Narula Institute of Technology
81, Nilgunj Road, Agarpara, Kolkata-700109

---

# Supporting Documents
# Criteria: 2.3.1

# Index

# TEACHING
# LEARNING
# METHOD

Narula Institute of Technology
81, Nilgunj Road, Agarpara, Kolkata-700109

# Power System I (EE502)

*By Sudhangshu Sarkar, Assistant Professor, Department of Electrical Engineering.*

## A Finishing Undergraduate Course on Power System Operations and Control: Objectives, Outcomes, Challenges, and Opportunities

"The term Power System generally refers to a class of technology people are using to bring electricity delivery from Generating Station to the Consumer point." This technology not only requires power engineers to have a better understanding of auxiliary fields like signal processing, controls, information technology, and communication networks but also needs experts in the auxiliary fields to understand the basic operations and control of power systems. There is great need in industry for such cross-trained professionals to meet the many challenges of modernizing the power grid.

**Table 1. The areas involved with Power System Operation and Control.**

| Sl. No. | Area |
|---|---|
| 1 | Overhead transmission line: |
| 2 | Overhead line construction: |
| 3 | Insulators, Corona, Cables |
| 4 | Performance of lines |
| 5 | Generation of Electric Power |
| 6 | Tariff, Indian Electricity Rule-1956 |

To train professionals and students in Power System Operation and Control, one needs a creative curriculum that crosses traditional divisions based on disciplines. For example, students taking advanced courses in the power systems area traditionally have an electrical engineering background, with relevant training in control systems. Furthermore, the discussions on the course experience from both the student and faculty perspectives are required and it is needed to highlight the key lessons learned and challenges faced. Building on these lessons and in view of the need to overcome such challenges, a general approach is evolved, one that can be applied to the training of students in Power System Operation and Control.

## Course Setting

This section will briefly describe the overall setting in which the course is being conducted. This includes aspects such as the team of instructors and the areas in which they contributed, the academic structure that permitted the offering of such a course, the backgrounds of the students who took the class, and the mode of instruction used.

Principal
Narula Institute of Technology
81, Nilgunj Road, Agarpara
Kolkata-700 109

# Narula Institute of Technology

81, Nilgunj Road, Agarpara, Kolkata-700109

## Instructor Backgrounds

Table2. Team of Instructors involved in teaching various modules since start of the course.

| Sl. No. | Area | July 2013 | July 2014 | July 2015 | July 2016 |
|---|---|---|---|---|---|
| 1 | Overhead transmission line | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar |
| 2 | Overhead line construction | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar |
| 3 | Insulators, Corona, Cables | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar |
| 4 | Performance of lines | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar |
| 5 | Generation of Electric Power | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar |
| 6 | Tariff, Indian Electricity Rule-1956 | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar | Sudhangshu Sarkar |

Table3. Background of Instructors involved in teaching various modules since start of the course.

| Sl No. | Faculty Name | Qualification | Experience |
|---|---|---|---|
| 1 | Amlan Chakrabarti | BTech(EE), MTech(Power System) | 6 years of Industry, Teaching and Research |

The instructor offered to teach various topics spanning a multitude of disciplines, as shown in Table 2 and Table 3. The instructor has 10 years of experience in design and implementation of large energy control centers for Power System Load Dispatch and 10 years of experience in teaching. He has collaborated on research with three senior faculty of eminent institutions in India and has international journal publications with them.

## Academic Structure

The academic structure of the department that allowed the offering of such a course should prove useful for those wanting to replicate our efforts. The department is called Electrical Engineering and has one of the faculty as Head of the Department. The department offers B.Tech. degrees in electrical engineering at the undergraduate level and M.Tech. degrees in Power System. For the course, in the two major areas of power systems operation and stability, it was agreed (in consultation with the Head of the Department) that the two instructors would take turns managing the offerings and receiving credits towards their teaching assignments.

Sarkar

Principal
Narula Institute of Technology
81, Nilgunj Road, Agarpara
Kolkata-700 109

## Class Roster Composition

The course had an enrollment of 60 graduate students till the 2012-13 academic session. All of these students identified themselves as majoring in Power System and undergoes two separate semester courses in Power Systems; From academic session 2013-14, the enrolment has increased to 120 students and two parallel classes are run for two sections.

## Mode of Instruction

The class was of a traditional nature, with three 55-minute class meetings used for lectures and discussions. Class notes, along with pointers to related reading, were posted using email. The instructor came to his assigned class days and delivered lectures and engaged in discussions with students. The instructor even sat through lectures by others and engaged in discussions specific to their areas of expertise and how various topics were connected with power system operation and control.

## Course Details

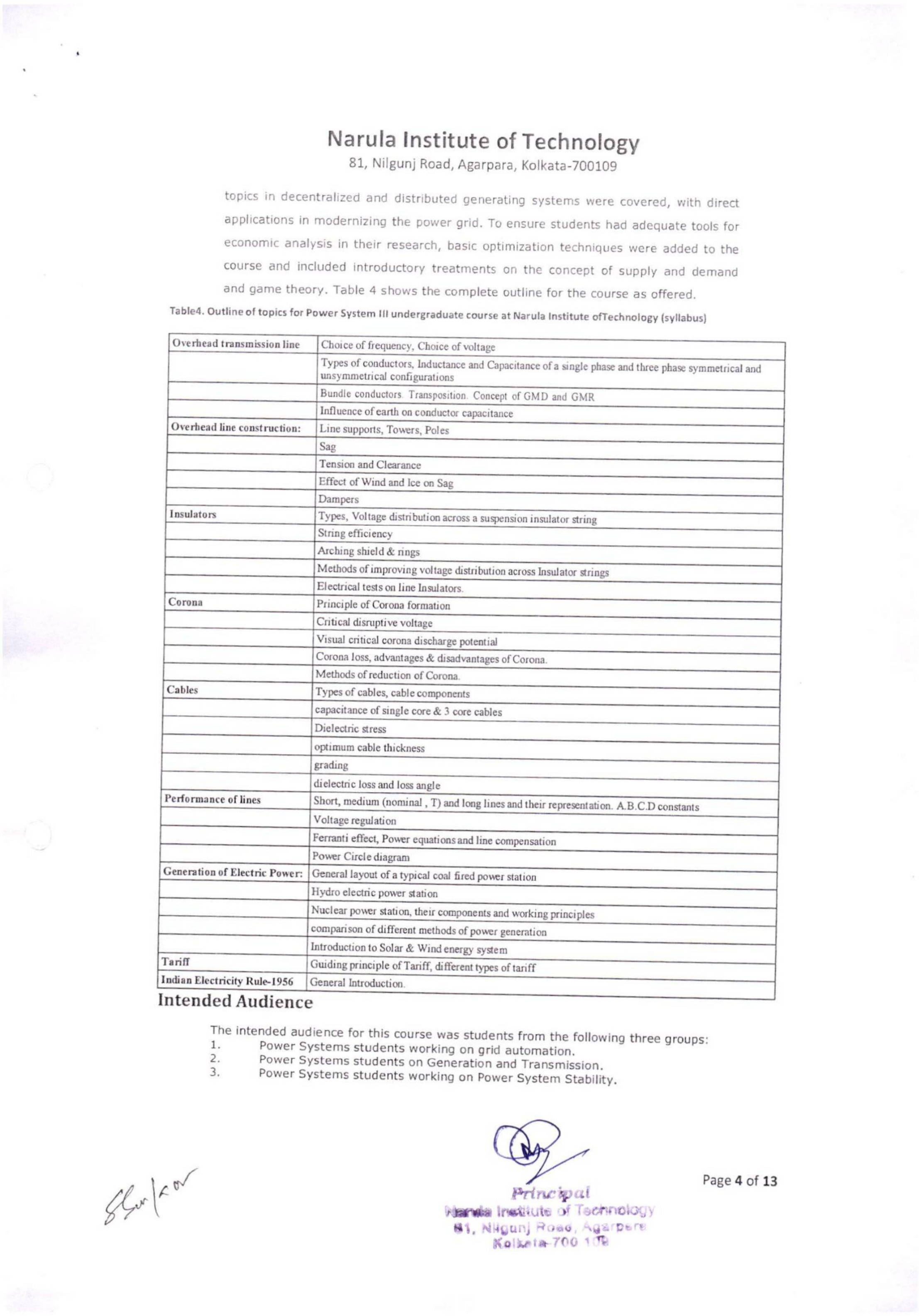
We next present additional details on the course offering, including the selection of topics covered, the intended audience, the sequence of execution, and the composition of research project groups.

## Selection of Topics

The course was intended to train graduate students in Power System operation and control, transients and compensation for stability. The course was divided into five parts: power systems in restructured environment and environment aspects, Economic aspects of energy generating systems, Automatic Generation Control, Compensation in Power Systems, and Power System Transients. The two main thrustsof the course were power systems operation and compensation and transients. The selection of topics was based primarily on two considerations. The first consideration was ensuring that power systems students were exposed to basic techniques of operation and control. The second was ensuring that the instructors had adequate expertise with respect to the chosen topics to involve students in research. There was also the additional consideration of adding breadth, which was accomplished by adding topics in compensation, transients and its applications and environmental issues.

The topics in the power systems area emphasized what the authors felt were emerging and important research topics, with a fair amount of attention given to the area of power transmission systems. The topics on environmental issues and power system restructuring added a focus on sustainable energy solutions and exposed the students to issues that relate to the expected impact of power grids. To provide a third focus apart from power systems operation, compensation and transients, various

Principal
Narula Institute of Technology
81, Nilgunj Road, Agarpara
Kolkata-700 109



Narula Institute of Technology
81, Nilgunj Road, Agarpara, Kolkata-700109

topics in decentralized and distributed generating systems were covered, with direct applications in modernizing the power grid. To ensure students had adequate tools for economic analysis in their research, basic optimization techniques were added to the course and included introductory treatments on the concept of supply and demand and game theory. Table 4 shows the complete outline for the course as offered.

**Table4. Outline of topics for Power System III undergraduate course at Narula Institute ofTechnology (syllabus)**

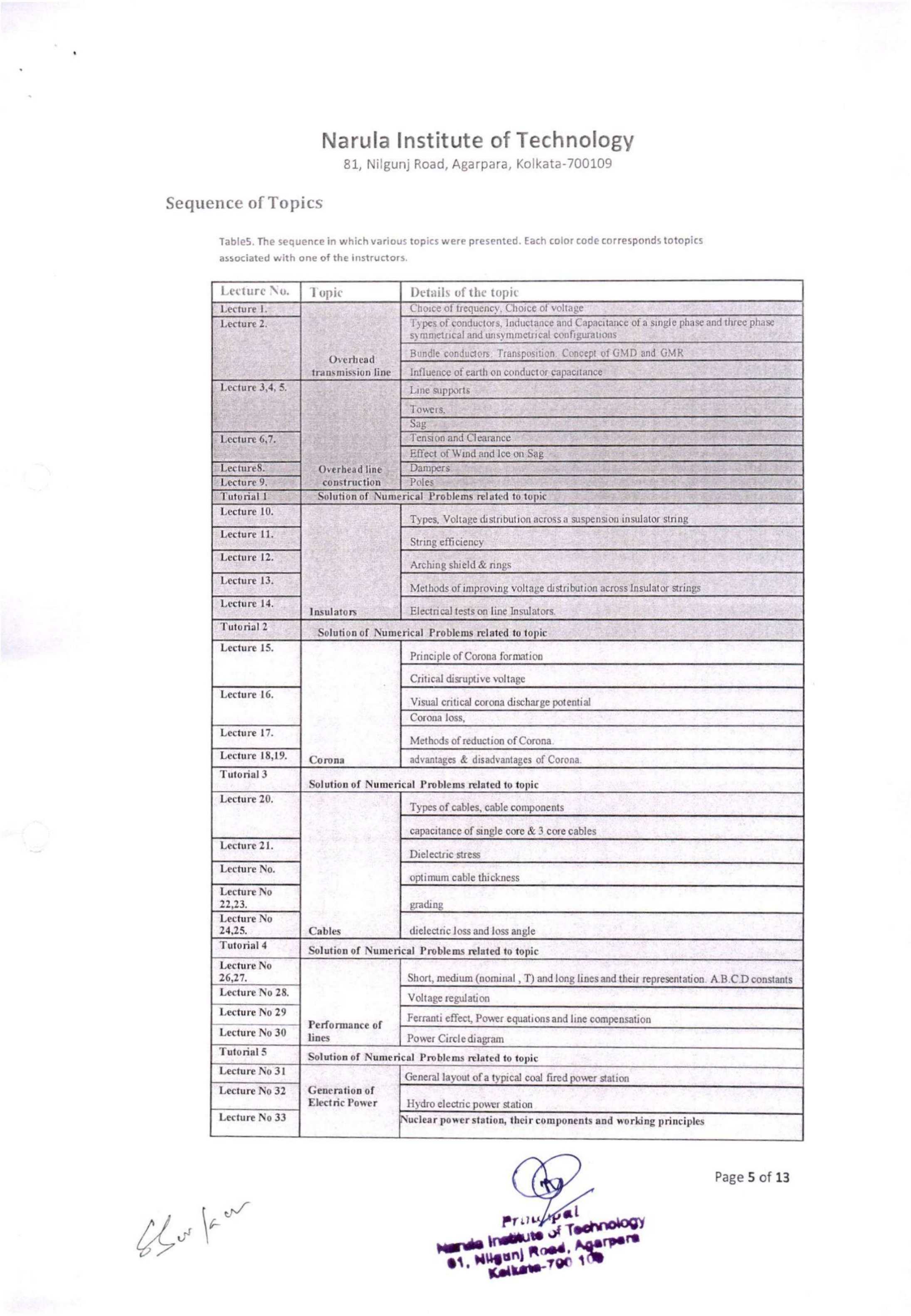
| | |
|---|---|
| **Overhead transmission line** | Choice of frequency, Choice of voltage |
| | Types of conductors, Inductance and Capacitance of a single phase and three phase symmetrical and unsymmetrical configurations |
| | Bundle conductors. Transposition. Concept of GMD and GMR |
| | Influence of earth on conductor capacitance |
| **Overhead line construction:** | Line supports, Towers, Poles |
| | Sag |
| | Tension and Clearance |
| | Effect of Wind and Ice on Sag |
| | Dampers |
| **Insulators** | Types, Voltage distribution across a suspension insulator string |
| | String efficiency |
| | Arching shield & rings |
| | Methods of improving voltage distribution across Insulator strings |
| | Electrical tests on line Insulators. |
| **Corona** | Principle of Corona formation |
| | Critical disruptive voltage |
| | Visual critical corona discharge potential |
| | Corona loss, advantages & disadvantages of Corona. |
| | Methods of reduction of Corona. |
| **Cables** | Types of cables, cable components |
| | capacitance of single core & 3 core cables |
| | Dielectric stress |
| | optimum cable thickness |
| | grading |
| | dielectric loss and loss angle |
| **Performance of lines** | Short, medium (nominal , T) and long lines and their representation. A.B.C.D constants |
| | Voltage regulation |
| | Ferranti effect, Power equations and line compensation |
| | Power Circle diagram |
| **Generation of Electric Power:** | General layout of a typical coal fired power station |
| | Hydro electric power station |
| | Nuclear power station, their components and working principles |
| | comparison of different methods of power generation |
| | Introduction to Solar & Wind energy system |
| **Tariff** | Guiding principle of Tariff, different types of tariff |
| **Indian Electricity Rule-1956** | General Introduction. |

## Intended Audience

The intended audience for this course was students from the following three groups:

1. Power Systems students working on grid automation.
2. Power Systems students on Generation and Transmission.
3. Power Systems students working on Power System Stability.

Principal
Narula Institute of Technology
81, Nilgunj Road, Agarpara
Kolkata-700 109



## Narula Institute of Technology

81, Nilgunj Road, Agarpara, Kolkata-700109

### Sequence of Topics

Table5. The sequence in which various topics were presented. Each color code corresponds totopics associated with one of the instructors.

| Lecture No. | Topic | Details of the topic |
|---|---|---|
| Lecture 1. | Overhead transmission line | Choice of frequency, Choice of voltage |
| Lecture 2. | | Types of conductors, Inductance and Capacitance of a single phase and three phase symmetrical and unsymmetrical configurations |
| | | Bundle conductors. Transposition. Concept of GMD and GMR |
| | | Influence of earth on conductor capacitance |
| Lecture 3,4, 5. | Overhead line construction | Line supports |
| | | Towers, |
| | | Sag |
| Lecture 6,7. | | Tension and Clearance |
| | | Effect of Wind and Ice on Sag |
| Lecture8. | | Dampers |
| Lecture 9. | | Poles |
| Tutorial 1 | Solution of Numerical Problems related to topic | |
| Lecture 10. | Insulators | Types, Voltage distribution across a suspension insulator string |
| Lecture 11. | | String efficiency |
| Lecture 12. | | Arching shield & rings |
| Lecture 13. | | Methods of improving voltage distribution across Insulator strings |
| Lecture 14. | | Electrical tests on line Insulators. |
| Tutorial 2 | Solution of Numerical Problems related to topic | |
| Lecture 15. | Corona | Principle of Corona formation |
| | | Critical disruptive voltage |
| Lecture 16. | | Visual critical corona discharge potential |
| | | Corona loss, |
| Lecture 17. | | Methods of reduction of Corona. |
| Lecture 18,19. | | advantages & disadvantages of Corona. |
| Tutorial 3 | Solution of Numerical Problems related to topic | |
| Lecture 20. | Cables | Types of cables, cable components |
| | | capacitance of single core & 3 core cables |
| Lecture 21. | | Dielectric stress |
| Lecture No. | | optimum cable thickness |
| Lecture No 22,23. | | grading |
| Lecture No 24,25. | | dielectric loss and loss angle |
| Tutorial 4 | Solution of Numerical Problems related to topic | |
| Lecture No 26,27. | Performance of lines | Short, medium (nominal , T) and long lines and their representation. A.B.C.D constants |
| Lecture No 28. | | Voltage regulation |
| Lecture No 29 | | Ferranti effect, Power equations and line compensation |
| Lecture No 30 | | Power Circle diagram |
| Tutorial 5 | Solution of Numerical Problems related to topic | |
| Lecture No 31 | Generation of Electric Power | General layout of a typical coal fired power station |
| Lecture No 32 | | Hydro electric power station |
| Lecture No 33 | | Nuclear power station, their components and working principles |

Principal
Narula Institute of Technology
81, Nilgunj Road, Agarpara
Kolkata-700 109

| | | |
|---|---|---|
| Lecture No 34 | | comparison of different methods of power generation |
| Lecture No 35 | | Introduction to Solar & Wind energy system |
| Lecture No 36 | | Guiding principle of Tariff, different types of tariff |
| Lecture No 37 | | General Introduction. |

Designing a course so as to keep students from diverse backgrounds engaged can be challenging. As a result, it was decided to start off with basic, introductory lectures in the two major thrust areas before advanced topics were covered in either of them. It was expected this would provide an early, common platform enabling all students to subsequently understand and appreciate more advanced topics. The power systems portion started with an introduction (or refresher) that included basic concepts such as circuit theory; this was aimed at any computer-networking students who may have been out of touch. Similarly, the course covered basic computer-networking concepts and how the Internet works for students from otherdisciplines. Figure 3 shows the order in which topics were taught throughout the course.

## Project Component

All course assignments and projects were assigned to students working in pairs, with the rule that in each pair, the students had to come from different concentrations. For example, power system students were paired with networking or controls students. This was designed to enable one student, well versed in an areaunder consideration, to be the lead in an area-specific assignment and help a student from another background catch up and learn from a peer. For projects, this procedure was expected to enable the formulation of interdisciplinary problems that would require students from diverse backgrounds to join together to move toward a solution.

**Table6. Some of the under gradate projects related to the power system conducted under theguidance of various faculty members of the Electrical department**

| Name of the project | Year of project | Project Guide | No of Students |
|---|---|---|---|
| Effect of Reactive power on voltage stability | 2013 | Dipu Sarkar | 5 |
| Effect of line contingency on voltage stability | 2014 | Kamalika Banerjee | 5 |
| Performance of a power network at different feeder reconfiguration | 2015 | Kamalika Banerjee | 5 |
| Reactive Power Compensation Using SVC | 2016 | Kamalika Banerjee | 5 |

## Course Outcomes and Challenges

This section will look back at the lessons learned and challenges identified from the

Principal
Narula Institute of Technology
81, Nilgunj Road, Agarpara
Kolkata-700 109

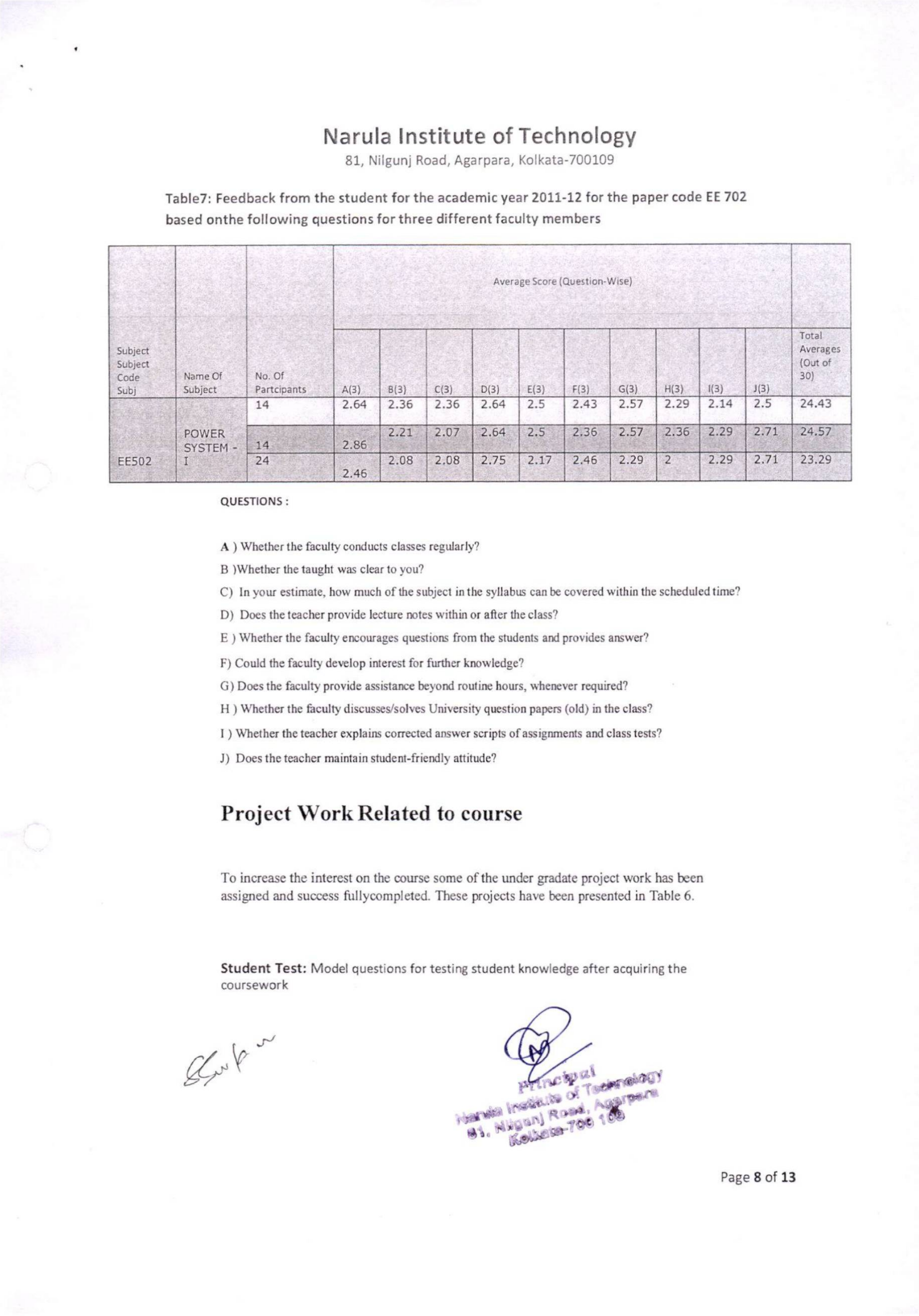
first offering of the course in the ODD session of 2009 and discuss how some of the lessons and feedback will be incorporated and certain challenges met the next time around.

For the offering of such an advanced course in Power System, the expected outcome was to have studentsunderstand the interaction of various disciplines in powergrids. Outcomes were to a great extent measured based on assessments: through a test, course projects, and student feedback. Overall, most students feltthey knew a lot more about power grids than they did when they arrived and had a fair idea of the role ofenvironment, economics, compensation and stability. Working together on projects with students withknowledge of other areas had helped them to look at power grids from a different perspective and learnfrom each other. Some students reported concerns that they had been exposed to a lot of topics and saidthey found it difficult to grasp a holistic view of the material. Some felt that it would have been better if thecourse had been offered in a top-down fashion rather than with a bottom-up approach. Some students feltthat there was not enough material presented in areas they were less familiar with.

### Course feed back

A Feed back format has been prepared by the Institute Academic and management committee based on the following important issue for the course as cited in a question pattern. Each issue carries 3 marks. There are total 10 issues. Total feed back marks are 30. The strength and weakness of each of theimportant issue may be estimated by the marks given by student average feedback out of 3. The feed back from the students for the academic year 2011-12 for the paper code EE 702 based on the following questions for three different faculty members (presented three different colors).

Principal
Narula Institute of Technology
81, Nilgunj Road, Agarpara
Kolkata-700 109



## Narula Institute of Technology

81, Nilgunj Road, Agarpara, Kolkata-700109

**Table7: Feedback from the student for the academic year 2011-12 for the paper code EE 702 based onthe following questions for three different faculty members**

| | | | Average Score (Question-Wise) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subject Subject Code Subj | Name Of Subject | No. Of Partcipants | A(3) | B(3) | C(3) | D(3) | E(3) | F(3) | G(3) | H(3) | I(3) | J(3) | Total Averages (Out of 30) |
| EE502 | POWER SYSTEM - I | 14 | 2.64 | 2.36 | 2.36 | 2.64 | 2.5 | 2.43 | 2.57 | 2.29 | 2.14 | 2.5 | 24.43 |
| | | 14 | 2.86 | 2.21 | 2.07 | 2.64 | 2.5 | 2.36 | 2.57 | 2.36 | 2.29 | 2.71 | 24.57 |
| | | 24 | 2.46 | 2.08 | 2.08 | 2.75 | 2.17 | 2.46 | 2.29 | 2 | 2.29 | 2.71 | 23.29 |

**QUESTIONS :**

**A** ) Whether the faculty conducts classes regularly?

B )Whether the taught was clear to you?

C) In your estimate, how much of the subject in the syllabus can be covered within the scheduled time?

D) Does the teacher provide lecture notes within or after the class?

E ) Whether the faculty encourages questions from the students and provides answer?

F) Could the faculty develop interest for further knowledge?

G) Does the faculty provide assistance beyond routine hours, whenever required?

H ) Whether the faculty discusses/solves University question papers (old) in the class?

I ) Whether the teacher explains corrected answer scripts of assignments and class tests?

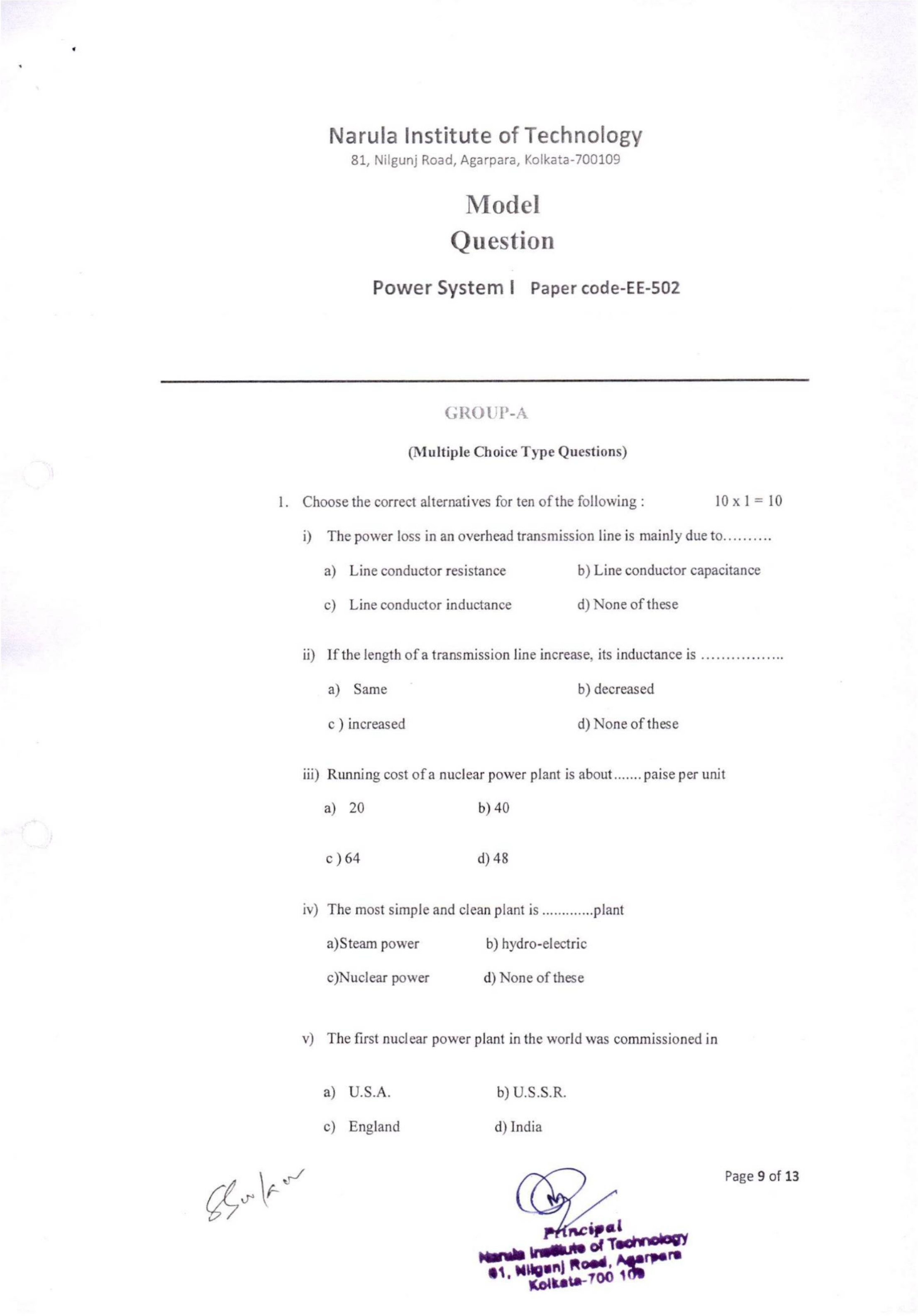
J) Does the teacher maintain student-friendly attitude?

## Project Work Related to course

To increase the interest on the course some of the under gradate project work has been assigned and success fullycompleted. These projects have been presented in Table 6.

**Student Test:** Model questions for testing student knowledge after acquiring the coursework

Principal
Narula Institute of Technology
81, Nilgunj Road, Agarpara
Kolkata-700 109



## Narula Institute of Technology

81, Nilgunj Road, Agarpara, Kolkata-700109

# Model Question

## Power System I Paper code-EE-502

---

### GROUP-A

**(Multiple Choice Type Questions)**

1. Choose the correct alternatives for ten of the following : 10 x 1 = 10

i) The power loss in an overhead transmission line is mainly due to……….

a) Line conductor resistance b) Line conductor capacitance

c) Line conductor inductance d) None of these

ii) If the length of a transmission line increase, its inductance is ……………..

a) Same b) decreased

c ) increased d) None of these

iii) Running cost of a nuclear power plant is about....... paise per unit

a) 20 b) 40

c ) 64 d) 48

iv) The most simple and clean plant is ............plant

a)Steam power b) hydro-electric

c)Nuclear power d) None of these

v) The first nuclear power plant in the world was commissioned in

a) U.S.A. b) U.S.S.R.

c) England d) India

Principal
Narula Institute of Technology
81, Nilgunj Road, Agarpara
Kolkata-700 109

## Narula Institute of Technology

81, Nilgunj Road, Agarpara, Kolkata-700109

vi) The ideal tariff for any type of consumers is …… tariff.

a)Two-part b) three- part

c)Power factor d) None of these

vii) The longer the cross arm, the.......... the string efficiency.

a)greater b) lesser

c)equal d) None of these

viii) Suspension type insulators are used for voltage beyond

a)33 KV b) 400 KV

c)11 KV d) 66 KV

ix) In short transmission lines, the effect of.....................are neglected.

a)capacitance b) resistance

c)inductance d) None of these

x) The length of a short transmission line is upto about…..

a)50km b) 120km

c)200km d) 300km

### GROUP-B

**(Short Answer Type Questions)**

Answer any three of the following. 3 x 5 = 15

2. Discuss the effect of wind and ice on sag.
3. What is Ferranti effect? Explain with phasor diagram.
4. Explain skin effect. On which factor does it depend?
5. What is meant by "transposition of conductors?" What is the need of transposition of conductorsof an overhead transmission line?
6. Why are transmission line classified based on their length? Define regulation of a transmissionline.

Principal

## GROUP-C

### (Long Answer Type Questions)

Answer any three of the following. 3 x 15 = 45

7. a) What is meant by the term "tariff"? 2

b) Explain the following:

i) Block rate tariff.

ii) Power factor tariff.

iii) Three-part tariff. 6

c) Determine the load factor at which the cost of supplying a unit of electricity from a Diesel and from a steam station is the same if the annual fixed and running charges are as follows.

| Station | Fixed charges | Running charges | |
|---|---|---|---|
| Diesel | Rs. 300 per KW | 25 paise/KWh | |
| Steam | Rs. 1200 per KW | 6.25 paise/KWh | 7 |

8. a) What do you mean by corona? 2

b) Discuss the factors which affect corona. 5

c) Discuss the methods of reducing corona effect. 3

d) A 132 KV line with 1.956 cm dia. Conductors is built so that corona takes place if the line voltage exceeds 210 KV (r.m.s.). If the value of potential gradient at which ionization occurs can be taken as 30 KV per cm, find the spacing between the conductors. 5

9. a) Determine the generalized constants of a medium transmission line-Nominal T method. 7

b)A 3-phase transmission line, 160 km long, has the following constant:
Resistance/phase/km = 0.2 ohms

Reactance/phase/km = 0.3127 ohms Shunt
admittance/phase/km = 1.875 X $10^{-6}$ S.
Determine the sending end voltage and current by rigorous method when the line is delivering a load of 25 MVA at 0.8 p.f. lagging. The receiving end voltage is kept constant at 110 KV. 8

10. (a) What do you mean by Grading of cables. 2

(b) Derive capacitance grading and intersheath grading 10

(c) What are the main components of overhead lines-discuss. 3

11. (a) What is sag? 2

(b) What are the effect of wind and ice loading on sag? 5

(c) A transmission line over a hillside where the gradient is 1:20, is supported by two 22 m high towers with a distance of 300 m between them. The lowest conductor is fixed 2 m below the top of each tower. Find the clearance of the conductor from the ground. Given that conductor weights1 kg/m and the allowable tension is 1500 kg. 8

## Challenges

One of the challenges that presented itself in our attempt to improve the motivation was using class time effectively to meet the learning needs of students while ensuring that the material taught was interesting to all and not repetitive for some class members. Future offerings may need to assign more out-of-class assignments and activities to students in their deficient areas so that class time is used for common activities that advance learning for all.

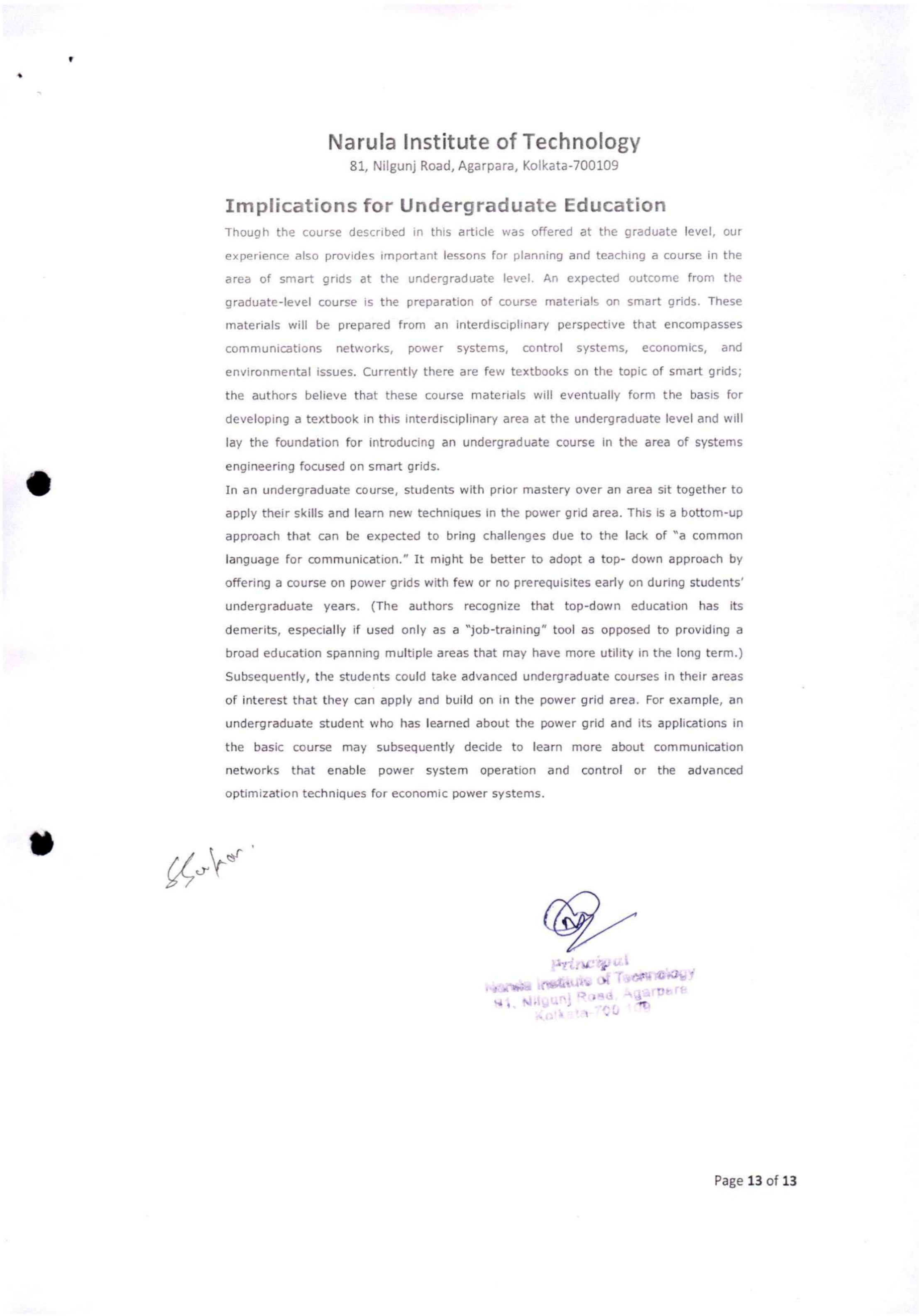
Another challenge was to bring together so many instructors at appropriate times for a semester-long course. Most instructors provided their valuable time to us on a voluntary basis and had to free up hours from their busy schedules to be a part of the course, which of course imposed some constraints on their availability. The flow of the course offering had to be designed bearing in mind the schedule constraints of each instructor. This also meant that some material was presented earlier or later than it would be in an ideal sequence of lectures.

The authors feel that the biggest challenge in interdisciplinary classes such as those on smart grids will be achieving depth while satisfying the requirements of breadth. By the end of the course that was offered, it was apparent that students had not really gone into much depth on any aspect of the material and that most of the class time was spent bridging deficiencies in the students' background knowledge. For example, students had to be taught the basics of optimization techniques. An ideal situation would have been for the students to come to class with background deficiencies removed and able to focus on achieving depth through classroom activities.

An ideal curriculum that supports an advanced course of this nature would let students from multiple backgrounds come to class and meet with learning outcomes specific to their backgrounds and subareas of interest, with significant depth achieved. This is almost impossible in current classroom teaching environments, where students enter with different core and free elective backgrounds and must first remove deficiencies, thus leaving no time for in-depth learning. This "bottleneck" prevents most courses offeredfrom being truly effective and could limit the capabilities of the next generation of engineers and scientists entering the workforce.

A peer-to-peer learning model would complement blending learning by having students from one background help students from another background learn course material, aided by online modules assigned by the instructor or instructors. In a undergraduate-level course with an end-of-semester project, there is additional incentive for students to teach others in order to maximize their success with the project.

Principal



Narula Institute of Technology
81, Nilgunj Road, Agarpara, Kolkata-700109

## Implications for Undergraduate Education

Though the course described in this article was offered at the graduate level, our experience also provides important lessons for planning and teaching a course in the area of smart grids at the undergraduate level. An expected outcome from the graduate-level course is the preparation of course materials on smart grids. These materials will be prepared from an interdisciplinary perspective that encompasses communications networks, power systems, control systems, economics, and environmental issues. Currently there are few textbooks on the topic of smart grids; the authors believe that these course materials will eventually form the basis for developing a textbook in this interdisciplinary area at the undergraduate level and will lay the foundation for introducing an undergraduate course in the area of systems engineering focused on smart grids.

In an undergraduate course, students with prior mastery over an area sit together to apply their skills and learn new techniques in the power grid area. This is a bottom-up approach that can be expected to bring challenges due to the lack of "a common language for communication." It might be better to adopt a top- down approach by offering a course on power grids with few or no prerequisites early on during students' undergraduate years. (The authors recognize that top-down education has its demerits, especially if used only as a "job-training" tool as opposed to providing a broad education spanning multiple areas that may have more utility in the long term.) Subsequently, the students could take advanced undergraduate courses in their areas of interest that they can apply and build on in the power grid area. For example, an undergraduate student who has learned about the power grid and its applications in the basic course may subsequently decide to learn more about communication networks that enable power system operation and control or the advanced optimization techniques for economic power systems.

Principal
Narula Institute of Technology
81, Nilgunj Road, Agarpara
Kolkata-700 109