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UNIVERSITY OF ROSTOCK
Department of Electrical and
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"Electrical Interconnection between Turkey and Europe: Problems and Solutions"

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Introduction

The main scope of this work is to study “Improvements of Primary and Secondary Control of the Turkish Power System for Interconnection with the European “Union for the Co-ordination of Transmission of Electricity” (UCTE) System. This topic covers two applications of primary and secondary control performance.

The objective of primary control is to maintain a balance between generation and consumption (demand) within the synchronous area, using turbine governors. Primary control starts within seconds.

Secondary control replaces primary control after minutes by the responsible partner .Secondary control maintains a balance between generation and consumption (demand) within each control area as well as the system frequency within the synchronous area and the exchange power, taking into account the control program, without impairing the Primary control that is operated in the synchronous area in parallel.

Secondary control makes use of a centralised and continuous automatic generation control (AGC), modifying the active power set points / adjustments of generation sets / controllable load in the time-frame of seconds up to typically 15 minutes after an incident. Secondary control is based on secondary control reserves that are under automatic control.

This project concerns the classical stability problems “Small Signal Stability (Rotor Stability)", which are the most important stability problems regarding the possible future parallel operation of the Turkish Power System with UCTE.

Small Signal Stability (or Rotor Stability) means the absence of increasing inter-area oscillations between the generators of the European and Turkish Power System.

This work is the result of an intensive joint collaboration of the power system operators who are directly concerned with the extension of the UCTE interconnected system by the power system of Turkey.

General Information

Title of the Project: Rehabilitation of the frequency control Performance of the Turkish Power System for synchronous Operation with UCTE
Sector : Energy
Location: The Republic of Turkey
Implementing Agency: Central Finance and Contracts Unit (CFCU).
Beneficiary: Ministry of Energy and Natural Resources
Overall Cost: 2,500,000 €
EU Contribution: 2,500,000 €

Overall Objective and Project Purpose

Overall Objectives: The overall objective is to fully integrate the Turkish Electricity Market to the EU Internal Electricity Market.
Purpose of the Project: Turkish Power System is prepared for future parallel operation with UCTE regarding power and frequency control, steady state and transient stability.
Static Studies: Concerning the Static Studies the objective is to:

Investigate (in terms of static security considering standard security rules) technical feasibility of the interconnection of the Turkish system to UCTE by three 400 kV lines, two lines between Hamitabat (Turkey) – Maritsa (Bulgaria) and one line between N.Santa (Greece) and Babaeski (Turkey to be committed later, the topological situation right after the connection of Turkey. Figure 1 illustrates the systems modelled for the purpose of the study. Calculate the maximum allowable total Import-Export between Turkey and Southeast European countries using load flow and small signal stability analysis.

Activities of the Project

Task	Process Aim	Process Steps	Responsibility
1	Survey of Power Plants' Control Systems	→ Review/Inventory of technical data of larger power plants → Analysis of current control systems (AVR, PSS, Turbine Governors) → Report	→ TEIAS, Manufacturer, Tübitiak, EUAS → AVR/PSS: Manufacturer, ESO (NEK) → HPP governor: Manufacturer, ESO (NEK), University of Rostock, SwissGrid, Tübitiak → TPP/NGCPP governor: Manufacturer, ESO (NEK), RWE TSO
2,3	Accomplishment of stable Frequency Control	→ Primary Control Performance **A** Determination of Test Procedures/Performance Criteria **B** Current Individual Unit Performance for specified operating conditions (Practical tests/Analytical consideration) ▪ Control Modes/Structures ▪ Contribution in Primary Control etc. **C** Determination of requirements for Stability of Frequency Control(30 seconds oscillation) **D** Comparison C with B → Catalogue of Measures → Secondary Control Performance **A** Analysis of current design and control performance **B** Catalogue of Measures **C** Implementation +Test	→ RWE TSO, SwissGrid, ESO (NEK) → EUAS, Manufacture, Tübitiak, (RWE TSO, SwissGrid, University of Rostock), ESO(NEK) → University Rostock, → Manufacturer, University of Rostock, RWE TSO, SwissGrid, EUAS → TEIAS, SwissGrid, University of Rostock, ESO (NEK)
4	Improvement of Small Signal Stability (Damping of inter-area oscillations)	→ Voltage Control and PSS **A** Determination of Test Procedures **B** Current Individual Unit Performance for specified operating conditions (Practical/Analytical) **C** Determination of requirements for voltage control and damping performance **D** Comparison C with B → Catalogue of Measures (e.g. Modification of existing voltage controllers/ implementation of PSS, Tuning Studies, Interaction of PSS with governors **E** Analytical Validation (Eigenvalue Analysis) → Turbine Governors (HPP) **A** Influence of governors on 7 second inter area oscillations **B** Determination of requirements to mitigate negative effects on damping performance **C** Comparison with Frequency Control Requirements **D** Catalogue of Measures **E** Implementation +Test → FACTS (SVC and STATCOM)	→ Manufacturers, University, ESO (NEK) → Manufacturers, University of Varna → Manufacturers, University of Varna, ESO (NEK) → RWE TSO → University of Rostock → EUAS, Manufacturer, Tübitiak, (RWE TSO, SwissGrid, University of Rostock), ESO(NEK) → University of Rostock
5	Elaboration of System Protection Schemes	→ SPS Within Turkish Power System (Phase 1) **A** Basic Principles and Settings → SPS Interface Turkey / UCTE (Phase 2) **A** Principle and Settings/Criteria for system separation → Analytical Validation (Simulation) → Implementation → Restoration Plan Elaboration	→ TEIAS → ESO (NEK) → RWE TSO → TEIAS
6	Training	→ UCTE Operational Handbook → Market rules / congestion management	→ RTE

Objectives and Contributions of the Task 2 and Task 3

The main objectives of this work are to:

1) Design of governor control and parameter optimization to prevent slow frequency oscillations generated by the governors, see measurements of Fig. 5 and 6.
2) Develop of Phasor Study Method
3) Coordinated Design
   - Isolated Turkish System

The investigation objective of isolated Turkish system is to stability of the overall frequency control for normal and disturbed conditions

- Parallel operation with UCTE

The investigation objective of isolated parallel operation with UCTE is to meet the UCTE requirements regarding the frequency control quality.

4) Compare the results obtained using the simulation with the measurements

Objectives and Methodology of Stability Studies of Task 4

The scope of this study is related to the field about system security, which deals with the ability of the power system to withstand disturbances by maintaining its function without violation of technical limits. The stability analysis deals with the system security under consideration of the dynamic characteristics of the power system, which are classified according to various relevant physical phenomena. This project concerns the classical stability problem "Small Signal Stability" , which are the most important stability problems regarding the possible future parallel operation of the Turkish Power System with UCTE.

System Modeling

1- Turkish Network

- **Modeling of static data (network data) of the Turkish Power System**

The static network data were converted from the PSS/E (Egypt used this program) software to the DIGSILENT software (Digital Simulation and Electrical Network calculation),

Total Generation [MW]	30000 MW
Number of Nodes	1556
Number of Lines	1343
Number of Loads	701
Number of Transformers	806
Compensation Elements	28
Total Number of Machines	690

- **Dynamic Model of the Turkish Power System**

Collection of dynamic data (Figure 2)

- detailed synchronous machine models
- speed governor and turbine control,
- automatic voltage regulators (AVR),
- power system stabilizer (PSS).

Figure 1: Interconnected systems in Europe

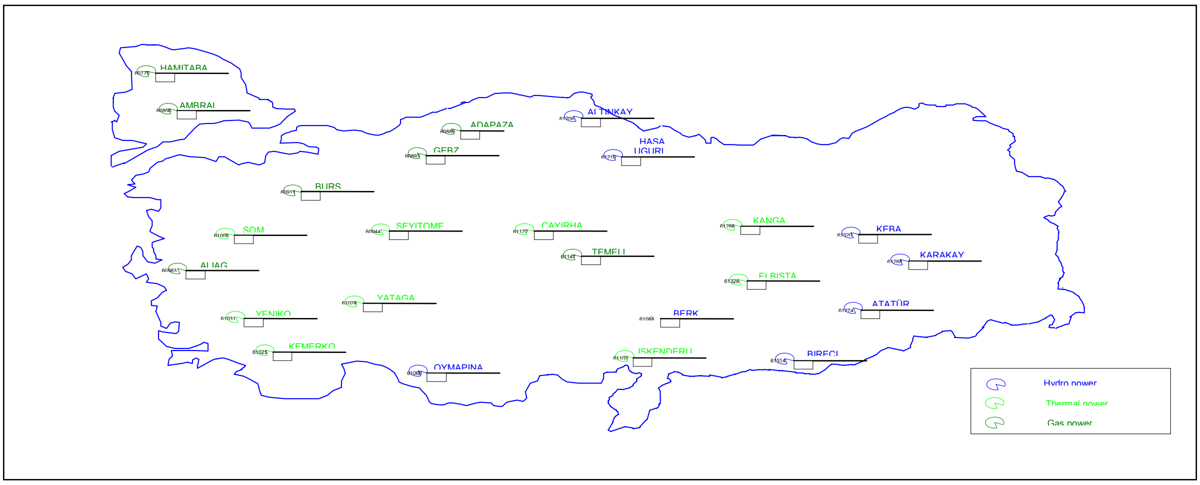

Figure 2: Turkish Network

2- UCTE Network (simplified dynamic model , 82 nodes)

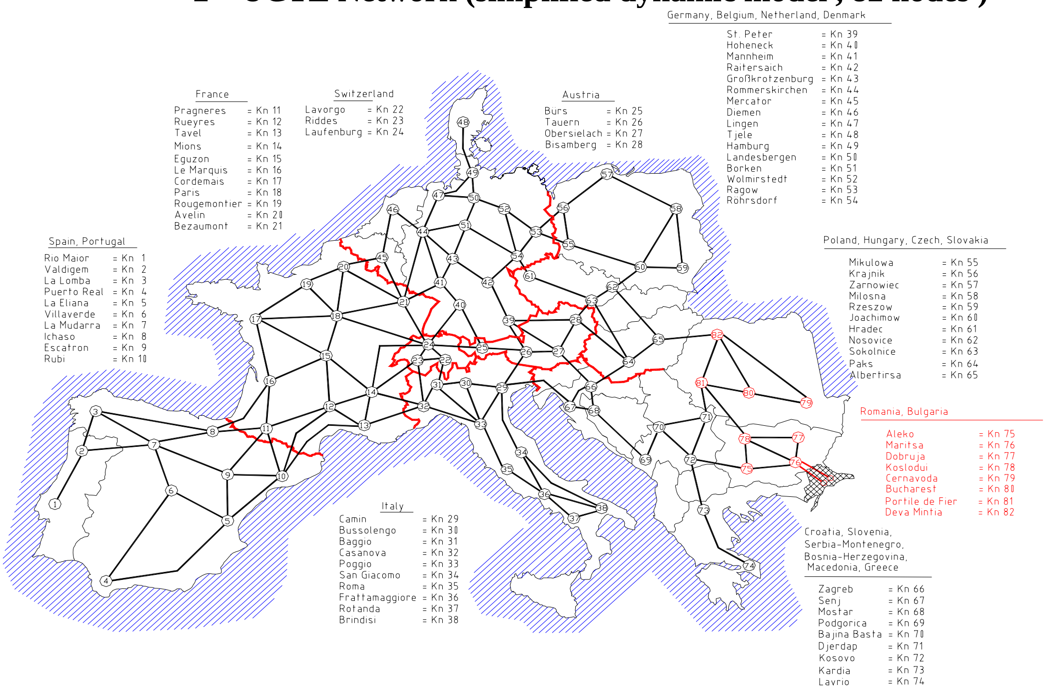

Figure 3: UCTE Network

3- Interface Turkey - UCTE

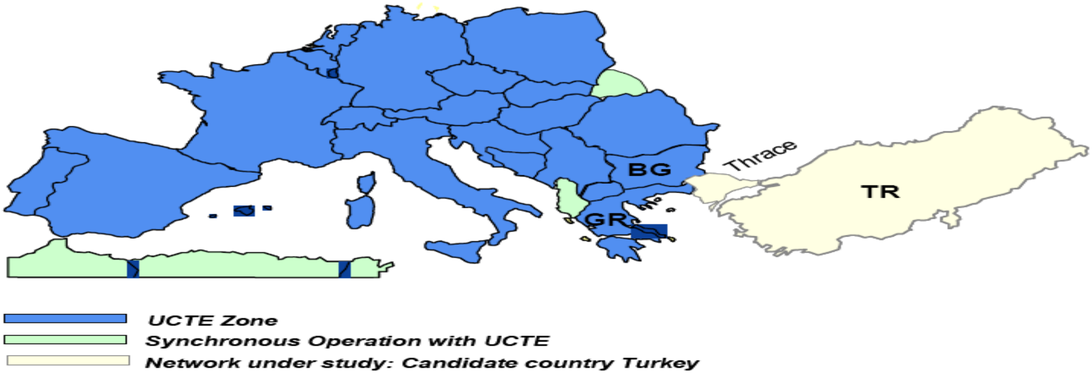

Figure 4: Interface Turkey – UCTE

WAMS in the Turkish Power System

The Wide Area Measurement System (WAMS) show a systematic frequency control problem within the Turkish Power System see figures 5 and 6.

- **WAMS-recording - Friday, 2006-05-12; 19:12**

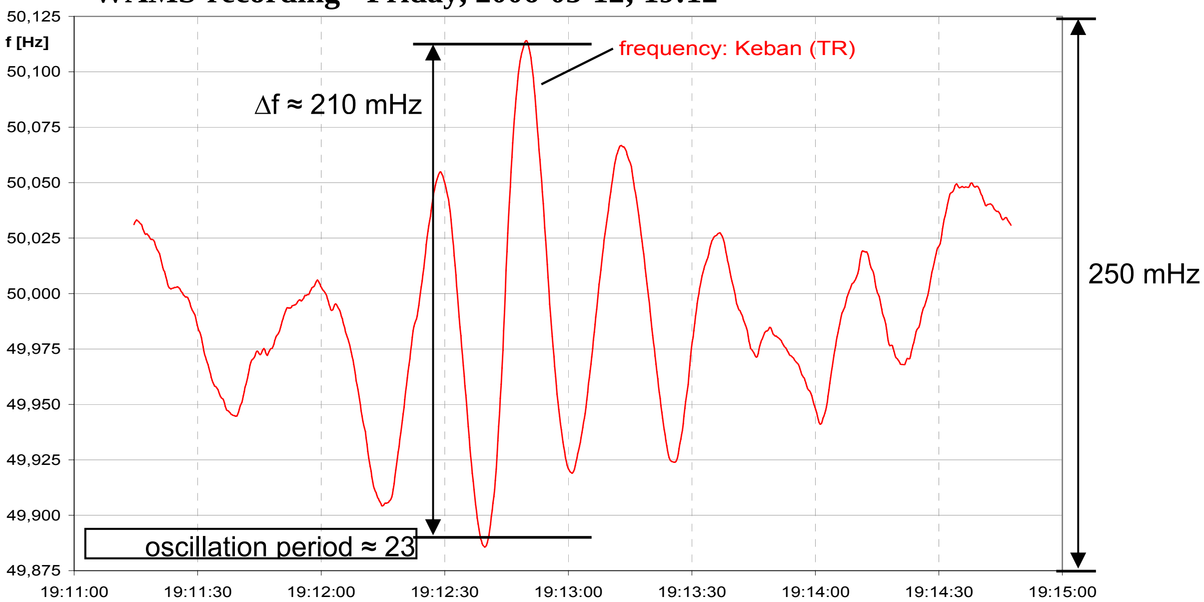

Figure 5: frequency of Turkey 2006

- **WAMS-recording Sincan (TR), 2007-01-08 16:00**

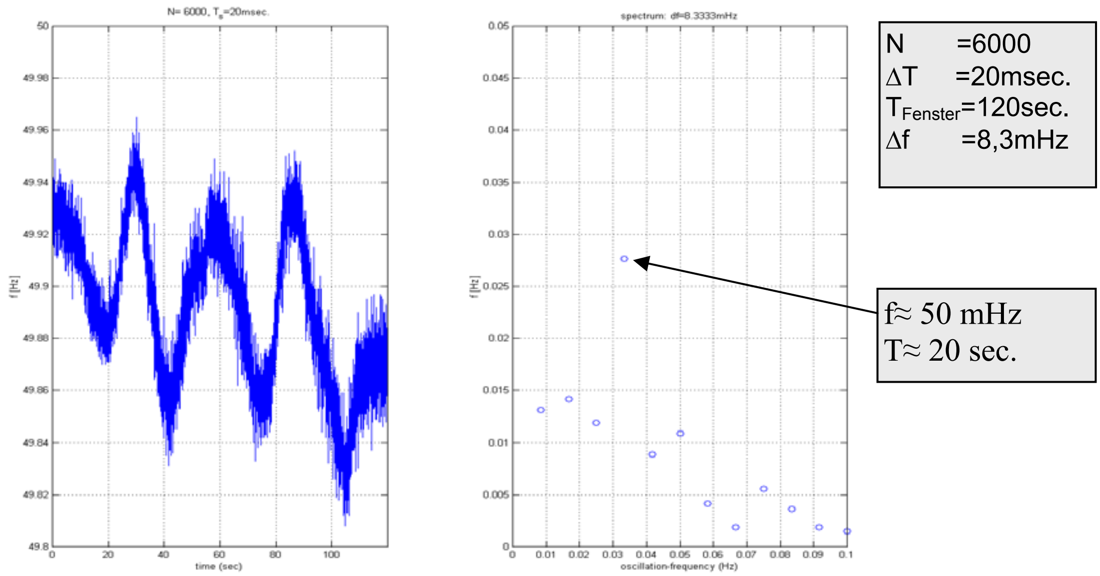

Figure 6: frequency of Turkey 2007

Simulation and Measurements (Task2 and Task3)

1) Island Mode

- **Outage of Temelli GPP (730MW) at 27/09/2009**

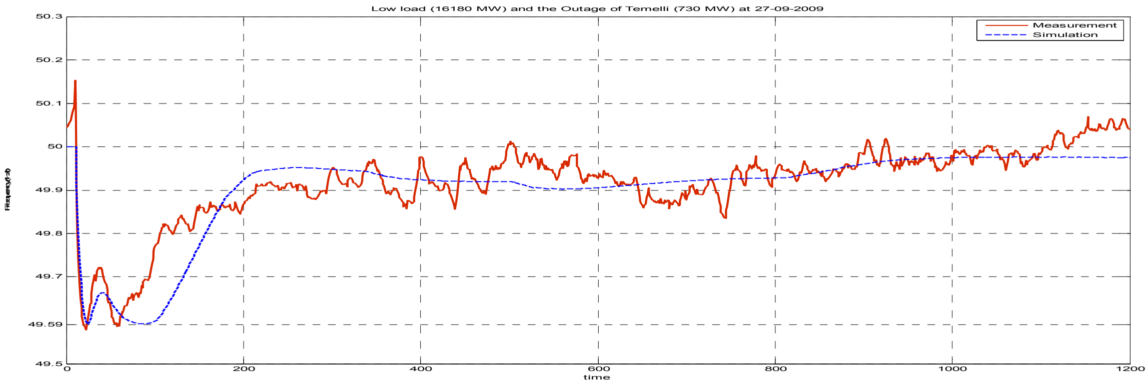

Figure 7: Island mode

- **Trumpet Curve Samples in 27 of September 2009**

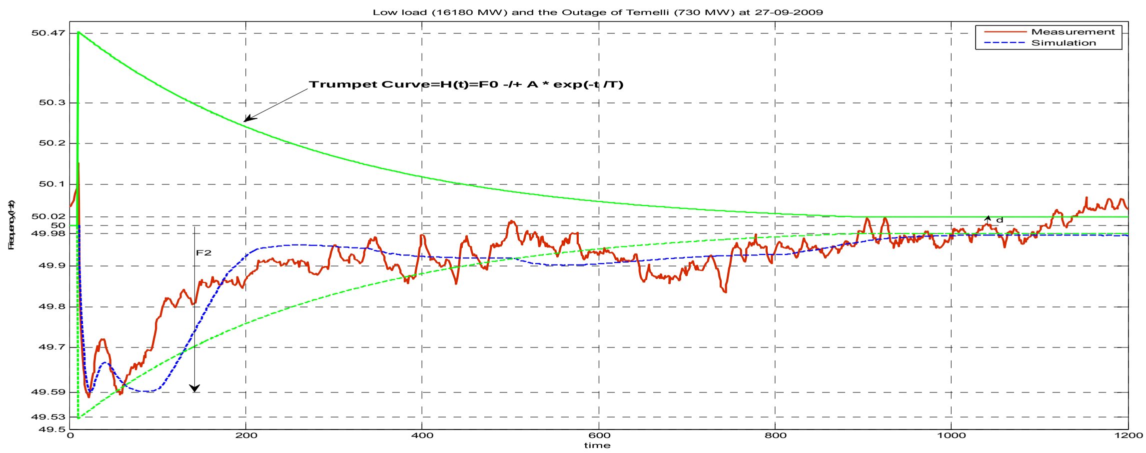

Figure 8: Trumpet Curve

- **Output Power of all Plants(GPPs,TPPs and TPPs)**

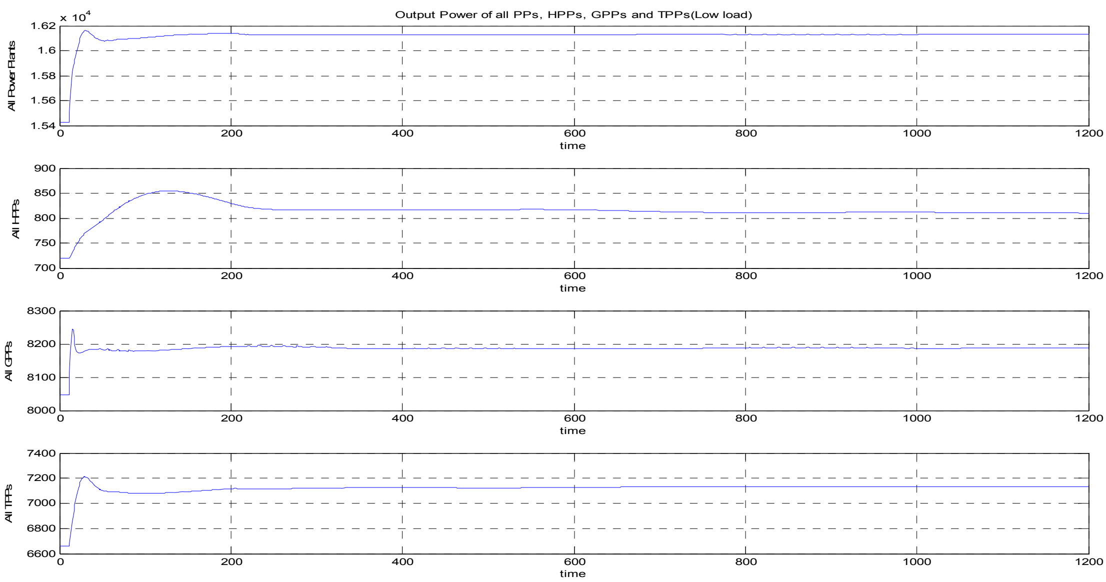

Figure 9: Output Power

2) Interconnected Mode

- **Outage of Can TPP (288 MW)**

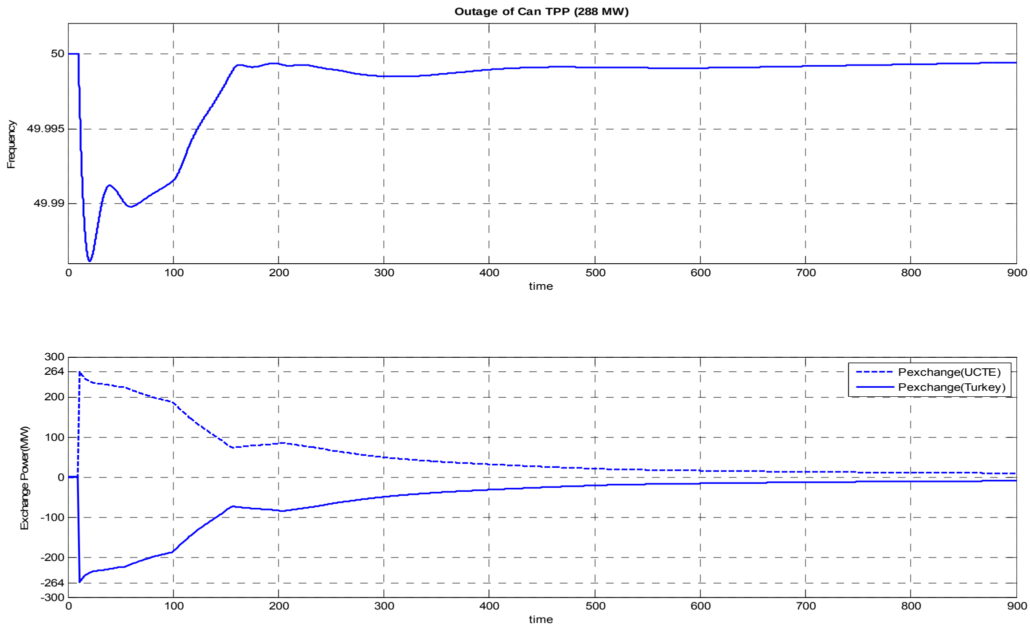

Figure 10: interconnected mode

- **Load behavior (20 second/sample) at 16 June 2009**

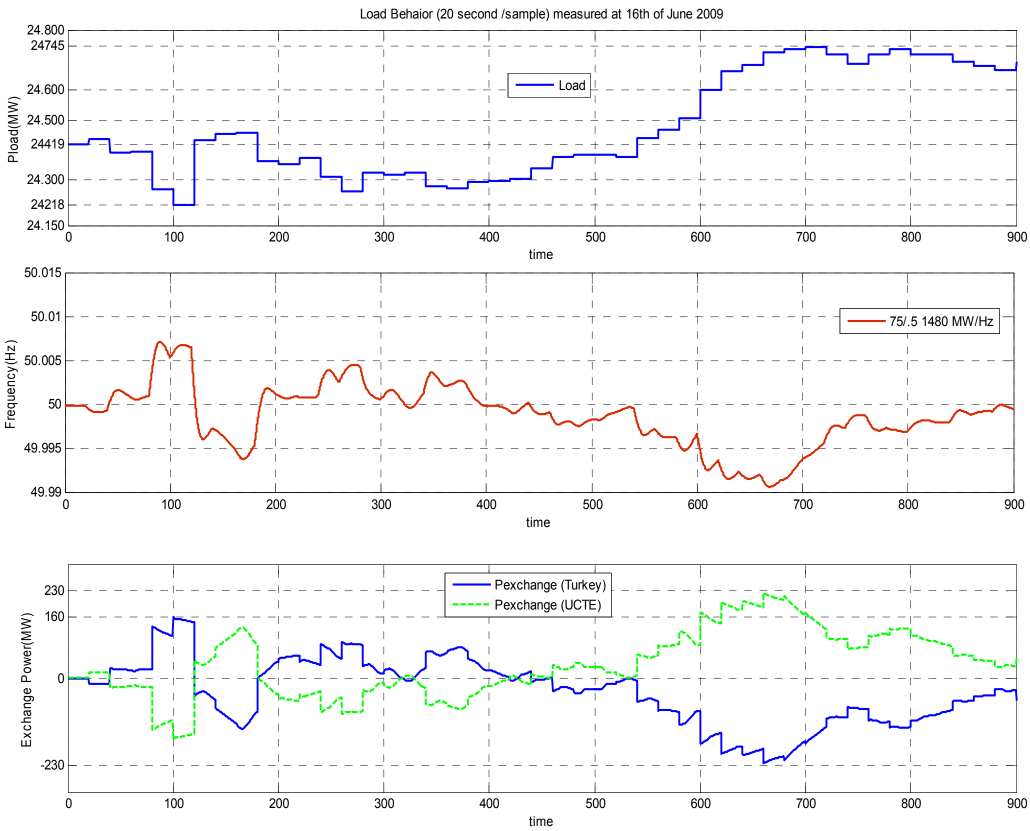

Figure 11: interconnected mode (Load behavior)

Simulation and Measurements (Task 4)

- **Case 1: Summer (July) Day, UCTE (345 GW), Turkey (29 GW).**

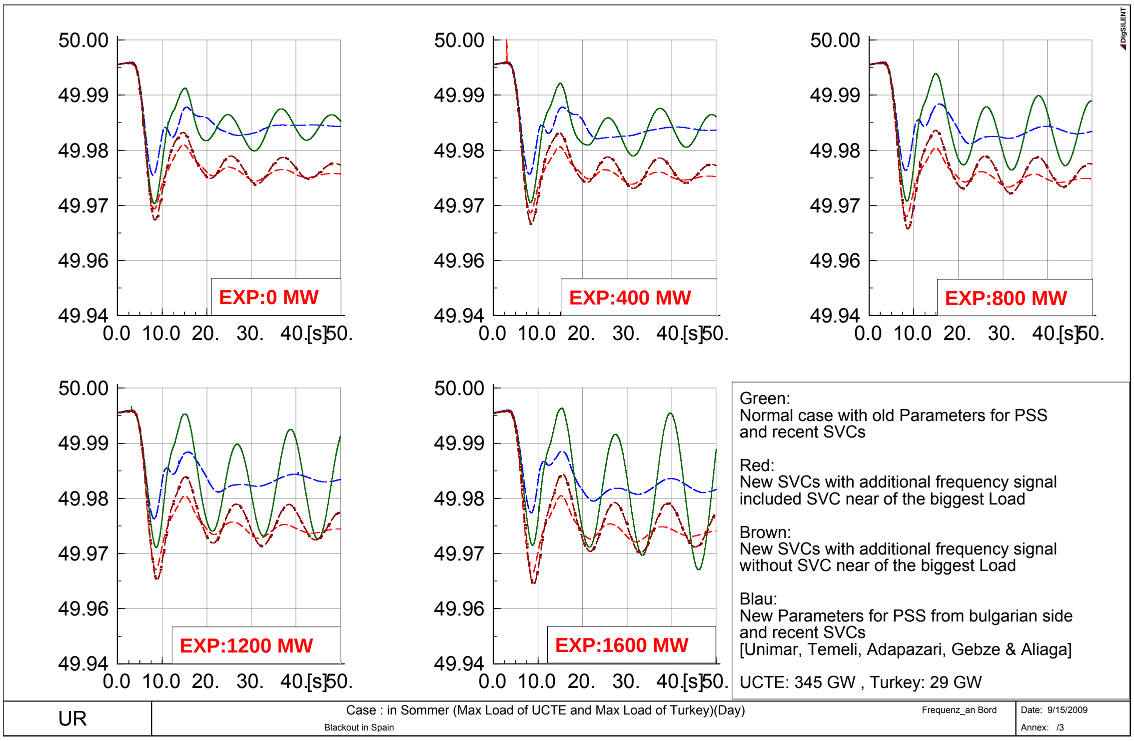

Figure 12: interconnected mode

- **Case 2: Summer (July) Night, UCTE (232 GW), Turkey (18 GW).**

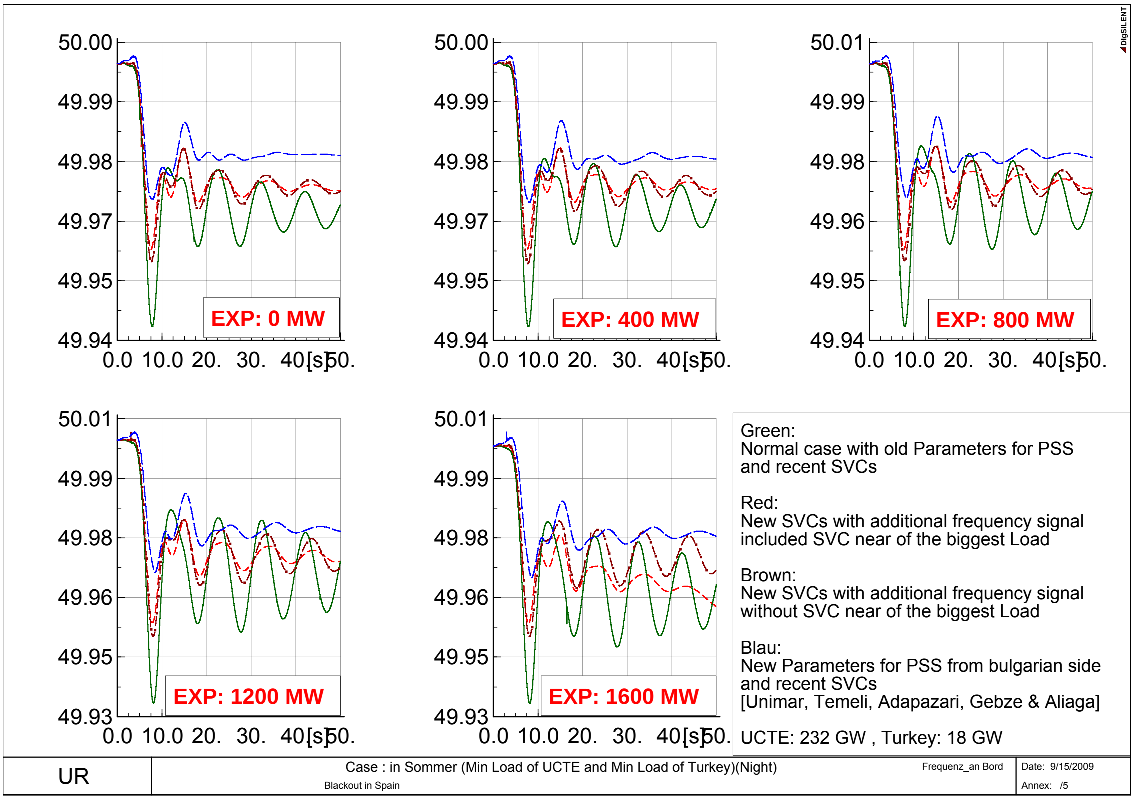

Figure 13: interconnected mode

Conclusion

All the models were created using MATLAB / SIMULINK software for Task 2 and Task3.

All the models were created using DIGSILENT software (Digital Simulation and Electrical Network calculation) for Task 4.

As a results the set of control parameters were reached taking into account:

- The requirements for UCTE,
- The Turkish system stable in island operation (30 seconds oscillations)
- The requirements peculiar to Turkish Power System before and after interconnection,
- The Turkish system stable with optimization parameters of Power System Stabilizer (PSS) of power plants (Gebze, Aliaga, Adapazari and Temelli) (7 seconds inter-area oscillations oscillations).
- By used the new Static VAR compensator (SVC) with additional frequency signal which led to the Turkish system stable.

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1. UCTE Operation Handbook – Policy 1: Load-Frequency Control - Final Version (approved by Study Committee on 19 March 2009)
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4. Policy 1 – Load-Frequency Control and Performance (Preliminary v. 1.2, draft, 03.10.2002)
5. UCTE Transmission Development Plan, Edition 2008, www.ucte.org

BIOGRAPHIES

Harald Weber was born 1954 in Heidenheim, Germany. He obtained his Ph.D. degree from University of Stuttgart in1990. He has worked in EGL Elektrizitats Gesellschaft Laufenburg AG. Currently he is a professor at the University of Rostock, Department of Electrical and Electronic Engineering and head of the Institute of Electrical Power Engineering. He is also IFAC Chairman of TC on "Power Plants and Power Systems".

Ibrahim A. Nassar (1976) was born in El-Beheria, Egypt. He received the B.Sc. and M.Sc. degrees in electrical engineering from Al Azhar University, Egypt in 1999 and 2004, respectively. Since 2001, he has been with the Power Engineering and Electrical Machines Department, Faculty of Engineering, University of Al Azhar, Egypt. He started his Ph.D. in the University of Rostock, Germany in 2007 supported by an Egyptian government scholarship.