Summary Report

About Department/Center/School:

The department was established during the inception of the institute in 1951. It took a pioneering role in establishing two inter-disciplinary undergraduate programmes in instrumentation engineering (1982) and energy engineering (1983). The major areas of faculty expertise include Opto-Electronics, Electromagnetics, Power Electronic Drives, Industrial Automation and Control, High Voltage Engineering, Power Systems, Superconductivity, Signal and Image Processing, Industrial and Biomedical Instrumentation and control and many more.

1. Academic Programs (Range of Degrees and Disciplines):

a. *UG Curriculum: B. Tech (4 Years)*
   1. *Electrical Engg.*
   2. *Instrumentation Engg.*

Dual Degree (5 Years) –
1. *B.Tech in Electrical Engg and M.Tech in Machine Drives and Power Electronics*
2. *B.Tech in Electrical Engg and M.Tech in Control System Engineering*
3. *B.Tech in Electrical Engg and M.Tech in Power and Energy Systems*
4. *B.Tech in Electrical Engg and M.Tech in Instrumentation and Signal Processing*
5. *B.Tech in Instrumentation Engg and M.Tech in Control Systems*
6. *B.Tech in Instrumentation Engg and M.Tech in Instrumentation and Signal Processing*

b. *PG Curriculum: Joint M.Tech PhD programmes where M.Tech (2years) curriculum is as below*
   1. *Machine Drives and Power Electronics*
   2. *Control System Engineering*
   3. *Power and Energy Systems*
   4. *Instrumentation and Signal Processing*

M. S. (by Research)
Ph. D.

2. **Major 4-5 Thrust Areas of Research:**

(i)Power Converters & Drives, (ii)Micro-Grid & Renewable Energy, (iii)Embedded Sensing & Systems, (iv)Signal & Image Processing, Machine Learning, (v)Advanced Control Theory & its Application

3. Curriculum and Courses & Teaching Environment

Items	**Ratio/ Number**	**Items**	**Number/%**
Teacher-student Ratio	1:24	Average No. of students motivated (%) to opt of careers Eng/ Tech. Sectors UG/PG/PhD	85%
No. of Faculty members as on today	30	Average No. of students motivated (%) to opt of careers in Science sectors UG/PG/PhD	NA

Average No. of Tutorial Assistants	80	No. of teaching labs	10
No. of UG/DD students	380/120	Average No. of students per experiments in core courses	3
No. of PG students/PhD students	170/54	No. of Students' workshops/``Tinkering'' Labs	10
Average no. of tutors with more than 100 students	10	No. of new courses introduced	10
Average Students placements (%) (UG/DD/PG)	93/95/59	No. of New program introduced	2 (modified)
No of major curriculum review in both UG & PG level	0/1	Undergraduate Vs PhD strength expressed as Percentage	10.8%
No of UG lab (teaching labs) developed/set-ups	10/100	No of PG/research labs developed/new set up	3
No of E class rooms	0	No. of lab classes per week	21
Average No. of Course done per student for B. Tech/DD/M. Tech/Ph.D	58/66/16/4	No. of core/elective/seminar/projects subjects taken for B. Tech, DD, and M. Tech respectively	49/6/1/2 54/7/1/4 7/5/2/2

4. Research and Development & its Environment

Items	**Number**	**Items**	**Number**	**Items**	**No.**
Total No. of Publications in Journals (2008-13)	259	Average no. of citation per paper	14	No of large interdisciplinary research projects	10
Total No. of Publications in Conference & Symposium	243	Average Journal publication per year	51.8	Number of Int. conf./workshops attended by students	30/10
Total No of Books & e-books published	6	h-Index of the department since 2008/overall h-index in Scopus	40	No. of PDF hired in the Institute	0
Total No of Edited Conference Proceedings/book chapters	2/8	Number of papers with citation more that the average no. of citation of the Journals	Not known	No. of international Students as PhDs/PDFs	0/0
Total No. of Technology Developed/transferred	*40/10*	No. of recognitions & Awards, fellows etc to faculty/students (provide break up if necessary)	5/	No. of International visiting researchers/adjunct faculty stayed here for at least a week	*2/0*
Total No. of Patents Filed/Obtained	*33/8*	Average Retention(%) of Young faculty for at least 10 years	85.7%	No. of short courses/workshops /conf. organized with international participations	*2*
Total No. of Copyright Filed/Obtained	*7/2*	No. of Sponsored research Project /fund(lakh) generated from non-internal source	62/3030	Average No. of PhD granted per year	*5.2*

No. of Publications per Faculty/Masters/PhD students	**16.7/ /**	No. of Consultancy /fund (lakh) generated from non-internal source	43/330	Average No. of PhD Granted per year per faculty	*0.173*
No. of Publications per Faculty/Masters/PhD students in Top Ten Journals as Identified by the department	**3.2/ /**	No of Internal and external Collaborations research papers/research projects/PhD students	75/5/2	Patent granted per faculty	*0.267*
Average No. of Citation per faculty per year	**37.4**	No of M. Tech students motivated into pursuing PhD/PhD graduates motivated to pursue career in Academics(abroad or IIT etc)	25	Number of articles in collaborations with Ten countries*	*15*
Ranking of the department in terms of average citations per paper within the Institute	Not available	Ranking of the department in terms of total number of Journal publications within the Institute/publications per faculty	Not available	No of articles of the dept. contributing towards h-index of the Institute since 2008	Not available

5. External Stakeholder Engagement and others

Items	**Number**	**Amount Lakh**
No. of PhD/Master students' thesis funded by Industries	10	100 (approx.)
Total number of Industry sponsored projects and its income (Lakh)	51	1225
No. of Curriculum Development Initiative for Industries	05	
No of Technology transfer/adopted by Industry/Labs	20	
No. of Nationally relevant research projects	5	
No of Policy inputs/consultancies provided	5	
No. of Research grant and seed money from internal savings of the Institute per young faculty of the department and its total fund	Total 3	15
No. of Community Relevant projects	03	

6. Vision for the Future (in brief):

(a) Departments/centers/schools should spell out its Mission and Vision Statements, (b) Plans for future to achieve the projected goals and (c) measures adopted towards above.

Vision

To be a global leader in the field of Education and Research in Electrical Engineering. To equip our graduates with the latest knowledge in their field of education and also inculcate human and social values of courage, conviction, integrity, sharing, empathy and social responsibility.

Mission

- *To be among the top 50 EE Dept. in the world by 2020*
- *To provide international standard facilities and laboratories for our students and faculty*

- *To inspire our faculty and students to carry out breakthrough research which will make a visible impact in national/international arena*
- *To play leadership role in major national mission projects*
- *To promote international and industrial collaborations to strengthen our academic and research capability*

Plans and measures

- *Recruit at least 8 faculty members per year to attain a teacher to student ratio of 1:10 in 5 years*
- *Setup state-of-the-art research laboratories at least one in each area of specialization within next 5 years*
- *Publish minimum 3 research papers per faculty every year in top rated journals in their field*
- *Earn research grants of 10 crores per year from sponsored/consultancy projects*
- *Setup innovation laboratories for students to work without curricular constraints*
- *File 10 patents/IPR per year and target a revenue generation of INR 1 crore in the next 5 years through commercialization*
- *Publish 5 books/monographs/e-books/video-lectures per year*
- *Develop 4 new state-of-art courses every year*
- *Organize at least one international conference/ workshop/seminar every year*
- *At least 25 faculty visiting abroad for international collaborations/conferences every year*
- *Conduct at least one international summer/winter program per year*

7. External peer review of the Dept./centre/schools (in brief):

(a) Date of the peer review: *23rd September, 2008*

(b) Name of the Experts involved and their affiliations in short: *Prof. M.Vidyasagar, Vice President, TCS, Prof. Anjan Bose, University of Washington and Mr. Bhanu Bhusan, Central Electricity Regulatory Commision*

(c) Comments:

1. *The division of research in the department into four major areas is an excellent strategy for strengthening research, but the further sub-areas seem to be too many suggesting that the emphasis is more on quantity rather than building critical mass and recognition.*
2. *Research and visibility impact needs to be increased not so much in terms of funding, publication and citation (which seems to be quite good already) but in terms of technology transfer, affecting national policy and faculty recognition.*
3. *The number of masters and doctoral doctoral students for the size of the faculty is large enough but it is not clear whether the talents of all these students are being utilized to advance research directions of the department in the best way.*
4. *The quality of masters/doctoral students and the encouragement of the more research-productive faculty members are key inputs to research directions of the department in the best way.*
5. *The undergraduate program is already excellent but some metrices to track the quality of the program over time will lead to continuous quality improvement while allowing the department to turn more attention to increasing research productivity and impact.*
6. *Make UG project optional, permit multi-student project*
7. *Need to be more hardworked on negotiating IPR and ensuring that laboratory prototypes get curved into world class technologies.*
8. *Organize half day or full day sessions where industrial R&D (both needs and well as achievements) get projected to the IIT Community.*
9. *Set numerical targets, such as get 50 Ph.Ds in Industrial R&D by 2018; earn Rs. 10 crore in royalities by 2018.*
10. *Organise a thorough review of " EECS", i.e EE,ECE and CS.*

(d) Measures adopted/action taken at the department level to address the recommendations of the peer review report:

1. There are some projects with international collaboration.
2.There is a drive to have more number of patents being filed.
3.More number of technologies have been transferred to the industries.

8. **Strengths, Weaknesses, Opportunities & Threats (SWOT) Analysis of the Department**

STRENGTHS 1. *Recognised as an excellent teaching department* 2. *High quality of students and research scholars* 3. *High quality of research output* **WEAKNESSES** 1. *Lack of sufficient initiative in transferring technologies developed in the laboratory to IPR, patents and Technology transfer.*	**OPPORTUNITIES** 1. *Increasing interactions with R&D organizations, industries and foreign collaborations.* 2. *More collaborations with other departments/centres of the institute.* 3. *Creating innovation and entrepreneurship start ups* **THREATS** 1. *Very low faculty :student ratio (1:24)* 2. *Lack of Technical staffs* 3. *Needs more space.*

9. Additional Information, if any *None*

***Note: Ten countries: US, UK, Germany, Japan, Canada, France, Italy, Australia, Singapore, South Korea (optional :China may be replaced with anyone if department wants)**

Important Highlights

The Department of Electrical Engineering is one of the first three engineering departments of the institute that started in 1951. The Department is running the B.Tech.(Hons.) program in Electrical Engineering since its inception. Later, B.Tech.(Hons.) in Instrumentation Engineering was introduced in 1982. Post graduate studies and research started at the very beginning in 1955 with the first M.Tech. program on Electrical Machines which was later restructured into a program on Machine Drives and Power Electronics. Subsequently, M.Tech.programs on Control System Engineering (in 1959), Power System Engineering (in 1965), and Instrumentation Engineering (in 1972) had been introduced. A dual degree program, B.Tech.in Electrical Engineering and M.Tech. in Instrumentation Engineering, started in 2002. This program was expanded to include M.Tech. in all the four disciplines subsequently. The department also runs one of the oldest and thriving Doctoral program in Electrical Engineering in the country with 153 Ph.D degrees awarded till date. It also runs an M.S. (by research) program that is predominantly based on sponsored research and development.

Throughout more than six decades of its journey, the Department continues to stay focused on research, abreast with the latest development and diversifications in its various fields of study. During this period, while maintaining its traditional focus on Power and Machines, followed by Control and Instrumentation, the Department has been able to develop expertise in modern areas such as VLSI Design and CAD, Embedded Systems, MEMS, Signal and Image Processing and Renewable Energy. The Department continues to participate in numerous R&D projects funded by governmental organizations such as MHRD, DST, DIT, DRDO, ISRO, CPRI, CDAC, and industries such as TATA Steel, SAIL, BHEL, Powergrid, Indian Rail, Megatherm, POSOCO etc. The Department is also involved in collaborative research with leading multinationals such as TI, GM, GE, Maxim and Freescale, universities such as University of Washington, North Carolina State University, University of Illinois at Urbana-Champaign, University of Colorado, Boulder, University of Padova, McGill University, Imperial College London, University of Tokyo, etc., and SRC, DFG, Humboldt foundations etc.

Presently the Department has 31 faculty members with 19 Professors, 1 Associate Professor, and 11 Assistant Professors. Members of faculty regularly publish in leading international journals/conferences. Academic laurels, such as the Fellow of IEEE, INAE, INSA, etc., and the Shanti SwarupBhatnagar Prize have been won by the faculty. They also serve in honorary positions of reputed Institutions, such as Senates, Faculty Councils, Committee, etc., and as Editors/Associate Editor, members of Editorial boards of IEEE journals andother reputed journals, and expert reviewers for organizations of national importance.

Since its inception, the tradition of teaching with passion and dedication, research excellence and active participation in corporate developmental activities continues to shape the career of our alumni. Graduates and Postgraduates of the Department demonstrated pioneering role in professional fields as well as in academics and research, and holding positions of rare distinction in leading industries and academic institutions of the world.

THE DEPARTMENT OFFERS THE FOLLOWING DEGREE PROGRAMS

B.TECH. (HONS.) PROGRAMS

The Department runs two 4-yearB.Tech. (Hons.)programs in (1) **Electrical Engineering** and (2) **Instrumentation Engineering**.

JOINT M.TECH. – PH.D PROGRAMS

The Department runs four 2-yearM.Tech. programs in (1) **Machine Drives and Power Electronics, (2) Control System Engineering, (3) Power and Energy Systems,** and **(4) Instrumentation and Signal Processing,** with an option for the students to get into a Ph.D program after one year.

DUAL DEGREE (B.TECH.+ M.TECH.) PROGRAMS

The Department runs several dual degree programs with B.Tech. (Hons.)in Electrical Engineering and M.Tech. in any one of the four M.Tech.

specializations. However, for B.Tech.(Hons.) in Instrumentation Engineering, M.Tech. is offered either in Control System Engineering or in Instrumentation and Signal Processing.

M.S. (BY RESEARCH) IN ELECTRICAL ENGINEERING

This program provides opportunity to work on a funded research or consultancy project and to work for a master degree in parallel.

PH.D IN ELECTRICAL ENGINEERING

This program provides opportunity to carry out potential research in emerging areas, both on theoretical and practical problems.

The thrust research areas of the Department are summarized below:

- Power Converters & Drives
- Embedded Sensing & Systems
- Integrated Power Management
- Micro-grid & Renewable Energy
- Advanced Control Theory & its Applications
- Signal & Image Processing, Machine Learning
- Automotive Engineering & Cyber Physical Systems

Teaching Laboratories

- Relay Lab
- Machine Lab
- High Voltage Lab
- Measurement Lab
- Control System Lab
- Machine Drives Lab
- Instrumentation Lab
- Power Electronics Lab
- Electrical Technology Lab
- Energy Lab
- Real-time Embedded Systems Lab



Research Laboratories

- NPMASS Lab
- TDM-CNIA Lab
- Wind Energy Lab
- Power System Lab
- Optoelectronics Lab
- Hardware Project Lab
- Computer Control Lab
- Machine and Drive Lab
- System & Information Lab
- Power Electronics Project Lab
- Signal & Image Processing Lab
- Bio-Process Instrumentation Lab
- Embedded Power Management Lab


A brief overview of the research activity of the department is highlighted below.

MACHINE DRIVES & POWER ELECTRONICS

FACTS: Research and development on FACTS devices like STATCOM, DVR, UPQC, etc.; High power converter topologies especially suitable for FACTS devices, various DSP and FPGAbased control strategies for the FACTS controller. **Voltage Regulator Modules:** Research focus on FPGA based digital controller design for high switching frequency (>200 KHz) dc-dc converters with target applications (1) Low voltage (0.7V to 1.5V) high current (60A-150A) power supply for digital processors such as Pentium,(2) Phase Modulated ZVS Resonant Transition Converters for telecom power supplies, (3) Multiphase (16 phase) dc-dc converters with bidirectional power flow for dual battery system electric/hybrid vehicles; Tested digital Phase Modulation algorithm on ZVS Resonant Transition Converter (24V, 10A); Developed and implemented a digital DCM controller with inherent per phase current sharing for 16 phase bidirectional dc-dc converter.**Power IC Design & Management:**Research focus on high frequency integrated switcher design, voltage regulator modules, digital pulse width modulation, EMI/EMC issues and various optimization and control issues in DC-DC converters; Principal collaborators are National Semiconductor (now Texas Instruments), Infineon, Maxim, Freescale.**Renewable Energy:** Wind power emerged as the most attractive renewable option in economic terms in recent years. Research initiative at IIT Kharagpur is directed towards: Development of speed sensorless DFIG based stand alone wind power generation system, Design optimization, optimal control of stand-alone wind-diesel hybrid power system.**Microgrid/Smartgrid Applications:** Research focus on hybrid AC/DC system for on and off grid network, cost effective storage, seamless integration, PLL for distorted supply conditions, solid state transformers (SST), efficient solar photovoltaic converters, network control, dynamic reconfiguration and load management.**High Performance Industrial Drives:** Research focus on development of modern motor drives for efficiency-optimized, improved reliability, reduced cost using speed-sensorless technology; Research focus on developing MRAS (model reference adaptive system) based speed sensorless schemes for both squirrel cage and doubly fed (slip ring) induction motor drive, using reactive power as the functional candidate; Investigating multilevel inverterfed induction motor drives; Investigating series and parallel connected converters, and novel filter-based feed forward schemes togenerate sinusoidal voltage output.**Electric Vehicles:** Plug-in electric and hybrid vehicle expected to take over future urban transportation; Research focus on development of efficient drive-train, battery chargers, EV motors etc.; Modeling of electric two, three and four wheelers; Developed experimental EVs for regularlab purpose and platform for further research and development.

CONTROL SYSTEM ENGINEERING

Guidance, Control and Tracking of Aerospace Vehicles– *Tracking and acceleration:* Research focus on design and analysis of homing guidance loop in the terminal phase of an aerial interception considering nonlinear kinematics, actuator saturation, time-varying tracker etc.; Developed Direct Acceleration and Jerk models for use in closed loop guidance for both midcourse as well as terminal phase. *Control allocation of over-actuated systems*: Research on control allocation method for over-actuated system, capable of efficiently handling actuator amplitude and rate constraint; Developed reconfigurable allocation method to tolerate actuator faults; Research on online reconfigurable allocation method with less computational complexity.

Modelling, Estimation and Diagnostics – *Estimation for maneuvering target tracking*: Developed methods for state and parameter estimation for maneuvering target tracking, fault tolerant actuation and control, in collaboration with ISRO and DRDO. *Vehicle health monitoring:* Research focus on vehicle health monitoring, engine state estimation and model based fault diagnosis and prognosis of engine faults.*Testing & verification:* Research focus on online testing, behavioural modelling for concurrent test program development, post-silicon validation, test support& optimization for in-house chip

designs.*Modelling & analysis of biomedical system:* Research focus on modelling, analysis of physiological system, arterial blood pressure regulation, glucose metabolism, respiratory regulation, calcium metabolism, cardiovascular dynamics. *Synergism & saturation system (S-system):* Research focus on nonlinear modelling of biochemical networks, synthetic robust controller design for the S-system biochemical networks.*Model order reduction (MOR):* Research focus on controller design of high order systems via MOR, achieved close matching of relevant characteristics with original ones.*Fuzzy logic:* Research focus on system identification, state estimation, optimal control of dynamical systems via orthogonal functions; Modelling, analysis and design of fuzzy logic based control systems.**Advanced Control Theory–** *Periodic controller:* Research focus on developing periodic controller theory for robust compensation to LTI plants having both unstable poles and non-minimum-phase zeros using loop-zero placement capability; Demonstrated simultaneous stabilization of two or more plants; Continuous-time periodic controller successfully tested.*Fractional order (FO) system:* Research focus on FO controllers for complex systems, more tuning parameters; Realizing FO system using finite order approximation; Design and Implementation of FO PID &optimal controllers.*Time delay (TD) system:* Research focus on robust stability criteria of additive TD systems, Lure systems, Markovian jump systems, networked controlled systems etc.; Controller design for uncertain systems with interval time-delay and interconnected time-delay systems.*Robust control:* Research focus on interconnected negative imaginary systems' control, four-block H∞ control, H∞ weight-optimization, loop-shapingtechniques, µ-synthesis and structured-singular value based approach.*Nonlinear Control:* Research focus on passivity based control, anti-windup control, sliding mode control, model predictive control, and switched linear system.**Embedded Power Management Circuits–** *Power management IC design:* Research focus on design of high frequency analog and mixed-signal power management ICs.*Bifurcation analysis:* Research focus on developing theoretical and practical tools for bifurcation analysis and control of digitally controlled high frequency DC-DC converters.*Embedded control:* Research focus on high performance and energy-efficient digital control for DC-DC.

POWER AND ENERGY SYSTEMS

Power System Security: Research focus on decision support tools such as power system contingency analysis, topology estimation, state estimation, risk based security assessment, multi objective optimal power flow method.**Power System Simulator:** Developed fully digital, comprehensive, versatile and easy to use operator training simulator "POWERDRAW" for power system (Sponsored by Power Grid Corporation of India Ltd.).**High Voltage Engineering:** Research focus on electric and magnetic field safety limit analysis under UHV AC transmission lines, Prediction of the Right of Way for UHV AC transmission lines to ascertain the horizontal safety limits.**Renewable Energy:** Research focus on development of a wind turbine emulator,Renewable hybrid energy power plant for stand-alone applications, development of prototype laboratory model of a Solar PV-Fuel Cell-Battery-DG hybrid system for reliable and regulated power supply to meet a 2kW stand-alone DC load; Grid interaction of wind energy systems.**FACTS and Power System Stability –** Development of EMTDC/PSCAD platform based HPFC for analyzing impacts on power system stability; Static and dynamic models of HPFC for use in large power system studies.*Thyristor controlled series capacitor (TCSC) control:* Power system stability assessment based on Lyapunov's direct method with higher order models of the alternators, Control of TCSC for oscillation damping.Trajectory sensitivity analysis for analysing impacts of DFIG based wind power generation on power system stability.**Power System Protection–** *WAMS based protection*: Research on fault identification, such as power swing, load encroachment, voltage instability using Wide Area Measurements Systems (WAMS). *Adaptive relay setting:*High impedance fault detection and solution to protection issues, Protection solution for fault current limiter, and micro-grid.**Distribution System Planning and Automation:** Research on distribution system design, loss minimization, congestion analysis and planning, automation of substation, feeder and user function; Developed substation monitoring and control for 220 kV substation forDamodar Valley Corporation; Estimated transmission and

distribution losses for NESCO.**Smartgrid –** Research on development of indigenous smart home energy management system for home energy management using wireless sensor networks, reconfigurable distribution network including design of micro-grids with power electronic interfaces to manage frequent on-grid and off-grid transitions for developing countries.

INSTRUMENTATION AND SIGNAL PROCESSING

MEMS Sensor Development: MEMS capacitive accelerometer along with back to back analog signal conditioning IC was developed and tested for mission critical applications.**Embedded Sensing and Systems:** The group has expertise in analog and Mixed signal VLSI circuits and systems. This is combined with advanced signal processing tools and techniques.Detection of adulterated milk, Development of automatic milk adulteration detection system using fractance based sensor.**Laser-based Instrumentation System:** The principal focus is to develop laser-based instrumentation, wireless sensor network for condition monitoring.**Signal/Image Processing and Machine Learning:** Online monitoring system for OHE traction parameters: Setting up of hardware related to instrumentation, mechanical systems etc. along with integration, Image processing, FPGA programming and C/C++ programming.**Human emotion recognition:** Research focus on modelling speech for different emotions, train them, identify the emotion associated with a test speech using the previous trained model using Hidden Markov Model.The major activities in this area are analysis of oral precancerous images, face and person authentication, online signal verification, speaker recognition and development of numerically stable signal processing algorithm.**Machine learning:** Non-parallel Plane Proximal Classifier along with its kernel version are developed for large data classification. This is targeted for microarray data and G-Protein coupled Receptor classification.