EES-UETP
Electric Energy Systems University Enterprise Training Partnership

NTUA
Electric Energy Systems Laboratory
School of Electrical and Computer Engineering
National Technical University of Athens

Pan European Grid Advanced Simulation and State Estimation

European Commission
7th Research Framework Programme

Course on:
Optimisation and Simulation Methods For Large Power Systems

Course Organiser:
Electric Energy Systems Laboratory
School of Electrical and Computer Engineering
National Technical University of Athens

Course Coordinators: Prof. Evangelos Dialynas (NTUA)
Christian Merckx (PEGASE)

National Technical University of Athens
May 2 - 4, 2012

1. Objectives

The operational environment of modern power systems has shown an increasing degree of uncertainty due to many reasons such as intermittent renewable generation, load evolution and unforeseen topological changes in the internal/external system. In order to carry out off-line security and reliability assessment studies, it is necessary to construct realistic steady state operating points. The need for determining such steady state conditions is typically encountered when the Transmission System Operators try to identify potential problems ahead in time or root-causes of encountered problems after the facts. Because of the diversity of questions and viewpoints to be addressed, the tremendous complexity of electric power systems and the existence of a large number of nonlinear constraints, the construction of realistic steady state operating points for practical large power systems is intrinsically an extremely difficult task.

A classical Security Constrained Optimal Power Flow (SCOPF) tool can be generally used for conducting security assessment studies. This tool allows the finding of optimal settings, according to a given objective, of some control means (e.g. generators active/reactive power, transformer taps, reactive power of shunt compensation banks, start/shutdown of generators, etc.) that satisfy operational constraints (e.g. branch power flow, voltages, etc.) under pre-and post-contingency states. Besides, the SCOPF tool must model accurately special new devices like PST, HVDC and FACTS. Special emphasis is also put on the effective coordination between corrective actions and preventive actions. Furthermore, a probabilistic constrained load flow method can be applied while additional power system studies can be conducted concerning the relations between voltage stability and maximum power transfer conditions.

Power system reliability assessment studies are usually conducted by using appropriate methods that realistically simulate the system operation by taking into account all relevant features and operational practices.

The Course has been designed to provide a solid understanding of the major issues concerning the planning and operation of modern electric power systems with a substantial penetration of distributed generation, especially, from renewable energy sources. More specifically, the following topics will be addressed:

- Optimisation in decision making.
- Challenges of current Security Constrained Optimal Power Flow computations.
- Role of discrete variables in modelling aspects and their handling.
- Steady state modelling of special devices (PST, HVDC, FACTS).
- Dealing with uncertainty in day-ahead operational planning (the worst-case approach).
- Handling of huge amount of post-contingencies constraints.
- Performance issues on Pan-European network.
- Probabilistic constrained load flow method.
- Voltage stability and maximum power transfer conditions.
- Reliability and operational performance of large power systems.

This Course is intended for all technical staff, engineers and managers from electric power utilities, independent generating companies (including renewable sources), electricity regulators, system operators, industrial customers, manufacturing and consulting companies as well as educational and research institutions who deal with the planning and operation issues of modern power systems. The number of participants is limited.

2. Course Duration and Venue

- Three days from Wednesday 2nd to Friday 4th of May 2012.
- National Technical University of Athens, Multimedia Center, Central Library Building
  9, Heroon Polytechniou street, 15773 Zografou, Athens, Greece

3. Course Content

Wednesday, 2nd May 2012

09.00 – 09.30 Registration and Documentation

09.30 – 09.50 Opening Session

09.50 – 11.00 **Relability and Operational Performance of Large Power Systems** (E.N. Dialynas):

- Simulation of power system operation by considering various types of conventional generating units, cogeneration units and installations of Renewable Energy Sources (RES).
- Integration of RES high penetration level (wind parks, photovoltaic stations).

11.00 – 11.20 Coffee Break

11.20 – 12.30 **Relability and Operational Performance of Power Systems Integrating a High Penetration Level of Renewable Energy Sources** (E.N. Dialynas):

- Calculation of appropriate indices that quantify the overall reliability and operational performance of the system.
- Analysis of a typical system based on the Hellenic electric power system.

12.30 – 13.30 Lunch Break

13.30 – 15.20 **Relations Between Voltage Stability and Maximum Power Transfer Conditions** (C. Vournas):

- Maximum power transfer is defined as the solution of an optimisation problem.
- Maximum power transfer conditions coincide with voltage stability limit (static bifurcation).
- Effect of inequality conditions:
  - Generator reactive limits and excitation current limit.
  - Corner points and stability limits due to switching (limit induced bifurcations).
- Maximum Transfer and Available (Total) Transfer Capability (ATC, TTC).
- Protective measures (load shedding) based on optimisation.

15.20 – 15.40 Coffee Break

15.40 – 17.30 **Probabilistic Constrained Load Flow for Power System Optimisation** (N. Hatziargyriou):

- PLF Formulation, convolution, linear dependence between nodal powers, multiple points of linearisation.
- Probabilistic constrained load flow.
- Practical examples.

Thursday, 3rd May 2012

09:00 – 10.00 **Need More Optimisation in the Decision Making** (P. Panciatici):

- Facing new challenges: intermittency of renewable generation, difficulty to build overhead lines, optimisation through the market pushing the system to its limits.
- More uncertainties but more possible controls (PSTs, DC links, active demand).

10:00 -11:00 **Power Systems Security Management** (L. Wehenkel):

- The security management problem: From real-time control to day ahead planning of operation.
- Further expliciting the technical challenges: What are the main computational and modeling problems?
- Possible directions for progress: What are the possible avenues towards better solutions?

11.00 – 11.20 Coffee Break

11.20 – 12.30 **Presentation of the State of the Art** (A. Marano Marcolini):

- The continuous SCOPF problem.
- Handling of discrete variables in SCOPF computations.
- State of the art solvers for constrained optimisation.

12.30 – 13.30 Lunch

13.30 – 14.30 **Challenges of Current SCOPF Computations** (F. Capitanescu):

- SCOPF problem features and formulation.
- Preventive mode - Corrective mode.
- Challenges related to the problem formulation.
- Choice of a limited number of corrective actions in SCOPF.
- Handling of voltage and transient stability.
- Challenges related to the problem solution techniques.
- Approaches to reduce the problem size.
- Approaches to deal with discrete variables stemming from power system equipments modelling.

14.30 – 15.30 **Modelling Aspects (**P. Panciatici):

- Different types of discrete variables (modelling of discrete behaviours of equipment, conditional corrective actions).
- Handling of uncertainties through a worst-case approach.

15.30 – 16.00 Coffee Break

16.00 – 17.00 **Modeling Aspects** (H. Crisciu):

- Steady state modelling of special devices (PST, HVDC and FACTS):
  - Why it is important to model these special devices.
  - Modelling hypotheses and equivalent circuit diagrams.
  - Basic relations describing the operation.
  - Criterion control.
  - Implementation in Load Flow and OPF algorithms.

Friday, 4th May 2012

09:00 – 10.00 **Worst-Case Approach** (P. Panciatici, S. Fliscounakis):
- Introduction.
- Computation of worst operating scenarios:
  - Equivalence between bi-level optimisation and a MILP for DC approach.
  - Formulation of the problem.
  - Examples.

10:00 – 11.00 **Worst-case Approach** (F. Capitanescu):
- Computation of worst operating scenarios wrt contingencies:
  - Problem formulation as a nonlinear bi-level optimisation problem for AC approach.
  - Problem decomposition and solution by a heuristic approach relying on successive OPF and SCOPF-like problems.
  - Numerical examples for worst-cases wrt overloads and under-voltages.
- Computation of strategic actions to cover worst operating scenarios:
  - Problem formulation as a three level constraint satisfaction problem.
  - Solution approach by an iterative algorithm combining MILP and SCOPF with multiple base cases.
  - Numerical examples on a large system.
  - Conclusions and future works.

11:00 – 11.20 Coffee Break

11:20 – 12.30 **Handling of Discrete Variables** (P. Panciatici, S. Fliscounakis):
- Modelling of discrete behaviour of equipment.
  - Formulation of the problem.
  - Decomposition in a sequence of mixed integer non linear problems.

12:30 -13:30 Lunch

13.30 – 14.30 **Handling of Discrete Variables** (P. Panciatici, S. Fliscounakis):
- Different possible implementations : Boolean, MPEC, NRS function.
- Comparison of MINLP solvers on a small test case (interior point method, SQP).
- Results of very large system.

14.30 – 15.30 **Handling of a Huge Amount of Post-Contingencies Constraints in Security Constrained Optimisation** (H. Crisciu):
- Motivation.
- Contingencies filtering approach used to identify the binding contingencies at the optimum.
- Network compression approach used to reduce the size of the post-contingencies models.

15.30 – 16.00 Coffee Break

16.00 – 17.00 **Handling of a Huge Amount of Post-Constraints in Security Constrained Optimisation** (L. Platbrood):
- Combining the contingency filter and network compression in an iterative scheme.
- Preventive and corrective approach (PCOPF + NC peculiarities).
- Performances issues.
- Prototype demonstration.

17.00 – 17.30 **Closing Remarks – Discussion**

4. Course Instructors

Evangelos Dialynas, National Technical University of Athens (Greece)
Prof. Evangelos Dialynas received the Diploma in Electrical and Mechanical Engineering from the National Technical University of Athens (1975) and the MSc (1976) and PhD (1979) degrees in Electrical Engineering from the University of Manchester Institute of Science and Technology (UMIST) in England. He is Full Professor in electric power systems and the Director of the Electric Energy Systems Laboratory at the School of Electrical and Computer Engineering in the National Technical University of Athens. He is also the Director of the Postgraduate Programme "Energy Production and Management". His main activities are concentrated in the areas of transmission and distribution networks, interconnection links, reliability modeling and evaluation, power system probabilistic assessment, power system operation, computer applications of power systems and integration issues of renewable energy sources. In these areas of interest, during the last twenty-five years, he has taught various undergraduate and postgraduate courses as well as he has organised and participated in various seminars and tutorials.

Costas D. Vournas, National Technical University of Athens (Greece)
Prof. Costas D. Vournas received the Diploma of Electrical and Mechanical Engineering from the National Technical University of Athens (NTUA) in 1975, the M.Sc in Electrical Engineering from the University of Saskatchewan, Saskatoon, Canada in 1978, and the NTUA Doctor of Engineering degree in 1986. He is currently Professor in the Electric Energy Systems Laboratory of the School of Electrical and Computer Engineering of NTUA. He has published more than 100 papers in International Journals and Conferences and has co-authored the book "Voltage Stability of Electric Power Systems". His research interests are in the area of power system dynamics, stability and control and include voltage stability and security analysis, wind generator integration in power systems, as well as the effect of deregulation on power system operation and control.

Nikos Hatziargyriou, National Technical University of Athens (Greece)
Prof. Nikos Hatziargryriou received the Diploma in Electrical and Mechanical Engineering from the National Technical University of Athens (1976) and the MSc (1979) and PhD (1982) degrees in Electrical Engineering from the University of Manchester Institute of Science and Technology (UMIST) in England. From 1984 he is working at the Electric Power Division of the School of Electrical and Computer Engineering of the National Technical University of Athens, where he is Full Professor, since 1995. Currently, he is teaching Power System Analysis (Steady State and Transient Analysis) and Digital Techniques for Power System Analysis and Control. He has also taught Electrical Machines, Economic Power System Planning and Operation and Computer Programming techniques. His research interests are in the area of Power System Modelling, Dispersed and Renewable Generation, Load Frequency Control of the Greek system, wind power integration studies, etc. He is author of 2 books and more than 100 publications in international magazines and conference proceedings.

Patrick Panciatici, RTE (France)
Patrick Panciatici graduated from the Ecole Supérieure d'Electricité (France) in 1984. He joined EDF R&D in 1985, managing EUROSTAG project and CSVC project. He joined RTE in 2003 and participated in the creation of the department "Methods and Support". He is the head of a team which develops real time and operational planning tools for RTE and ensures operational support on the use of these tools. Member of the R&D ENTSO-E Working Group. RTE's representative in PSERC and several European projects (PEGASE, OPTIMATE, TWENTIES, etc.).

Louis Wehenkel, University of Liège (Belgium)
Louis Wehenkel graduated in Electrical Engineering (Electronics) in 1986 and received the Ph.D. degree in 1990, both from the University of Liège, where he is Full Professor of Electrical Engineering and Computer Science. His research interests lie in the fields of stochastic methods for systems and modelling, optimisation, machine learning and data mining, with applications in complex systems, in particular large scale power systems planning, operation and control, industrial process control, bioinformatics and computer vision.

Alejandro Marano Marcolini, University of Seville (Spain)
Alejandro Marano Marcolini was born in Argentina in 1977. He received the Engineering Degree form the Univerity of Malaga (Spain) in 2001 and the Ph.D. degree from the University of Seville (Spain) in 2010. He is currently an Assistant Professor at the University of Seville and a member of the Electric Power Systems research group coordinated by Prof. Antonio Gómez in the same University. He is engaged in researches involving power system optimisation and state estimation in collaboration with some of the biggest Spanish distribution companies. His primary areas of interest are voltage stability, power system control and operation and optimisation applied to power system engineering.

Florin Capitanescu, University of Liège (Belgium)
Florin Capitanescu is a research associate with the Interdisciplinary Centre for Security, Reliability and Trust (SnT) at the University of Luxembourg. He graduated in Electrical Power Engineering from the Polytechnic University of Bucharest (Romania) in 1997. He obtained the Ph.D. degree from the University of Liège (Belgium) in 2003. His main research interests lie in the field of power systems planning, operation and control. His research is particularly focussed on applications of optimisation methods in the field of power systems, in particular (security-constrained) optimal power flow and voltage stability.

Horia Crisciu, Tractebel Engineering (Belgium)
Horia Crisciu is an Electrical Engineer graduated from the Polytechnic University of Bucharest (Romania). After obtaining his Ph.D. degree in Electrical Engineering in 1982, he joined Polytechnic University of Bucharest as Professor. Since 1989, he joints the Power System Consulting group of the Energy & Industrial Solutions department of Tractebel Engineering in Belgium where he was involved as a principal expert in studies concerning EMS algorithmic, state estimation, optimisation, secondary and tertiary voltage control and reactive compensation of Belgian Power System and of power system development projects in Russia, Dubai, Vietnam, Chile, Nigeria, Egypt.

Stéphane Fliscounakis, RTE (France)
Stéphane Fliscounakis received the M.Sc. degree in Applied Mathematics from Université Paris Pierre et Marie Curie (France) and a M.Sc. degree in Industrial Automation and Control from Université Paris Sud Orsay (France). Since 1992 he works as research engineer for EDF R&D then RTE.

Ludovic Platbrood, Tractebel Engineering (Belgium)
Ludovic Platbrood was born in Belgium in 1977. He graduated as mathematician from the University of Namur (Belgium). After obtaining his Master degree in Operational Research and Applied Mathematics in 2002, he joined the Power System Consulting group of Tractebel Engineering where he is Design Engineer. His main areas of interest are optimisation, numerical analysis and numerical algebra.

5. Organisation

5.1. Course Fees

- Members of the EES-UETP: 367.50 EUR
- University non members of the EES-UETP: 900 EUR
- Industry non members of the EES-UETP: 1500 EUR

Course fees will include lectures, course aids (lectures on CDs, leaflets, brochures, etc.), coffee breaks, three lunches and a dinner in a restaurant (3rd May 2012).

An invoice will be given to each registered participant during the Course.

Payments are requested before the beginning of the Course.

5.2 Payment details

(a) By Bank Remittance (indicating the Participant name):

NATIONAL BANK OF GREECE SA
38 Stadiou Steet, 10564 Athens, GREECE
Account No. 080545098-59
IBAN: GR4801100800000008054509859
Swift Code: ETHNGRAA
Account holder: National Technical University of Athens

Note:
Participants must provide to course Secretariat the proof of course fees bank payment (i.e. invoice) by fax not later than 1 week before the starting date of the Course.

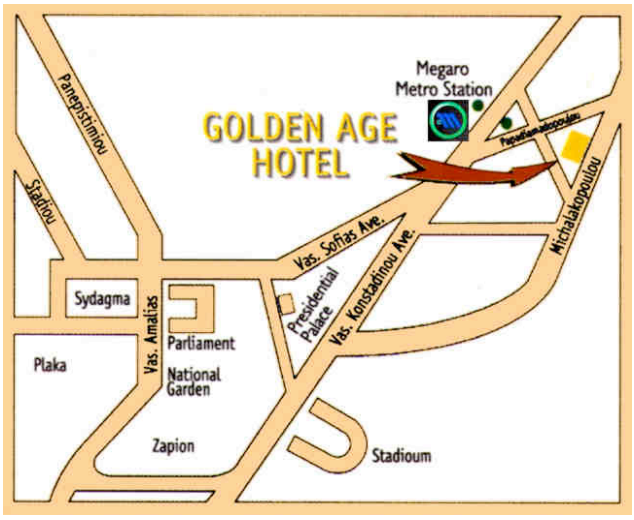
(b) By Credit Cards:

Please, complete the relevant information as described in the Registration Form.

6. Accommodation

Recommended Hotels

Golden Age Hotel (Highly Recommended)



Address : 57, Michalakopoulou, Athens
Tel. : +30 210 7240861 – 9
Fax : +30 210 7213965
e-mail : goldenage@ath.forthnet.gr
Correspond. Ms Dokopoulou

Metro Station: Close to Metro Station MEGARO MOUSSIKIS

Room Rates:

Single room: 90 €/day, double room: 100 €/day, Breakfast and taxes are included in the above prices.

Reservation by Tel. or Fax or e-mail:

Mention National Technical University of Athens for the above prices.
Password: NTUA Course

Web: http://www.goldenage.gr

Hotel : AMALIA
Address : 10, Amalias ave. Syntagma sq., Athens
Tel. : +30 210 6072000
Fax : +30 210 6072135
e-mail: reservations@amaliahotels.com
Correspond. Ms Nika

Metro Station: Very close to Metro Station SYNTAGMA

Room rates : Single (standard):110 €/day, Double (standard):120 €/day
Breakfast and taxes are included in the above prices.

Reservation by Tel. or Fax or e-mail:

Mention National Technical University of Athens for the above prices.
Password: NTUA Course

Hotel : ELECTRA
Address : 5, Ermou str., Syntagma sq., Athens
Tel. : +30 210 3370097
Fax : +30 210 3220310
e-mail: **olga@electrahotels.gr**
Correspond. Ms Mantopoulou

Metro Station: Very close to Metro Station SYNTAGMA

Room rates : Single: 100 €/day, Double: 115 €/day.
Breakfast and taxes are included in the above prices.
Reservation by Tel. or Fax or e-mail:

Mention National Technical University of Athens for the above prices.
Password: NTUA-Course

Hotel : ARETHUSA
Address : 6 – 8 Mitropoleos & 12 Nikis str., Syntagma sq., Athens
Tel. : +30 210 3229431
Fax : +30 210 3229439
e-mail: **arethusa@arethusahotel.gr**
Correspond. Ms Nikolopoulou

Metro Station: Very close to Metro Station SYNTAGMA

Room rates : Single: 50 €/day, Double: 70 €/day.
Breakfast and taxes are included in the above prices.
Reservation by Tel. or Fax or e-mail:

Mention National Technical University of Athens for the above prices.
Password: NTUA-Course

Please make sure to book your rooms in due time.

7. Travel Information

7.1. How to get to the NTUA Campus in Zografou

The Course will take place in the Multimedia Center of the CENTRAL LIBRARY Building in the Campus of the National Technical University of Athens, 9 Heroon Polytechniou street, Zografou, Athens.

(a) For participants staying at the Golden Age hotel: Transportation by bus will be organised for all the days of the Course (in the morning and at the end of the lectures).

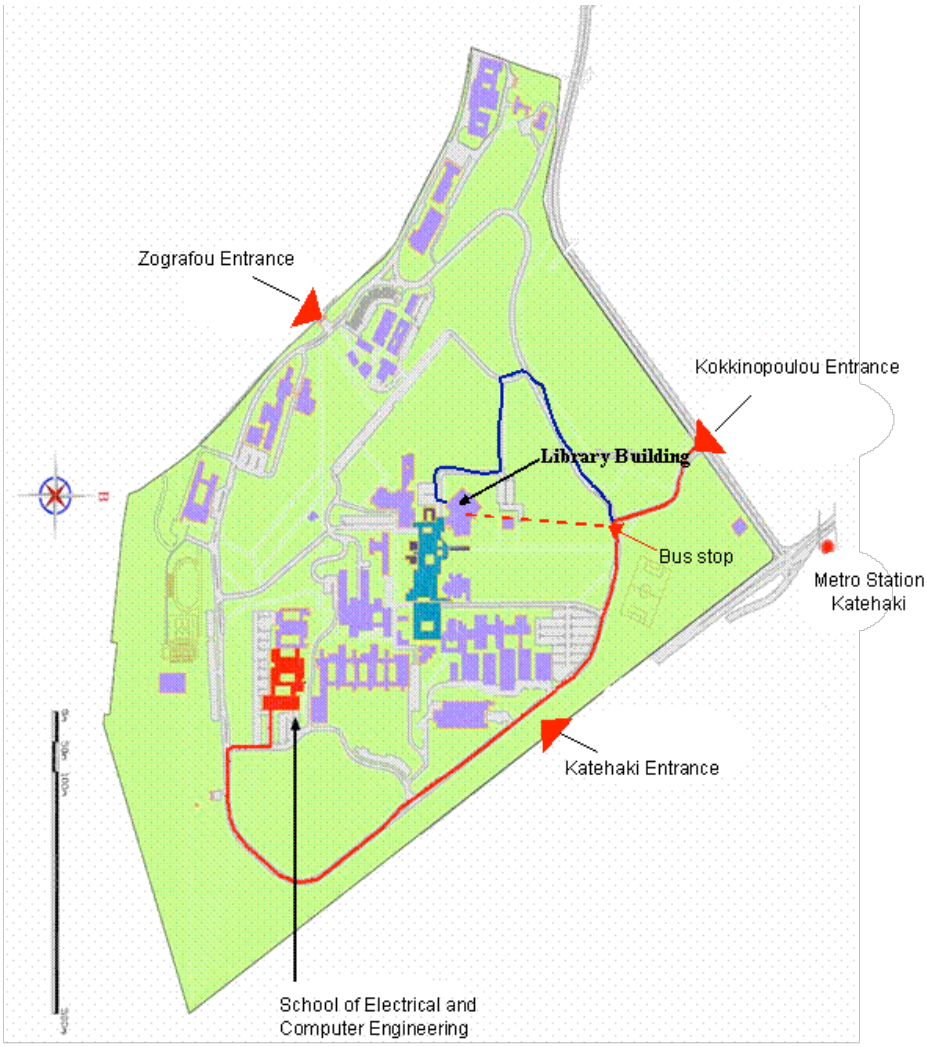
(b) For the remaining participants using public transportation:
Take Metro line EGALEO - DOUKISSIS PLAKENTIAS and arrive at metro station "KATEHAKI". Take bus line 242 to NTUA Campus from the stop just outside the exit of the station and get off at bus stop "THIRORIO" inside the Campus.

If you experience any problems when you are inside the NTUA Campus, please do not hesitate to call Prof. E. Dialynas (office: +210-7723692, mob. 6945933019) or Eleni Avlonitou (office: 210-7723696 mob. 6944184866).

7.2. Other Information

The Athens International Airport "Eleftherios Venizelos" is located in Spata, 27 km southeastern of Athens. It can be rapidly accessed via a six-lane motorway and public transport. An express airport bus can be used on a 24 hours basis. The airport is also accessible via Metro line "EGALEO – Athens International Airport".

Additional information about the airport express lines can be found at http://www.aia.gr.



8. Contacts

Executive: Prof. Evangelos Dialynas
National Technical University of Athens
School of Electrical and Computer Engineering
Electric Energy Systems Laboratory
Phone: +30-210 7723692
Fax: +30-210 7723968
Email: dialynas@power.ece.ntua.gr

Secretariat: Ms. Eleni Avlonitou
National Technical Univesity of Athens
School of Electrical and Computer Engineering
Electric Energy Systems Laboratory
Phone: +30-210 7723699, Fax: +30-210 7723968
e-mail: eavlon@power.ece.ntua.gr

EES-UETP (Electric Energy Systems – University Enterprise Training Partnership)
Web-page: http://www.ees-uetp.com

9. Registration Form of Participants

Please send the following form to the Secretariat

Name	
Surname	
Company Name	
Participant Position	
Participant Main Activity	
Address	
Phone	
Fax	
E-mail	
Main Activity of the Company	
Registration FEES	EURO
VAT No. (for which the invoice will be issued)	**Company VAT No. ……**
	Participant VAT No. ……..

Payment by Credit Card:

Please, complete the relevant information as described below (note that if we receive incomplete or wrong data of the credit card, the registration can not be processed)

I authorise **ICCS-NTUA** to debit my Credit Card for the total amount of registration fees indicated above.

VISA ☐ MASTERCARD ☐

Credit Card Number: ☐☐☐☐ – ☐☐☐☐ – ☐☐☐☐ – ☐☐☐☐

Expiration Date: ____/____

Name as it appears on Credit Card: _____

Please give the three last numbers written on the opposite side of your credit card (signature window) ☐☐☐

I agree with the above Conditions

Signature _____ **Date: ____/____/____**