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Analysis of The Awareness of Present Day Undergraduate Electrical Engineering Students About Contemporary Technologies

An Educational Survey About FACTS Devices

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Abstract: Electrical energy demand keeps increasing every year, while the generation tries to keep pace with the increased demand, the existing transmission system fails to absorb the additional power. Extension of the current transmission system is usually not the merited solution because of huge capital input required, in addition to various environmental and political constraints. This means the transmission lines usually operate at near or even beyond their power transfer capacities. This overutilization of the lines causes reduced efficiency and increased risk of faults. FACTS - Flexible AC Transmission System devices, are used all over the world as a possible solution to these issues. FACTS are power electronic devices enabling increased control and improvement of power transmission system. This paper compiles the results of an educational survey which was carried out to check the basic knowledge of electrical engineering students, about this technology. The results of the initial survey were analyzed and a series of informative sessions were then carried out to make the students learn about FACTS devices. Other study material was also provided to the students. Another survey was then carried out to examine the change in knowledge of students and a drastic increase was observed.

Keywords: Transmission system, Energy crisis, Power factor improvement, Line capacity, Blackouts, FACTS devices

I. INTRODUCTION

Transmission is the back bone of modern electrical power system. The efficiency of transmission system determines how effectively the power system resources are put into use. Realizing the importance of the transmission sector, FACTS – Flexible AC Transmission System devices are devised. It is unfortunate to observe that despite the importance of such devices in power system, there are no curriculum requirements, compelling the power/electrical engineers to learn the concepts underlying the machinating and development of FACTS devices.

Knowing the importance of a particular contemporary technology, educational surveys are conducted worldwide to gather statistical evidences and data to assert the need of proper teaching and learning methodologies for such technologies. [1, 2]

For the same purpose, a survey was conducted in Electrical Engineering department of NED University of Engineering and Technology, which verified the proposition of utmost requirement of electrical engineering course on FACTS devices.

The survey was conducted twice on the same pool of students from all batches. Second survey was conducted after introducing the students with basics of FACTS devices.

II. SURVEY QUESTIONS

The students were asked following survey questions:

1. Do you think there is an energy crisis in Pakistan?
2. What do you think is the cause of energy crisis in Pakistan?
3. What in your opinion can improve the stability and power factor of transmission system?
4. Where are FACTS devices used in power system?
5. Do you think FACTS can play a role in bridging the gap between electricity demand and supply?
6. Do you think FACTS can improve power quality at consumer end?
7. Do you think FACTS can improve voltage stability at consumer end?
8. Do you think FACTS can reduce blackouts in Pakistan?
9. What solution do you propose for resolving energy crisis in Pakistan?

III. SURVEY METHODOLOGY

Having designed a set of questions on Google survey, the survey form was circulated to the students of electrical engineering department through various student forums and social media networks. A total of 150 responses were gathered. The survey pool was chosen so as to have students of all batches including fresh graduates. To make the proposition, stand well justified, a greater proportion of the surveyed audience was selected from senior year students and fresh graduates. The population statistics are depicted in Fig.1.

Once the survey results were obtained, they were compiled and studied to analyze the areas that required considerable attention. A literature was designed, retorting to the survey questions. It was then shared with all the respondents of the survey.

In order to create awareness in the students of Electrical engineering department, of the key aspects of power system and the role of FACTS devices in bridging the gap between electric power demand and supply, various methods were used. An informative video was made and circulated using the same student forums. A booklet, explaining the basics of power system and FACTS devices was designed and spread amongst students. A series of short informative sessions were conducted in classes.

As a result of the awareness campaign, students responded positively towards the idea of FACTS devices being used in industry and being taught in their curriculum. A total of 135 students out of 150 students surveyed previously could become part of the awareness campaign and were asked to fill out the same survey form once again. It is to ascertain the validity of the result that the proportion of students of various batches was tried to keep almost same, in spite of few respondents dropping out.

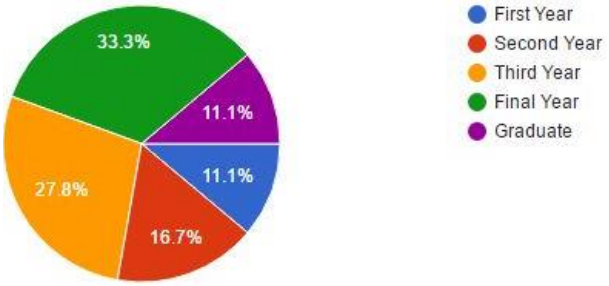

Fig. 1 Population distribution for initial survey

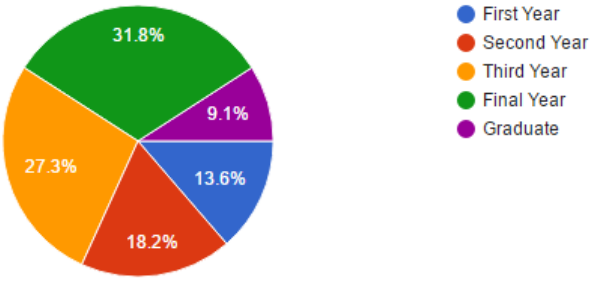

Fig. 2 Population distribution for final survey

IV. LITERATURE SHARED

A. *Current Situation of Power System in Pakistan*

Electrical energy crisis is a never-ending cry of Pakistan, and the world at large. In spite of several claims of increasing generation, the gap between electricity demand and supply never seems to end. The ever increasing population and fast deteriorating power system further worsens the situation.

Pakistan faces an annual deficit of Rs. 1.4 Trillion in lieu of load shedding, the most immediate effect of energy crisis and seemingly the easiest solution for the same. This cost is equal to the cost of adding 20,000 MW to the grid, which makes the actually confronted deficit even greater. Interestingly, there are more UPS (Uninterrupted Power Supply) being used in the country, than the entire population of Baluchistan. [3]

In addition to the huge gap between the power demanded and that supplied, the poor health of today's power system cannot be ignored. The high frequency of blackouts, plunging majority of the country into darkness and poor voltage stability at the consumer end also demand attention. The cost incurred in restarting a system from scratch, after a blackout and the reduction of equipment's life as a result of an unstable voltage output, make these issues as justified to be addressed, as is the shortfall of supplied power.

If the solution to the problems mentioned, is assumed to be an increase in generation, then the spokesperson of NEPRA best clears the doubt. Murtaza Haider - Dawn news story author, writes in his article "Pakistan's Power Crisis; Trans-Mission Impossible" that, "NEPRA revealed that KE, despite its tall claims of adding thousands more megawatts to the generation capacity, is limited to carrying no more than 2,200MW." [4]

On one hand the Alternate Energy Development Board (AEDB) exempts taxes and import duties for Independent Power Producers (IPPs), investing in green energy projects while there are at least 10 IPPs with pipelined projects and getting the generation license denied.

These indicate that, the root cause of the power shortage is the poor transmission system which is not able to keep pace with the increasing demand and the resulting increase in the generation. The transmission system is unable to accept the increased generated power and so there's no point in expanding the generation, but not being able to transmit the power. [8]

B. *Maximum Power Transfer Equation*

The maximum power that a transmission line can allow to flow, is given by Eq. (1)

$$P = \frac{VsVr}{X} \sin \delta \quad (1)$$

Where,

P = maximum power flow in a transmission line
Vs = sending end voltage
Vr = Receiving end voltage
X = reactance of a transmission line
δ = angle between Vs and Vr

Eq. (1) shows the dependency of maximum power flow on certain parameters. Starting from the sending end voltage V_s, it is the most important system constraint. The insulator ratings, line to line and line to ground clearance are all designed according to the voltage level decided for a transmission network. Thus, V_s is not subjected to change in an already built line.

V_r can be controlled, by maintaining a good voltage regulation, but this again has an upper bound, the V_s. Controlling the angle δ is not cost effective. The system's stability is limited to δ=90º In order to make system capable of sustaining the transients, usually its value is between 15º to 30º.

However, reactance of the transmission line has the greatest scope for alteration and can play an important role in increasing the power transfer capability of the transmission system.

One immediate solution therefore seems to install parallel lines, decreasing the overall inductive reactance. However, erecting new transmission lines in not an effective solution to increase the line capacity as it increases the cost of transmission network. Also, it takes a huge amount of effort and time to gain the rights of way. It is said that;

"It can take 15 years to negotiate the rights of way and complete a power line project; with FACTS the same project would take only 15 months" [5]

As long lines usually have a very pronounced inductive reactance, introducing capacitive effect (Xc) can effectively help reduce its impact.

$$P = \frac{VsVr}{Xl - Xc} \sin \delta \qquad (2)$$

As seen in Eq. (2), a smaller effective reactance (X_L-X_C) means increased capacity of line, paving way for more power to be transmitted efficiently, without overloading the lines.

Introducing capacitive effect is yet another challenge. Bulky capacitors with their fixed values, is not the solution to the ever varying load of a power system. There arises the need of a device that can produce both capacitive and inductive effect, properly addressing the load demands and still maintaining a good power factor and voltage regulation.[10]

C. FACTS – A Viable Solution

FACTS, Flexible AC Transmission System – is such a solution device. FACTS is the term used for a group of power electronic devices that are destined to enhance control over power flow through existing transmission network and to increase its capacity by about 50%. FACTS devices are best solution for meeting the electricity demand of the country and transmit the generated power efficiently.

FACTS devices, as the name suggests, make the transmission system "flexible", which means, these devices when incorporated in the power system enable it to operate more efficiently and provide the major advantage of real time reactive power control.

These devices compensate for the reactive power losses in the line, thus the reactive power required to drive the system need not be taken from the generating side now, thereby controlling the system power factor.[7,9]

Electricity blackouts occur due to the lack of voltage support, leading to voltage collapse and poor quality of power. FACTS devices have also proved to be a viable tool for improving voltage stability of transmission line, increasing grid reliability and reducing the frequency of blackouts. The voltage stability is attained by reactive power management by FACTS devices like STATCOM, SVC, UPFC and SSSC.

Also, since the power generated from wind and solar power plants is always fluctuating, some method is needed to stabilize it and protect both the plant and power grid from failure due to transients. With this increased protection, not only efficiency of plant is increased due to increased fidelity but the life of plant equipment is also increased. Thus, FACTS devices provide a stable and reliable solution for integration of renewable energy plant with the power grid, thus making the best use of all sorts of available resources.[6]

V. SURVEY RESULTS

Results of the survey forms before and after awareness campaign were gathered and compared to analyze the trends. Following are the observations obtained from the statistical comparison;(A) indicating before and (B) after.

First question: Whether there's an electrical energy crisis in Pakistan or not. Most of the respondents answered in affirmation, before the awareness campaign too, as shown in Fig. 3. However, there were a small percentage of people who were not sure if Pakistan meets the electricity demand or not. This percentage reduced to zero in the second survey.

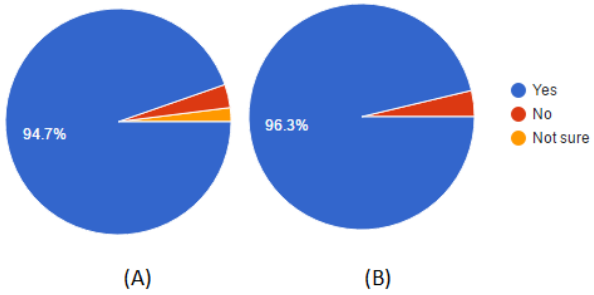

Fig. 3 Survey results of first question

Second question required the students to brainstorm possible reasons for the prevailing energy crisis. It provided multiple options out of which one or more were allowed to be chosen. It is evident from Fig. 4, that most of the students held opinion that the primary causes of the energy crisis in Pakistan are political issues and lack of attention on renewable energy sector. The awareness campaign succeeded in convincing a majority of the surveyed students that the transmission system of Pakistan is also one of the main areas that demand considerable attention.

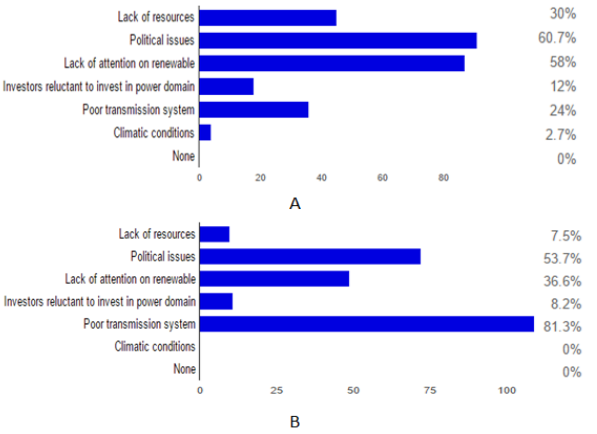

Fig. 4 Survey results of second question

Third question asked for an effective solution for the improvement of power factor and stability of a transmission system. As a result of the awareness drive, the percentage of students opting for FACTS as the

most viable solution, increased from 36.7% to 91.8%. This increase is shown in Fig. 5.

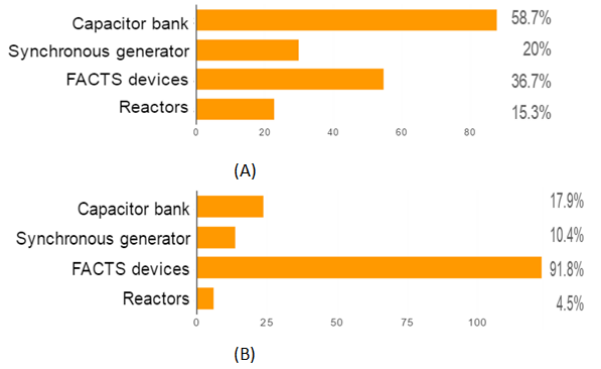

Fig. 5 Survey results of third question

The fourth question checked, whether the students knew that FACTS is deviced to be used at the transmission side. It is evident from Fig. 6, that many of the students were unaware of this basic fact. However, there were very few to respond the same question incorrectly after the awareness campaign was carried out.

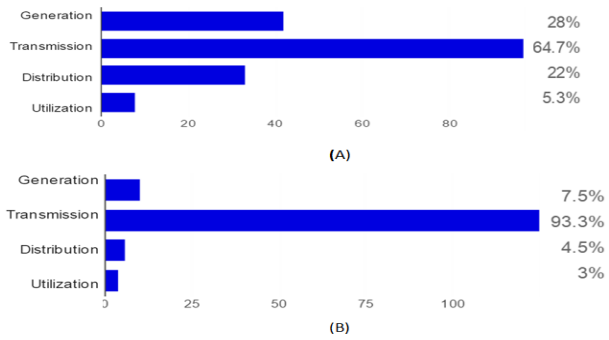

Fig. 6 Survey results of fourth question

In response to the fifth question shown in Fig. 7, which surveyed whether FACTS devices can help in increasing the demand with the supply of electricity, percentage of students were increased to around 82.8% from 36% as giving positive responses that yes, these devices can play an important role in bridging the gap between demand and supply by increasing the line capacity of the system.

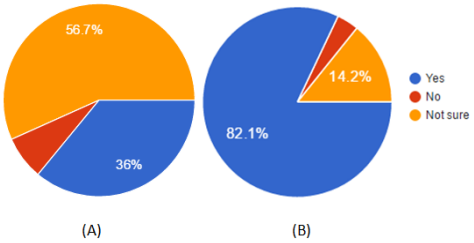

Fig. 7 Survey results of fifth question

Figs. 8~10, give the analysis of the questions asking whether FACTS devices can improve power quality, voltage stability and reduce blackouts respectively. The positive responses towards the power quality improvement, voltage stability, and reduction of blackouts by FACTS were increased by 30%, 33.7% and 33.7% respectively.

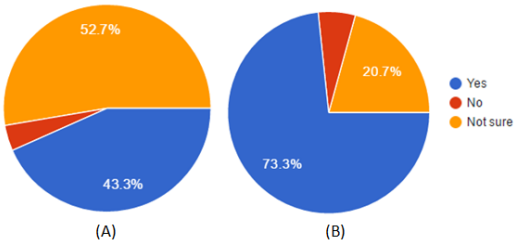

Fig. 8 Survey results of sixth question

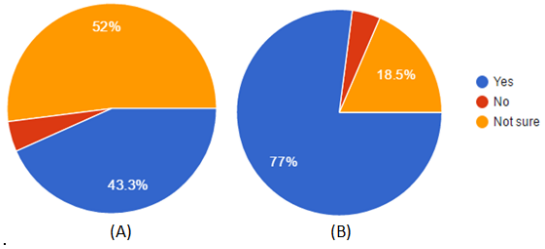

Fig. 9 Survey results of seventh question

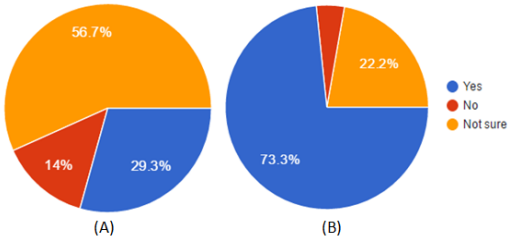

Fig. 10 Survey results of eighth question

The last question asked the students to propose the most effective solution for energy crises in Pakistan. The replies to the question were significantly changed after awareness drive as 91% of answers were in favor of FACTS devices. Fig. 11, shows this change.

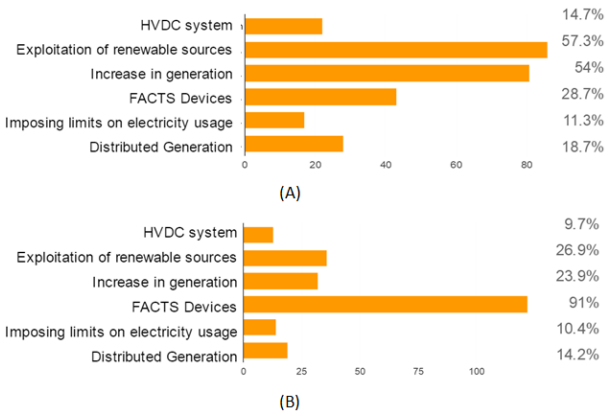

Fig. 11 Survey results of ninth question

VI. CONCLUSION

FACTS devices, despite benefitting the electrical transmission systems around the world since long, are

an idea unknown to many young electrical engineers and engineering students in Pakistan.

The survey results before and after, clearly signal a lack of attention towards research and development on FACTS devices and the teaching of its design and development in engineering universities. The interest and enthusiasm of the students towards these devices, observed during the awareness drive, evidence that the energy crisis in Pakistan can fast end if focus is laid on the teaching of these devices. Hence, increased curriculum content of power system courses on FACTS devices, is a valid proposition.

Similar Educational Surveys on other emerging technologies can be conducted and analyzed for curriculum development, seminars, workshops and symposia.

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