Power Engineering Education using NEPLAN software

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Abstract- **Many electrical and power systems engineering laboratories must be virtual ones, because practical experiences cannot be performed on a HV transmission system and some of the equipments required are often expensive. Since 2002, the Electrical Engineering Department from "Petru Maior" University of Tg.Mureş has incorporated into its curriculum computer aided design and analysis with the aim to enhance the students' theoretical understanding and develop power engineering practical skills. The paper describes the authors experience in the assessment of laboratory activities based on NEPLAN software used extensively for the Power Systems Course at "Petru Maior" University of Tg.Mureş : the main capabilities, features and benefits of this professional software for education process and research activities. Finally, the paper highlights the future works and concerns of our Power Systems Group to develop the practical advantages of one of the most successful power system software – NEPLAN .**

I. INTRODUCTION

In order to assure and promote the quality in higher education, a significant care of academic staff was the updating the practical activities (laboratories and project work classes) of students. The Electrical Engineering Department of "Petru Maior" University has made efforts to provide to students and researchers simulation tools that cover different aspects of electric power system analysis. Two of advanced and professional software packages are using currently by our Power System Group: NEPLAN (since 2002) and EDSA (since 2006).

The basic aim of computer-based simulation for power system analysis is reproducing real phenomena through computer-based simulations as an efficient solution for didactic and research purposes.

To provide an unitary education in electric power engineering, there are uniform standards elaborated by Romanian Agency for Quality Assurance in Higher Education and international power engineering committee (i.e. Power Engineering Education Committee) which has been charged with coordinating the Electric Power Engineering Curricula. In this respect, in most cases a similar contents of Power System Courses are developed in Romanian and abroad universities.

At the Faculty of Engineering from "Petru Maior" University of Tg.Mureş over 1100 students attend 8 Bachelor Degree and 5 Master Degree and post-graduate studies programs. In this frame, the Power Engineering bachelor program and Energy Systems Management master program has enjoyed continuous development.

II. POWER SYSTEMS COURSE AND LABORATORY – SUBJECT AND CONTENTS

A. Power System course

The Power Systems Course (PSC) deals with basic models and methods that are used in analysis of the electric power systems. The models and methods are fairly general and can be applied to a power system of any scale ranging from a small-scale distribution grid to a national transmission network. For bachelor degree program, this is intended to be a basic course covering modeling, analysis, operation and control techniques in power generation and transmission networks. The course consists of two main parts (PSC I and PSC II) corresponding of two semester of didactic activities and includes 28 lectures (56h).

PSC I discusses the general considerations, modeling and steady state analysis techniques of power systems:

1) General considerations about modern power systems. Power Systems evolution, structure, requirements and design.
2) Electric power system equipments parameters and modeling. AC Transmission System. Synchronous machine theory. Power system loads.
3) Power Flow Analysis. Performance methods for power flow studies.
4) Power and energy losses in electric power systems.
5) State estimation of electric power systems.

PSC II covers the topics about operation, control and stability performance methods:

6) Steady-state optimization (Optimal Power Flow).
7) Power system control. Reactive power and voltage control. Active power and frequency control.
8) Unsymmetrical conditions in power systems. Faults Analysis.
9) Power system stability. Small-signal stability. Transient stability.

To pass the course or to receive a higher grade there are some well-established criteria. The students should demonstrate that they are able to: describe how a power system is designed and operated; explain and detail the power system static parameters, mathematical models and equivalent diagrams of different power system elements; perform load flow calculations with the help of Seidel-Gauss and Newton-Raphson methods; analyze the results obtained in the load flow calculations; describe the measures to reduce the energy loses and efficiency assessment in electric networks ; present the reactive power/voltage control principles, methods and devices; perform analysis of power system under unsymmetrical conditions; present the models and methods for the analysis of power system static and transient stability.

B. Power System laboratory and project work

The Power Systems laboratories for Bachelor Degree programs are focused currently in using NEPLAN commercial software for power system education to provide to students the ability to build models, perform calculations and analyses the results of different applications. The practice activities (laboratories and project work classes) include 42 hours.

It is known that for several years the basic tools for almost of power systems software have been power-flow analysis and short-circuit analysis. In the last decade, personal computers have made it possible to perform additional calculation modules: time domain simulations (e.g. transient stability), optimal power flow, reliability analysis, small-signal stability, voltage stability. In recent years, the worldwide deregulation of electricity markets has strongly stimulated the investigation of complex mathematical programming problems involving innovative power network models and innovative market clearing procedures.

The main topics of the Power System laboratory and project works that the Bachelor students have to cover are the following:

1) A general overview of power systems design and analysis software NEPLAN: particularities, main features and capabilities. Graphical interface highlighting.

2) Power system static components (AC line, transformers and static loads) parameters and modeling.

3) Power system dynamic (synchronous generators, asynchronous motors) components parameters and modeling. Power system shunt control and compensation devices.

4) Power system networks on-line diagram building and managing tools in NEPLAN. Applications for two power system test model (5 and IEEE 14 buses).

5) Power flow analysis of power system. Models and performance methods (Newton- Raphson). Results interpretations and comments. Application for a small (5 buses) and complex network test (IEEE 30 buses or IEEE 39 buses).

6) Power system steady-state optimization. Performance methods in real/reactive power losses and voltage level optimization. 8 buses network test application.

7) Voltage control and reactive power control. Series and shunt compensating device. Test system application.

8) Unsymmetrical conditions analysis. Test system application.

9) Small-signal stability analysis.

10) Transient stability analysis. Results, analyzes and comments.

For Master Degree program and research activities there are other applications which are developed e.g. Reliability Analysis, FACTS devices modeling and simulation, Voltage stability analysis, Load flow with load profiles.

III. COMPUTER METHODS AND SOFTWARE IN POWER SYSTEM ENGINEERING

The importance of simulation in power system engineering can be seen in the variety of simulation tools there are available in various forms and brands around the power engineering academic/research centers, electrical utilities, industries and companies.

Software packages for power system analysis can be divided into two classes of tools:

A. Commercial software

These tools represent a conventional and an attractive option for education process due the many advantages of using it. These software packages are created and developed by important research or electric utilities companies, are well-know in a concurrent market, typically well-tested, computationally efficient but don’t allow changing the source code or adding new algorithms. For students, represents a favorable opportunity to meet and use these well-known packages. At the same time, it is becoming increasingly important that system operators have efficient computational tools and software for accurately model and analysis. Reference [1] presents an extended overview of most illustrative power engineering software (NEPLAN, EDSA, EUROSTAG, CYME, ETAP, PSS/E).

B. Educational software

Educational/research software are created and used mainly in universities or research institutions. For educational activities, the flexibility and open-source characteristics are more important aspects than computational efficiency [2]. These aspects correspond to the main advantages of these tools which can be a valid alternative to commercial software for power engineering education. In the last decade, several high-scientific languages, such as MATLAB, have become very popular for research and educational purpose (e.g. PSAT). At this aim, there is a variety of open source educational tools. Most of them are oriented to a specific aspect (application) of power system analysis and usually coexists together with the first class of tool. A very argued paper relating competition commercial versus educational software in power engineering education is [2].

IV. NEPLAN SOFTWARE IMPLEMENTATION FOR POWER SYSTEMS LABORATORY

NEPLAN is a power system software applied worldwide for network planning, modeling and analysis. NEPLAN is used in more then 80 countries by more then 600 companies, such as small and large electrical utilities, industries and universities.

"Petru Maior" University of Tg.Mureş through the Power System Group and Energy Systems Research Centre became the first research and education institute in Romania which used NEPLAN software in 2002. Recently, due to a fruitful partnership with BCP team, the latest 5.3.5 version of NEPLAN and the university student version for students education are implemented for the Power System Laboratory.

Tracking the course content in a logic way, the Power Systems laboratories and project works focuses on modeling, simulation an analysis on computers, which represent a very efficient method for obtaining experience and enhance skills with power system. The recent availability of NEPLAN 5.3. and the university version for students, with advanced features and friendly interface permit an excellent practice–oriented work for each power system engineering phase and has plenty possibilities to enter graphically all the power systems elements, various analysis tools and flexibility.

Some features and modules of NEPLAN software are performed also at the appropriate courses for (e.g. Electric Networks, Reliability of power systems, Protection Systems, Power Quality).

NEPLAN permits to define, develop and manage the power systems elements, data, library and graphics. The main elements used currently in educational process for network design and applications are:

1) *Transmission network elements*: AC and DC transmission lines, two, three or four windings transformers, buses;
2) *Classic compensating and Voltage Control devices*: shunt capacitors, series capacitors, shunt reactors, synchronous condensers, regulating transformers such as tap-changing transformers;
3) *FACTS devices*: Controlled static VAR compensators SVC, Static Compensators STATCOM, Thyristor Controlled Series Capacitors TCSC, United Power Flow Controller UPFC, Phase Shift Transformer PST;
4) *Generating Units Controls devices*: Generators, Excitation system, Automatic Voltage Regulator AVR, Power System Stabilizer PSS;
5) *Power System Loads*: static loads, induction motors and load models parameters.

The Power System Group developed a set of theoretical descriptions, modules, practical exercises and case studies, which allow students to become familiar with NEPLAN. The main applications, features and contents which has currently available for Bachelor Degree and Master Degree programs are:

1) *Graphic User Interface*: The main toolbars and work menus; network input and representation; elements and symbol libraries.
2) *Elements parameters and modeling*: Power system static elements; Power system dynamic elements.
3) *Load Flow analysis*. The load flow analysis calculate the steady state buses voltage (magnitude and angle), branch currents, real and reactive power flows and losses: calculation parameters; setting of reference values; result representation in single line diagram and tables; limits control and change of buses type; automatic tap-changer of transformers; area interchange schedule; calculation of sensitivities of active power losses; contingency analysis.
4) *Short circuit calculation*: calculation parameters; short circuit between different voltage levels; calculation of extreme short circuit currents ; results representation on single-line diagram and tables.
5) *Optimal Power Flow*: control variables; limits and constraints; objective functions.
6) *Small-signal stability analysis*: eigenvalues analysis of power systems; computation and plotting of eigenvalues, eigenvectors, mode shapes, participation factors for eigenvalues and state variables.

V. CONCLUSIONS AND FUTURE WORKS

This paper presents the authors' experience in the assessment of laboratory activities based on a professional software package for power system analysis used for educational process at "Petru Maior" University of Tg.Mureş.

The Power System Group intends to deal with the new modules and applications using NEPLAN software: Harmonic Analysis, Transient Stability, Distributed Generation, Wind power applications, Reliability Centered Maintenance.

REFERENCES

[1] D. Bică, "Moderns Informatics Systems in Power Engineering. Models and applications in NEPLAN software", *Petru Maior University Publishing House*, Tg.Mureş, 2005, pp. 127-159.

[2] F. Milano, "An Open Source Power System Analysis Toolbox", *IEEE Transactions on Power Systems*, vol. 20, no. 3, pp.1199-1206, August 2005.

[3] D.Bică, "Performant software in Power Engineering Education", *Proceedings of Romanian National Symposium on Electrotechnics*, Bucharest, October 2007, pp.231-234.

[4] Power Engineering Society, Power Engineering Education Committee, "Electric Power Engineering Curricula content in the 21st century" *IEEE Transactions on Power Systems*, vol. 9, no. 3, pp.745-756, August 1994.

[5] BCP Busarello+Cott+Partner Inc., NEPLAN Planning and optimization system for electrical network, http://www.neplan.ch.