# Analyzing Breadth and Depth of Electrical Engineering Program in GCC Region Universities

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*Abstract:* **Electrical engineering (EE) curricula in Gulf Cooperation Council (GCC) region have gone through an evolutionary process, and now approaching a maturity level. Recently, there has been no integrated approach to analyze curricula taught in GCC region universities. Some of the programs offered are general in nature while others offer some depth in one or more areas like communications, electronics, or power engineering. Another aspect of these programs is that some are intensive in delivering the hands-on experience while others are more focused on developing the theoretical background. This paper focuses on comparative and analytical study of general and some focused programs in GCC region with respect to their breadth and depth. Using cluster analysis, five major distinct EE program clusters are identified, each grouping a set of universities. Using informal analysis, challenges to address the local industrial needs, and demands for higher education are examined.**

*Indexing Terms:* Electrical Engineering Curriculum, GCC Region Universities, EE Program Comparison

## I. INTRODUCTION

During recent years, electrical engineering program has continued to evolve, resulting in what seems to be a very different career trajectory for engineers than even 20 or 30 years ago. Electrical engineers contribute to virtually every product, or the manufacturing process for that product that we have in our society. Their contributions shape the design of computers, microelectronics, integrated circuits, communication systems, medical equipment, and many other forms of technology that impact the quality of our lives. Imagination and ingenuity are required to convert recent advances into useful and effective applications. Such advancements and changes, ultimately, form a challenging task for educators. Although, engineering basics may not change in the immediate future, the global economy, the explosion of knowledge, and the way engineers work will reflect an ongoing evolution. If countries have to maintain edge on world economics and sustain in providing jobs to its nationals, it must prepare for this wave of change [1].

The curriculum design seeks to address two major objectives in undergraduate education: firstly, to enable students to experience in-depth learning; and secondly, to facilitate the development of transferable skills. Strategies to develop transferable skills in areas such as thinking and learning, self-management, communication, group work and information management, are intended to prepare students for work outside of the academic contexts in which they are taught initially. Some of the studies have involved the exploitation of appropriate technology to support open and distance learning, and the design of curriculum based upon constructivist and experiential learning principles [2, 3]. Other approaches such as in [4], discuss adapting different structural aspects of the EE degree program such as balancing and integrating lectures and laboratory sessions, advancing into interdisciplinary studies coordinated among all the subjects of the course, and strengthening the work in teams to tackle real engineering problems. A recent study on comparison of programs in systems engineering has been conducted [5], where authors have examined undergraduate and graduate programs in systems engineering to understand uniformity in systems engineering program. A comparative study can also be found in [6] outlining differences between engineers and practice in engineering in U.S. and the Japan.

Traditionally, lecturers have not been encouraged to draw upon theoretical developments as a means of improving curriculum design and delivery. However, more recently, a number of initiatives have been unleashed to create the conditions for innovation in these activities. These teaching innovations add on the current level of curricula and are most suitable to institutions where evolution has reached to stable levels, but in contrast GCC regions universities are relatively new and most of the programs are in early levels of academic process accreditation. The GCC region EE program structures need to stabilize with respect to local industrial needs and in conformance to future industrial directions.

This paper analyzes the EE curricula domain within GCC region with special emphasis to what is being is taught in the universities, such as strengths in theory, design, laboratory experiments, local industry related skills, and presence of a graduate program. We picked a set of the universities for analysis, minimum of a one university from each country. However, the universities/colleges with specialized tracks were not included in the detailed EE program comparison, but were included in the analysis meant for deriving EE program clusters in GCC region.

In the next section, a survey of industrial directions in GCC region is presented to highlight existing and emerging careers in EE education. Section III presents the structure of EE program of various GCC region universities. In section IV, these programs are compared based on the parameters outlined in section III. Furthermore, program clusters are developed to identify directions where EE education in GCC region is headed.

## II. INDUSTRIAL OUTLOOK OF GCC REGION

Early in their economic development, the GCC countries liberalized their trade and exchange regimes, opened their capital markets, and imported foreign labor, thus avoiding many of the costly distortions experienced by other developing countries. In almost all these countries, traditional sectors, such as trade, construction, and services have continued to develop in response to the growing demand from the domestic household sector. The sign of a mature industry is its ability to produce a diverse range of products needed by the domestic market and to export surplus production to other countries. GCC environment is expected to see its industrial sector contribution to the nation's overall development continue to grow in the coming years. Diversification has allowed industry to expand in new directions, producing a wide range of goods, such as plate glass and electronic components, for the domestic market and for export. The development plans introduced by GCC countries depict cohesion and a steady expansion of heavy, medium and light industries. Government emphasis on expanding non-oil industry through the provision of financial and technical support has brought about a spectacular growth of petrochemicals, as well as metals, plastics, construction materials, electrical appliances and consumer goods. The GCC governments are pursuing a comprehensive policy of economic reform that emphasizes privatization as a strategic option to promote the role of the private sector and to boost efficiency and productivity. Thus the EE graduates in GCC region have careers range from general engineering that includes technical supervision of electrical engineering installations, skills necessary for its maintenance, and small scale unit level automation, to related engineering management.

Educators from all over the world are getting attracted to most of the GCC region institutions due to industrial growth and economic development of countries in particular, and flexible social environment (with a mix of east and west), in general. As industrial strength due to free market economy grows so do technical, societal and economic systems. This requires integrated views and evaluations, not only of the systems themselves, but also of their mutual interactions and their interaction with the environment. All of the GCC region institutions have tailored their programs based on the expertise of human resource available and the understanding of market needs by the respective departments. Furthermore, universities generally revise their curricula and program objectives, therefore flexibility and reliability to accommodate curricula changes in a unified way is deemed necessary for GCC region universities to evolve and address industrial needs and growth of the society. Tracking the process of change and comparing different program systems is a needful thing that can exhibit some degree of uniformity in EE programs within GCC region.

## III. EE PROGRAM STRUCTURE

In this section, we present and discuss the structure of electrical engineering programs at some of the well known universities in GCC region. Most universities in this region were investigated (Table 1), and information used in the analysis was taken from the respective university websites and catalogues available in the public domain [7-22]. In order to analyze mapping of EE program outcomes to that of industrial outlook and future industrialization in the region, EE program outcomes of a set of universities (in Table 1) were compared, and most of them seemed to focus on points shown in Table 2. The only variation observed was in number of courses/credits dedicated to outcomes 1, 2, 3, and 11. Due to space considerations, it is not possible to show individual detailed curriculum, but an effort is made to highlight the number of courses versus various program components. It should be clarified that breakup of the program into its components may vary from institution to institution but in this work, we considered a uniform approach across all of the institutions. For example, EE core and elective courses do not include general engineering courses outside EE department, and hands-on/laboratory means a laboratory component within a course or offered as an independent unit of EE curriculum. The program components used in the analysis are shown in Figure 1. We set these components to define the breadth of EE program and range of various courses/modules that can be offered. The presence of a graduate program was considered to see a degree of higher learning and promotion of academic research in that particular university.

| No. | Name of University | Abbreviation | No. | Name of University | Abbreviation |
|---|---|---|---|---|---|
| 1 | King Fahad University of Petroleum & Minerals, Saudi Arabia | KFUPM | 9 | King Abdul Aziz University, Saudi Arabia | KAA |
| 2 | United Arab Emirates University, UAE | UAEU | 10 | Etisalat University College, Sharjah, UAE | EUC |
| 3 | Sultan Qaboos University, Oman | SQU | 11 | University of Sharjah, UAE | UoS |
| 4 | Kuwait University, Kuwait | KW | 12 | King Saud University, Saudi Arabia | KSA |
| 5 | American University, Sharjah, UAE | AUS | 13 | Ittihad University, Ras Al-Khaima, UAE | IU |
| 6 | Qatar University, Qatar | QU | 14 | Texas A&M University @ Qatar | TAMU-Q |
| 7 | The Petroleum Institute, Abu Dhabi, UAE | PI | 15 | George Mason University, Ras Al-Khaima campus, UAE | GMU-RAK |
| 8 | University of Bahrain, Bahrain | UoB | 16 | American University in Dubai, UAE | AUD |

Table 1: Universities used for EE Program Analysis

| | |
|---|---|
| 1 | An ability to apply knowledge of mathematics, science, and engineering |
| 2 | An ability to design and conduct experiments, as well as to analyze and interpret data |
| 3 | An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability |
| 4 | An ability to function on multi-disciplinary teams |
| 5 | An ability to identify, formulate, and solve engineering problems |
| 6 | An understanding of professional and ethical responsibility |
| 7 | An ability to communicate effectively |
| 8 | The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context |
| 9 | A recognition of the need for, and an ability to engage in life-long learning |
| 10 | A knowledge of contemporary issues |
| 11 | An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice |

Table 2. EE Program Outcomes

For each of the program component (except the graduate program), we counted the number of respective credit hours required in the program. In most of the GCC region universities, a three credit hour means three classroom or contact hours per week. The Table 3 represents undergraduate program credits in various GCC region universities. The detailed break-up of these credits into respective program components is shown in Table 4. The core and hands-on experience/laboratory components signify the required EE courses and lab sessions either associated with core courses or offered independent laboratory sessions respectively. The mathematics & science components include science courses such as mathematics, physics, chemistry, information technology etc. Ignoring the total number of credits for the program and corresponding variations per number of credits in each program component, it was noticed that most of the GCC region universities have addressed all of the components under investigation. It should be noted that we ignored other credits of the program like general engineering, humanities, and social science courses due to objectives laid down for this work, though most of the universities were found to include similar credits in their EE program.

## IV. COMPARISON AMONG EE PROGRAM STRUCTURES

In this section, the program component credits/courses are compared among various universities. Before EE programs are formally contrasted, it is important to know that EE program, in general, is developed to address needs of the industry and is often divided among its specialization tracks like communications, power and control, digital systems, electronics etc. It may be clarified that grouping of courses across tracks may vary from institution to institution, however in this work we have taken a uniform approach across all of the institutions, for example, digital systems track may include all courses related to computer hardware and software. In order to compare these program components with respect to the specialization tracks, we considered the set of core/elective courses and laboratories in Tables 4. The results are highlighted in Table 5.

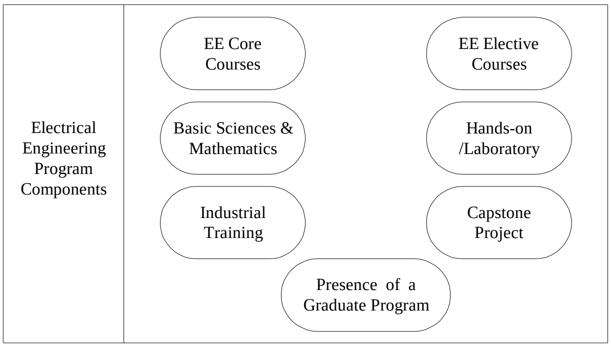


Figure 1: Various components used in analysis of EE Program

**Core courses:** Looking Table 4, we identify that the range of core courses is from 12 to 19. Except SQU, most of the universities have between 12-16 courses for EE program. Since SQU offers independent specialization tracks for graduation, hence common overlap of courses is added to general core. The detailed breakup is visible by looking at core courses only (in Table 5). It is clear that PI program core courses are geared towards imparting strong theoretical knowledge in power and control, where as AUS program is slightly more towards communications area. All other programs are generic and develop equal strengths in respective specialization tracks.

**Elective courses:** With exception to PI, the range of number of elective courses is from 3 to 5. The strong push towards power and control track is noticeable in case of PI similar to what was observed with respect to core courses. In case of SQU, three courses from each specialization tracks are offered to the student to complete specialization track requirements.

**Basic sciences & mathematics:** Looking at Table 4, it can be deduced that all of the universities under analysis have adequately addressed conventional science courses (like Physics-I & II, Chemistry, Mathematics I, II, III, IV and Statistics). In other words, they seem to address equivalent depth in basic sciences with exception to PI. This exception is relevant to power and control area in PI program, where specific attention is to address needed (science) depth for a number of courses in that particular area.

| Universities / Program Components | KFUPM | SQU | UAEU | KU | PI | AUS |
|---|---|---|---|---|---|---|
| Core credits | 45 | 61 | 54 | 52 | 47 | 55 |
| Elective credits | 10 | 9 | 12 | 13 | 18 | 13 |
| Basic Sciences & Mathematics credits | 32 | 31 | 26 | 34 | 40 | 32 |
| Industrial Training credits | 9 | 0 | 15 | 3 | 3 | 0 |
| Capstone Project credits | 3 | 5 | 6 | 3 | 5 | 4 |
| Other general engineering, social sciences, etc. credits | 34 | 34 | 18 | 39 | 14 | 36 |
| Total credits | 133 | 140 | 147 | 144 | 139 | 140 |
| Presence of Graduate Program | * | * | | | * | * |

Table 3: Undergraduate EE program component credits in various GCC region universities

| | Capstone project: no. of semesters/credits; Industrial Training: no. of sessions/credits; Others: No. of Course/No. of credit hours | | | | | | |
|---|---|---|---|---|---|---|---|
| | KFUPM | UAEU | SQU | AUS | KU | PI | QU |
| Core Courses (excluding labs) | 12/36 | 15/45 | 19/51 | 16/42 | 15/45 | 12/35 | 15/42 |
| Elective Course | 3/9 | 4/12 | 3/9 | 4/13 | 5/13 | 6/18 | 5/12 |
| Basic Sciences & Mathematics | 9/32 | 8/26 | 9/31 | 10/32 | 10/34 | 11/40 | 9/33 |
| Hands-on/Laboratory | 9/9 | 9/9 | 10/10 | 12/13 | 7/7 | 12/12 | 6/6 |
| Industrial Training | 1/9 | 1/15 | 2/0 | 1/0 | 1/3 | 1/3 | 1/3 |
| Capstone Project | 2/3 | 2/6 | 2/5 | 2/4 | 2/3 | 2/5 | 2/3 |

Table 4: Undergraduate EE components strengths in various GCC region universities

**Hands-on experience/Laboratory:** The range of laboratories in EE programs of GCC region is from 6 to 12. From Table 4, it is clear that PI and AUS programs seem to be more hands-on with respect to developing skills compared to other universities in the region.

**Industrial Training:** Generally, it is argued that the education of an engineer is a partnership between university and industry, with the university providing the theory and industry giving experientially accumulated instinct. Additionally, the relatively longer duration in industrial training helps in job placements later. All of the universities in GCC region require their students to conduct internship or industrial training after students have finished their third year of engineering education. The duration of this training ranges from six to twelve weeks, with UAE University being the only university to provide this training for 18 weeks at specialization specific industries.

**Capstone Project:** The primary goal of capstone project is to allow students to synthesize solutions to real open-ended engineering problems in addition to providing a laboratory for the learning, development, and practice of those non-technical skills that turn good engineering graduates into outstanding new engineers. The Table 4 suggests that each of these universities have a year long capstone project with design and development emphasis. The variation lies only in number of credits allowed for the project.

**Accreditation:** A thorough investigation was carried out whether accreditation for EE program has been planned to formalize respective program structure, and follow an on-going improvement process. In addition to acquiring local accreditation through government channels, an independent academic process accreditation is considered necessary by most of the GCC region universities to validate ongoing process. The programs at UAEU, KFUPM, KU and AUS are accredited by Accreditation Board for Engineering and Technology (ABET). AUS EE program has also received independent U.S.A. accreditation. SQU and QU have initiated program of accreditation with ABET, where as PI is relatively new and still has to go through the accreditation process.

**Graduate Program:** The status of graduate program was investigated in most of the universities in GCC region, and it turned out that seven of the universities have started a graduate program in electrical engineering. Some of these universities are highlighted as "*" in Table 3. It was also noticed that at least three other universities were in the stage of launching it in next couple of years.

| | | KFUPM | UAEU | SQU | PI | QU | AUS | KU |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Core courses | | | | | | | | |
| | Circuits & Electronics | 4 | 4 | 4 | 3 | 4 | 4 | 4 |
| | Communications | 4 | 4 | 4 | 1 | 3 | 6 | 4 |
| | Power & Control | 2 | 3 | 4 | 7 | 3 | 3 | 3 |
| | Digital Systems | 2 | 4 | 3 | 1 | 3 | 3 | 2 |
| Total core credits and no. of courses | | 12/36 | 15/45 | 15/51 | 12/35 | 13/39 | 16/43 | 13/39 |
| Total no. of core lab credits | | 9 | 7+2*=9 | 10 | 9+3**=12 | 7 | 12 | 7 |
| | | | | | | | | |
| Electives | Circuits & Electronics | 4 | 1 | *** | 0 | 4 | 1 | 6 |
| | Communications | 10 | 3 | *** | 0 | 4 | 5 | 10 |
| | Power&Control | 11 | 3 | *** | 5 | 10 | 8 | 12 |
| | Digital Systems | 2 | 3 | *** | 1 | 8 | 1 | 0 |
| Total elective credits and no. of courses | | 3/9 | 4/12 | 3/9 | 6/18 | 5/15 | 4/13 | 5/13 |
| | | | | | | | | |
| **Legend:** | | | | | | | | |
| * Freshman Lab is introduced to give students hands-on experience on instrumentation and process control | | | | | | | | |
| ** A dedicated Matlab laboratory course of 3 credits is conducted during the second year | | | | | | | | |
| *** SQU offers separate tracks of specialization in power, communications, electronics etc; hence electives from general EE | | | | | | | | |
| degree can not be obatined. | | | | | | | | |

Table 5: Comparative table with detailed structure of core/elective components

**EE Program Clusters**: In order to classify programs, an effort was exercised to cluster EE programs of various universities based on their course content. Clustering is the classification of similar objects into different groups, or more precisely, the partitioning of a data set into subsets (clusters) [23]. The clustering algorithm used was unsupervised neural network [23], as it allows the network to find its own energy minima and is therefore more efficient with pattern association.

In our previous analysis (through Tables 4-5), it was noticed that higher the number of core courses per sub-area (like circuits & electronics/communications/power and control/digital systems), the higher was the listing of respective electives in each program institution. Thus, we used course content or the number of core courses (per sub-area) as a variable to develop clusters. The Industrial Training, Basic Sciences and Mathematics, and Capstone Project were not used, as these are common components in EE programs, and hence they were not selected to infer specialization track of the program. The specialization track of the program was chosen by setting a threshold of 4 courses in each sub-area. This was selected as an average of core course per sub-area and calculated as ((min course number + max course number)/2) in Table 5. The presence of a graduate program was decided by placing a 0 or a 1 as an additional variable in classification. The number of variables, thus used, was five. The EE program core courses used for training of the neural network were from universities shown in Table 1. The total number of GCC region universities used in overall analysis was 20. Thus, four universities were used for testing of the trained neural network. The clusters thus formed are shown in Figure 2. It should be clarified here that university programs with dual offerings (like general degree program, and a separate specialized track) were marked as "university_name-1" and "university_name-2". This was obvious in case of UAEU, which offers two programs, namely "EE general" and "EE communications" track. A look at the clusters reveals five major clusters. One cluster shows those universities where graduate program is running for some time or has been launched recently. Another cluster groups universities where general EE program is offered. The remaining clusters group respective university programs into specialization tracks such as electronics, communications, and power and control.

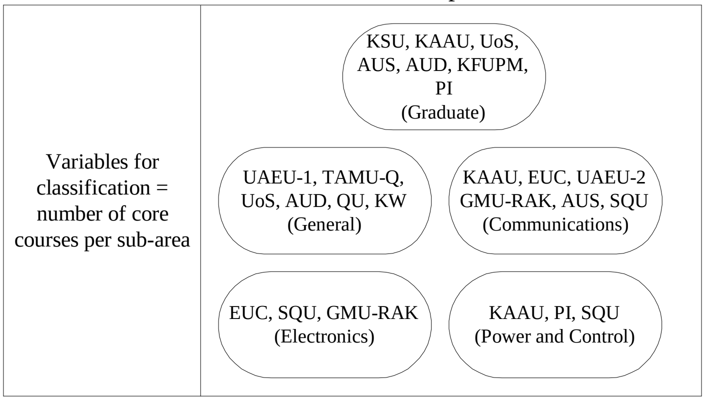


Figure 2: Program Clusters developed using a classification algorithm

## V. DISCUSSION AND CONCLUSIONS

Looking at Figure 2, it is obvious that the cluster marked as "Graduate" shows that seven of the universities offer graduate programs in EE, with some even offering up to a PhD. degree. This cluster highlights depth of higher learning and research in EE program. There are a number of universities, which offer a general degree in EE (marked as "General" cluster in Figure 2), and thus provide breadth in their EE program. These universities are geographically spread out in the GCC region. The other three clusters show a list of universities each depicting depth either in electronics, communications or power and control. These universities are also spread out in the GCC region. The absence of digital systems specialization track was noticed, and it was found out that either a separate degree program in computer engineering (CE) was offered by respective departments or an independent department was noticed within a college of engineering in general, or college of computer science and engineering, in particular. Additionally, control sub-area was mostly found together with power sub-area, in contrast to western institutions where control area grows independently in EE discipline. It should, however be clarified that our classification approach identified some universities to be specialized in one of the specialization tracks like in communications or power and control, but in practice these programs have been declared as "General EE Program" in public domain and are advertised as such on respective websites. This was visible in case of AUS and PI, and likewise the AUS and PI claim their respective program as EE (General).

When we examined literature provided by the departments (when it existed) pertaining to post degree jobs, we found roughly the same groupings in EE careers in GCC region. The better prospects were quoted in power and communications tracks. This explains why some of the "General" EE programs were found to be more towards either power or communications tracks. The results suggest that EE education in GCC region has four major directions: general EE degree with similar depth in each sub-area, specialized track in electronics, specialized track in communications, and specialized track in power and control. This provides four different answers to one question pertinent to GCC region: What is the theme of undergraduate EE education in GCC region? Some schools have chosen to offer only specialized tracks through same or different departments, and some schools have chosen to offer two different degrees in EE i.e., one as a general and another a specialized one, through the same department. A unique EE program offer was noticed in case of KFUPM, where EE department offers "Bachelor of Science" degree in EE, and another one in "Applied EE" degree. Thus it provides two different paths in EE education career.

Despite detailed analysis on program structure of individual institutions, unified direction for future target industry remains elusive. This has most likely been caused by absence of local (and non-governmental) academic accreditation process, which accounts local industrial needs in particular, and local society requirements in general. Generally, the local accreditation process roots in local industrial needs and is well supported by active local (EE) professional bodies. With international accreditation process gaining momentum in this region, and visible improvement in terms of collaboration between local industry and respective institutions, it can be expected that local accreditation process and active university and industrial collaboration may surface in this region in near future. Though participation between industry and universities does exist, but its level of influence with respect to higher learning and research was not noticed in our research, and thus its impact on development of strong graduate programs remains minimal. This probably could be attributed to absence of high-tech industry or relevant design and development industry in GCC region.

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