InnoGrid2020+

The European Research & Development Dissemination Seminar
23 – 24 February 2012

PEGASE

A EUROPEAN DYNAMIC DISPATCHER TRAINING SIMULATOR PROTOTYPE

AN ENHANCED COORDINATION BETWEEN TSOs IS MANDATORY

Europa Press Releases

IP/07/110

Brussels, 30 January 2007

Blackout of November 2006: important lessons to be drawn

The final report on the incident of 4 November 2006, released today by the Union for the Coordination of Transmission of Electricity (UCTE), demonstrate that common action at European level is urgent.[1] Energy Commissioner Andris Piebalgs stated, "Europe should draw lessons from this Blackout that left millions of Europeans in various Member States without electricity and develop stronger network security standards".

[...]

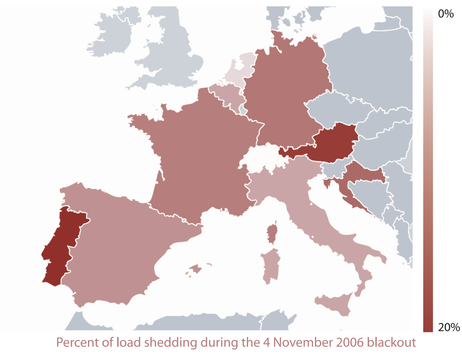
These causes confirm the Commission's analysis in favour of common action for ensuring the security of electricity supply throughout the European Union. As outlined in its recent Energy Package, announced on 10 January, the Commission considers it urgent to:

- Accelerate the adoption, in the context of a new Community mechanism and structure, of essential common binding network security standards;
- Enhance the coordination between Transmission system operators to ensure an effective real-time operation of the European grid;Efforts should be made to have a gradual evolution towards regional system operators; this should require effective unbundling as discussed in the Commission Strategic Energy Review;
- Improve investments in the European grid both to ensure its reliability and the construction of a truly competitive European market; The

zone automatic devices had to switch customers off in the countries affected. The most affected area was France where 5 million customers were cut off. In Germany also millions of customers were affected, in Belgium, Netherlands, Italy and Spain some hundreds of thousands of customers were without electricity.

the Commission considers it urgent to:

Enhance the coordination between Transmission system operators to ensure an effective real-time operation of the European grid



Percent of load shedding during the 4 November 2006 blackout

→ A European Dispatcher Training Simulator is the response to ensure coordination between actors

DYNAMIC SIMULATION IS A MUST TO TRAIN OPERATORS WITH REALISTIC SCENARIOS

SLOW AND FAST PHENOMENA REPRESENTATION IS REQUIRED

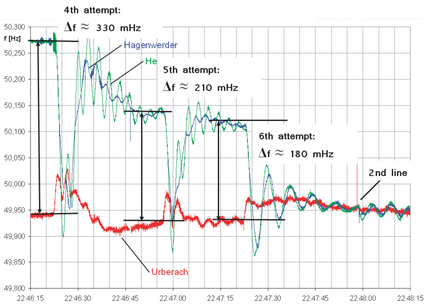
TO REPRODUCE ACCURATELY LOCAL AND GLOBAL BEHAVIOURS

- SLOW VOLTAGE STABILITY PROBLEMS CAN LEAD TO PARTIAL BLACKOUTS
- FAST ANGULAR STABILITY PROBLEMS CAN LEAD TO A LOSS OF SYNCHRONISM
- FAST CASCADING EFFECTS CAN LEAD TO A SPLITTING OF THE SYSTEM

SUCH PROBLEMS ARE MORE LIKELY TO APPEAR IN A POWER SYSTEM

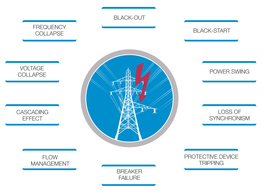
OPERATED CLOSE TO ITS STATIBILITY LIMITS

→ Classical DTS cannot cope with this requirement



Resynchronization attempts on 4 November 2006 blackout

THE FIRST REAL TIME DYNAMIC DTS ENGINE READY TO SIMULATE THE ENTIRE EUROPEAN GRID



Scenarios requiring dynamic simulation

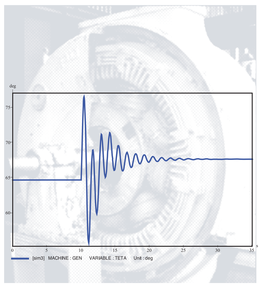
INCLUDES A DETAILED MODEL OF ALL COMPONENTS

- DETAILED TOPOLOGY
- FULL PARK MODELS OF SYNCHRONOUS / ASYNCHRONOUS MACHINES
- ACCURATE CONTROLLERS MODELS

INTEGRATES WITH VERY HIGH ACCURACY

- USE OF AN IMPLICIT & SIMULTANEOUS INTEGRATION SCHEME
- BASED ON EUROSTAG: A REFERENCE FOR FULL ACCURACY SIMULATION

ACCURACY



EMBEDS PEGASE RESEARCH OUTPUTS

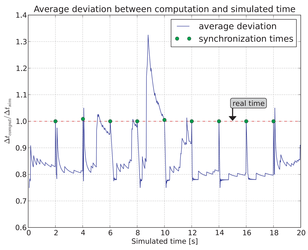
- INNOVATIVE INTEGRATION SCHEME
- ADVANCED PARALLELIZATION TECHNIQUES

ABLE TO HANDLE VERY LARGE SYSTEMS

- 24.000 BUS BARS
- 12.500 LINES
- 3.800 GENERATORS
- 125.000 VARIABLES

RESPECTS REAL TIME CONSTRAINT AT EACH SYNCHRONIZATION TIME

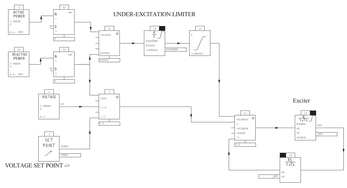
PERFORMANCES



FLEXIBILITY

READY FOR ADVANCED MODELIZATION

- GENERATORS, MOTORS, LOADS, WIND FARMS, HVDC, ...
- ALL CONTROLLERS CAN BE USER DEFINED BY BLOCK DIAGRAMS



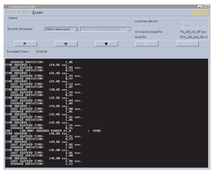
AN OPEN ARCHITECTURE FOR DECENTRALIZED VISUALIZATION AND OPERATION

DTS ENGINE EMBEDDING TELEMETRY MODEL

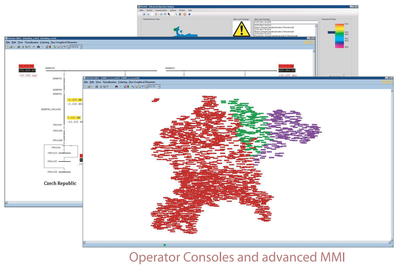
OPC-UA TECHNOLOGY

- ABILITY TO ACCEPT CONNECTIONS SECURELY THROUGH TCP/IP NETWORK

POSSIBILITY TO CONNECT ANY SCADA OR ADVANCED MMI


Simulation Engine embedding telemetry model in OPC-UA server

TCP/IP Network


Operator Consoles and advanced MMI

READY TO TRAIN OPERATORS TO INCREASING POWER GRID COMPLEXITY

LOOKING AT THE RECENT PAST, WOULD HAVE NOVEMBER 2006 BLACKOUT HAPPENED IF

- OPERATORS FROM DIFFERENT COUNTRIES HAD BEEN TRAINED TOGETHER?
- OPERATORS HAD BEEN TRAINED ON A SIMULATOR SHOWING THE EFFECT OF A CRITICAL LINE OPENING WITHOUT SECURITY CHECK?
- OPERATORS HAD BEEN TRAINED TO COPE WITH RESYNCHRONIZATION ISSUES?

TODAY AND IN THE COMING YEARS, HOW DO OPERATORS NEED TO REACT WITHIN MASSIVE RENEWABLE ENERGY INTEGRATION CONTEXT?

...

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PEGASE

EFFICIENT GRID MANAGEMENT TOOLS TO ACHIEVE AN INTEGRATED SECURITY ANALYSIS AND CONTROL OF HIGH VOLTAGE PAN-EUROPEAN TRANSMISSION NETWORK

INTRODUCTION

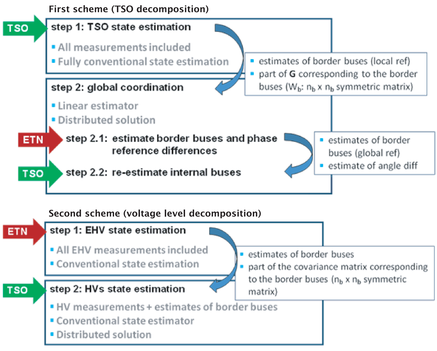
With a substantial increase in the use of renewable sources of energy, the power system will have a central role in the delivery of green power to all customers in Europe. With renewable energy from off-shore wind, solar power from the South and hydropower from Scandinavia and the Alps, more electricity will flow across borders.
Therefore building tools aiming to allow the operation and control of the European Transmission Network (ETN) in a more efficient and reliable way, closer to its limit becomes one of the main tasks of PEGASE project.
The global challenges addressed by PEGASE project are:
To develop smart transmission grid algorithms to provide all TSOs with a synchronous display of the state of the ETN very close to real time
To develop Optimal Power Flow programs determining realistic system operating points that include TSOs operating rules, typically for real-time congestion management, including a worst case approach
To improve the existing state of the art technology in time simulation of very large systems in order to be able to offer off line studies of the ETN including possibly interconnections with neighbouring system (i.e. Mediterranean Ring and Russia)
To develop preventive security assessment in on-line emergency conditions, faster than real-time simulation, with simplified dynamic simulations

SPECIFICATION AND ARCHITECTURE

Analysis of interviews held with all the major European TSOs organised by PEGASE project had the global objective of improvement of Pan European coordination. Based on this analysis specifications and requirements for the research work have been developed. There are currently several reasons that are significantly influencing the grid operation including:
•The massive integration of renewable, generally intermittent, generation in the system is inducing variable power flows in the grid. These new power plants are generally small units connected to the distribution grid. TSOs have a poor observability of these power injections and have no control at all over them;
•The inconsistency between the relatively short time to build new wind farms (2 or 3 years) and the time to go through all administrative procedures to build new lines (well over 5 years);
•At the European level, the best locations for wind farms are mostly along the coasts and offshore, while for photovoltaic generation they are in the south of Europe. Since these locations do not generally match those of the large load centres, a transmission network is required that will be able to cope with the variability of the flows. Currently available commercial software for power system simulation cannot accurately simulate a European-wide transmission system within a reasonable time for real-time operation and planning purposes.
•The system is no longer able to survive (remain stable) all single faults without post fault-actions; To improve this "state of affairs", the most advanced and innovative techniques and algorithms, to make detailed real-time simulation of the ETN reality, have been developed by PEGASE consortium. They have been implemented through calculation engines able to perform system wide dynamic simulations at the European level in real time and reproducing the system behaviour, under any type of scenario including cascading switching, the complete black-out of the interconnected system and its black-start. By selecting the best combination of achieved improvements it is now possible to simulate a pan-European power system with around 120,000 state variables, with full accuracy in reasonable time.

ALGORITHMS FOR STATE ESTIMATION OF PAN-EUROPEAN POWER SYSTEM

The objective of a European state estimation is to make available to each TSO a real-time data base with the parameters and operating state of the ETN. Standard methods are inappropriate for the real-time estimation of the European system.
Preliminary analysis led to resorting to Two-Step State Estimation (TSSE) methods and different schemes were proposed: ETN decomposition according to TSOs or according to voltage levels.
Associated algorithms have been analyzed, along with possible implementations, for the two proposed architectures:



Two alternative architectures (schemes) for a two-step state estimator have been developed and validated, along with different possible implementations. These implementations implied different levels of simplification and, therefore the accuracy of the results. The main topics analyzed were the required data exchange, the quality of the estimate and the bad data detection capabilities. It was shown that, thanks to an appropriate representation of state variables and phasor measurements, a slight modification of a conventional Weighted Least-Squares algorithm can easily incorporate phasor measurements in addition to conventional ones.

STEADY STATE OPTIMISATION

In order to identify potential problems ahead in time, it is necessary to construct realistic steady state operating points corresponding to the expected operation conditions for the Pan-European Transmission Network. In this context implementation of a tool such as a Security Constrained Optimal Power Flow (SCOPF) which can schedule the power system controls in some optimal way while satisfying operating constraints for the base case and all postulated contingencies is necessary.
The SCOPF modelling challenges are mainly coming from the characteristics of the mathematical formulation. The nonlinearity of the underlying power system model, the presence of discrete controls, and the enormous dimension of the problem are adding significantly to the complexity of the problem. The aim of the PEGASE work in this area was to cope with these challenges and thereby to advance the state of the art in SCOPF so that it becomes a practical tool for the operation of the Pan-European electrical network. To achieve this aim, the following tasks have been carried out:
•Modelling of the steady state operation conditions as an optimization problem,
•Review of the state of the art in constrained optimization and identification of outstanding requirements
•Development of prototype software for steady state optimization of the ETN.

TIME DOMAIN SIMULATION

The dynamic simulation of power system behaviour is a highly useful and in some systems a critical tool for power system planning, operation and for operator training. It carries out system trajectory analysis during the transitions from one operating point to the other. This transition can be triggered by the natural load demand evolution, the changes due to the market transactions or sudden contingencies and disturbances such as faults and switching operation in substations. For a system as large as the European Transmission Network, the total computation time is the bottleneck for time domain simulation especially for Dispatcher Training Simulator (which must run in real time) and Dynamic Security Assessment (where many runs must be performed in a limited time). The PEGASE project developed several new algorithms and parallelization procedures to reduce this computation time. These new algorithms have been integrated and tested in real industrial prototypes.

MODELLING ISSUES

In the European transmission networks (ETN) the number of new power devices and systems such as electronic interfaces, FACTS devices, digital controllers, protection systems, active distribution networks, etc. is rapidly growing. The proper modelling of these devices and systems is crucial for accurate simulation of the overall system. Currently used models of these devices and systems however, are widely perceived to lack accuracy, computational efficiency and robustness. To improve that a number of steps has to be undertaken:
•Identification of modelling gaps, as an initial step to advance the current state-of-the-art in modelling of these devices for a more accurate and reliable security assessment;
•Proposal of generic model for evaluation and validation procedure;
•Development of a computational platform for the certification and the exchange of models between different TSOs.

Identification of modelling gaps
Regarding the primary power equipment, devices and systems containing voltage source converters as key components, such as HVDC VSC, FACTS devices, and wind farm aggregate models were singled out for detailed consideration.

Methodology for model validation
A general methodology based on norms that takes into account the variety of physical parameters, simulation timeframes and phenomena to be simulated has been proposed.

Methodology for model development and customisation
Simplified models for wind turbines (WT), wind farms (WF) and VSC based HVDC lines and other similar devices have been derived and implemented. Additionally, a library of standard elements as well as standard protection and automation models has been developed.

Computational platform for model exchange
An open computational platform based on Modelica has been developed. The open computational platform is intended for use in building reference models and to exchange and certify models.

DEMONSTRATION

Having the appropriate tools, there are no more technical obstacles towards a more coordinated and secure operational framework of the interconnected power system, at all stages : from planning to state estimation and dynamic simulation, as well as for dispatchers training. Newly developed or improved algorithms discussed above are able to handle large power systems at the European and Russian scale. The leading role in demonstration of these algorithms is delegated to TSO partners who will be in charge of:
•Building realistic scenarios, with the base case data and within the frame of the defined methodology;
•Running the demonstration scenarios;
•Assessing and discussing the results of validation

DISSEMINATION OF PEGASE RESULTS

During 4 years of the project dissemination activity continuously intensified. A wide range of dissemination activities has been undertaken including publication of a large number of scientific papers, organization of international workshops, international training courses, and technical seminars (for TSOs, control centres manufacturers, consulting engineering, generators and traders), organization of special panels within the international conferences and participation in international exhibitions.
Since 2007 more than 40 scientific papers prepared by PEGASE consortium specialists have been published and submitted for publication in leading international journals and large number of technical workshops was held.
Additionally, 16 newsletters that present project results and achievements were issued for wider dissemination to all stakeholders and general public.
Key research results concerning Pan European Grid Advanced Simulation and State Estimation were presented at PEGASE panel session at IEEE PES International Conferences on Innovative Smart Grid Technologies, IGST Europe 2011, in Manchester, UK in December 2011.
Members of PEGASE consortium have initiated Special section on "Analysis and simulation of very large power systems" in leading International journal in the area, IEEE Transactions on Power Systems. Furthermore, 2 EES-UETP courses on "Optimisation of Power System" and "Large power system dynamic simulation and associated modelling of wind turbines/wind farms & of HVDC VSC" based on the project results, are planned to be held in April-June 2012 at National Technical University of Athens (NTUA), Greece and at University Duisburg-Essen, Germany.

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