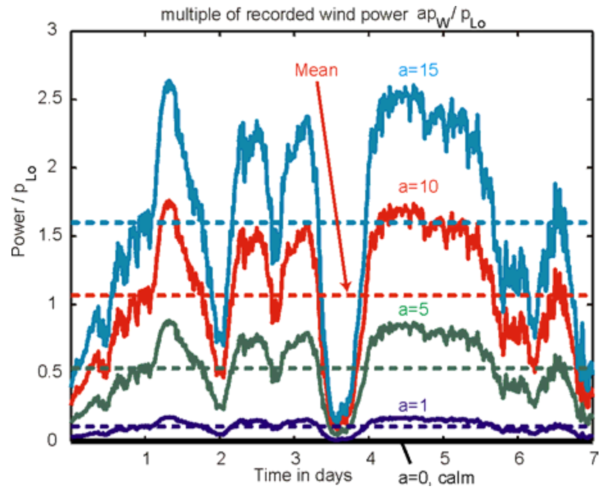

Figure 1b A-fold of recorded wind power scenario

Energy Storage with Pumped Hydro Plants, "Wind and Water"- Model

Pumped hydro power stations employ a long- established method for storing mechanical potential energy by using surplus power for pumping water from a lower level, a reservoir or a river, to a higher level reservoir; when returning the water to the lower level, dispatch able peak- or control- power is generated at an efficiency of up to 80 %. Both modes of operation may be combined in a single hydraulic machine acting as a turbine or a pump. World wide close to 280 pumped hydro storage installations exist with a total power of about 90 GW or ca. 3 % of installed generating capacity, having power ratings up to several GW and storing energy for generating periods of hours to days [11].

Large pumped storage plants in the Alps with hundreds of m head serve for secondary grid control, where short response times of a few minutes are important; other plants are strategically sited in mountainous areas. Recently, after decades of planning and 7 years of construction, a large pumped storage was put in service near Goldisthal in Thuringia (in another control area); for improving the efficiency, two of the four units are operating with adjustable speed.

In principle, a sufficient number of large pumped storage plants could provide dispatch able control power for future offshore wind farms, but the high voltage grid would have to be enlarged and new lines built for connecting the plants to the shore. Possibly DC links from remote wind farms could be extended with HVDC to the inland hydro power stations. It has been suggested to employ the Scandinavian grid with its large hydro content for storage but this would also call for new long transmission lines, apart from political problems; as the example of Finland shows, the available hydro resources there are insufficient and thermally generated power has to be imported in dry years; another difficulty would be the high cost of subsidized German off-shore power, hindering international trade. Similar problems exist with regard to the proposed creation of a single European control area, trading control power on a larger scale; however, in view of recent black-outs, questions would arise about the wisdom of transmitting additional blocks of non-dispatch able power over ever longer distances.

Pumped storage plants, while employing an existing technology for storing large amounts of energy with acceptable efficiency and converting it to dispatch able control power, require a suitable topography and have a strong environmental impact, not to mention the long construction time and often-high cost; they would meet with strong public opposition. Still, as the combination of wind power and pumped storage could in principle be part of a sustainable energy scenario, this "wind and water"-model may serve as an example, using recent data from a large control area in Germany.

Note: As with all prognoses, estimates are needed, where the **wind power** is subject to particularly large statistical changes, extending from occasional storms to totally calm periods. With the **grid load** the situation is less critical, because it may be accurately forecast and major increases are unlikely in a service-orientated society with a diminishing population.

Figure 1a depicts the recorded grid load p_L in the control area during a week in December 2002, having a peak load P_{Lo}= 20 GW, subsequently used for normalization, and an energy content of 2.67 TWh. In Figure 1b, the curve marked with the parameter a = 1, presents the wind power p_W injected into the same control area during an earlier week with high winds; the recorded peak power was 3.5 GW and the energy 0.36 TWh or about 13 % of the load during the week.

Next it is estimated, by which factor a > 1 the wind power would have to be increased, mainly by off-shore production over the next decades, in order to supply today's grid load solely with wind power, assuming a gradual phasing out of existing generating plants.

When comparing the curves in Figures 1a and 1b it appears that enlarging the wind power generation by a factor a = 10 to a peak of 35 GW and an energy potential of 3.6 TWh might be adequate; this is in line with projections by the German Environment Ministry (which however includes all the four German control areas); hence a = 10 is chosen for the subsequent discussion.

Since the traces of the grid load $p_L(t)$ and the projected wind power a $p_W(t)$ are differing strongly, while the total power fed to the grid must be balanced to maintain the grid frequency, it is assumed that the necessary control power $p_{control}$ (t) is produced by pumped storage power plants. (Thermal power is ignored for the time to remain consistent with the sustainable "wind and water"-model). A control scheme is shown in Figure 2, where the varying need for control power $p_{control}(t)$ is derived from a simulated grid-frequency control loop. In view of the widely differing time scales, considerable simplification of the grid control is possible,

$p_{control} + a\, p_W - p_L \approx 0$, resulting in

$p_{control} \approx p_L - a\, p_W$.

This signal could serve as power reference for all available storage plants.

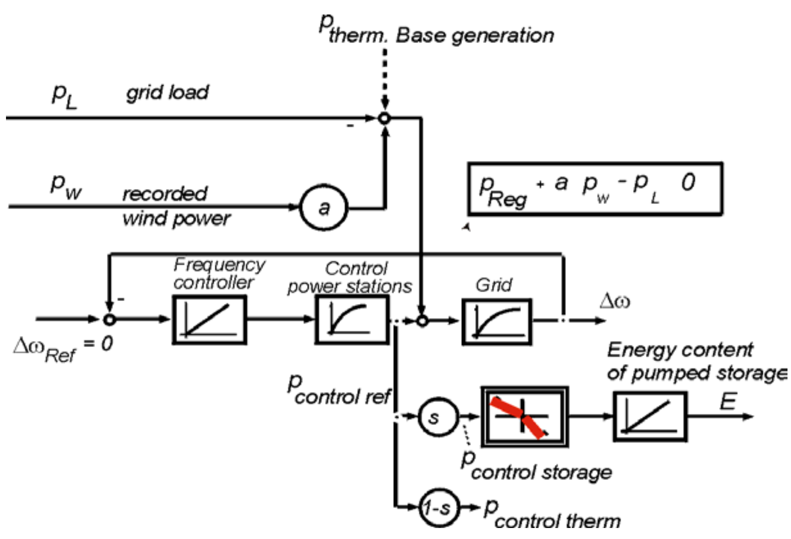

Figure 2. Scheme of grid control with wind power andpumped storage, "wind and water" model

For $p_{control} > 0$, supplementary electrical power is needed for maintaining the grid frequency, when the hydro plants operate in generating mode and the stored energy, corresponding to the water level in the storage reservoirs, is reduced. For $p_{control} < 0$, pumping is called for and the water levels are rising. Unavoidable power losses may be estimated or could be more accurately accounted for by the non-linear function generator in Figure 2, which causes an overall reduction of stored energy during a periodic control power cycle. Figure 3 shows the resulting control power $p_{control}$ for the chosen power scenario, ranging from total calm to a 10-fold increase of today's recorded wind power.

The maximum storage power lies between $p_{control}$ = 20 GW (generating) and $p_{control}$ = -21 GW (pumping); it could be reduced by using the wind rotors for grid control, i.e. throttling them during periods of high wind and cutting down on the pumping operation at the expense of diminishing reserves for later low wind periods.

Finally, the stored energy in the reservoirs during the week is plotted in Figure 4 for the scenarios a = 0; 1; 10, ignoring losses and possible power constraints. With a = 10, i.e. very large future off-shore generation, an energy surplus would result, but for a = 1, corresponding to present wind power generation, and even more for a = 0 (no wind at all) and including power losses, the stored energy would decay by nearly 3 TWh during the week, threatening the reservoirs to run dry and enforcing current rationing. including power losses, the stored energy would decay by nearly 3 TWh during the week, threatening the reservoirs to run dry and enforcing current rationing.

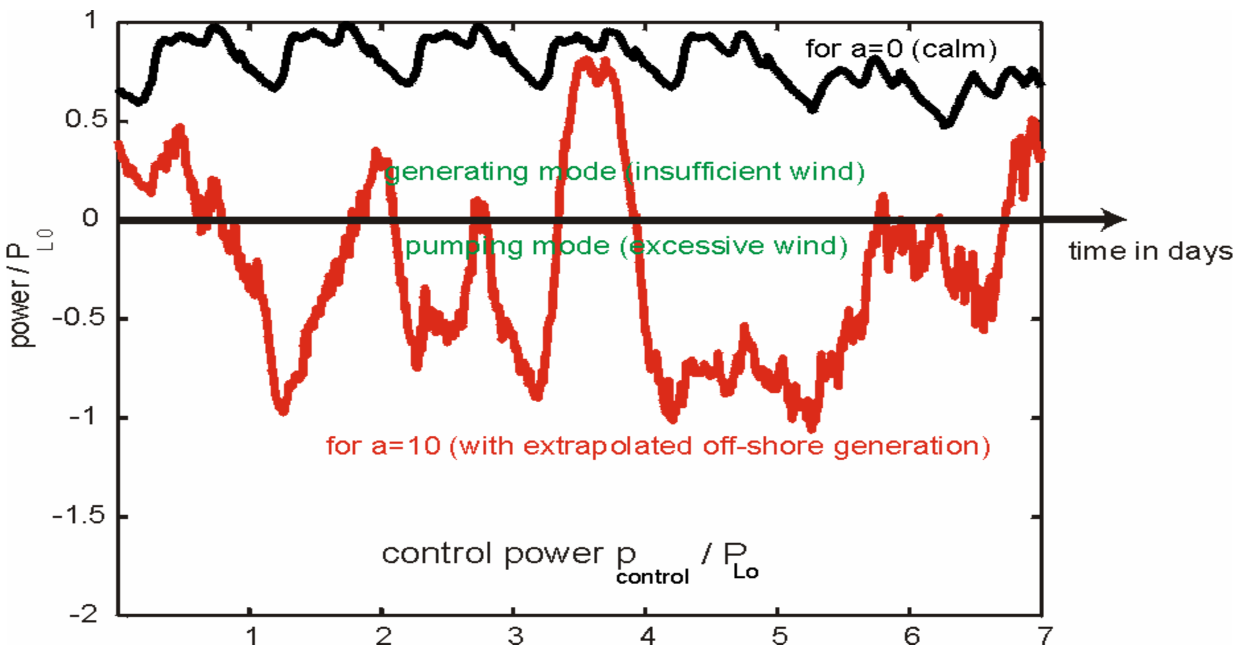

Figure 3 Control power during the week

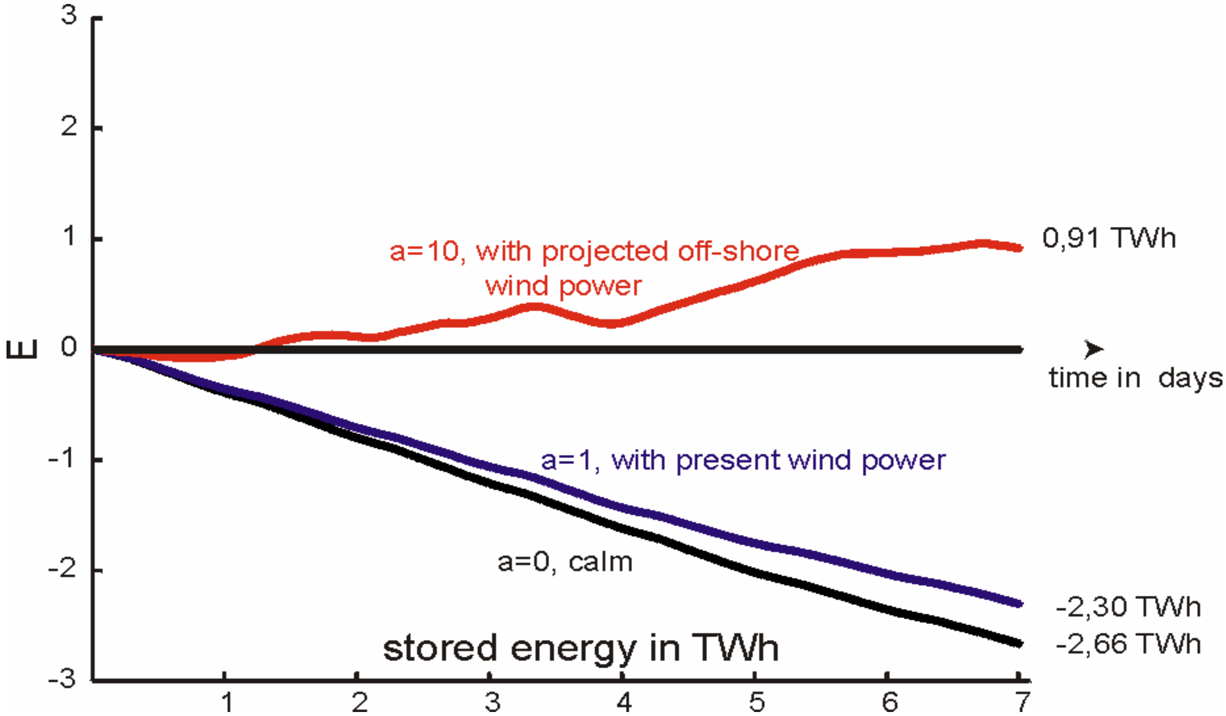

Figure 4 Change of stored energy

This result should be related to the total presently available pumped storage capacity of the control area of only 1.2 GW and 6.5 GWh. For comparison the capacity of the new Goldisthal pumped storage plant is 1.06 GW and 8.5 GWh.

So, implementing the sustainable "wind and water"-model would require, just to be able to maintain supply for one week of calm weather, a 20-fold larger pumped storage power and a 350-fold larger storage capacity than is available in the new Goldisthal plant. This obviously is impossible for topographical reasons and totally out of question, considering environmental effects and cost.

A recent report by the federal agency for renewable energy sources [12] indicates that the total potential of biomass in Germany may be about 220 TWh/a. Since biomass must be used locally and there are other possible uses, such as the conversion to Biofuel, only a limited amount will be available for producing electricity in the control area discussed. Assuming a 40% share of the total biomass potential for electrical conversion in the control area would allow an additional sustainable base load generation of 10 GW from biomass.

Including this in the power balance of Figure 2, an extension of wind power by a factor a = 4 proves to be adequate but the required pumped storage in the control area would still amount to an 11-fold increase in power and a 115-fold rise in storage capacity of the large new Goldisthal plant. So, one clearly is faced with an unsolvable problem.

Only by abandoning the goal of sustainability and admitting the use of dispatch able resources in coal- or gas-fired plants (including cogeneration) [13] or nuclear energy can the storage problems created by the large wind power infeed be handled.

Another option according to Figure 2 is to use hydraulic storage for only a part of the needed control power $sp_{control}$ and assign the rest $(1\text{-}s)\ p_{control}$, $s < 1$, to gas-fired power stations with compressed air

energy storage (CAES), which in contrast to normal gas turbine plants can accommodate both signs of control power; they too consume natural gas, but in reduced quantities [14, 15, 16]. The storage there takes place in large pressurized cavities created by solution mining in underground or undersea salt domes. By mechanically separating the compressor from the combustion turbine, storage is achieved by driving the compressor through an electric converter with fluctuating wind power, while dispatch able generation takes place with the compressed air and the now compressor less turbine. With the example of the 290 MW peaking plant in Huntorf, Germany, successfully operated for over 20 years, CAES plants optimized for balancing fluctuating wind power, are now in the planning phase.

Summary

A future electrical energy supply system based on a "wind and water"-model, where the fluctuations of greatly increased off-shore wind power are balanced by pumped storage hydro stations, appears as a remotely conceivable possibility for a sustainable energy scenario, given today's technology (Figures 5 and 6). However, as the extrapolation from recent data of a German control area shows, this would call for a prohibitive enlargement of the existing pumped storage capacity which is not only incompatible with topography but also out of question for ecological and cost reasons, even when including the projected available biomass. Therefore thermal power stations will still be needed in future and the idea of a sustainable electrical energy supply fed only by wind power and biomass is quite unrealistic.

Assuming that the surely immense potential of uncontrolled off-shore wind power is technically accessible, it would make more sense to use it for the production of secondary fuel, such as hydrogen, that can be stored and distributed [17]. With the depletion of fossil resources, such fuels will be in worldwide demand for fuel cells in stationary and mobile applications. Developing these enabling technologies in parallel with the primary energy acquisition from off-shore wind power would indeed be a challenging and rewarding long-term strategy, instead of endangering the electrical grid by feeding it with ever rising quantities of fluctuating wind power.

Figure 5. Off-shore wind and pumped storage—Wind Farms: Not the road towards a sustainable energy supply

Figure 6. Off-shore wind and pumped storage—Pumped Storage: Not the road towards a sustainable energy supply

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Biographies

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1986	Advisory Professor of Shanghai University of Technology
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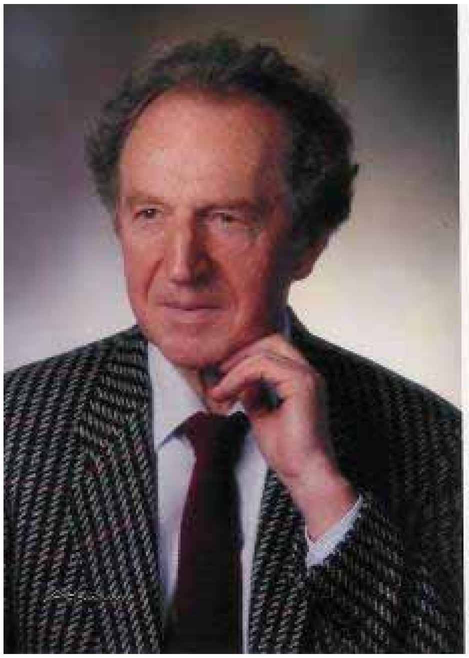

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2. STATUS OF RESYNCHRONIZATION OF THE TWO UCTE SYNCHRONOUS ZONES

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On September 26, 1991, all connections between the Eastern and Western parts of the electric power system of former Yugoslavia broke (the last disconnection being the 400 kV transmission line Ernestinovo – Tumbri) and the UCTE synchronous zone was split into two synchronous zones. Since then, the electric power systems (EPSs) of Yugoslavia, FYROM, Greece, part of Bosnia-Herzegovina and Albania have been operated separately (as the 2nd UCTE zone) from the main part of the UCTE system (1st UCTE zone). In April 1994, the EPS of Romania, and in April 1996 the EPS of Bulgaria started parallel operation with the power systems of Serbia, FYROM and Greece, and this is in fact the state of interconnection in the Balkans at the present time.

2.1 Synchronization of Bulgaria and Romania with the UCTE Second Zone

With a view of a permanent synchronous interconnection of the electricity networks of Bulgaria and Romania to the UCTE system, as well as of rehabilitation of the interconnected operation in south-east Europe, the UCTE – Bulgaria/Romania Technical Committee (TC BG/RO) was established in 1997.
The Technical Committee achieved the following main results of work:

- The states of progress of the technical and organizational measures were evaluated. This evaluation was made on the basis of data submitted by the companies NEK (BG) and Transelectrica (RO).
- Delimitation contracts were concluded for the permanent separation of their electrical power systems from the power systems of Moldova, Ukraine and Turkey.
- The Tests on “Island Operation” and “Interconnected Operation” of the systems of Bulgaria and Romania were successfully carried out in 2001 and in 2002/2003.
- The Catalogue of Measures, the Interim Report (including the report on the test “Island Operation”) and the Final Report (including the report on the test “Interconnected Operation”) cover all tasks successfully performed by the TC BG/RO.
- Transelectrica and NEK decided to carry out projects for joining the UCTE Accounting and Co-ordination Centre North in Brauweiler (RWE). Transelectrica, NEK and RWE Transportnetz Strom declared their readiness to carry out these projects in due time prior to the re-synchronization of the UCTE 1st and 2nd synchronous zones.

The General Assembly of UCTE finally approved the results and conclusions of the TC BG/RO and admitted Romanian and Bulgarian TSOs as full members of UCTE in May 2003. The TC BG/RO was desolved

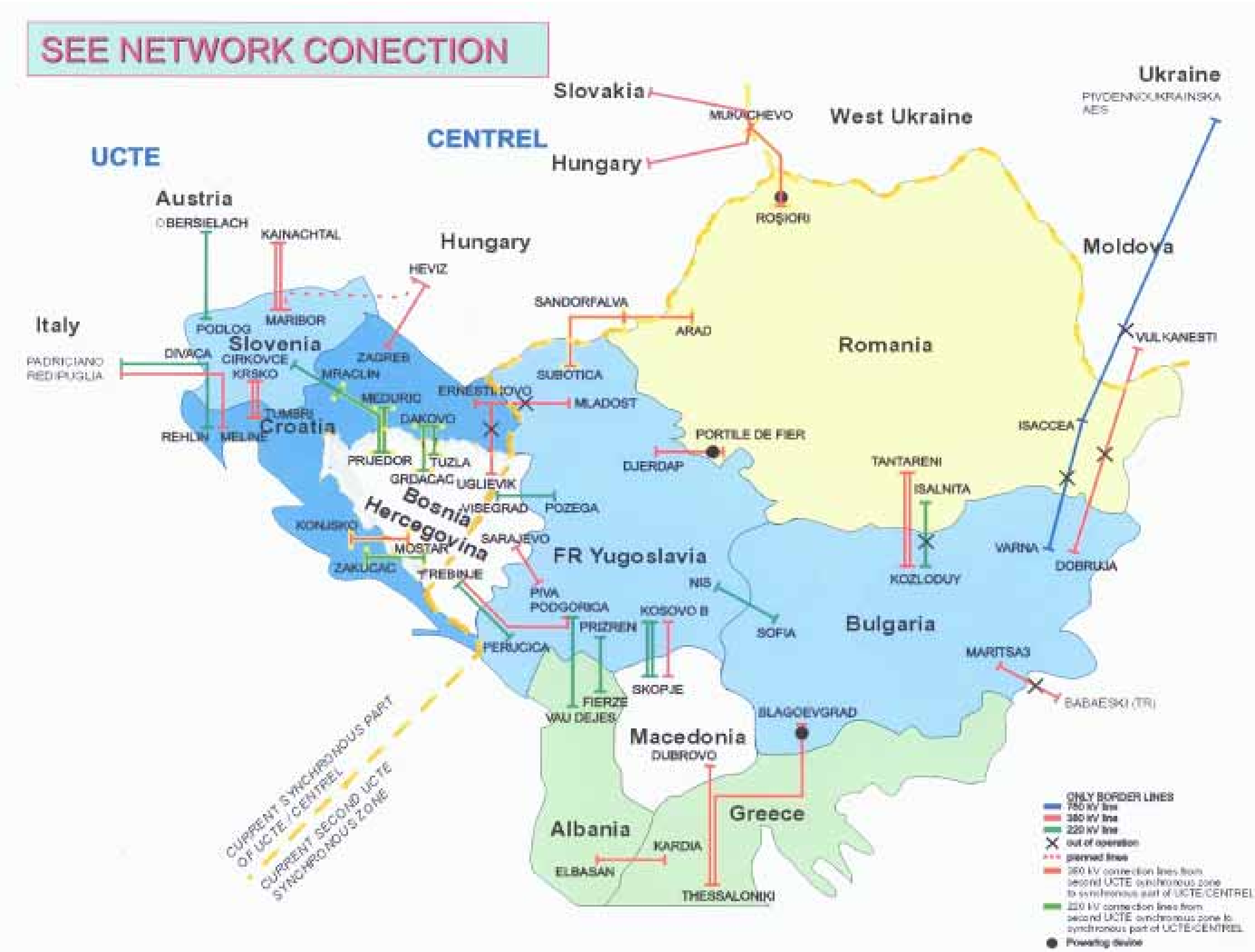
2.2 Restoration Process of the Systems of Croatia and Bosnia-Herzegovina

In recent years, extensive restoration work has been carried out especially on elements of the power systems in Bosnia-Herzegovina and Croatia. All activities in Bosnia-Herzegovina (financed by the international project POWER III) aim at restoring the transmission network of this country to achieve again the status of the year 1991. Yet, though the networks of Bosnia-Herzegovina and Croatia formed the interface between the systems of today’s first and second UCTE synchronous a zone before the UCTE grid was split up, there is a need for analyzing the status of the reconnecting systems.

Also, Electric Power Utility of Croatia (HEP) started to reconstruct and restore the 400 kV Ernestinovo substation and to build the new 400/110 kV substation at Zerjavinec by using domestic financial resources. This work was completed at the end of 2003.

In May 2001, on the occasion of establishing the new UCTE association, the "Memorandum of understanding on the realization of the UCTE northern with the southern synchronous interconnected area" was signed to support the process of restoration and reconstruction of the electric power systems of Croatia, Bosnia-Herzegovina and Serbia.

All parties to the Memorandum declared their vital interest not only in the restoration of the electricity systems of HEP and JPCC, but also in the development of the interconnected electricity systems of all member countries in the Balkan region and also in relation to the further extension of the UCTE synchronous area to the South and to the East.



Interconnections in South-East Europe.

Source : DVG study (adapted)

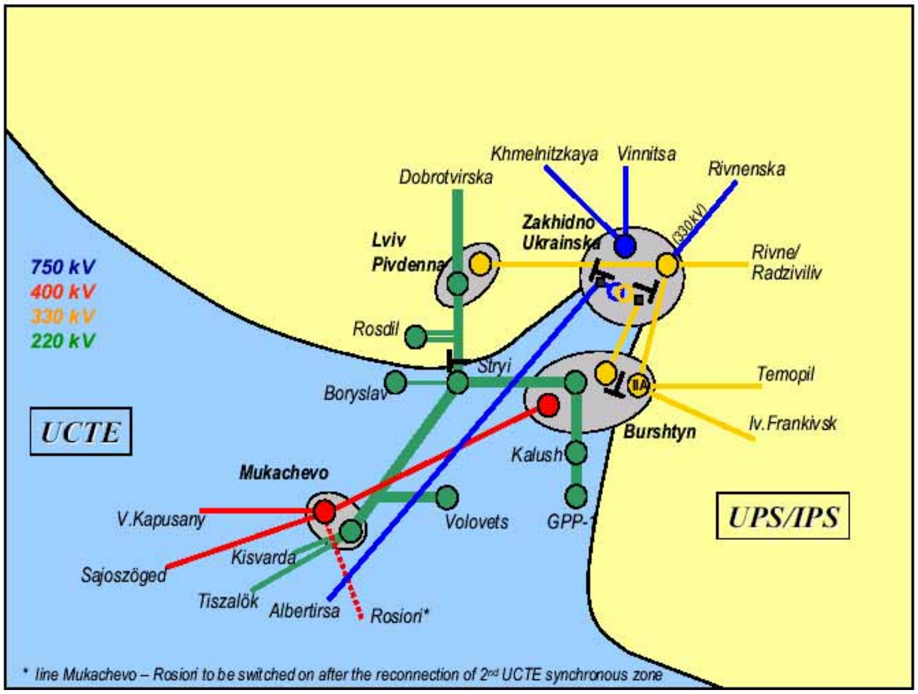
Moreover, the parties declared that:

- UCTE will take initiatives towards the European Union and possibly other international authorities or institutions with a view to facilitating the financial and technical feasibility of the project,
- HEP and JPCC will do their best endeavors to obtain full support from their respective governments to grant the necessary priority to the restoration process,
- HEP and JPCC will give unconditional priority to the swift completion of necessary reconstruction work.

2.3 Technical Committee UCTE/Ukraine=Burhstyn Island

The Technical Committee UCTE/Ukraine was established immediately after the CENTREL and UCTE systems were synchronized in 1995.
The scope of the Technical Committee UCTE/Ukraine included:

- Elaboration of the Catalogue of Measures (CoM)
- Evaluation of technical and organizational measures written down in the CoM
- Elaboration of the Demarcation Agreement
- Implementation and assessment of the tests in the “isolated operation”
- Carrying out and assessment of the tests in the “interconnected operation”
- implementation and assessment of the tests of “interconnected operation”



Scheme of the interconnection of the Burshtyn Island. Source: TC UCTE/Ukraine

Burshtyn Island was incorporated into the Accounting and Control Block of CENTREL. The mutual co-operation in scheduling and accounting between the Western Power System of Ukraine and CENTREL Energy Accounting and Control Centre in Warsaw was very satisfactory, and did not give rise to any serious problems.

Successful interconnected trial operation confirmed the previous analyses, and the Technical Committee UCTE/Ukraine requested the UCTE Steering Committee to accept the permanent synchronous operation of the “Burshtyn Island” with the UCTE 1st synchronous zone. After the Steering Committee of UCTE had agreed to that in September 2003, the TC UCTE/Ukraine was dissolved.

2.4 The UCTE Executive Team for North-South Re-synchronization

Having regard to:

- the top priority of UCTE–North-South re-synchronization (re-connection of the second UCTE zone),
- interim reports from TC UCTE/BG-RO and UCTE/Ukraine
- large-scale activities of the TSOs involved in terms of analytical work, re-construction and modernization

- the necessity of co-ordination of actions along the whole interface between both zones and with the new partners – Bulgaria, Romania and the Bursthyn Island,

the UCTE Steering Committee decided to establish (in March 2002) the Executive Team (ET) that was charged to coordinate actions of TSO executives of the countries involved relating to the reconnection of the zones.

The TSOs had to establish the basis to secure reliable operation of the interconnected transmission grids of the interface, i.e.:

- to co-ordinate common progress,
- to harmonize time actions
- to establish common rules, procedures and mechanisms.

The UCTE members along this interface (UCTE ET members) will guarantee to other UCTE members that overall reliability criteria are maintained during the re-synchronization process.

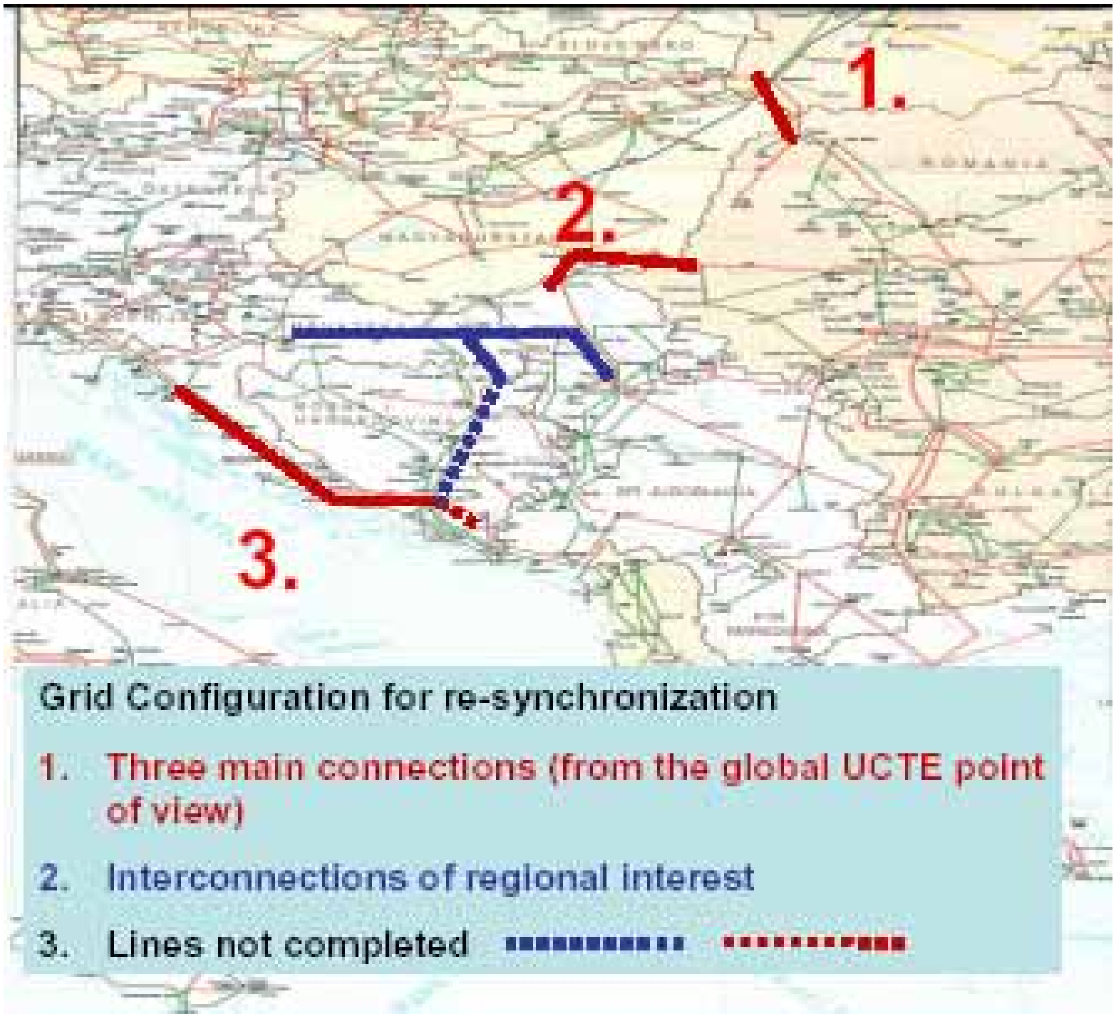
The main objectives of the UCTE ET refer, inter alia, to the **Multilateral Re-synchronization Program** and **Multilateral Operational Co-ordination.**

The UCTE ET decided to:

- work out the inventory report of civil works of the grid restoration which shall be regularly updated
- define the minimum grid configuration
- define control blocks and sharing of responsibilities
- carry out the network analysis.

The present status of work (end of 2003) is as follows:

- all necessary projects for reconstruction and rehabilitation were contracted with scheduled finalization by mid-2004
- the minimum grid configuration was defined.



1. 400 kV line Mukacevo-Rossiori
2. 400 kV line Sandorfalva-Arad/Sandorfalva-Subotica
3. 400 kV line Konjsko-Mostar-Gacko-Trebinje
   400kV line Tumbri (Žerjavinec)-Ernestinovo -(S.Mitrovica) – Mladost
   400 kV line Ernestinovo-Ugljevik-Tuzla-Sarajevo-Mostar

- The control blocks were designed
- Network analysis including update of previous dynamic analysis was launched. First results of the study including re-synchronization scenarios were presented.

The critical points of the project are:

- Albania is not a UCTE member and implementation of its EPS to a UCTE Control Block is under procedure. However, KESH (Albanian Power Company) declared full support to this project and to meet UCTE criteria.
- Meeting the deadlines (mid of 2004) of restoration works is crucial for the whole process.
- The operational readiness of newly created control blocks has to be checked and approved by UCTE, and the trial operation of the control blocks is planned.

2.5 Global Aspects of The North-South Re-synchronization

Reconnection will have a Europe-wide impact in the electricity sector, as it will physically integrate regional electricity markets in South-East Europe into the Internal Electricity Market of the European Union. UCTE and its TSO members, covering all technical and organizational aspects of the reconnection of both UCTE zones plan to re-synchronize the two zones in mid-2004.

Jiri Feist (born 1962), Director, Strategy&Development, CEPS, a.s., graduated from the Czech Technical University′s Faculty of Electrical Engineering in Prague. In 1986 he joined the Czechoslovak Control Centre, where he worked in the Operation Planning Department. Later he worked at ČEZ – from 1990 in its Network Development Department and from 1992 as Head of the System Analyses Department. From 1993 he worked in ČEZ s Transmission System Division as Director of the Transmission System Development and Investment Unit. From 1996 he worked as Director of the National Control Centre (formerly part of ČEZ and since 1999 part of ČEPS – Czech TSO company). Since 2002 he has been Director for Strategy& Development of CEPS. From 1993 to 1996 he was project manager for the interconnection of the Czech power system to the UCTE system. He was a member of the Technical Committees for the interconnection of the CENTREL systems, the western part of the Ukrainian power system and the Balkans power systems to the UCTE system. He is a member of the Council and Steering Committee of UCTE and CENTREL. Since 2002 he has been Vice-president of CENTREL and Co-convenor of the UCTE Executive Team for the North-South. Re-synchronization

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3. PROGRESS OF THE MEDITERRANEAN RING AND THE INTERCONNECTION WITH EUROPE

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Abstract-- The paper will firstly address the status of the Mediterranean interconnections and the evolution of demand and power exchanges in the area. Thereafter, the main driving forces prompting full integration of the power systems will be discussed. These refer mainly to different load patterns in the various countries (see shifted weekly cycle in some Arab countries), imbalance in generation availability and the introduction of market rules that are going to eliminate custom barriers for energy trading.

From the technical point of view, the closure of the MedRing sets challenging problems that shall be investigated and suitably solved before starting the system operation. These are essentially related to the capability of reacting to small and large disturbances keeping the system stability. To this end, the paper will highlight the potentially critical dynamic phenomena that might occur and the most appropriate countermeasures to be undertaken. As will be shown, due to the very stretched structure of the grid in the South-Eastern area, even a single contingency can cause heavy repercussions on cross-border cut-sets thousands of kilometres away from the disturbance's location. Other phenomena of concern are related to steady-state stability. As a matter of fact, interconnecting systems by adding HVAC tie-lines creates new natural oscillation modes that, if not properly damped, can cause instability even in highly meshed systems such as the European one. Some of the results presented in the paper have been obtained by the "MedRing Feasibility Project", a study project completed in June 2003, supported by the European Commission and with the objective of defining a framework for coherent development of interconnections between the power systems of the Mediterranean Basin.

Finally, the perspectives for a further extension of interconnections towards South, the Gulf Countries and North-East of the MedRing will be presented.

Index Terms—interconnected systems, network reliability, power system dynamic stability, power system economics

3.1 Introduction: present status of eletrical interconnections around the mediterranean basin

Since the beginning of last decade we have been witnessing a remarkable boost to interconnect power systems or to strengthen the interconnections within synchronous pools. The main driving forces favoring the creation or the strengthening of interconnections involve a mix of factors ranging from technical to economical and political aspects [1] Large interconnection projects are either under commissioning or in a feasibility stage in all the Continents [2] In the European Continent, major changes have occurred since the beginning of the nineties: in Central Europe the increased East-West co-operation allowed the extension of the UCTE pool [3] eastwards in 1996 to include the CENTREL pool [4]. Moreover, the progressive liberalization of the electricity markets is causing an increasing cross-border energy exchange and is fostering the implementation of new interconnection projects (e.g.: HVDC links between Norway and UK and the Continental part of Europe).

The creation and the reinforcement of new interconnections between countries is a phenomenon particularly evident in the Mediterranean region where in the near future four power pools, presently isolated from each other, will be synchronised, giving origin to a huge tri-continental system surrounding the Mediterranean basin called MedRing (Mediterranean Electric Ring). The basic choice for this project is to resort to synchronous interconnections with embedded North-South HVDC submarine cables enabling

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The MedRing Feasibility Study project has been co-funded by the E.C. in the framework of the MEDA programme.

direct export of power from countries rich in fossil resources to European countries with few primary resources, but with very high electrical consumption.

Presently, the power systems around the Mediterranean basin are operated in five as yet non-interconnected electric pools (Figure 1).

These are:

1. the Western bloc, including the central-western European Countries, Morocco, Algeria and Tunisia,
2. the bloc made up of the south-eastern European countries (or UCTE second zone),
3. a bloc consisting of Turkey,
4. the south-eastern bloc, covering the zone from Libya to Syria;
5. the bloc composed of the Israeli and the Palestinian Authority grids.

However, though still operated in isolated mode, some of the tie-lines across the various blocs have already been completed and their exploitation is related to the outcomes of tests being carried out under the supervision of UCTE together with the involved countries. More specifically the situation is as follows:

- Tunisia-Libya: two lines at 220 kV (1 single circuit and 1 double circuit) have been completed. The permanent synchronisation between the two blocs is subject to the outcome of the testing phase that shall be terminated likely by 2004;
- Syria-Turkey: a 400 kV line (Birecik-Aleppo) is now completed, but its exploitation will probably not take place prior to the connection of the Turkish system to UCTE;
- Turkey-UCTE: Turkey is presently interconnected with Bulgaria through two 400 kV lines.

However, power exchanges take place in “isolated mode” between the power plant of Maritsa East and the Istanbul region. As for the interconnection between Turkey and Greece, a Memorandum of Understanding was signed in 2002 for the construction of a 400 kV line (Filippi-Babaeski), which shall be commissioned by the end of 2006.

In addition, four other systems are operated in isolated mode (Cyprus, Crete, Malta and Balearic Islands): for these islands there isn’t at present any project of interconnection to the mainland. On the contrary, the islands of Corsica and Sardinia are interconnected to the mainland through a tri-terminal HVDC link (mixed OHL and submarine cable). Sicily is linked to the rest of Italy with a 400 kV AC cable crossing the strait of Messina.

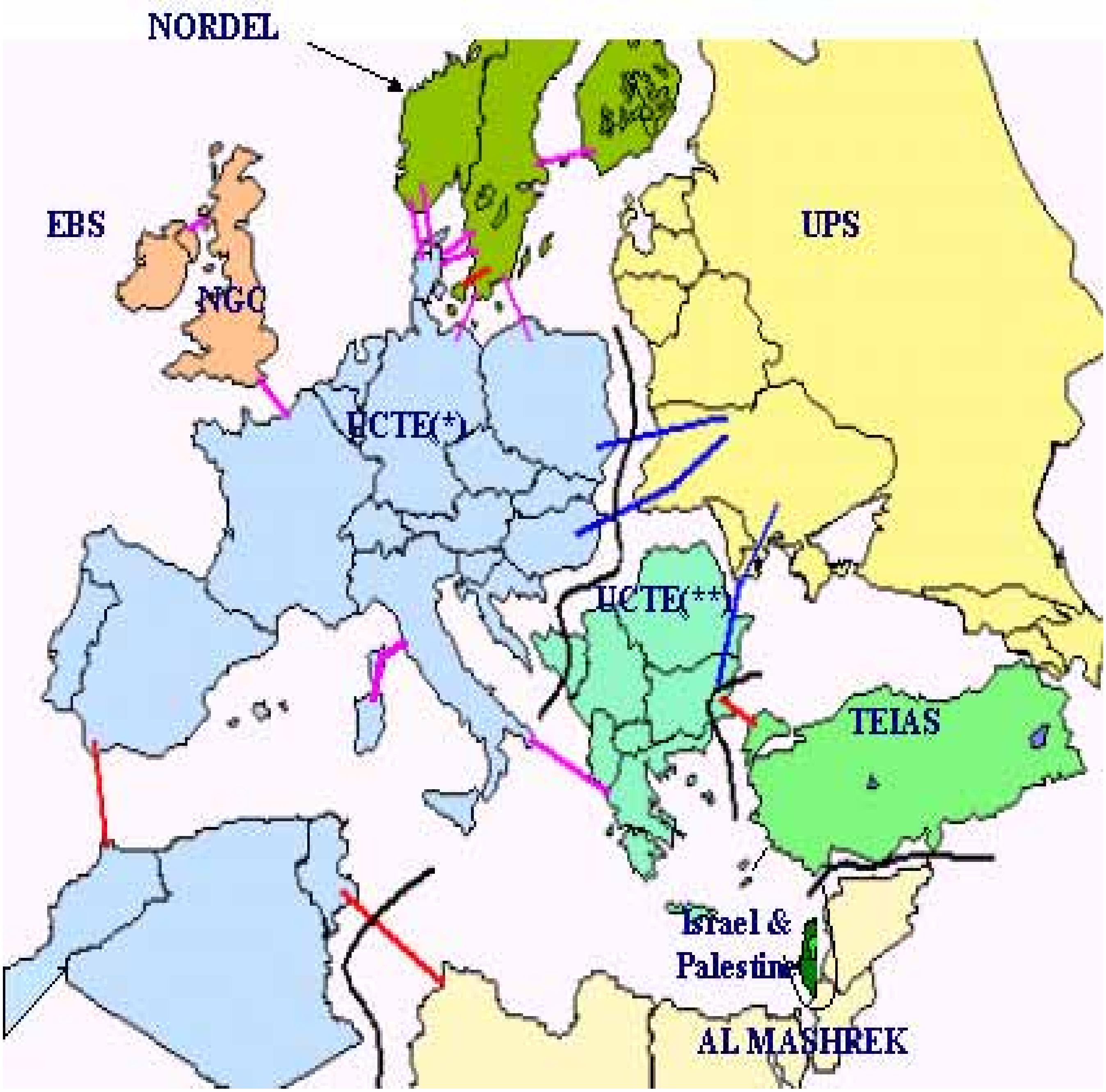

Figure 1 – The Euro-Mediterranean synchronous blocs

The five blocs mentioned above have very different characteristics, both in terms of load density and topological structure. The biggest bloc is composed of UCTE **Error! Reference source not found.**] whose first synchronous zone has a consumption exceeding 2,100 TWh/year with installed capacity of about 530 GW. Other blocs are characterised by much weaker demand, f.i. the south-eastern bloc registered a demand of 128 TWh in the year 2001 and has an installed capacity of 31 GW.

On the other hand, the five different pools have some common standards such as frequency (50 Hz) and voltage level (transmission is basically made at 400-220 kV with few exceptions, such as Egypt where the backbone of the transmission grid is operated at 500 kV). Indeed, a common standard for frequency and voltage profile is a basic requisite for synchronous interconnection among isolated pools. In the following will be addressed the mid-short term perspectives to achieve the synchronisation of four out of five Euro-Mediterranean pools, giving origin to a tri-continental interconnected system spreading 4000 km in latitude, from Jutland to the border between Egypt and Sudan, and 6500 km in longitude, from the Western Sahara to the borders between Turkey and Iran. The creation of such a huge system sets technical challenges to be overcome for ensuring reliability and secure operation, particularly in dynamic conditions.

The bloc composed of Israel and Palestine Authority will be operated in isolated mode in the near future and might be interconnected with Egypt and Jordan only in a later stage.

3.2 The evolution of the electricity sector in the Euro-Mediterranean region

The Northern Mediterranean Countries (NMC), well industrialized and developed, have high per-capita level of electricity consumption (5800 kWh/year in 2000), but low rate-of-growth (around 1.4% per year), while the South-Eastern Mediterranean Countries (SEMC) have much lower per-capita consumption (1400 kWh/year in 2000), but very high (around 6%) annual growth. Moreover, NMC are almost all very poor in primary energy resources, while SEMC are mostly very rich in fossil fuel resources. Therefore, beyond North-South gas pipelines and oil shipping though tankers, HVDC connections between the two shores of the Mediterranean basin are now being investigated as a complementary route for supplying energy to South-European countries and to allow a direct electricity trading from Maghreb to the European IEM.

In addition to the growth in load demand, electric energy exchanges are also pushed upward by the introduction of integrated energy markets. In Europe, electric energy exchanges are presently already very high and the implementation of a common IEM is likely to force a further increasing of the cross-border energy trade. Inside the Central-Western interconnected pool UCTE the exchanges attain 13% of the total internal consumption with a steady increase experienced in the last years. This is putting more and more strain on the European grid where ISOs and TSOs are struggling to increase the inter-area transfer capacity even adopting non-transmission solutions or market-based transmission expansions. The recent blackouts occurred in some European regions are a first warning of the trade-off between market and security requirements.

On the contrary, power exchanges among the SEMC are presently very low (Figure 2), or in some cases, even null due to the lack of infrastructures [5] In the year 2000, the total electric energy exchange was only 1% of internal consumption. Due to the high rate of demand growth and the forthcoming introduction of regional electricity markets, the electricity sector in the SEMC is now undergoing an impressive boost concerning the reinforcement of the existing corridors and the creation of new ones. By considering only the cross-border links, 17 projects have been listed as having high priority in the SEMC [6].

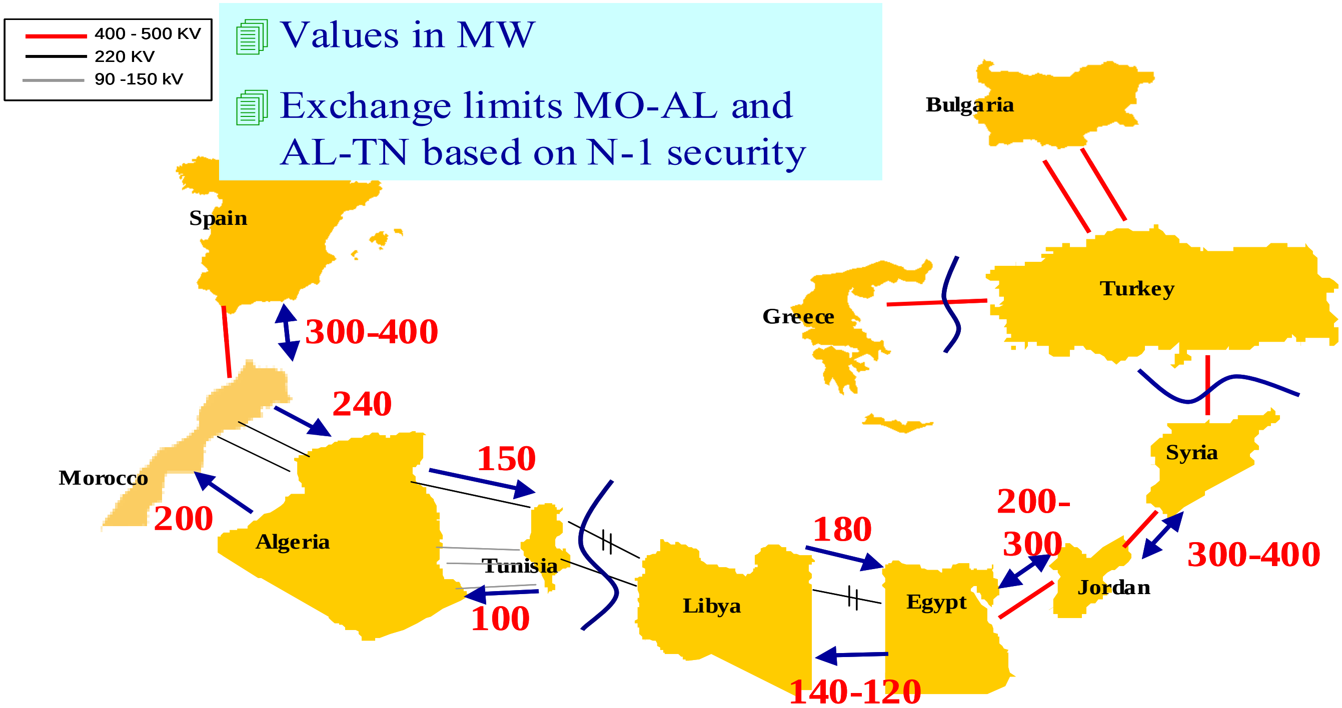

Figure 2 – NTC among SEMC countries in the year 2003

All that prompts also greater economical integration among the SEMC and between SEMC and NMC. This need has been recognised by the EU who launched since 1995 the so-called Barcelona process, establishing a partnership between the 15-EU member states and 12 SEMC (MEDA countries) with the final aim of creating a free trade area in the Mediterranean basin around the year 2010.

3.3 Closing the Mediterranean Electric Ring

The basic choice for the creation of the MedRing is the adoption of synchronous links. This choice is in line with the decision of the SEMC to adopt the same rules recommended by the Central-Western European pool UCTE both in terms of security criteria (e.g.: N-1 security) and regulating capacity (e.g.: maximum frequency deviation, LFC). Moreover, some of the SEMC have already applied to become full members of UCTE, namely Turkey.

Benefits from the closure of MedRing can be classified in:

- Economical: reduction of production costs and consequently electricity prices;
- Technical: enhanced reliability level; possibility of sharing reserve capacity; improved performances in dynamic conditions;
- Environmental: possibility of replacing old, polluting units with new more efficient ones; energy trading among countries to comply with the Kyoto protocol;
- Social and political: close collaboration among the teams of planning and operational departments of the interconnected countries.

On the other hand, the above benefits could be sharply limited unless the potential adverse interactions among national power systems that might arise in perturbed conditions are suitably investigated and appropriate measures are taken in advance. As a matter of fact, due to the stretched network structure in the South-Eastern part of the Ring, perturbations can provoke repercussions in other South-Eastern areas even very far, thus potentially limiting the cross-border power exchanges. Therefore, the operation of the MedRing requires the adoption of appropriate post-contingency corrective actions as will be highlighted in section 3.6.

3.4 Economic Benefits

The economic benefits deriving from the interconnection of the four Mediterranean blocs have been assessed by estimating the possible reduction of the production costs on a yearly basis. Two scenarios have been examined: the first one refers to an operation mode with the North African corridor composed of lines at 220 kV, while the second scenario foresees the increase in the power transfer capacity from Morocco to Egypt resorting to internal and cross-border links at 400/500 kV. The analyses for the first interconnection scenario are referred to the year 2005, while the second scenario is envisaged around the year 2010 [7].

It was estimated that, passing from 4 separate blocs to the first interconnection scenario, the gain in production cost reduction is about 140 MUS$/yr. Moreover, passing to the second scenario the additional gain is 220 MUS$/yr.

It is important to recall that:

- the yearly reductions in operating costs, due to the added interconnections, should be considered as present-worthed values and cumulated for the entire life of the connections, with consequent total savings of the order of a few billions US$;
- the percentage of gain is higher for the smallest countries, previously not (or scarcely) interconnected;
- power transits are not economical over very long distances due to penalisation for the transmission losses;
- the economic dispatch, based on international prices of fuel (and on efficiency of power plant), does not take into account possible market strategies, which could create much higher energy exchanges, nor was taken into account the benefit due to possible reduction in operating reserves.

The main exporting countries turn out to be: France, Algeria, Egypt and Syria, this latter only in the year 2005 (exports generally from countries with nuclear, gas and coal). The main importing countries are: Spain and Italy from France; Tunisia from Libya and Algeria; Jordan from Egypt; Turkey from Syria and UCTE.

The above benefits were compared to the cost for the realisation of the necessary network infrastructures. The cost-benefit analysis, carried on considering the network constraints, highlighted that the most profitable projects are related to interconnections linking countries showing a potential lack of power production (e.g.: new lines between Algeria and Tunisia) or in regions that will be likely subject to remarkable power flows (e.g.: new line between Turkey and Greece).

3.5 Reliability improvement when closing the MedRing

In addition to the economic benefits related to an optimised energy exchange, system interconnection will bring substantial benefits to improve the reliability levels of the SEMC. Then, a quantitative assessment of the reliability indexes has been carried on considering the detailed generation and transmission system. For a thorough evaluation of the profitability of the interconnections among electrical pools a general approach, considering a whole spectrum of the possible operating conditions of the composite generation-transmission system, has been applied. The adequacy assessment of the grid, based on probabilistic methods, allowed finding out potential bottlenecks in the various areas of the system [8]. The evaluation of the generation-transmission system reliability was carried out examining the operation of the system over a significant time span (one year) considering different load conditions and different generators and transmission facilities (lines, transformers, compensation devices, etc.) availability as a consequence of both planned and forced outages. Within the MedRing project the reliability analysis has been applied to the year 2005, taking into account all the network components.

The advantages of the interconnection, in terms of reduction of the estimated curtailed energy in the SEMC, are shown in Table 1.

Table I. Curtailed Energy in case of isolated and interconnected countries

Country	Country Demand	Lack of Power		Line Overload		Lack of Interconnection		Total		Total	
		[MWh/year]		[MWh/year]		[MWh/year]		[MWh/year]		[p.u.]	[p.u.]
	[GWh/year]	Isolated	Interc.	Isolated	Interc.	Isolated	Interc.	Isolated	Interc.	Isolated	Interc.
MOROCCO	18,418	21	0.0	1013	616	-	74	1034	690	6E-05	4E-05
ALGERIA	35,879	13	0.0	4155	1765	-	159	4168	1924	1E-04	5E-05
TUNISIA	12,814	3280	0.0	421	381	-	222	3701	603	3E-04	5E-05
LIBYA	28,131	199	0.0	6	34	-	216	205	250	7E-06	9E-06
EGYPT	102,555	580	0.0	2966	2957	-	96	3546	3053	3E-05	3E-05
JORDAN	10,773	196	0.0	511	0	-	0	707	0	7E-05	0E+00
SYRIA	38,622	0	0.0	1228	333	-	4	1228	337	3E-05	9E-06
TURKEY	162,197	519	0.0	5742	1905	-	83	6261	1988	4E-05	1E-05
TOTAL	**409,389**	**4808**	**0.0**	**16042**	**7991**	-	**854**	**20850**	**8845**	5E-05	2E-05

As it can be seen, the systems are all very reliable (Expected Energy Not Supplied –EENS- index $<10^{-4}$ p.u./year), being all of them normally planned without resorting to the help of the interconnections. When interconnecting all the countries, a total reduction of the EENS attains, on a yearly basis, about 12 GWh/year, disregarding local problems such as network splitting. Considering an average cost of the energy not supplied around 2000 US$/MWh, the benefit of interconnections can be estimated approximately 24 MUS$/year (economical gain related to the risk reduction). A further benefit deriving from the interconnection is related to the possibility of postponement the construction of new power plants without jeopardizing the quality of the energy supply.

3.6 MedRing behaviour in dynamic conditions

When increasing the system size through an extension of the interconnections, one should warrant that the overall system can be operated in a secure way and be able to face possible outage of generators or network components. Considering the stretched structure of the MedRing, an accurate study of the expected behaviour in dynamic conditions is of utmost importance.

- **Dynamic phenomena**

The most important dynamic phenomena to be considered are:

- electromechanical oscillation modes at low damping and, more in general, steady-state stability problems, mainly due to power transfers along very long distances;
- transient instability of large network areas, sometimes involving an entire country or more than one country, subsequent to loss of important connections and evolving on a relatively long time scale;
- critical transients due to long term dynamics, with voltage instability, or with unacceptable final operating points due to voltage collapses;
- possible final operating conditions critical in terms of operability because of low voltage profiles or high current values.

All such phenomena should be carefully examined in order to characterise the system dynamic behaviour in terms of steady state stability, transient stability, long term stability and post fault equilibrium point existence.

The aim of the analysis is to grant the system security for a great number of operating conditions and to verify the feasibility of the most convenient power exchanges derived from economic studies.

- **Advantages from the Ring closure related to its dynamic behaviour**

Apart from the economical gains, the main advantages of the Ring closure related to its dynamic behaviour are:

- a more secure operation from the viewpoint of the frequency and voltages constancy;
- more robust system against the tripping of single connection not causing the Ring opening;
- the single generator tripping doesn't cause instabilities even in case of very large units (e.g.: loss of Kuraymat generator 600 MW in Egypt).

- **Potential problems detected**

The main problems detected simulating the dynamic behaviour of the MedRing are the following:

- Opening of the interface UCTE-Turkey, with consequent instability of the Southern-Eastern part of the system (in conditions of "heavy" power import of Turkey)[1] .
- Some ring openings along interfaces between countries in the Southern part.
- Connection between Egypt and Libya. This link represents for the Ring a bottleneck in the year 2005 when the two countries are connected with a very long line (double circuit) at 220 kV. When, following a disturbance, the transit increases beyond 320 MW, a voltage collapse, followed by angle instability, in the neighbouring regions appears, with probably line tripping in proximity of the electrical centre.
- Operation with Ring opened. In case of the Ring opened in one section, the tripping of important units located in the Southern part can lead to instability (more probably voltage instability, but also angle instability).
- In some situations, to avoid possible transient instabilities, the maximum amount of imported power in a country had to be limited with respect to the theoretical economic values (e.g.: Tunisia in the scenarios examined for the year 2010).

[1] *It is worth mentioning that the disconnection between Turkey and UCTE is to be considered an "extreme" contingency, taking into account that, for the envisaged scenarios, the two systems will be connected through three 400 kV lines: two of them between Bulgaria and Turkey and the last one between Turkey and Greece.*

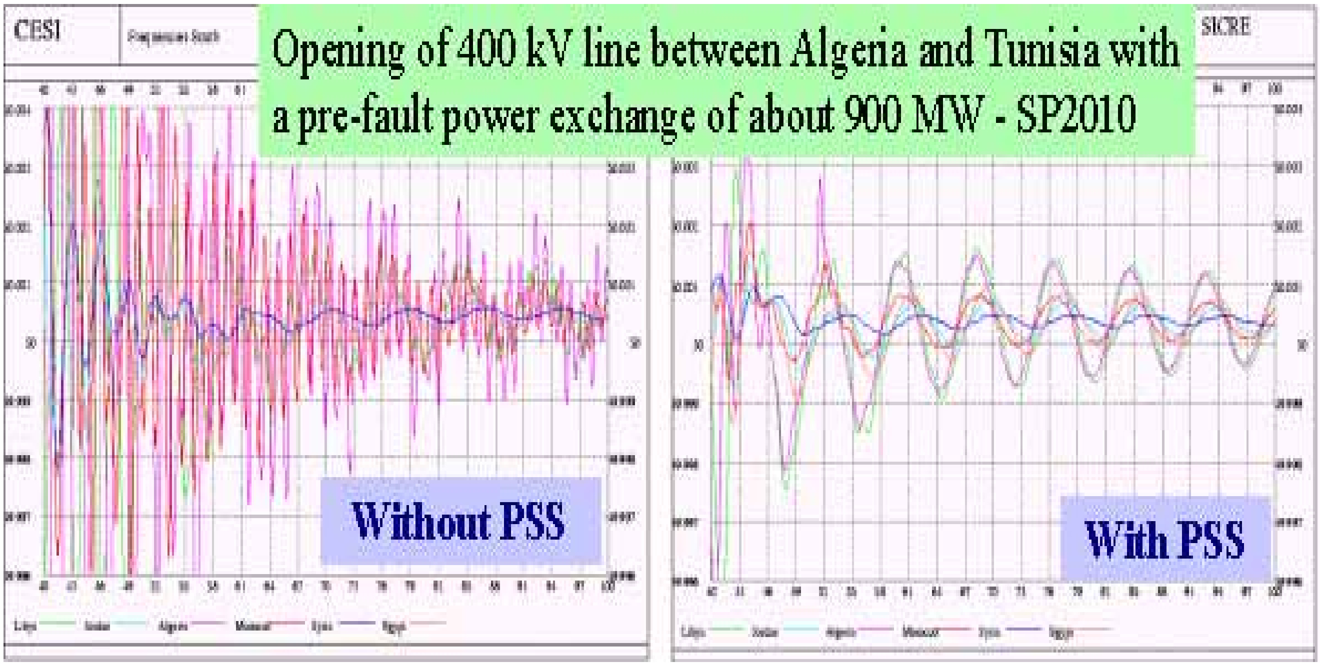

Figure 3 – Effect of PSS on oscillation damping in the MedRing

- **Enhancing power transfer capacity**

To avoid too low power transfer capacity some measures have to be adopted. These can be classified in “soft” measures and “structural” measures.

“Soft” measures are essentially based on the adoption of special control schemes or defence plans aimed at preserving the system integrity and avoiding to spread the disturbances from the affected areas to the neighbouring ones. **Error! Reference source not found.** shows how the power transfer capacity can be enhanced through the adoption of appropriate automatic control actions.

“Structural” measures to enhance dynamic security are based on the installation of devices having the capability to control specific electrical quantities, such as SVCs, Back-to-Back or HVDC links. The installation of the above devices requires a non-negligible investment effort and its profitability shall be based on accurate analyses aimed at defining:

- the optimal location of the device;
- the size;
- the control strategy, especially for the converter stations in case of DC links;
- the consequent enhancement of the power transfer.

Tab. II. Interconnection Capacities in presence of Defence Plans

Country 1	***Country 2***	***(N-interface) (MW)***		***(N-interface) (MW) with defence plans***	
		2005	**2010**	**2005**	**2010**
SPAIN	**MOROCCO**	200	400	350[2]	700[1] ÷1000[5]
MOROCCO	**ALGERIA**	200	400	400[2]	*900[1]*
ALGERIA	**TUNISIA**	200	400	300[2]	*450[3]*
ALGERIA	**SPAIN**	-	1500	-	2000[1]
TUNISIA	**LIBYA**	200	400	470[2]	*600[1]*
LIBYA	**EGYPT**	120	400	*120[4]*	600[1]
EGYPT	**JORDAN**	200	400	300[2]	600[1]
JORDAN	**SYRIA**	200	400	350[2]	*600[1]*
SYRIA	**TURKEY**	200	400	600[2]	600[1]

1) *in presence of actions to be undertaken to preserve system integrity*
2) *automatic device of opening Egypt-Libya or action to be undertaken to preserve system integrity*
3) *limitation due to loss of synchronism in Tunisia*
4) *allowed maximum mutual aid*
5) *further increase of the Spain-Morocco interchange up to 1000 MW can be attained provided that widespread bilateral actions are undertaken in case of the whole interface outage in order to avoid reversing the interchanged power along the ring*

With reference to the MedRing system, examples of possible profitable structural measures are:

- installation of SVC (or similar devices) at the Egyptian-Libyan border to enhance voltage stability;
- installation of a DC link between Egypt and Jordan to increase the power transfer capability fully exploiting the capacity of the submarine cables between the two countries.

- **Steady state stability**

From the steady-state stability viewpoint, the importance of adequate PSS for all the most important generation units of the system has been demonstrated in order to obtain satisfactory damping of the electromechanical oscillation modes with periods in the range 0.5÷5 s. Figure 3 depicts the effect of PSS in damping oscillations caused by line tripping in presence of a heavy power transfer exchange between Algeria and Tunisia.

Slowest oscillation modes (periods >5s) proved to be well damped on condition that a well designed primary frequency regulation is installed on the units.

3.7 North-South HVDC connections

Due to losses caused by electricity transmission and transit fees, power exchanges are normally profitable only on short/mid distances. Therefore, to enhance the possibility of electricity trading between SEMC and Europe, some South-North HVDC links are under study. The corridors under investigation are the following:

- Algeria-Spain: the feasibility study for a HVDC connection from Terga to Litoral de Almeria through a submarine cable (connection of about 240 km) with a capacity of 2000 MW has been completed. The construction of 2000 MW of new generation (possibly CCGT) in Algeria – out of which 800 MW for local needs and 1200 MW for export - has been planned. Because of the difficulty in getting foreign investments, the project will be commissioned in two stages. At the beginning a bipolar HVDC link rated 1000 MW will be realised with marine electrodes for emergency current return;
- Algeria-Italy: the project of a potential interconnection rated 1000 MW between Algeria and Sardinia (Italy) is on a pre-feasibility stage. This project will be integrated with a second HVDC link, developed in two modules (500MW+500MW), between Sardinia and Continental Italy.

Further envisaged HVDC links are relevant to Tunisia-Italy (2000 MW) and Libya-Italy (600÷1000 MW). For these latter projects no detailed feasibility analyses have been carried out so far.

The profitability of North-South HVDC links crossing the Mediterranean Sea is however quite limited due to the heavy investment costs. Moreover, the estimated North-South energy exchanges are heavily influenced by the Brent oil price (e.g.: with reference to the Spain-Algeria HVDC link the sensitivity coefficient associated to the Brent oil price turned out to be ΔEnergy-export/ΔOil-price ≈ -1.23 TWh/$).

Furthermore, for the electricity trading between Maghreb countries and Europe reciprocity in market rules shall be warranted. To this aim, a regional electricity market is going to be implemented in the Maghreb countries with the support of the EU.

3.8 Future Perspectives

Looking ahead into the future, further steps are envisaged related to the extension of the Euro-Mediterranean synchronously interconnected system, namely:

- extension to South: synchronous interconnection between Egypt and Sudan (220 kV line);
- extension in the Middle-East with the interconnections Syria-Iraq (400 kV line), Turkey-Iraq (400 kV line) and Jordan-Western part of Saudi Arabia (voltage level to be defined).

Even more appealing are the projects aimed at interconnecting Turkey with Georgia: a new 400 kV line is under study in view of the creation of an electrical ring around the Black Sea by means of the Trans-Caucasian lines as proposed in 1994 by RAO UPS of Russia [9].

To East, regional interconnections between Turkey and their Eastern neighbouring countries are already in operation, namely: the Iğdir – Babek (Nahicevan) 154 kV line exploited to feed the local load in Nahicevan and the D.Beyazit – Bazargan (Iran) 154 kV line exploited to import power from Iran. The existing Kars-Gumri (Armenia) 220 kV line isn’t at the moment energised, but in the near future it can be fruitfully exploited to better integrate the Turkish and South Caucasian power systems.

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Biography

Bruno Cova graduated in Electric Engineering in 1985 at the University of Pavia (Italy). In 1985 he joined Network Study Department at CESI where he has been involved in power system modeling, studies and simulations. In 1997 he has been appointed Responsible of power system studies within CESI System Dept. Since February 2003 he is Scientific Manager within B.U. T&D Networks at CESI.

From 2001 to 2003 he was appointed Project Manager of the Mediterranean Electrical Ring (MedRing) project, aimed at investigating the expected behaviour in static and dynamic conditions of the synchronously interconnected Mediterranean system.

4. THE ITALIAN POWER SYSTEM: RECENT EVOLUTION

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(Presented by Sandro Corsi, CESI R&D, Italy)

Summary

The Italian power system has gradually carried out its deregulation, ruled in Europe by the Directive 96/92/EC and in Italy by the new "Electric Law", the so-called Bersani Decree 79/99 of 31 /3/1999.

Italy has an Independent Regulator for Electricity and Gas, enforced with the law 14 November 1995, n 481.

The previous monopolistic Vertically Integrated Utility, ENEL Spa, has been unbundled.

In the Generation Sector, 15 GW, grouped in three GenCos, have been displaced by ENEL within November 1992, sold to Suppliers with mixed (directly/indirectly) Italian /Foreign capital (French, Spanish and Belgian). Even if ENEL has still the majority share in the production, the competition for the free market has started even if the number of actors on the supply side is still limited to "big Companies".

In the Transmission sector a new independent Transmission System Operator (TSO), the GRTN, has been created responsible for Operation and Control. The shares of the GRTN are in the hands of the Treasury and in its turn the GRTN owns the Market Operator. So far, the ownership of the "wires" was left to the previous owners, the major - but not the sole - being ENEL's daughter Company TERNA. A re-thinking of this model has been made and in a recent Bill (n. 251 of 28 October 2003), the Parliament approved the reunification of the system operation and ownership in a new Transmission Company. The shares will be placed on the market even if public control is anticipated. No company having direct interests in Production, Import, Distribution and Supply will have, by 1 July 2007, more than 20% of the new Transmission Company. This move is in the framework of the Regulation EC n. 1228/203 of June 2003, on conditions for access to the network for cross-border exchanges in electricity.

In the Distribution, in the Municipalities (MUNIS) where both ENEL spa and MUNIS were competing, only one Company is now present, after a mandatory agreement, market based, between the two previous owners. The deal has been carried out in the two directions: in 2002, 10 Distribution Companies have two been sold by ENEL to Municipalies, while 12 have been purchased by ENEL.

The Supply has been opened down to the clients having 0,1 GWh/yr in March 2003; in a Bill under examination by the Senate the further opening to clients with yearly consumptions down to 0.05 GWh/yr has been proposed. The complete liberalization is due for the industrial and commercial consumers by 1 July 2004, with a full opening by July 1, 2007, according to new EU Directive 2003/54/EC of June 26 2003, concerning common rules for the internal market in electricity and repealing Directive 96/92/EC.

The adoption of the *market model*, originally a compulsory pool with bilateral contracts only as exceptions to be approved by the Regulator, has been rather troubled. In the model set up, both the two-sided (supply and demand) exchange and bilateral contracts are allowed. On the Exchange, while the suppliers will be paid different area prices to take into account the existence -when present - of *inter-areas* congestions, the consumers will pay a uniform nation-wide purchase price. At the moment of writing (December 2003), the "go to live" of the market is foreseen by January.2004.

Competition for the free market already exists, based on bilateral contracting, but is suffering for an asymmetry due to lack of offer in respect to demand. The market is "short". Italy has a generation mix mainly oil-gas based, with relatively old units, only a modest percentage of coal and no nuclear at all. The hydro resources are almost exploited. Also the import capacity from Central Europe is limited, lower than the 10% figure in respect of the installed capacity suggested by the European Commission. Consequently, the wholesale price in Italy is almost double that of the wholesale price in Central Europe.

This situation explains the saturation of the interconnections in the Northwestern and Northeastern borders. It has impacted the rules for allocation of import capacity that evolved in the years--also with recourse to the Courts-- to the present pro-rata mechanisms.

In 2002 out of a total demand of 310.4 TWh and sales of 290.5 TWh, the sales to the captive market were 60% (175 TWh) and 40% to the free market (95 TWh + 20.5 TWh of self consumption). The Ministry of Productive Activities (formerly Industry) made some moves to fuel the free market, with preferential allocation of import capacity and sales at reduced prices of the purchase contracts of renewable and assimilated energy GRTN has inherited from ENEL. In 2002, the offer for the free market, netted of the self- consumption was: i) import 30 TWh (out of a total of 50.6 TWh); -ii) 40 TWh of renewables out of 55 TWh, and –iii) purchase from national producers of only 25 TWh.

The problem of the high percentage of import has raised new concerns after the blackout that Italy suffered on Sunday morning September 28 2003 (the import was 6.4 GW, out of total demand of 24.6 GW).

Various inquiries have been launched to understand the reasons and to suggest remedies: the one of the Union for the Coordination of Transmission of Electricity (UCTE) which presented an Interim Report on October 27 and recent statements of the Swiss ETRANS, the Swiss grid coordinator, seem to present some disagreements. The report of the Enquiry Commission launched by the Italian Government is expected soon.

It is to be mentioned that the recent blackouts in Europe were a key trigger for intention of the European Community to launch a package of measures on electricity supply security, scheduled in time for the Energy Ministers' Council session of 4th December, to ensure proper functioning of the EU internal electricity market.

In Italy, the lack of "cheap power" has triggered in recent years the development of a huge program from new entrants and the related request of connection to the National transmission network. At the moment of writing (December 2003), some 62 GW of total projects, all of the CCGT type, have been submitted for approval, 44 GW of which following a new procedure set up by the Government in order to speed up the authorizations. Out of this amount, the plant so far authorized are only some 12 GW, and some perplexities still exists concerning the amount of the CCGT, new and transformed, the system could accept with the number of utilization hours capable of ensuring the required return on investments.

The "go to live" to the market, the formation of a transparent market price and the related start up of corresponding futures should give impulse to the investments, still uncertain.

A very sensitive political problem, so far unresolved since entails also constitutional issues, is the balance of powers between Regions where the plants are to be sited and the Central Administration in issuing plant authorization.

It is important to underline that, in order to support the renewables with a marked based approach, the Government ruled that each Producer/Importer must inject a percentage of 2% of its production/import with Green Power, certified by the GRTN with related Green Certificates. The Green Certificates, in force since 2002, are a coupon that can be traded or on an Exchange run the Market Operator since March 28th 2003, or through bilateral contracting Developers- Producers/Importers. The progressive increase of the said percentage of 0.35 %/yr from 2005 to 2007 is foreseen in a Bill under approval by the Senate. Further increases are not improbable, due to need of compliance with the EU Renewable Directive 2001/77 of 27 September 2001, aimed to promote by 2010. An increase up to 22.1% of the contribution of renewable energy sources to electricity production in the European Internal Market against a 1997 baseline of 13.9% is foreseen. The burden share for Italy is 25%, against a 1997 baseline of 16%.

A related issue is the impact on Industry of the Kyoto protocol. The KP shall enter in force when a minimum of 55 Countries that account for least 55% of the CO2 emission in 1990 have ratified. Thus far, after the refusal of the US to ratify, the ratifying countries are 116, accounting for some 44%: a decision of Russia, which could increase the percentage up to 61,6% at the moment of writing (December 2003), is not yet sure. Political discussions and possible agreements are presently explored.

The European Union has agreed a reduction target of 8%; its 15 Member States (MS) made on 4/3/2002 an internal agreement to distribute the total target in various "burden sharing". EU and its MS ratified the KP on 2/4/2003.

Italy ratified the EU burden sharing with the bill 120/2002 on 1/6/2002; correspondingly it is committed to a reduction of –6.5% of the 1990 emission level, 521 Mton, with a corresponding target of 487 Mton by 2010.

The KP establishes three mechanisms to allow flexibility in compliance:

The Emission Trading (ET), a cap and trade mechanism based on an "ex ante" allocation of allowances by various Governments to each sector. The ET Directive will start in 2005 and will be implemented in two phases: 2005- 2007 and 2008-2012. While common issues have been already established, the criteria for the punctual allocation of allowances to the various sectors by the Governments, which directly impact the cost allocation, and the competitivity of the various sectors- is still an open issue.

The two others mechanisms provide flexibility in compliance by introducing, within some limits, the equivalence of "credits" acquired by project-based solution to the allowances allocated by the Government. The rationale is that both a minor compliance cost and increase of efficiency will be obtained by a reasonable recourse to such mechanisms.

The Joint Implementation (JI) mechanism will be applied only to countries that under KP have a cap, namely developed countries *or to countries with economies in transitions*. Since the countries have caps, the mechanism is a zero-sum operation: it is expected that JI will take place especially in Russia, having a great potential for transfer of advanced technologies. Emission Reductions Certificates (ERCs) will be recognized for reductions against a baseline.

The Clean Development Mechanism (CDM) allows investors of the developed countries to make investments in *developing nations* which have no quantitative targets but have ratified the KP. The investors will receive Certified Emission Reduction (CER) credits by a UN body.

A draft Directive on criteria to be applied to link the ET Directive and JI and CDM was issued by the EU on 23 July 2003. The mechanisms are expected to enter in force as of 2008, subject to the KP entering into force.

A basic issue is the relation between the cost (Euro/Mton) of the allowances – and the related penalties for not compliance- which will materialize with the ET and the cost corresponding to the "credits" – in perspective well lower- gained with the JI and CDM.

To accomplish with the Italian burden, the Ruling of CIPE n. 123/2002 "Revision of the Guidelines for National Policies and Measures for GHGs Reduction" presents, against the 1990 baseline, two possible scenarios as follows:

Baseline 1990: 521 Mton CO2, out of which 124.9 Mton CO2 due to thermal production
Business as usual 2010: 580 Mton CO2, out of which 150.1 Mton CO2 due to thermal production
Reference scenario2010: 540 Mton CO2, out of which 124.1 Mton CO2 due to thermal production

In order to obtain the reduction target of –6.5% in respect of 521 Mton, namely a final level of 487 Mton, a reduction of 93 Mton of the Business as Usual (BAU) is needed.

Correspondingly, not only the targets (triggered by the existing legislation but not necessarily implemented) included in the Reference scenario are to be obtained, but a further reduction of 53 Mton CO2 will be needed.

In particular the burden of the Electric sector is huge: a reduction of 26 Mton is anticipated, being equal to some 66% of the total (580-540)= 40 Mton reduction required.

A great concern for the Government and Industry is the impact that the cost for purchasing emission allowances utilizing the ET mechanism could have on the Italian economy: various unit costs, ranging from 10-50 and even up to 100 E/tonn, are anticipated on which various scenarios can be examined. The Government is correspondingly pushing for an enlarged utilization of the other two flexible mechanisms (JI and CMD), which should allow a much lower compliance cost. On another side, it is presently updating the assumptions for the two scenarios considered.

It is worthwhile to mention that the Bill on the "Energy Sector Restructuration", approved by the House on July 2003 and presently under examination by the Senate, contains various provisions (clean coal technologies, CO2 specific emissions, penalties for not compliance…) which, together with the criteria which will be adopted for allocation of the allowances, could affect the compliance approach of the electric sector and, within it, of the various competitors.

In the near future many of the present incertitude's will be the focus of the Government and Parliament's initiatives.

Luigi Salvaderi was born in Ancona, Italy, in June 1938. He received his PhD. Degree in Electrotecnic Engineering from the University of Genoa, Italy in March 1962.

After an initial experience in the automatic control field, he joined ENEL in 1965, the Italian Electricity Board, where he held the following positions and responsibilities:

- *Design & Construction Department:* Design of 220-380 kV stations and commissioning of the SACOI HVDC link
- *Research & Development Department:* Development of techniques for generation & transmission system reliability evaluation
- *Planning and Strategies Department (1997-1996):* Responsible for Generation planning of the Italian system and Manager of the Strategies & Technologies Sector
- Relations with the Energy Authority Department (1996-1999): *Responsible for Tariff Studies, Coordination of the Grid Code for the new Italian Independent System Operator.*

On behalf of ENEL Spa he has been acting as a Senior Consultant Engineer in various countries. Since 1968 Dr. Salvaderi has been a very active member of various International Bodies. These include:
:

- Eurelectric- Bruxelles: Member of the WG on "Transmission Tariff"
- CIGRE-Paris: Italian Member of the Study Committee SC 37 "Power System Planning" 1992-2000 and member of the WGs: "Transmission Pricing", "Adequacy evaluation in the new liberalized environment", "Impact of regulation structure on power system planning"
- Chairman of the WG "Transmission Cost Benchmarking"
- Presently is Member of WGs in the two CIGRE SC: C1: "System Development and Economics; C6 "Distribution Systems and Dispersed Generation"
- Institute of Electrical and Electronics Engineers (IEEE)-New York: Member of WGs "Reliability, Risk, Probability Applications" and " International Practices for Energy Development and Power Generation"
- World Energy Council-WEC- London: Member of the Committee "Performance of Thermal Plants".

Dr. Salvaderi has co-authored more than 120 technical papers published in international reviews on power system planning, reliability evaluation, and energy issues. He has given lectures and tutorials in Institutions, Associations and Universities in various countries of Europe and North America.

He is co-editor of the IEEE book on "Applied Reliability Assessment in Electric Power Systems" used by Consultants, Utilities, and Universities.

He was Panelist and Special Reporter at many IEEE and CIGRE sessions on various issues related to planning and new unbundled structure of the electric utilities.

Dr. Salvaderi received in 1996 the "CIGRE Technical Committee Award", in recognition of his outstanding contribution to the work of the Study Committee "Power System Planning and Development".

He was elected a Fellow of IEEE in 1996. He has received twice the Award of the Italian Electro technical Association. Dr. Salvaderi, since January 1 2000, has been acting as International Consultant for Power System Issues, Market Organization, and for a major Italian Wind Source Developer.

Sandro Corsi received his Doctorate in Electronics (Control Systems) from the Polytechnic of Milan (Italy) in 1973. In 1975 he joined ENEL's Automatica Research Center. His main interests were power system voltage control, generator control, power electronics devices, advanced control technology, power system automation and protection. Research manager at ENEL S.p.A Ricerca from 1997, in charge of the "Power System Control & Regulation" office. After ENEL reorganization, research manager at CESI in charge of the "Network & Plant Automation" office from 1999 and of the "Electronics & Communications" office in the Automation Business Unit beginning in 2000. With CESI R&D and Sales since 2001. From 2004 Project Manager at T&D Networks Business Unit. Member of CIGRE, IEEE-PES, CEI and IREP Board. Author of more than 60 papers on power system advanced controls.

Rec'6 Jan 26, 04

5. TECHNICAL RULES AND STANDARDS HARMONIZATION IS A KEY ISSUE FOR REALIZATION OF UCTE, NORDEL AND IPS/UPS SYNCHRONOUS OPERATION

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Abstract

At creation of conditions for development of joint operation of large European Interconnections UCTE, NORDEL and IPS/UPS it is being offered not to bring rules and standards to a uniform, obligatory form for all the participants but to carry out only their harmonization. Such harmonization is necessary, both for interconnection by means of flexible connections, and for synchronous operation. At transition to synchronous operation Interconnection with not quite high quality of frequency control is to accept standards of the partner with more strict requirements on frequency as well as carry out a number of organizational& technical actions. Before realization of synchronous operations it is necessary to carry out joint researches.
Keywords: Interconnection, System, Standards, Harmonization.

5.1 NECESSITY of HARMONIZATION of TECHNICAL STANDARDS AT DEVELOPMENT of the INTERCONNECTIONs JOINT OPERATIONS.

The largest European electric power interconnections (PI) UCTE, IPS/UPS, NORDEL – in the course of their construction and further evolution set up certain rules of interaction and norms, stipulating the requirements to operation and development of particular national and regional power system, forming these PI. The fulfilment of these rules and norms is usually a necessary prerequisite for new members to join the PI.

The integration strategy in power industry tends to creation of favorable environment for broader interaction of the existing interconnections by their conjunction on acceptable mutual platform. In such cases it is not always necessary to accept as a uniform the norms of one of the united PI. In particular, while considering a problem of interconnection of such PI as UCTE, NORDEL and IPS/UPS, which seize essentially different norms of operation and development, we propose to avoid an obligatory unification of these norms, but to carry out their harmonization. This will provide certain economic merits and will prevent from possible negative consequences.

5.2. DEVELOPMENT of the INTERCONNECTIONS'S JOINT OPERATIONS BY MEANS of FLEXIBLE CONNECTION.

The minimal requirements to such harmonization exist under interconnection via DC – links and other connection means, like FACTS, that essentially simplify the frequency control and dispatching matters between united PI. By now we have gain a positive experience of normative harmonization in the process of PI uniting in such a manner: UPS of Russia and NORDEL, NORDEL and UCTE, and parts of large PI: UK power system and UCTE, interconnection of four regional systems in PI of USA and Canada, formation of national systems in China and India, etc. Under such interconnection, the requirements of standards harmonization come up mainly to conformity of regime and reliability demands at the interface, i.e. at the very connection point between PI. The contents of such requirements should match standards and rules of the united PI (for instance, the power output from the back-to-back station busbars at the Russia-Finland link should not exceed 1000 MW, that correspond to normative requirements in NORDEL).[1]

5.3 SYNCHRONOUS OPERATIONS

The similar approach to standards harmonization of the united IP may be taken in the case of the synchronous interconnection (single frequency). But in this case it is necessary to consider the peculiarities, proceeding from technical conditions of operation under single frequency. The following additional requirements are the most essential in such case:

1. The IP, retaining lesser-installed generating capacities, is charged to control power overflow along the interface link in accordance with authorized schedule and to dampen down occasional power oscillations on the link, caused by irregular load deviations.
2. The loading parameters of interface elements should not exceed the magnitudes, under which an emergency failure of any of the interface elements may cause a disturbance in one of united PI, that goes above the rated acceptable magnitude of disturbance for particular PI (N-1 principle).
3. The united PI should undertake measures, preventing from occurrence of contingency disturbance at the interface, which exceeds the limits of acceptable parameters, rated by the norms of the other PI.

In all the considered cases of interaction, a PI with lower quality levels of frequency control should accept the higher frequency control standards of the partner. All the PI will have to specify the transmission capacity of the main cross-sections; to clarify fault current degrees at the neighbor edging facilities; to readjust relay protection and emergency control systems; to match operation regimes of transformers neutral points; to solve the problems of electromagnetic compatibility; to revise the requirements for substation equipment at the neighbor edging facilities, including commutation ability of the circuit breakers; to reequip facilities with controlled sources of reactive power etc. [2]

At synchronous interconnection of NORDEL-IPS/UPS-UCTE, observance of above mentioned positions demands from NORDEL to organize an automatic power flow control for a intersystem link NORDEL-IPS/UPS.

It, obviously, will result in necessity to revise existing rules of frequency regulation, especially regarding organization of secondary control in NORDEL.

It can turn out to be a rather complicated problem for the IPS/UPS to execute the third requirement from the above mentioned. It is necessary to take into account the fact, that the IPS/UPS now embraces a number of national power systems, and their common normative base has not completely adjusted yet. Transition to a parallel operation of the IPS/UPS and the UCTE can be executed by closing Ukrainian power links. Transmission capacity of that links can turn out to be much greater, than transmission capacity between power systems Ukraine and Russia. Thus power stations of Russia realize secondary frequency control in the IPS/UPS. Emergency power shortage balancing in the UPS to prevent inadmissible load rise on the link IPS/UPS-UCTE should be executed mainly in the power system of the Ukraine.

An emergency automatic system, created in the USSR time, allows to provide the given requirements. However it is required to develop and put into effect a number of additional normative rules for emergency automatics with taking into account observance of requirements on the interface IPS/UPS-USTE. To shift the responsibility for provision of reliability in emergencies to an automatic frequency&power control system, as it takes place in the UCTE, in conditions of the IPS/UPS, where the main network contains a plenty of relatively weak links, it is not expedient in the foreseeable future. However necessity to achieve quality of power plants regulation accepted in the UCTE in the IPS/UPS, is not excluded. [3]

Interconnection of NORDEL-IPS/UPS-UCTE will affect UCTE's existing normative base in the least measure. Interconnection UCTE with the IPS/UPS at observance of the above mentioned stipulations for

UCTE in practice could be considered as connection of one more partner with characteristics determined by the interface characteristics. Thus the main principle of distribution of responsibilities for emergency imbalance compensation (which together with optimization of a rotating reserve, mainly determines a necessity to maintain frequency in a strict manner that is characteristic for UCTE) is preserved completely in the UCTE.

Thus, the synchronous interconnection, that allows refusing to use expensive devices of "unbundling" on frequency, demands more essential revision of a normative base in each of interconnected power systems. With reference to interconnection NORDEL-IPS/UPS-UCTE and with taking into account specific features of these power associations it is expedient to reduce the coordination of the normative bases to obligations to perform certain requirements on the interfaces. [1]

5.4 NECESSARY JOINT RESEARCHES

Before realization of synchronous interconnection it is necessary to execute special joint researches aimed at definition of reasonable for scheme-regime requirements on the interfaces, and also aimed at development of an economically proved system of measures in each of power associations, that provide for observance of coordinated requirements on the interfaces. At synchronous interconnection of these three power associations it is necessary to take into account their mutual influence that will require to fulfill special researches and to develop for it an appropriate model. This model should display inter influence not only of the Interconnections, but also influence of power systems, included in the Interconnections, especially at presence of relatively weak links between them (for example, between some power systems in the IPS/UPS, power systems of Sweden and Finland in NORDEL, power systems of Poland and Germany in UCTE, etc.).

5.5 CONCLUSION

1. In Europe there are three neighboring large Power Interconnections: UCTE, NORDEL and IPS/UPS. A degree of their interaction does not correspond to potential opportunities.

2. Development of interaction of UCTE, NORDEL and IPS/UPS, is a part of the European integration process. Thus a mutual diversification of power sources can be achieved, efficiency of a generating equipment use can be raised, and a basis for exchange of high technologies and so forth is set up. Taking into account the fact that cooperation in the field of electric power industry in Europe does not have alternative, the question is reduced to a choice between synchronous and non-synchronous interconnection.

3. The organization of synchronous operation provides an opportunity of large-scale interaction between partners, reliability of operation and quality of the electric power can be raised to the greatest degree, and expenses on the further development of a technological infrastructure can be reduced.

4. Main principles of synchronous interconnection are: equal partnership, mutual preservation of quality and reliability of operation, non-distribution of emergency disturbances, coordination of minimal mutual requirements to the parallel operation, directed to external characteristics of Interconnections and to the interface.
5. Technical rules and standards harmonization is a key issue for realization of a UCTE, NORDEL and IPS/UPS synchronous operation.

5.6 REFERENSES

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3. *Y.N. Rudenko, V.A. Semenov, Automation of dispatch control in Electric Power Industry. Moscow: MPEI,2000.*

5.7 BIOGRAPHIES

Yuri KUCHEROV was born in Leningrad Region, Russia in January 1951. He graduated from the Novosibirsk Electrotechnical Institute in 1973.

After a post-graduated course –1976-1979 - he received his PhD Degree in 1980. In 1986 – 93 he worked in the Siberian Power Institute- Siberian Division of Russian Academy of Science- as a senior researcher, a leading researcher, head of laboratory on security and reliability of large power systems. From 1993 to 1997 he headed International Power Laboratory in Budapest/Hungary. He received his Degree of Doctor of Technology in 1998.

In 1997 he joined Russian Joint Stock Company of Power and Electrification – RAO "EES Rossii" where he headed Department of Development and Scientific&Technical Policy.

From November 2002, when due to liberalization processes in the Russian Electricity Industry the Federal Grid Company of the Unified Power System – was formed, and up to now he holds a position and responsibility as Head of Department of Research & Development and International Co-operation.

Y. Kucherov is an author of more than 140 technical papers, including six monographs (in the co-authorship).

In recent years he was involved in studies that have a great importance in the transient period to the Market, among them:

- provision of vitality, security and reliability of the Unified Power System (the UPS) of Russia, power plants and networks with taking into account power security of Russia as a whole and its regions,
- new technologies in the field of electricity transport, distribution and supply,
- development of dispatch&technological control,
- environment protection.

In his papers he proposed methodology and algorithms for investigations on reliability of large power systems.

Practical significance of his work is contained in the fact that theoretical principles are developed to the level of specific recommendations, rules, that are used in planning stage of power project development, in the concept of the UPS development, in updating a dispatch control's automatic system.

Y. Kucherov is an active member of various scientific and technical organizations:

- Chairman of the section "Strategy of the Power Industry Development and international power projects" of the RAO EES's Scientific Council,
- Member of scientific councils of the Russian Academy of Science on problems of the Power Industry development and high technologies,
- Member of the Russian Academy of Electrotechnical Science,
- 1998-2000: Representative of RAO "EES Rossii" in EURELECTRIC,
- 1991-2000: Member of UCTE&EURELECTRIC Working Group "SYSTINT".

- Real member of the New-York Academy of Science,
- Deputy chairman of WEC Russian Member Committee,
- Member of CIGRE Study Committee C1 “System Development and Economics”.

Lev KOSHCHEEV was born in Tashkent, the USSR, in April 1932. He graduated from the Leningrad Electrotechnical Institute in 1955. He received his first scientific degree in 1967 and doctor of science degree in 1987.

He joined Leningrad Power Transmission Research Institute (NIIPT) in 1955, where he held the following positions:

- since 1955 to 1972 – engineering and scientific positions,
- since 1972 to 1986 – head of the Power System Department,
- since 1987 – Scientific director, Deputy Director General.

All the time he has been a lecture in the Leningrad Polytechnic University, from 1970 – as a docent, from 1987 – as a professor.

Main fields of his scientific activity are:

- AC and DC long distance power transmission lines,
- stability and reliability of large power systems,
- emergency control systems.

Professor KOSHEEV is author and co-author of more than 100 technical papers published in magazines and reviews including CIGRE reports.

In 1985 Prof. KOSHEEV received the “USSR State Award”.

He participated in many international working groups, among them:

- East-West High Power Electricity Transmission System – Baltic Rout,
- Baltic Ring,
- System Committee on Russian-Finland power connection between RAO UES of Russia and Fingrid.

Yuri TIKHONOV was born in Baku / Azerbaijan, in 1937. He graduated from Moscow Power Engineering Institute in 1961.

From 1961 up to nowadays he has been working in Moscow Electric Power Research Institute (VNIIE), where he held the following positions:

- since 1961 to 1976 – engineering and scientific positions,
- since 1976 up to nowadays – head of Power Systems Stability Laboratory, head of Power System Regimes Department.

In 1975 he received his PhD Degree.

The main field of activities is reliability, stability and emergency control of power systems. Dr. Tikhonov contributed a lot in the development of Russian power system emergency control, national rules and standards on the UPS operation.

Dr. Tikhonov is author and co-author of more than 40 technical papers published in Russian and international magazines and reviews on power system modeling, transient stability, reliability evaluation, emergency control of the turbine power etc. He is as a lecturer in the Institution of upgrading professional education of electrical engineers.

6. STABILITY ANALYSIS FOR LARGE POWER SYSTEM INTERCONNECTIONS

Bernd Michael Buchholz, Vice President, Siemens AG, Erlangen, Germany and Dietmar Retzmann, Director, Siemens AG, Erlangen, Germany

Abstract

A worldwide trend in the development of power systems is to build interconnections with the goal to achieve economical benefits.

The interconnections are mostly realized by synchronous links where such solutions are technically feasible and economically justified (AC solution). In cases where the synchronous interconnection is technically constraint, an HVDC coupling station or HDC log Distance transmission (DC solution) can be used (DC solution). Finally, the DC solution can also be applied in combination with a synchronous interconnection in order to support the operation of the interconnected systems and thus makes the synchronous AC link more reliable (Hybrid solution).

The evaluation of the best solution for large system interconnections requires detailed system models for stability analysis. In the paper, examples of very large power system simulations for Europe are shown. Simulation results are given for DC and AC interconnections. There are practically no limits for the size of the systems, which can bee handled by modern computer simulation tools, e.g. the advanced NETOMAC simulation program.

Finally, the challenges of further system interconnections in Europe are considered on the base of the existing experience in stability analysis.

Keywords: Development of Power Systems - Power System Interconnection - Power System Simulation - System Dynamics - Stability Analysis - Transmission Efficiency - AC, DC and Synchronous Hybrid Transmission Technology

The challenge of interconnections in Europe

A worldwide trend in the development of power systems is to build interconnections with the goal to achieve economical benefits. Such large interconnected systems can cover many countries or even wide continental areas.

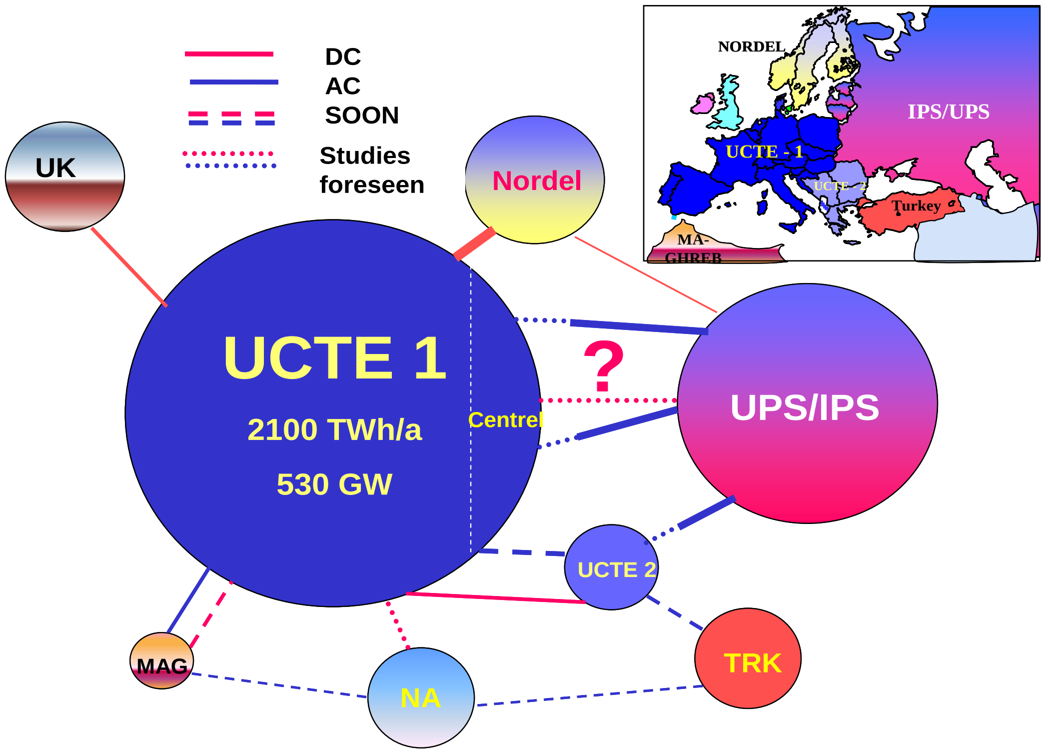

Figure 1: European Power Systems (2003)

An example is shown in Figure 1 for the European systems, where the area of UCTE-1 is already a very large synchronous system with options for further extensions towards IPS/UPS and the Mediterranean area.

Interconnections of power systems may offer significant technical, economical and environmental advantages. Issues are pooling of large power stations, sharing of spinning reserve and use of most economic energy resources, taking into account also ecological constraints: nuclear power stations at special locations, hydro energy from remote areas, solar energy from desert areas and connection of large off-shore wind farms.

The liberalization in the power industry also supports for more interconnections to enable the exchange of power among the regions or countries and to transport cheaper energy over long distances to the load centers. Examples for such interconnections are systems in Russia, North America, Western Europe and Asia. However, there are technical and economical limitations in the interconnections if the energy has to be transmitted over extremely long distances. In future, the situation can, however, change if ecological and political terms change or the present cost conditions alternate.

Alternatives for interconnections

The interconnections are mostly realized by synchronous links where such solutions are technically feasible and economically justified (AC solution). In cases where the synchronous interconnection is technically not feasible, an HVDC B2B station or HDC long Distance transmission can be used (DC solution).

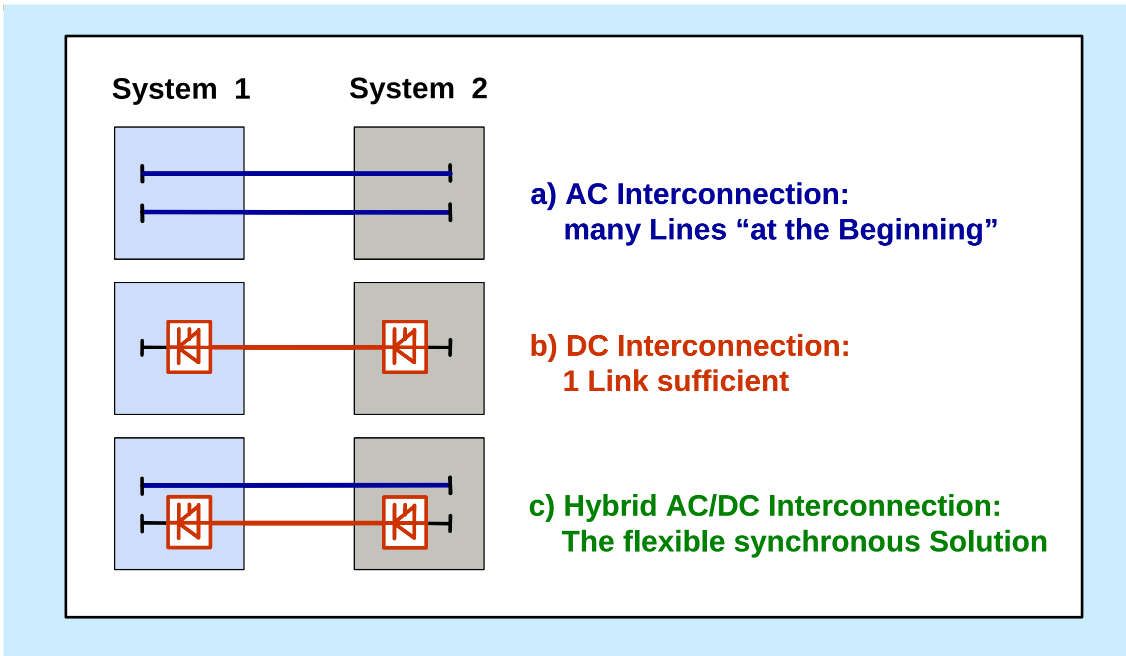

Figure 2: Configurations for Power System Interconnections

Finally, the DC solution can also be applied in combination with a synchronous interconnection in order to support the operation of the interconnected systems and thus makes the synchronous AC link more reliable (Hybrid solution). These possibilities are depicted in Figure 2.

Analysis experience

Evaluation of the best solution for large system interconnections requires detailed system models for stability analysis. An example of such an investigation is given in Figure 3.

It can be seen, that in very large systems the evaluation of stability measures such as power oscillation damping is a very important issue.

The task of the stability analysis consists in development of methods for keeping the system stable in different emergency situations.

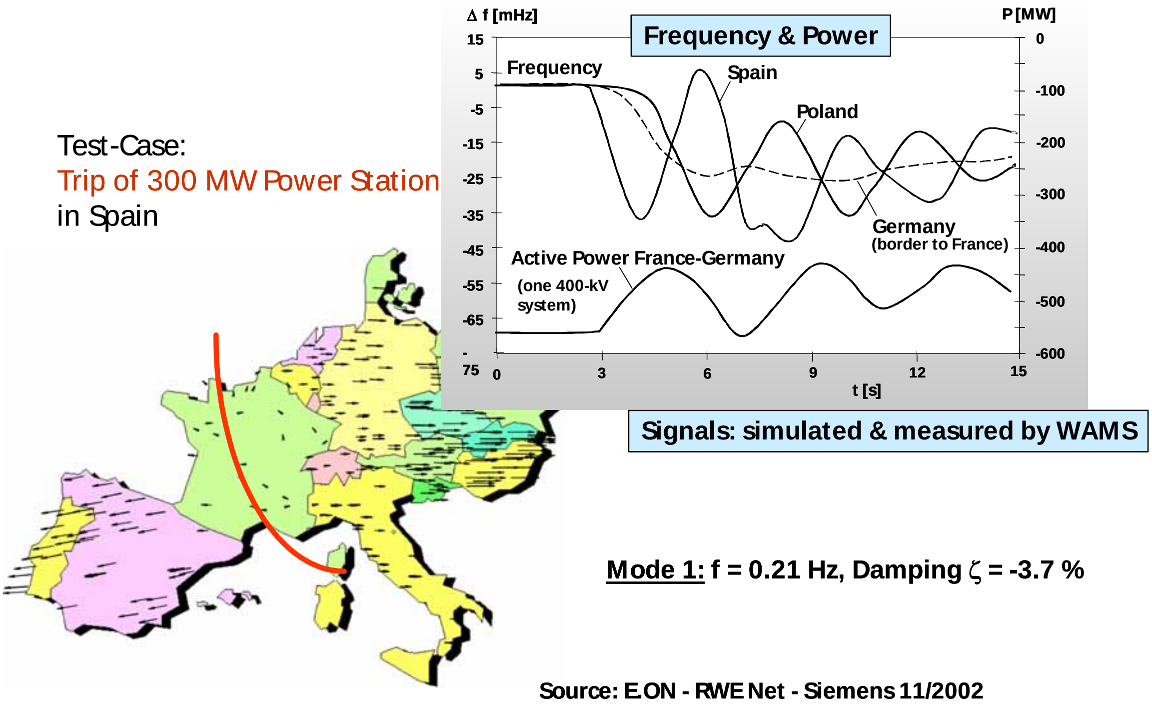

Figure 3: Interarea Oscillations in a large synchronous System: Example UCTE

It can be seen, that in very large systems the evaluation of stability measures such as power oscillation damping is a very important issue.

In the presentation, examples of very large power system simulations for system interconnections via HVDC in Europe are shown as well.

The models in use are explained and simulation results are given for AC, DC and hybrid interconnections. There are practically no limitations for the size of the systems, which can bee handled by modern computer simulation tools, e.g. the advanced NETOMAC simulation program, ref. to Figure 4.

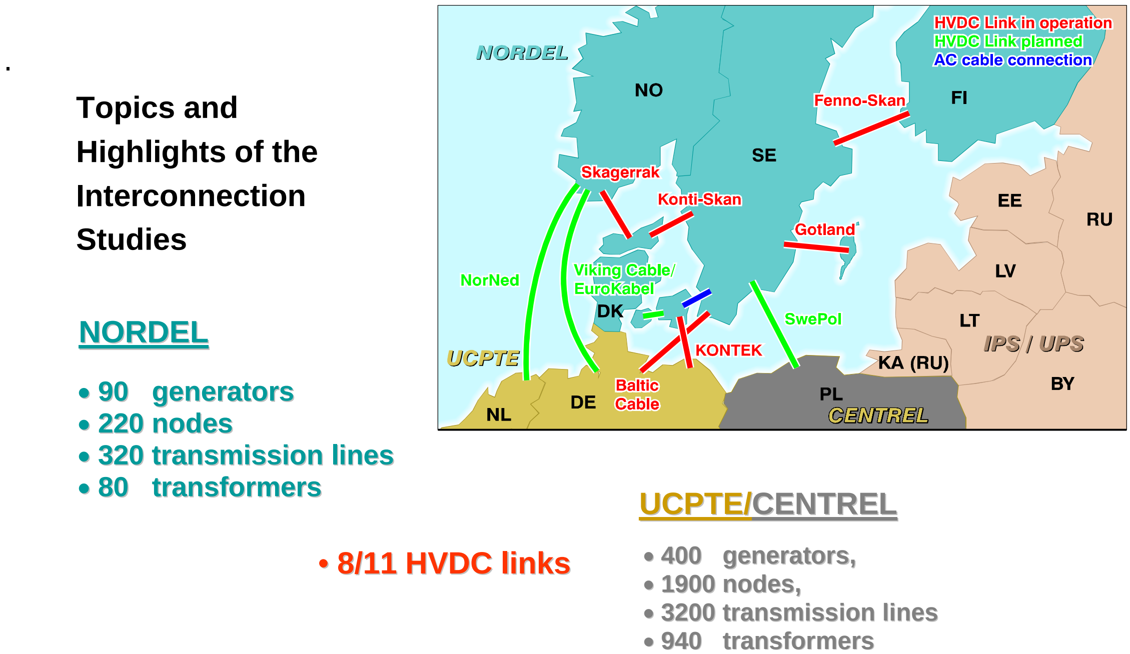

Figure 4: Studies for Large Power System Interconnections with NETOMAC

With the example of the Italian blackout it was shown that risks for the stability of internal synchronous interconnections between countries exist within the large European UCTE-1 system as shown in Figure 5.

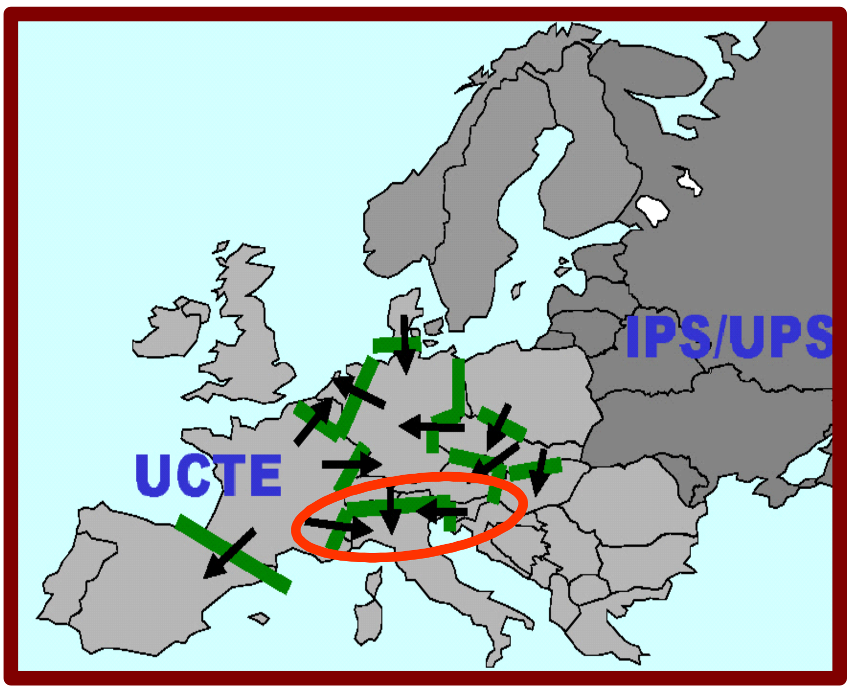

Figure 5: Transmission bottlenecks in the UCTE grid

Further investigations of system extensions through additional interconnections with the neighboring systems have to care the internal congestions of both systems to be interconnected. In many cases the hybrid solution helps to solve the stability problems.

Conclusions:

Actually, the European grids are interconnected in a hybrid way, using both synchronous AC and asynchronous DC links. The challenges for a further extension of the interconnections can only be solved properly by means of advanced simulation facilities, which are capable of detailed modeling of all relevant parts of the systems.

The topics of the European interconnection issues can be summarized as follows:

- European system interconnections are still developing by erection of new DC and AC links;
- DC links are partly foreseen to strengthen existing synchronous interconnections;
- Each interconnection requires detailed analysis;
- Experience is gained since many years and universal tools are proven in studies and in practice;
- Mostly congestions occur not at the interconnections but at bottlenecks in the existing grids, partly far away from the connection points of the systems;
- Stability problems may be solved by FACTS and HVDC, especially hybrid interconnections with AC and DC links in parallel are highly efficient for these tasks;
- UCTE and UPS/IPS interconnection is a new challenge and shall be investigated in the near future.

Similar investigations are actually undertaken in other regions of the world, e.g. in Asia, South America, Australia

Dietmar Retzmann (1947), Cigré, VDE, graduated in Electrical Engineering (Dipl.-Ing.) at Technische Hochschule Darmstadt/Germany in 1974. He received Dr.-Ing. degree in 1983 from the University of Erlangen-Nuremberg.

Dr. Retzmann is with Siemens Erlangen, Germany since 1982. His area of expertise covers Computer and Real-time Simulation; Design & Development and Testing for more than 40 large FACTS & HVDC projects with advanced controls & protections; R&D works; Design & Development and Testing of Analogue, Hybrid and Fully Digital Real-Time Simulators. Currently, he is technical director for Project Development in High Voltage Division, Power Transmission Solutions.

Bernd Michael Buchholz (1948) received his MS and PhD at the Power Engineering Institute in Moscow in 1973 and 1976 respectively. After that he was assigned project manager and later director of R&D at the Institute of Energy Supply in Dresden. In 1990 he joined the Siemens AG and took over the head oft the R&D department of the division “Protection and Substation Control Systems” in Berlin and Nuremberg. Since February 2000 he is president of the business unit “Network analysis and Consulting” in the “Service” division of the Power Transmission and Distribution group in Erlangen. He is member of the SC C6 of CIGRE “Dispersed generation in distribution systems”.

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