ROLE OF NON-COMMERCIAL SOFTWARE IN UNDERGRADUATE ELECTRIC ENERGY SYSTEMS PROGRAMMES

Federico Milano[1], Luigi Vanfretti[2]
[1]*School of Electrical and Electronic Engineering, University College Dublin (IRELAND)*
[2]*KTH Royal Institute of Technology (SWEDEN),* [2]*Statnett SF (NORWAY)*

Abstract

This paper describes the potential and challenges of open-source non-commercial software tools for undergraduate electric energy systems programmes, and their impact on student's potential work opportunities. This paper also describes how different academic traditions have an impact on the choice of educational software, and how that has repercussions on the students' learning and the learning outcomes of programme modules. The matter presented in the paper is based on the authors' experience as both developers of open-source software tools, as PhD students and lecturers with several universities.

Keywords: Open source software, proprietary software, electrical energy systems, electrical engineering education.

1 INTRODUCTION

During the assessment of an electrical energy programme, the result of using non-commercial software in different programme courses (i.e. modules) is put into an uninformed scrutiny. This scrutiny arises when non-commercial open-source software (OSS) is used in technical courses such as Power System Analysis, Power System Design and Power System Control. The main argument in such an uninformed scrutiny concerns the usefulness and adequacy of these tools with respect to standard proprietary (and costly) standard *de facto* tools. This paper aims to provide a meaningful answer to this frequently asked question, and to describe the background that originates such enquire, which is peculiar of the power systems community and is, virtually, absent in other scientific and technical areas of knowledge.

The authors have more than one decade experience in teaching power systems modules, and in developing open-source software tools for research and educational purposes. A comprehensive discussion on the achievements in the topic can be found in [1-7]. These references focus mainly on the impact of open source software tools on the education of engineering students with a major in electrical energy systems. In this vein, the lifetime learning value enabled by open-source software tools is discussed in [8]. The papers cited above focus on how the students react and how their learning is influenced by the use of open-source software tools. However, a relevant point that has not been discussed so far is: how do both academia and industry perceive the usage of open-source software?

Based on the experience matured in different academic environments, namely Italy, Canada, Spain, Ireland, Guatemala, United States of America, and Sweden; as well as the authors activities within the IEEE society and several industry collaborations, the authors have been able to determine that the perception of the open-source software for education varies considerably depending on the country and, hence, the academic tradition. This has a relevant impact on education and, in turn, on the opportunities that the students have to enter into the work market after obtaining a degree in electrical energy systems.

The contributions of the paper are as follows. On one hand, the paper describes the features, in terms of educational value, of commercial and non-commercial software tools for power system analysis. These features are discussed and compared in an unprejudiced manner. Then, the paper provides an overview of the aspects that are considered more important for each institution where the authors have studied and worked. The paper also describes the first author's experience obtained from the maintenance of the web forum dedicated to the PSAT project [9], as well as the authors' formal roles in the leadership of the IEEE Task Force on Open Source Software [10]. The main outcome is a *mapping* of how the value of commercial and non-commercial software tools for power system analysis are perceived within academia. The same exercise is repeated considering the viewpoint of practitioners and system operators, which are among the potential employers of the graduates in electrical energy system programmes.

The paper is organized as follows. Section 2 recalls the definitions of software categories while Section 3 provides a brief overview of software tools for power system analysis. This section explains the reasons why power system software tools are currently a proprietary *de facto* oligopoly. Section 4 describes the state of the art of OSS for power system analysis and the ongoing activities related to OSS in the IEEE Power and Energy Society. Section 5 discusses the role and the perception of OSS on power system analysis at the university and industry. The authors' experience with moderating the PSAT Forum as well as in the leadership of the IEEE Task Force on OSS are also discussed in this section. Finally, Section 6 draws relevant conclusions and outlines future work directions.

2 SOFTWARE CATEGORIES AND DEFINITIONS

This section briefly recalls the main categories into which software can be divided. Definitions are provided here to familiarize the reader with concepts that are used in the following sections of the paper. The interested reader can find more details on software paradigms, with particular regard to power system analysis, in [11] and references therein.

Software can be divided into three categories based on the development paradigm: Proprietary Software, Open Source Software (OSS), and Free Software (FS). Commonly accepted definitions are given below.

Proprietary Software is the term used to refer to software that has restrictions for its use, modification and, more importantly, restrictions on copying, distributing, and publishing unmodified or modified versions of it. The restrictions are defined by the owners of the intellectual property of the software and are detailed in the software license. Proprietary software is also referred as commercial, non-open, or non-free software. Sometimes these terms are considered derogatory, which is actually unintended, due to the fact that terms like freedom and openness are more appealing than their opposites. In [12], the term ‘closed software’ has been coined to refer to all this type of software and avoid the derogatory misunderstanding.

Open Source Software permits anyone, anywhere and for any purpose to copy, modify, and distribute the software for free or for a fee. Therefore, anyone has to have full access to the source code. OSS is commonly developed in a public a cooperative manner. However, there exist certain specific limitations that described in the software’s license. The Open Source Initiative (OSI) maintains a list of licenses that comply with OSI’s OSS definition.[1]

Free Software is software that can be used, studied, and modified without restriction. The term “free software” was coined by Richard Stallman who founded the Free Software Foundation, its formally defined by the Free Software Definition [13]. One of the most important instances of the definition is that software can be copied and distributed in modified or unmodified form. Restrictions may be used only to ensure that future recipients of the software are guaranteed to copy, study, modify and distribute the software (this is the main difference with respect to OSS). Moreover, the source code of the software must be made available, and it may be accompanied by a software license. The license should state that the copyright holder permits these acts, or alternatively that the software can be released into public domain so that the rights mentioned above automatically hold. It is customary to explain the FS concept by saying that the idea is not that the software should be free “as in beer”, or available at no charge, but that it should be free “as in speech”, so that the software can be reviewed and modified. Often, FS and OSS are merged together thus leading to free and open-source software (FOSS).

3 BRIEF OVERVIEW OF SOFTWARE TOOLS FOR POWER SYSTEM ANALYSIS

The current situation of power system engineering software tools is the following. On one side, there are a few proprietary tools that are commonly accepted as state-of-the-art or standard *de facto* by both power system companies and academic research groups. On the other side, there is a number of open-source and/or free research and/or education-oriented projects, which are developed by a individuals or small teams. Such tools are typically oriented to solve specific technical or mathematical problems that are not covered by proprietary tools.

[1] http://opensource.org/osd

There are very few open-source tools that are considered “mature" products by the power system community, being OpenDSS a relevant exception [14]. Although this situation is commonly accepted as the “natural order of things" by the power system community, in other scientific areas this situation is drastically different. For example, physicists have at their disposal well-assessed open source tools developed and accepted as standards by a wide community of experts. In fact, the importance of OSS for this field can be evidenced by the creation of dedicated projects such as Open Source Physics sponsored by the National Science Foundation to spread the use and maintain key tools used in numerical simulations [15].

In the early age of computers, practically all software code was open source *de facto* and was freely shared among experts of the same area. To a large extent, back in the 70s, all scientific communities were in the same condition. Unfortunately, in the specific case of the power systems community, proprietary software companies eventually imposed their products and did not leave much space for open source and/or free solutions. The main reason for that is likely the fact that the potential market for power system software tools is relatively small and composed of few powerful companies (at least until the world-wide deregulation process of the beginning of the 21th century). So, the expertise concentrated in relatively few groups of people that developed the commercial tools commonly in use.

The role of universities and research laboratories in this process is twofold: (i) to collaborate with the developers of proprietary software under strict confidentiality agreements or (ii) to develop in-house computational tools aimed to solve specific unconventional problems or to implement novel analytical techniques. Both activities are perfectly reasonable but, clearly, have not promoted at all the development of free and open source alternatives to proprietary solutions.

Another trend that has in recent years characterized important software operations is the release of traditionally proprietary software tools as open source (e.g., Java by Sun Microsystems). This trend is almost totally extraneous to the power system community (again, OpenDSS by EPRI is the only noticeable exception).

4 OPEN SOURCE SOFTWARE FOR POWER SYSTEM ANALYSIS

Remarkable efforts have been made by the academic community to provide educational software for teaching power system topics. However, most available tools do not fully apply the FOSS rules and present at least one of the following deficiencies: (i) a lack of wide distribution of the software, (ii) access to the source code of the software, (iii) a community of users, (iv) a comprehensive documentation, and (v) the distribution of the software with some kind of license that allows freely modifying and redistributing the code.

To better promote the diffusion of FOSS among power system practitioners, the IEEE Task Force on Open Source Software was created in 2007 and chaired by the first author. This TF explores the potential of OSS in the Power Engineering Society (PES) [10]. The mission of the Task Force is twofold: (i) to diffuse the philosophy of OSS in the power systems community; and (ii) promote OSS for the benefit of the PES ranging all the way from simple pedagogical OSS to commercial-grade OSS. A list of most relevant OSS projects are listed on the TF website along with a brief description of the software purposes, main developers and links to project websites. An overview of some of these tools is also provided in [11]. Among these it is worth citing, UWPFLOW [16], MatPower [17], PSAT [18] and OpenDSS [14].

For the purposes of this paper, the power systems community is divided into two areas: the Education and R&D area, which refers to academia and research & development groups within national laboratories; and the Power Business, which refers to power system analysis software developers, power utilities, system operators, etc.

4.1 FOSS in Education and R&D

In the area of Education the FOSS approach has proved to be successful for teaching power system analysis. References [3], [5] and [6] show that teaching using a FOSS can be effective and is well received by students. An example of the use of FOSS for research is given in [7], which reflects PSAT users' experience in this field. FOSS is commonly exploited and developed in the R&D sections of most U.S. National laboratories. For example, Dome [2] is being used at the Los Alamos National Laboratory, whereas the Pacific Northwest National Laboratory has developed the GRIDLAB-D [19] simulation software as a part of the Gridwise Project [20]. GRIDLAB-D is open source and incorporates novel modelling techniques and high-performance algorithms for power system analysis.

The Oak Ridge National Lab has developed a successful application that enables simulation of hybrid systems [21]. This is an example on how interdisciplinary research (in this case, computer networks and power systems) takes full advantage of FOSS, which is able to provide the required flexibility and scalability for new modelling and simulation needs.

4.2 FOSS and the Power Business

Currently the main developers of power system analysis software have adopted the proprietary development model, e.g., Siemens PTI, PowerWorld, GEPSLF, CYME, Neplan, Simpow, Eurostag. In the power system analysis community the *scripting* and *user defined modelling* features in proprietary software have often been misinterpreted as a sort of *open* feature of these type of software. However, proprietary software companies are the only ones that can make changes or enhancements to the core software, they will charge for the end product as well as for the support, and the infringement of the software license is punishable by law.

The FOSS development method offers an alternative where small or big companies can charge for the support services of maintaining, modifying and improving software. This opens the service market for small software maintainers, and at the same time can trigger competition among these companies and the proprietary software counterparts. FOSS can be also a medium of publicity for a company. The example of OpenDSS, which is an EPRI product, is promising. Companies developing power system analysis software interested in investigating the different business and economic models for FOSS are referred to Part IV of [22].

A frequent question raised by professionals in the power business is: Apart from research and development, to what extent can the power business take advantage of FOSS? Actually, the potential is huge and FOSS could reshape the entire power business as it is known. Most professionals are likely already taking benefits from FOSS without realizing it. In [23], KEMA analysed in which way the OSS approach can be used for energy solutions at different levels of the Service-Oriented Architecture. The number of opportunities is overwhelming and exciting, especially in the emerging field of smart grid applications. Interesting descriptions of applying OSS to numerous fields of enterprises can be found at [24] and [25].

5 ROLE AND PERCEPTION OF FOSS FOR POWER SYSTEM ANALYSIS

This section discusses the experience of the authors in several universities as well as members of the IEEE Power and Energy Society and chairs of the IEEE Task Force on Open Source Software. The experience of the first author as developer of the software tool PSAT is also included in this section. In particular, the section discusses the feedback obtained through web forum dedicated to PSAT users and the impact that such a tool have on industry collaborations.

5.1 Experience at University of Genoa, Italy

The first author obtained his Master and PhD degree in Electrical Engineering at University of Genoa (UNIGE), in 1999 and 2003, respectively. He has thus experienced the role of software as both an undergraduate and research student.

For undergraduate modules, the Electrical Engineering programme at UNIGE does not impose any particular software tool. Matlab and Simulink are the most common tools used by the students to carry out laboratory activities. Lecturers and/or the TAs provide in-house made Simulink models of electrical machines and power devices and ask the students to implement given control schemes or to determine the dynamic response of such models after given events and disturbances. For example, a lab activity of the module on Power System Analysis consists in determining the time response of a synchronous machine following a three-phase short-circuit a the stator terminal bus.

Graduate students use proprietary software tools, such as Cyme or PowerFactory or, again, Matlab, depending on their needs. There is no particular interest in developing any in-house “product”, nor to provide on-line the tools developed for education or research purposes. The concept of OSS is considered irrelevant for research or education; and the development of such projects is not only unsupported, but may also be frustrated. Moreover, the dominant operating system is Windows, which is a clear indication of a lack of interest for OSS. Such aptitude is likely a consequence of the strong impact that the long term collaboration with CESI (formerly ENEL Research) has had on the research group.

The power system division of CESI, formerly ENEL Research, develops and maintains its own tools (e.g., LEGO code) and is not particularly interested in either third party proprietary or open source solutions. This neutral posture with respect to software tools reflects on education, as neither lecturer nor practitioner consider relevant that student has any particular experience with common proprietary tools for power system analysis. Programming skills and experience are certainly positively considered but OSS projects are classified as unnecessary and generally ignored.

This scenario is quite common in Electrical Engineering Departments in Italy, although there are noteworthy exceptions. For example, it is relevant to cite the in-house stability analysis tools developed by Massimo La Scala at Politecnico di Bari [26]. This tool is not publicly distributed but is used and maintained by La Scala's research group and constitutes a valuable milestone of the department. However, this exception and other similar ones (as in the case of PSAT), are a consequence of the sojourns of the Italian lecturer in North American institutions, and not a product of the academic tradition of power system research groups of Italian universities.

5.2 Experience at University of Waterloo, Canada

While pursuing his PhD degree at University of Genoa, the first author was a Visiting Scholar at University of Waterloo, Ontario, from 2001 to 2002. During this period he was introduced to the Red Hat Linux chapter and learned about Unix and Linux systems, as well as OSS projects. The research group of Claudio Cañizares is popular for the software tools that has developed and provided free of charge on the group's website. UWPFLOW and SRLS are excellent examples of this continuous effort to divulgate computational tools for power system stability analysis (see uwaterloo.ca/power-energy-systems-group/downloads/).

In this environment, it was natural for the author to develop PSAT, which has become a quite popular tool for power system stability and optimal power flow analysis [4, 5]. PSAT was first posted on line on the website of the EECE of University of Waterloo and warmly encouraged by Prof. Cañizares. On the other hand, note that PSAT has been fully ignored by University of Genoa, which has thus lost the opportunity to publicize and exploit the research emerging from the development and use of PSAT.

Undergraduate as well as graduate students at University of Waterloo are encouraged to develop their own tools. Of course proprietary software tools for power system analysis are available and used for undergraduate labs. However, since most research focuses on the development of novel models and techniques for the stability analysis of power systems, proprietary tools are generally deemed inadequate. The knowledge of a particular proprietary package is not considered a key skill of either undergraduate or graduate students. It is relevant to note that several important industries that develop software tools for power system analysis are located in Canada (e.g., PSCAD and Powertech). Hence, good programming skills are much more appreciated than the knowledge of a specific tool.

The proactive aptitude towards open source software has its roots in the North American culture. The concept itself of OSS and FS were born at MIT in United States (see also Richard Stallman and Free Software Foundation). OSS is considered an opportunity and happily coexists with proprietary solutions.

5.3 Experience at University of Castilla-La Mancha, Spain

The first author was with University of Castilla-La Mancha (UCLM) for almost ten years, starting from September 2013. During this period, he taught almost all modules of the Industrial Engineering programme but in particular, Electrical Machines, Power System Analysis at the undergraduate level, and Power System Stability at the graduate level.

The power system research environment at UCLM was particularly oriented towards optimization techniques for electricity markets, state estimation and stability analysis. This heavily reflected in both undergraduate and graduate modules. The only proprietary power system tool used within the group was PowerWorld, which was used only for demonstrative purposes in some undergraduate courses. Other modules used GAMS, which is a general purpose language for solving optimization problems, or PSAT for the modules offered by the first author. It should also be noted that until 2012, there was no specific Electrical Engineering programme in Spain and power system modules were part of the Industrial Engineering programme, hence the number of modules dedicated to power system topics was limited.

The strong research orientation of the group did not put any relevance on the usage or the teaching of proprietary tools for power system analysis and this was not perceived as a drawback by industry (the vast majority of EE students were employed by the Spanish ISO). Other Spanish groups are more oriented to consulting activities and, for this reason, the use of proprietary software such as PSS/E is needed, but this was not major drawback of the groups at UCLM. The average quality of graduate students in Electric Power Systems, in particular at the PhD level, at least until the end of 2013, at UCLM was well known by Spanish industries (the TSO in particular) and this was considered way more important than the knowledge of a specific power system software tool.

In general the aptitude of Spanish universities towards software tool is quite pragmatic. Most industries requires specific proprietary software tools, more often than not, because of the warranty that comes with such tools. So, research groups adapt to industry requirements. However, the use of proprietary tools for undergraduate modules is not common. On the other hand, the development of software projects, such as PSAT, is not impeded. The first author had the chance to use PSAT for most undergraduate modules he has offered at UCLM [5, 6] as well as for the supervision of final BE projects [1], with mixed results. In general, however, the OSS paradigm is not particularly relevant in Spain and the aptitude of both academia and industry is, at least for what concerns power system analysis tools, quite neutral.

5.4 Experience at University College Dublin, Ireland

The first author has been with University College Dublin (UCD) since June 2013. UCD has a strong commitment with respect to the exploitation of IP and was happy to help define ad hoc licenses for the software tools developed by the author, namely PSAT and, more recently, Dome [2]. Both “products” are licensed through the website of Nova UCD, which is the UCD office that focuses on patents and intellectual property. Dome is also used fro the BE ME modules taught by the author, namely, Power System Dynamics and Control, and Power System Stability [6].

UCD provides support to academic staff with regards to any research exploitation; the perspective of the university is clearly oriented to leverage any opportunity possible to obtain an economical benefit. While OSS is not impeded in any way and lecturers have obviously the full freedom to decide what to do with the software tools they develop, there is also clear preference of preserving the IP and creating start-ups and spin off activities whenever possible.

With regard to the use of proprietary or OSS software tools for teaching power system courses, the general trend is to prefer the former. In fact, there is the *belief* (unfounded claim) that industry would prefer to hire students with basic knowledge of some proprietary package, e.g., PSS/E or DigSilent. The use of non-standard software packages or, at least, of software packages that are not recognized by industry, is considered a potential issue for the future working opportunities of the students. Clearly, this point of view is not the official posture of UCD nor is it shared by all lectures (for example, the first author), but is symptomatic of a very pragmatic aptitude, for which the basic knowledge provided to undergraduate students should be very practical and of immediate use in the working environment.

On the other hand, the author's experience with Irish practitioners, in particular the Irish TSO as well as small consulting companies, is that programming skills are highly appreciated especially when making employment offers to newly graduated students. The knowledge of proprietary software tools is not particularly binding, as it is assumed that anyone with good technical background and programming skills can master a software tool in a relatively short time.

5.5 Experience at Universidad de San Carlos de Guatemala

Shortly after the release of PSAT, there were many students attracted to the tool for education purposes, all around the globe [7]. One particular case, documented in [5], was the use of PSAT in Universidad de San Carlos de Guatemala (USAC), Guatemala City. Circa 2003, the second author was one of the Teaching Assistants in a Power System Analysis course offered to students of the Electrical Power Engineering major at the School of Electrical Engineering at the aforementioned university, where the use of the software was first attempted in a 'computer lab'.

At that time, the institution, as common in many developing countries, did not have access to proprietary software for education activities. In courses where computers were necessary for learning the subjects of the course, the students were usually required to program their own software, e.g. differential equation solvers; however, this was limited to modules in mathematics. Although, lecturers or practitioners serving as instructors had knowledge and/or access to proprietary power system software, the attitude of the teaching staff was to "kill competition by the root" – meaning that it was desirable not to instruct students on the use of the proprietary tools as they could be potential competitors in the consulting service market in the near future. In this context and time, OSS was either relatively unknown (except for the Applied Physics and Applied Mathematics communities) or viewed as "toy software for the students to play with". This 'low threat' environment allowed for the use of PSAT.

Note that, in general, most modules were taught without the use of computer software. However, it was customary to accompany every learning module with laboratory practices, e.g. electrical machines laboratories, electronics. The availability of PSAT, together with a perceived 'low threat' level, created an opportunity to experiment on the development of a 'computer lab' for the course. For further details on the use of PSAT, and at that time period in USAC, the reader may consult [5].

5.6 Experience at Rensselaer Polytechnic Institute

The positive experience gained with PSAT at USAC prompted the second author to exploit the software at Rensselaer Polytechnic Institute, Troy, NY, USA, were he was MSc and PhD student in the Electrical Power Engineering programmes. The second author served as Teaching Assistant to the course "Power System Fundamentals," where PSAT was used to carry out an undergraduate course project [3, 7, 8].

Rensselaer Polytechnic Institute is a leading research university in the USA, and thus, OSS is either extensively used or developed within different education and research activities at the institution. At the time when the second author attended the institution, there were licenses available for different proprietary software; however, the attitude was to encourage students to develop their own software or contribute to tools developed at specific research groups, such as the case of PST [27], which the second author maintains and distributes.

The knowledge of proprietary software is not considered a key skill for either undergraduate or graduate education; it is actually irrelevant as students are expected to be able to develop software for their own purposes. This is perhaps why there was no resistance by the faculty for the use of PSAT in the undergraduate course project, and it was viewed as an attractive tool as it was easy to explore and modify [8]. In fact, the values of OSS in PSAT were among the most attractive and long-term learning aids for students that were part of the experience in [8].

5.7 Experience at KTH Royal Institute of Technology

Given the second author's positive experiences as a Teaching Assistant in different institutions, the use of PSAT was adopted for teaching and research at his research group at KTH Royal Institute of Technology, Stockholm, Sweden. The software has been used in research since 2010, and in a power system analysis course from 2011 – 2014, for different purposes. For example, several turbine-governor models were developed for PSAT as an MSc thesis project [28], and PSAT is used for teaching robust and continuation methods for power flow solutions in module lectures and homeworks.

The use of proprietary software tools for teaching power systems courses at KTH is preferred. This is product of long-term collaborations with ABB and STRI, which used to maintain the SIMPOW software. With the purchase of SIMPOW by a small consulting company, and the raise of DigSilent PowerFactory as the predominant tool of use in Northern Europe, many lecturers (but not the authors), have opted for the use of either PowerFactory or other tools. Even this, it is seen by the Swedish TSO as a drawback, who would prefer the use of the PSS/E software in the university, as it is the main tool for their planning studies (and also across Scandinavia).

In fact, it is very challenging to adopt OSS tools in Scandinavian universities for power system analysis. The dominance of the PSS/E software is such that there are dedicated job postings searching for students with knowledge specific to the tool for different analysis departments. Thus, both faculty and students question the use of OSS tools instead of their proprietary counterparts. However, resistance from students minimizes after a positive experience using OSS tools or developing their own code, both in learning modules and in research. The resistance to the use of OSS tools is difficult to avert, and it has been observed in other fields [29]. The research group of the second author is now working on the development of a new OSS project using the Modelica language [30], which has required the adoption of techniques to deal with resistance to change [31]. This initial experience is positive, however, the effectiveness of such techniques can only be evaluated in full once the OSS project is released to the public.

5.8 Experience as moderator of the PSAT Forum

The first author founded the PSAT web forum in 2003 to help users of his software tool PSAT [9]. The forum is very active and counts about 4000 members, which is a quite surprising number taking into account the very specific niche of the applications of PSAT. The vast majority of members of the forum are PhD or research MSc students. Practitioners and undergraduate students are a marginal percentage. This fact indicates that PSAT is mostly used for research, not for education or analysis of real-world systems. This is not a surprising conclusion as PSAT was born as the project of the author when he was a PhD student, which makes PSAT best suited for research.

It is also noteworthy that the vast majority of members of the PSAT forum are from Asia and Middle East. While there are certainly exceptions, these students are mostly interested on the “free beer” rather than the “free speech” aspect of OSS and PSAT. A discussion on the reasons for the fundamental failure of OSS projects for power system analysis is beyond the scope of this paper. However, the interested reader can refer to the last chapter of [32].

5.9 Experience in the leadership of the IEEE TF on Open Source Software

The task force was formed under the Power System Analysis, Computing and Economics Committee of the IEEE Power and Energy Society (PESs). The authors have chaired the IEEE Task Force on Open Source Software from 2007 to 2014. In this period they have organized four panel sessions on Open Source Software at the PES General Meeting, one every two years starting from 2007. These panels provided a very good chance to understand the “feeling” of the power system community and, in particular, of practitioners, with regard open source software tools for power system analysis. The IEEE PES is, in fact, mainly a society for practitioners, not academia.

All panel sessions have had a great attendance, despite always being scheduled in the last afternoon slot of the last conference day. This fact is actually symptomatic of the mixed feeling of the IEEE PES towards OSS. The audience at the panel session has been typically composed of two kinds of people. On one hand, enthusiastic students and young researchers, but also few independent practitioners, willing to share ideas and learn about new tools and techniques. On the other hand, very conservative practitioners attending the panels more due to concerns regarding the possibility that a new OSS tool could reduce the market share of "well assessed" proprietary products. Particularly relevant was the discussion originated by the proposal of an Open Data Model (ODM) in the OSS panel session of the PES GM in 2009 on the CIM format [33]. This discussion was unnecessary and originated by the fact that such an open model could be seen as an alternative to CIM. The open model was not developed any further, but it is interesting to note that even a very small and early-stage project such as the ODM could originate an over-reaction from people worried about alternatives that may jeopardize their business. It is a strong belief of the authors that only a continuous education effort aimed to show to students (and the broader community), the advantages and drawbacks of both proprietary and OSS approaches for power system analysis, can eradicate unmotivated fears from the power system community.

5.10 Collaborations with Industry

The first author has collaborated with several European industries as part of his work with academia. Most of these collaborations originated because of his notoriety as an experienced programmer (achieved with the software tool PSAT) and consisted in developing software tools. On the other hand, the first author has had to relinquish collaboration opportunities because the industrial partner demanded the use of specific proprietary software packages, which is not possible given that typical academic licenses do not allow using proprietary tools for consulting activities.

Proprietary software tools are imposed whenever warranty is concerned, which generally happens when the results of the collaborations are part of a project where third parties are involved. Unfortunately, OSS projects, by purpose, do not provide any warranty and thus are often inadequate for industry collaborations. For this reasons, OSS, while it is a viable solution for R&D, faces challenges to support or evolve into products.

6 CONCLUSIONS

The general conclusion that the authors can draw based on their experience in several universities with different cultural backgrounds and academic contexts, is that the preparation of students should be both broad and deep. Industry appreciates that students know common proprietary tools for power system analysis, but it does not offer any advantage because a student with a solid preparation on power system concepts can master any tool in few weeks. Some companies also require good programming skills and the educational value of OSS for developing such skills is indisputable. Moreover, students that will be hired in the R&D departments of system operators, or of any other industry in the power system business, should have better chances if they have knowledge of available research tools, which in most cases are OSS projects. OSS naturally allows for both, providing means to explore a specific topic (e.g., power flow) in practical (and rather superficial) ways, and deepen into advanced methods (broad experience) and their implementation (deep learning). By its nature, proprietary software only allows learning of practical aspects (superficial or surface learning).

In academia, North American institutions appear to have the best approach with regards to OSS for power system analysis as students, in particular PhD ones, have access to both proprietary and open-source software tools with no prejudice of any kind. This generally leads the student to choose the best tool depending on the application. On the other hand, the “product-oriented” approach of UCD, which is largely also that of UK universities, and the “indifference” shown by Italian, Spanish and Swedish institutions appear to be less effective with what concerns OSS projects, but are clearly well integrated in their working environments of their respective countries. In the case of developing countries, such as Guatemala and others [34-36], OSS offers often the only option for teaching and research activities. In this context, OSS has a large global impact on incalculable social welfare value. Proprietary tools on the other hand are prohibitive and, not only they do not contribute to the contexts, but prevent their development.

The first author is currently evaluating the opportunities offered by OSS in terms of founding spin off companies for ME and PhD students in electrical energy systems.

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