Power Education Revolution-A Journey Towards a Smarter Future Power Sector

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***Abstract*— In today's world as power sector is growing smarter in application, the required input to power sector has become more and more diversified. Therefore, expectations from power engineering graduates coming to the industries are also growing higher and hence revolutionizing the curriculum becomes an urgent need. But maintaining and teaching a modern curriculum in power engineering is a mighty challenge due to lack of interdisciplinary association and industry-academia consortia. It has, therefore, become inevitable to imbibe associated fields and technologies as an integral part of power engineering education and also to initiate industry-academia collaborations. A power engineer needs to be highly dexterous not only in core power system stream but also in communication, networking and management. This paper presents the strategic approaches to build up a more efficient power engineering education system for developing a smarter future power sector.**

Keywords*— *Power Engineering Education, model curriculum, e-Learning, MOOC.

I. INTRODUCTION

Electricity is an indispensable commodity of the human society. Since the last six decades, power sectors all over the world have been expanding quantitatively as well as qualitatively. The ever increasing population growth and increased standard of living demand a higher consumption of energy. In fact, it has been witnessed that the standard of living of a city or country is measured by per capita energy consumption. Increased standard of living is a result of technological advancement which includes industrialization, automation of industries, automation of transport and traffic system, development of automatic household appliances, etc, to mention a few. All these technologies run on the most flexible energy currency "the electric energy". Electric energy has now become not only basic necessity but also the backbone of economic development.

With power industry becoming the major anchor over which virtually all other industries rely [1] further more expansion of the sector become inevitable. Human society development and power sector development are intricately intertwined. Power sector development leads to increasing standard of living, increased standard of lifestyle calls for further energy demand and so on. Therefore, the increase in power demand is compounding. To meet the increasing demands, power sector has been continually expanding over half a century and the expansion has to go on further. Growth of power sector definitely requires well trained power engineers in bulk. This indicates that power engineers are going to become the giants over whose shoulder the technological advancement of the world stands upon. Unfortunately, the current numerical figure of power engineers graduating per annum all over the world is well below the mark to cope up with present as well as future requirements. It is, therefore, evident that a huge shortage of technical personnel no doubt exists in the power sectors across the globe. Also, power industries are not keeping up pace with the current standard as demanded by current societal standard. So, at present power industries over the world are facing problem of quantity as well as quality of trained power engineers.

To cope up with the requirement of quality, power sector has been evolving, though not sufficiently. Also, it is worthwhile mentioning that this evolution is speeding faster than before over the last two decades. This increase in pace of evolution can be attributed to the fact that there has been development in allied field like power electronics, control, measurement, internet-networking and communication, artificial intelligence, fuzzy logic, optimization techniques, power system economics, management, and many more fields which find valuable application in modernizing power industries. Power engineering field has now become more of a field, where in, interdisciplinary knowledge are pooled together to bring out a more evolved power system. In [1], it is stated that "Not only is the electric power industry generating much new technology itself, it is also an important consumer of new technologies produced by other electrical engineering disciplines. This emphasis on technological know-how will require people trained to work in these areas, as well as innovators whose creations must respond to changing requirements for electric power systems." This means that power engineers should possess multi-dimensional knowledge with depth in core power engineering and breadth in terms of ability to assimilate and imbibe technology of allied disciplines that supports power system revolution.

However, the pace at which power industries are adopting and adapting to the development in other fields is not sufficient to meet the demand requirements. A gap exists between the power industries current implementation status and findings from academic research that could be adopted. One key reason is that most of the new R&D findings come up from individual research theses from academia and/or

dedicated R&D wings of industries which stay confined within the particular unit alone. It is high time that our power industries and government take up appropriate steps to start bridging this gap.

One of the hindrances in the development of power engineering world is the curriculum followed in universities/institutes across the world. The curricula followed in universities across the world have their own drawbacks. While some universities are still sticking to 30-40 years old outdated syllabi, some others have scraped away a lot of essential core power engineering topics in their attempt to allocate space for supporting disciplines or due to lack of faculty. Considering first case, many old and very traditional topics have now been migrated to technician's domain and so these needs to be dropped out from power engineering curricula. This would provide space for introducing more relevant technology that go at par with current trend. Power engineering education curricula need to strike the right balance between core knowledge requirements and incorporating the latest technology.

Looking from the perspective of industry recruiters and power utilities, the major hobble they encounter is that most of the available power engineering graduates come with an incomplete background because of the curricula they have followed in their graduating university. In other words, available work-force is less competent to cope up with the sophisticated technology incorporated in (and to be incorporated in future) power industries to deal with expanding demand of quality and quantity. Industries no doubt have high level R&D units where in new technology are developed and tested but large scale application is lagging far behind due to shortage of adequate well trained work-force in the fields. Fresh graduates lack the capability to handle latest R&D coming either from higher level academia or high level R&D units of industries. Graduates with round background are preferred by recruiter also. Since most graduates do not possess round background, a post-graduation or some additional training become a requirement for enhanced employability.

Furthermore, a problem of quantity also is very much alive in this sector. Though the demand for power generation and power engineers are steeply increasing, the rate of production of power engineering graduates is not increasing. In fact, it is declining, especially in the U.S.A. Author in [1] showed a table indicating a steep decline in electrical engineering (EE) bachelor's degrees awarded in the U.S.A. between1987 to 1997. In [2], it is mentioned that India and China are also witnessing reduced enrolment, though not as severely as the U.S.A. The reduction in enrolment of power engineering graduate students in the U.S.A. in particular and the world in general can be attributed to the fact that in the U.S.A. energy and power engineers are lagging far behind in salaries compared to most other fields of electrical and electronics engineering[1]. Also, from the perspective of young people in industrialized countries contemplating their future and the possibilities of an academic study, the current curriculum in power engineering lacks attraction [3].

In addition to these issues, [4]-[7] identified the aging workforce as a challenge in electric power industry and the education system that supports it is facing currently. There is an impending danger of losing the experience and expertise of the veterans, which would in-turn affect safety, productivity, reliability, etc. In [7], it is stated that 'After World War II, industrial America underwent a huge surge and a corresponding expansion of the electric utility infrastructure. As the economy and industry grew, the workforce increased, and many college educated engineers get jobs in the electric power industry. But those "baby boomers" are now retiring and leaving the workforce.'

The various problems faced currently by power and energy sector are highlighted in this paper. Strategic solutions to these predicaments are presented in detail. Further, some measures already been enforced are pointed out in Section VII.

II. CURRENT SCENARIO AND CHALLENGES

The growth of power engineering sector in terms of breadth of expansion and height in quality is at present rather hampered by many factors mentioned earlier. The various impediments, the power engineering sector is currently facing, can be broadly classified into two heads, quantity issue and quality issue. The major issues are listed below:

- First, there is the problem of quantity due to retirement of workforce and decline in enrollments in universities.
- Second is the issue of the curricula currently followed in universities across the globe. The current curricula do not go hand in hand with industrial requirements, and therefore, employability of fresh graduates is low.
- Another issue is the shortage of funding for R&D projects in academia as well as industries.
- Lack of industry-academia collaborative innovation
- Power engineering graduates get lower paid job compared to computer science or electronics and communication engineers. As such, power engineering education lacks attraction and hence, enrolments are relatively less and also declining.

III. DESIGNING A MODEL CURRICULUM

The present day power sectors require innovators whose creation must respond to changing requirements. As such, graduating power engineers need to be multi-talented. They need to acquire adequate core power engineering knowledge along with knowledge of a large number of areas whose ideas power system utilizes for its betterment. Teaching and education content, therefore, should go parallel with R&D requirements of industries. Under-graduate courses should have a solid grounding in basic power engineering fundamentals and should also have extension of courses or minors in appropriate sub-disciplines like control theory, applied mathematics, economics, probability theory and risk analysis, computer engineering, software engineering, data structures, electronics, power electronics, communication technology, etc [8]. Furthermore, some very old and traditional topics which have been migrated to technicians' domain can be eliminated [2]. Another very much viable

option is push these traditional topics into introductory course on the foundation of which more industrial R&D relevant courses currently in high demand could be planned. This would, in-fact create some time slots for introducing more relevant and useful topics.

The average division of various groups/fields of courses in electrical engineering curriculum currently followed at Indian universities is shown in Fig. 1 and 2. The data in the figure corresponds to B. Tech. electrical and electronics engineering (EEE) curriculum of University of Calicut[1], Kerala (Revised on 2009). Universities in India in general follow more or less similar distribution with slight variation from university to university. Out of the total credit about 5% is accounted by projects, 12-13% is allocated to laboratory and workshops, and remaining major portion of about 82% is allocated for theory courses. It can be seen that there is only 10% provision for optional or elective courses. Also, project works too accounts for a small fraction of the total course.

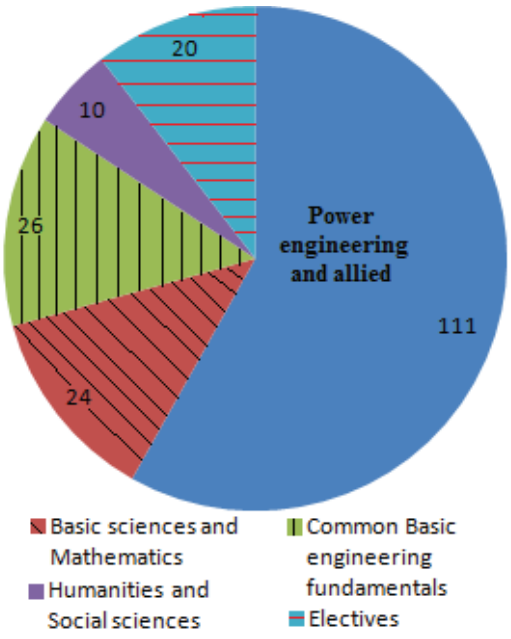

Fig. 1. Credit distribution of courses (major fields) in Electrical Engineering undergraduate curriculum at Indian universities[1]

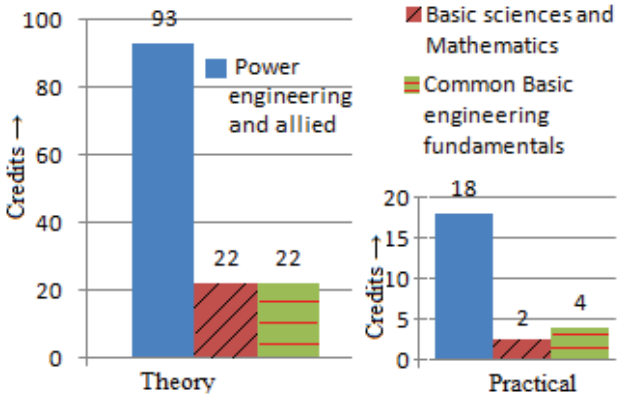

Fig. 2. Theory courses and laboratoty courses distribution

The structure of such a distribution for the central government funded premier institutes in the field of engineering and technology in India i.e. the Indian Institute of Technology (IITs) and the National Institute of Technology (NITs), is slightly different from the figures shown here for State universities. They have higher percentage of advanced elective courses and deeper penetration of Humanities and Social Science courses like courses on business management, marketing, economics, etc. which might later become very useful in professional life. Further, in these institutes, apart from the mandatory major B. Tech project, a certain percentage of grades/marks out of the total for particular theory course is usually allocated to project work tending towards research. It is noteworthy to mention that in most IITs 'electrical engineering' and 'electronics and communication engineering' are not separated as different specializations or departments, unlike many of our Indian universities. Rather, based on elective opted, students are given minor specialization [19].

A model curriculum should strike the right balance between depth in core subject content and flexibility in terms of introducing new technologies and inter-disciplinary courses. In other words, the course contents should be flexible. Nearly 40-60% of the course content can be kept as mandatory basic courses and remaining 60-40%, preferably in later semesters, could be kept as vast choices of electives or minors. The mandatory courses should include two major requirements; first, enough depth in core power engineering material to built up a deep insight on power engineering fundamentals and secondly an introductory or basic fundamentals on various subjects or topics which invariably find application in power system engineering. These introductory courses will serve as foundation for the electives specialization. Smart grids & bulk renewable integration, distributed energy management systems, micro-grid, HVAC system load calculations, integrated substation condition monitoring etc [9] are some courses/topics that can be offered for elective/minor specialization.

Lack of resource person or adequate number of faculties for particular specialization is a downside in introducing a large number of specialized/advance courses. Situation like this can be taken care of by utilizing the benefits of e-learning and web-knowledge sharing. Educational institutes should collaborate and share resources with other institutes to fill up each others' requirements. Resources could be shared physically through students exchange programs and faculty exchange/visits or electronically by knowledge network, video courses, web courses etc. Boosting e-learning technology and their benefits are discussed in Section IV.

The authors in [3] quote that "Environmental concerns are expected to impose higher requirements from society as well as from international treaties." It is a well established idea that renewable energy sources have environmental advantage over conventional sources. Introducing courses in renewable energy generation and integration could prove to be very beneficial for future energy requirement as well as future workforce requirements.

The model curriculum should also create room for introducing projects as a part of credit courses so that students can get involved in the latest technological development and earn some experience in dealing with industry relevant issues. Industry relevant topics or courses and research projects should be introduced within the mainframe curriculum as an integral part of it. This can be achieved by increasing industry-academia collaboration. Prospective collaborative courses and research schemes are detailed in Section V.

IV. E-LEARLING - A BOOST IN EDUCATION SYSTEM

E- learning initiatives is a very useful tool to make up for lack of teaching resources, especially in developing institutes. E-learning is the use of information and communication technology to enable people to learn anytime and anywhere and also a support tool for educators. E-learning facilities promote specialization/expertise sharing among the broad users and serve as a measure to face the challenges of shortage of faculties.

In order to cope up with rising demands of engineering graduates, the governments of several countries are establishing new institutes/colleges/universities in developing countries in general and India in particular. For example, in India, during the year 2008-2010 the central government established new IITs and NITs to take up their toll to 15 and 30, respectively. Such newly formed institutes have to develop at a great pace to cope up with the standard benchmark to their older counterparts have. Sharing expertise of expert faculties from earlier established premier institutes through National Knowledge Network (NKN)- a real time or live- online course delivery by faculty from one institute to one or more virtual classrooms of other beneficiary institute(s) is a very effective way of giving quality education in developing institutes in the grooming period. The NKN is basically a dedicated revolutionary state-of-the-art multi-gigabit pan-Indian resource-sharing network established by Ministry of Information Technology, Government of India, to digitally connect all national universities, colleges and research establishments to create country-wide virtual classrooms. The network consists of an ultra-high speed core (multiples of 10Gbps and upwards), and over 1500 nodes. The NKN facilitates high speed classroom sessions [9].

Massive Open Online Courses (MOOCs) is another very useful means of enhancing learning opportunity that have captured the imagination of the current generation of academicians, educationalists and students. MOOCs are a path breaking new concept that has stormed the education world in the past few years. The MOOC revolution has taken the education world by storm and has opened vast opportunities for students. In fact, the MOOC revolution is a means of transformation of the teaching and learning process [10], [11]. It is not only the regular students that benefit from these but any person who has the interest to learn. The "National Programe on Technology Enhanced Learning (NPTEL)" is the most widely used and highly appreciated MOOC system in India established under the '*National Mission on Education through Information and Communication Technology*' (NMEICT) mission undertaken by the Ministry of Human Resource Development, Government of India. These MOOCs are a very beneficial means for working industry personnel with an interest or otherwise requirement to improve their knowledge pool. These also serve as a means of continued education, where in industry personnel can continue education without to be relocated. Online education portals like edX, Coursera, Udacity, NPTEL, OCW [12] are getting a large influx of new learners as MOOCs have gained a notable significance in the present educational scenario. Their certificates [13] are gaining more and more importance every day as they can be used to gauge a candidate's adaptability to use computer as a learning tool.

V. BRIDGING THE GAP

It is an irrefutable fact that a huge gap exist between demand of power sector and the supply of quantity as well as quality engineers, and also between academic or industrial R&D and the actual field implementation. Even though, there is advanced research in the field of power engineering by researchers from academic institutes as well as industries, the research product remains confined mostly in research lab. Their implementations to field are lagging far behind. Bridging this gap is the utmost necessity of the current time. A major reason behind this lapse in implementations is that the engineers in field lack the right mix of rounded background, flexibility and knowledge to adapt to changing requirements owing to drawbacks in the curricula they have followed. An industry friendly curriculum now would solve similar problem in future power engineers. Industry-academia collaboration will help bridge this gap and expedite the progress towards a smarter future power industry.

A promising way to handle this issue is to build consortia of industries and academicians [6]-[9]. A consortium like this can work towards symbiotic dependency whose outcome would bring out quality human resource or power engineers. Frequent workshops, seminars, conferences, panel discussions, etc. should be organized as joint venture by industries and educational institutes in educational campus and industrial campus to highlight the latest development and requirements in their respective sectors. Subject experts can elaborate the new technologies, their benefits and how to incorporate them in existing power system thereby gradually bridging the gap between latest theoretical practices and industrial approaches. On the other hand, professionals from power utilities bring out current practical implementation issues, scope of enhancements and also defined certain R&D problems on which academia can work on. Resource person from industries of allied fields whose products power engineering sector consume, like control engineers, IT engineers, etc, should also be invited to show case their latest technologies and detail their implementation agenda including hands on session on gadgets and softwares. A wider door toward bilateral knowledge flow will open up. Such program will make the working professionals aware of new innovation and state-of-the-art engineering practices in one hand and on the other hand, it will prove beneficial to students not only in knowing the latest know-how but also in gaining a perspective of key requirements to build up a strong background toward a 'Smart-Efficient Future Power Engineer'. Such a program will also lead to joint projects between industries and academic institutes.

VI. TRAIN THE TRAINERS

The two topics 'enhancing the teaching techniques and contents' and 'designing a model curriculum' have been discussed unduly in the education reform societies. Student communities will come under the vibe of these reform measures and enhancement techniques if and only when the revised curriculum shows a positive growth towards success. The success of such a program is very much dependent on the individuals on whose shoulder the responsibility of enacting the process lie. Therefore, incorporating the enhancing techniques would definitely have to go along with the professional experience, teaching philosophies, strength, limitations, vision and style of teaching of the teaching faculties. In fact, in the current scenario of Indian universities (State universities and central universities alike, including IITs and NITs), 'overall effectiveness' or the so called 'likability factor' of the faculty delivering the course, from students' point of view, serves as a major criterion based on which students opt for their elective courses. As such, mediating specific changes in the teachers' or trainers' conception and philosophies become a requirement; otherwise, teaching innovative cutting-edge materials will get outside the comfort zone of existing power engineering professors and trainers [14]. Therefore, currently existing teaching faculties and industrial trainers indeed need to be trained in/with dedicated training facilities.

The National Power Training Institute (NPTI) has contributed largely in this context in India in special and the world in general. The NPTI is a national apex body of training the human resource in power sector with industry specific technical interface. It is an autonomous body under the Ministry of Power, Government of India, catering to the training needs of core power and allied industries. NPTI is a leading integrated power training institute in the world and has trained 180,000 power professionals over the last four decades [18]. The NPTIs offer regular undergraduate and postgraduate program in power engineering and power management. Also, they organize various short term courses, seminars, workshops covering the state-of-the-art development in power technology, use of simulation tools, use of instruments, field application techniques, etc. to train the trainers.

The government should also establish technical teachers training institutes focused on power engineering sector in order to improve quality of trainers and teachers.

VII. PROACTIVE STRATEGIES IN ACTION PROVING THEIR WORTH

In this section, some measures adopted by certain institutes, government, autonomous bodies, etc. towards a better power-engineering world, which has not only gained popularity but also has proven to be worthwhile, are listed.

- In Sweden, a very good cooperation is maintained between the electric power industry and the universities. For Ph.D. student projects, committees are formed with supervising faculty members and suitable industry engineers. One of the most important tasks of these committees is to guide the student, and the faculty supervisor, so that the work performed is of interest to the industry [1].
- The Electric Power Research Institute continues to support research part of which is research at U.S. universities, including a program known as 'Tailored Collaboration' in which some EPRI sponsor funds are earmarked for research. Some of these funds form an important part of university research budgets in power [2].
- A National Science Foundation (NSF) program in USA for power engineering continues to support university research in power. This program impacts not only US programs but also international students who populate the programs [2].
- In the United States, an NSF Industry University Cooperative Research Center program supports one power engineering center that has a total budget in the 2.0 M$/year range. The program has an international component spanning four countries - and expanding presence mainly in Europe [2].
- In India, Central Power Research Institute (CPRIs), a group of institutes dedicated to research in power engineering latest technology supports research scholars from educational institutes like IITs to work on their projects, in their campus, as a part of their(scholars') PhD research project. CPRI with Ministry of Power also provides the fund for research in power engineering areas.
- At the University of Missouri-Rolla, several power engineering faculty are involved in multidisciplinary research initiatives that combine electromechanics, power electronics, electromagnetic compatibility, vibrations, and audible noise as applied to the design of electric and hybrid vehicles. These activities are, in turn, leading to lecture topics and lab exercises at the undergraduate and graduate levels. The school's traditional electric machines course has been converted into an introductory electric drives course focused on the principles of electromechanics with an emphasis on control aspects—an area that is gaining more R&D funding from industry [1].
- Power Grid Corporation of India Limited (PGCIL), a power transmission company, has started a B. Tech (Power Systems) degree course in Indian Institute of Technology, Delhi. This program is supported by the PGCIL, and all graduates from this program will be employed in the corporation. Students will get scholarships from the PGCIL. It is the first program of this nature in India [19].
- In India the Ministry of Human Resource Development (MHRD) started a mission entitled '*National Mission on Education through Information and Communication Technology*' (NMEICT) which includes several revolutionary and interesting projects to tackle the problem of faculty shortage and to promote quality education in engineering. NPTEL is a part of NMEICT mission. NPTEL provides e-learning through free online

Web and Video courses in Engineering, Science and humanities streams developed by subject experts of respective fields. NPTEL hosts lot of resources beneficial to power engineers [9].

- The National Knowledge Network (NKN) established by the Ministry of Information Technology, Government of India is being extensively utilized by many centralized institutes like IITs, NITs as a means of mutual sharing of expertise and recourses among them [9].

VIII. Other Strategies – Miscellanea

This section lists few strategies other than the various strategies mentioned in previous section that have been and will become driving force in enhancing power engineers' and engineering education quality.

- The area of recognized strength on basis of high level capability in universities has to be funded in research, fellowships, & scholarships by government. There is need to support new education initiatives in technical schools across the country and also provide a minimum of 20% overheads without ceiling on the R&D projects sanctioned to these institutes [15], [16].
- All students whose parental income is less than the limit specified by government from time to time should be paid scholarships covering 100% fees, and a monthly stipend. This will help in eliminating the issue of enrollment decline [15].
- Policies and schemes should be made to reduce rate of drop outs. Financial austerity often leads students to prefer joining for job rather than opting for higher education or continuing in one. Increasing fellowship can attract more students to enroll in power engineering education as well as to stick to the program, they are already enrolled in.
- Establishing research parks with significant industry presence in the universities so as to enable university-industry collaborations is one effective way of promoting innovation and enterprises born out of universities and turned to products and process. This brings in a new dimension to research. It enables faculty and students to learn commercial aspects and make their research so much more relevant [9].

IX. Conclusion

It is undeniable that currently the whole world is facing the problem of shortage of proficient power engineers while on the other side improved standard of lifestyle call for more and more energy and power engineers who can dexterously deal in providing reliable, uninterrupted, well automated and efficient electrical energy. There is a huge gap between demand and supply which needs immediate attention. This paper recommends some strategies that can tackle the currently prevailing and impending issues effectively. This paper also lists out some effective measure already in action. This article suggests that to solve the problem of shortage of efficient power engineers a close confluence of utilities and academician need to be maintained. It also points out that there is a requirement to restructure the university curricula. The new curricula should be realistic and must focus on job-related competencies; and should also have future oriented perspective built in it. It should strike the right balance between core knowledge requirements and incorporating the latest technology. Such a curriculum would invoke the inculcation of industrial experience and familiarize industrial requirements from the very inception of engineering course while still holding on to core power engineering fundamental requirements.

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