

# Development of Numerical Protection Laboratory through Industry Institute Interaction

**Dr. Rashesh P. Mehta<sup>1</sup>, Sushil Joshi<sup>2</sup>, Pankaj Savani<sup>3</sup>, Aditya Danayak<sup>4</sup>, Mitul Munjani<sup>5</sup>**

<sup>1,3,4,5</sup>Electrical Engineering, Department, Birla Vishvakarma Mahavidyalaya., Vallabh Vidyanagar, Gujarat, India

<sup>2</sup>Distribution Automation, ABB India Ltd., Vadodara, Gujarat, India

<sup>1</sup>rpmehta@bvmengineering.ac.in

<sup>2</sup>sushil.joshi@ac.abb.com

<sup>3</sup>pankaj.savani5997@gmail.com

<sup>4</sup>adityadanayak1@gmail.com

**Abstract**—The development of a numerical protection laboratory is implemented through industry-institute interaction under an MOU. This paper documents the contribution of the major project of final year students on using a digital over-current and earth-fault relay. The latest numerical protection relay has been provided as a replacement for an older version by ABB India Ltd. as a part of corporate social responsibility (CSR). The laboratory experimental panel has been developed through the major project of the final year student group. There was the active participation of ABB India Ltd. by way of providing dedicated training to the student group and faculty members involved in the installation, commissioning, and design of the experimental panel. The results obtained from various case studies are reported in this paper. The facilities created are used for regular laboratory practicals for undergraduate and post-graduate students. The laboratory manuals are prepared to facilitate the implementation of the experiments. The laboratory curriculum has been updated for the UG course "Power System Protection" and the PG course "Advanced Power System

Protection and Switchgear". It has resulted in improvement in the placement of UG and PG students. The training of industry and state power utility engineers can also be performed on the experimental panel developed. The outcome of this academic innovation related to industry-institute interaction is that the industry readiness of students has increased.

**Keywords :** Industry Institute Interaction; Power system protection; laboratory development; Test setup; Over-current protection.

## 1. Introduction

Employability of engineering graduates is a major area of concern worldwide including in India. There have been various studies and surveys that indicate that there is a serious downfall in the percentage of employable students in engineering disciplines (IUCET ITF Team, 2017). The expectations of industries from any engineering graduate are not fulfilled. There have been various remedial actions from the regulatory bodies in terms of mandates, initiatives, and schemes (AICTE, 2020). The various initiatives suggested in the AICTE Mandate and the best practices documents available from premier institutions (IUCET ITF Team, 2017; AICTE, 2020; Ananthanarayanan et al., 2014; Revana et al., 2014; Chavan & Bhujanga Rao, 2015; Anilkumar et al., 2015) are as follows:

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### Rashesh P Mehta

Electrical Engineering Department,  
Birla Vishvakarma Mahavidyalaya  
Engineering College, Gujarat, India.  
rpmehta@bvmengineering.ac.in

1. Mandatory internships in the industry
2. Industrial Visits of students
3. Joint guidance by industry and academia for major projects
4. Professional skills training of the students
5. Industrial projects of six months duration by students
6. Training of faculty members in the industry,
7. Joint research, development, and consultancy by industry and academia
8. Training of industry personnel for theoretical, conceptual, and latest trends in technical areas of expertise of academic institutions
9. Expert talks or workshops conducted by industry experts in engineering institutions
10. Mock group discussion and interviews conducted by industry human resource personnel in physical and online modes
11. Professional aptitude and technical tests to be conducted for identifying the strengths and weaknesses of the students
12. Industry-supported laboratories or Center of Excellence (COE) to be developed at Institutes
13. Signing a memorandum of understanding (MOU) to formalize and implement the above arrangements between the industry and institutes.

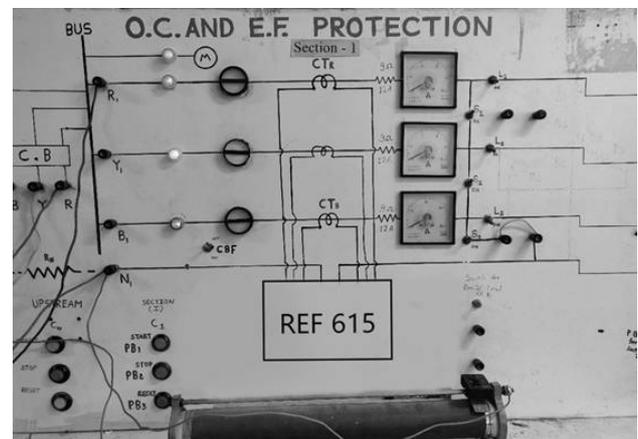
The industry bodies like FICCI and CII are also trying to work closely with engineering institutions and regulatory bodies to bridge the gap between the finished products i.e. the engineering graduates and the trends in the industry.

The laboratory component is a very important contributing factor to increasing the industry readiness of engineering students. Various initiatives worldwide have been reported in the literature for industry-supported laboratories (Liang-ping & Shan-lin, 2010; Roessner et al., 1990). It enhances the practical exposure to the students. The various efforts to develop a power system protection laboratory and

their contribution to the pedagogy and the laboratory curriculum have been reported in the literature (Fernaõ Pires et al., 2008; Shahnian et al., 2016; Wei-Jen Lee et al., 2002).



**Fig. 1: Group photo of a training program organized at ABB PowerTEC, Vadoda**



**Fig. 2. The hardware laboratory panel**

The faculty members at Electrical Engineering Department have developed an in-house power system protection laboratory equipped with electromagnetic, static relays, and numerical relays in the past (R. Mehta et al., 2012; R. Mehta & Oza, 2010; R. P. Mehta et al., 2020; R. P. Mehta & Oza, 2008; Oza & Brahma, 2005). The focus of this paper is to report the laboratory development carried out with the technical and financial support of an Industry, ABB India Ltd. It is located in Vadodara and manufactures products related to electrical power systems as mentioned in (ABB, 2020b). It has also been recruiting students from our Institute since last so many years. Our Alumni students have contributed to the progress of ABB in multiple ways. To take benefit of the professional experience of such a reputed company, we jointly decided to sign an MOU for the various aspects of Industry Institute Interaction.

The initiatives taken for industry-institute interaction and laboratory development are explained

in section 2. The explanation of the hardware setup is done in Section 3. The results of the laboratory development through industry-institute interaction are briefly described in Section 4. Section 5 gives the conclusions.

## 2. Implementation Of Industry Institute Interaction

### A. Initiatives for Industry Institute Interaction

The model of Industry Institute Interaction implemented at our College is as below:

1. There is an encouragement to all departments and faculty members to identify companies for joint III activities like internships, projects, expert talks, visits, joint research projects, joint consultancy, etc. (Patel & Shah, 2020). As of date, there are MOUs with 83 companies.
2. The various industrial visits and activities done are enlisted in a document (BVM, 2021) available on BVM Engineering College's website. The activities arranged under the industry-institute interaction (III) in the Electrical Engineering Department are available in (Electrical Engineering Department, 2022).
3. A new experiment has been done in our institute for improving the outcome of laboratory sessions. Projects and assignments are included in the lab sessions. The scheme is titled "Continuous Assignments and Project Activity Based Learning and Examination (CAPABLE) System". This scheme is implemented in successive batches of UG B.Tech courses. The details are available in (Bakhrū & Mehta, 2020)
4. In the Electrical Engineering Department, there are MOUs done and implemented in word and spirit with 11 companies. The industries have provided support for the development of various laboratories. Regular interaction activities like joint projects, expert talks, and industrial visits are organized in coordination with these Industries. Under the MOU with ABB PowerTEC, a global training center at ABB, Vadodara, various training programs for students and faculty members of the EE Department have been organized. A glimpse of one such training program organized on 31st August 2019 is provided in Fig. 1. The details are

available in (Electrical Engineering Department, 2021).

5. The internship scheme implemented at BVM Engineering College under Autonomous regulations from the academic year 2015-16 is that of a six-week mandatory internship during the four years of studies in summer vacation. On gaining experience and feedback the scheme is revised since the academic year 2018-19. Now, the students have to complete the first 3 weeks of internship after second-year completion during the summer vacation. Then after the third year of study completion, they have to do another 3 weeks of internship during the summer vacation. The internship is considered a non-credit mandatory course. It helps in providing industrial exposure to the students. Various avenues and training opportunities are provided to the students with the help of Alumni and Industry support. The internships also help the students in preparing them for identifying their problem definition for the major project to be completed in the eighth semester.

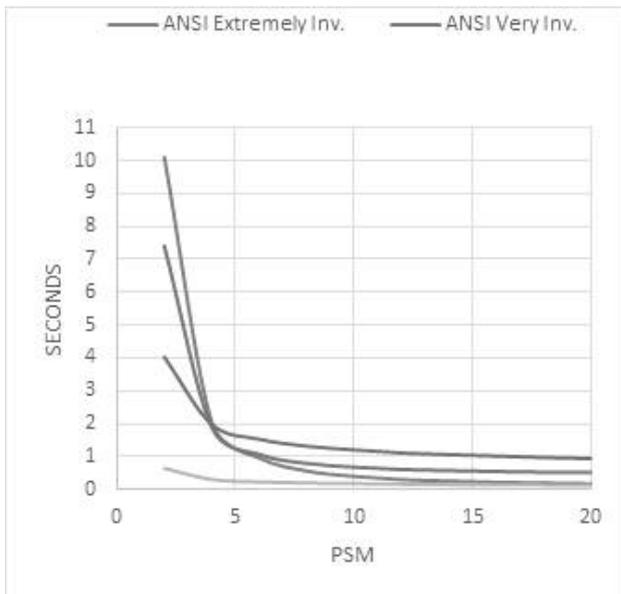
### B. The laboratory development under III

At the Electrical Engineering Department of Birla Vishvakarma Mahavidyalaya (BVM Engineering College), we signed an MOU with ABB India Ltd. in October 2018. The various activities performed under this MOU for laboratory development are enlisted in Table 1.

**Table 1 : Summary of III Activities for the Lab Development**

Sr. No.	Activity	Month and Year
1	The signing of the MOU between ABB India Ltd. and BVM Engineering College	November 2018
2	Request to ABB for providing replacement of an older version overcurrent relay SPAJ140C relay with the latest numerical overcurrent relay	January 2019
3	Receiving the numerical overcurrent protection relay REF615 from ABB	February 2019
4	Training of Faculty members and project student groups on REF615 at ABB	February 2019
5	Interaction on phone and email regarding the configuration of interfacing software, hardware wiring, commissioning, and installation by student group and faculty guide	February to May 2019

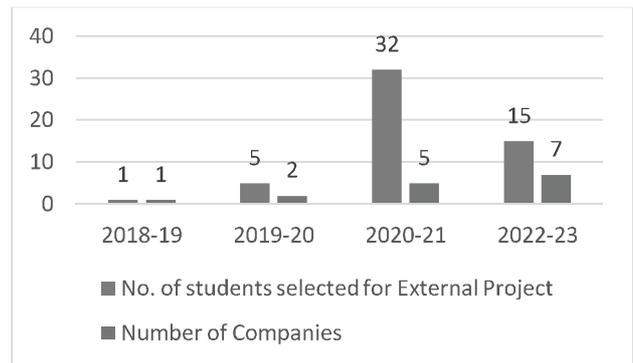
Numerous activities have been jointly undertaken since the signing of the MOU which include the participation of ABB experts as Jury members in Project Expo, Industry Consultative Committee (ICC)



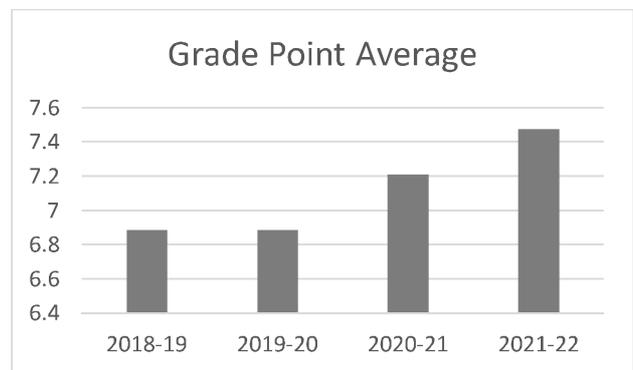
**Fig. 3 : Observed Characteristics for IEC Normal, Very, Extremely, and Long Inverse Characteristic**

for curriculum development, faculty training, student workshops, industry projects at ABB PowerTEC, a global training Center of ABB India Ltd. located at Vadodara, Gujarat. The activities have been mutually beneficial to the Institute as well as the Industry.

A hardware setup for the physical realization of protection of a two-section, 3-phase transmission line has been developed through the final year student projects. The latest numerical relay REF615 (ABB, 2019a) has been provided by ABB India Ltd. under corporate social responsibility and an MOU signed for industry-institute interaction. The training for hardware connections and interfacing through the dedicated software is provided to the students and faculty members by experts from ABB India Ltd. The project was completed in one semester. The computations of relay settings, the configuration of the software, testing of the relay using a standard test set, and developing the applications of the relay are accomplished. The documentation and lab manual preparation for the experiments is completed. The professional field practices and communication protocols are followed in the laboratory environment. The various characteristics available in the relay in compliance with the IEEE/ANSI and IEC standards are plotted. The adaptive protection features and the other advanced features in the relay are exploited and demonstrated practically through the setup and the case studies.



**Fig. 4: Improvement in external projects in Industry**

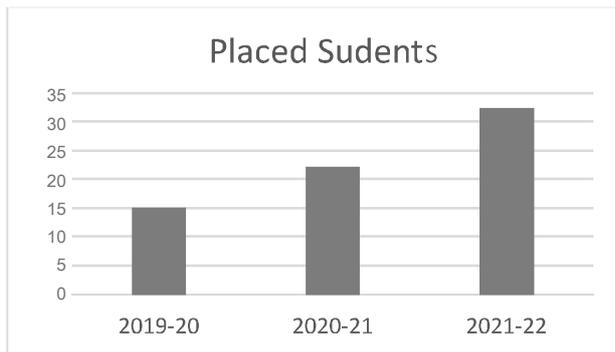


**Fig. 5: Grade Point Average for the course of Power System Protection**

### 3. Hardware Setup In Laboratory

Transmission lines are protected in the field by overcurrent protection using numerical overcurrent relays for voltage levels up to 132 kV (Oza et al., 2011). Hardware simulation of transmission line protection is achieved using a numerical Relay REF615. The various components used in the scaled model in the laboratory simulate the actual components used in the real field. The summary of the simulation is as follows:

1. The generation source is simulated by a 415 V, 3-phase supply.
2. The auxiliary supply for the relay and its digital inputs is provided by 110 V D.C. through a rectifier.
3. The variable source voltage is achieved by a 3-phase auto-transformer.
4. Circuit-breaker is represented by a 3-phase contactor.



**Fig. 6: Improvement in student placement in**

5. Stepped-down current and voltage signals to the relay are provided through the current transformers (CT) and potential transformers (PT).
6. The mimic diagram effect is provided by drawing lines on the panels with semaphore indicators in between to exhibit whether the circuit breaker of that line is ON or OFF.
7. Various ON, OFF and RESET functions of the line and relay are achieved by the push buttons.
8. Single-pole single-throw toggle switches are used for the creation of various faults on the lines.
9. The transmission line is simulated by lumped resistances.
10. The loading effect is realized through a 3-phase load bank.
11. A numerical overcurrent relay (REF615) is commissioned and connected to the power and control circuit..
12. The picture of the panel is shown in Fig.2.
13. The REF615 numerical relay of ABB make complies with the IEC standard as well as IEEE/ANSI Standard C37.112-1996. The expression for the time of operation of the relay for different values of fault currents is as follows.

where;

t = operating time in seconds

k = time multiplier setting (T.M.S)

I = measured current value

I<sub>0</sub> = set pickup current value.

#### 4. Results Of Laboratory Development Through Industry Institute Interaction

##### A. Plotting various characteristics using the Test-Set

The CFB Test-set of English Electric make comprises two units; (1) the Current control unit and (2) the Injection transformer unit. The Pickup setting Multiplier (PSM) can be changed by adjusting the knobs K1 and K2 in the test set. The observed time of operation is compared with the calculated time of operation. The time multiplier settings (TMS) are kept at 1. The testing and validation for all IEC and IEEE characteristics available in the REF615 relay are done.

The observation and computation table for the IEC normal inverse characteristics is shown in Table 2. The IEC characteristics for Normal Inverse, Very Inverse, Extremely Inverse, and Long Inverse characteristics are plotted for different PSM and TMS=1 in Fig. 3.

##### B. Results of the Laboratory Development and Industry Institute Interaction

###### 1. Increase in the Industry Collaboration for Student Major Projects

The project scheme offered to the EE students from 2018-19 onwards comprises three stages. The first stage in the sixth semester is that of Electronics Design Laboratory in which the basic guidance for project development is given. The students have to complete a mini-project based on the skills taught during this course. In the seventh semester, the students have to undergo Project Stage-I. In this course, they have to identify the problem definition, complete the literature review and acquire the skills required to complete the major project in their eighth semester. In the eighth semester, there are two tracks available to the students. They can select to do an internal project with 8 credits or they can go for a full semester external project in any Industry or Research Organization. Once again, there is a huge role of Industries and Alumni in this scheme of industrial projects. The count of the external project in the EE

**Table 2: Observation and computation table for IEC Normal Inverse Characteristics**

Sr. No	Current through Relay	PSM	K1	K $\phi$ TM (K1*K2)		Meter Current Im=Ir/CTM	Calculated TOP in sec	Observed TOP in sec	% Error
1	1	2	0.5	1	0.5	2	26.6666	27.499	3.12
2	2	4	1	1	1	2	5.3333	5.449	2.17
3	3	6	1	2	2	1.5	2.2857	2.43	6.31
4	4	8	1	2	2	2	1.2698	1.354	6.63
5	5	10	2	2	4	1.25	0.8080	0.84	3.95
6	6	12	2	2	4	1.5	0.5594	0.595	6.36
7	7	14	1	4	4	1.75	0.4102	0.449	9.44
8	8	16	1	4	4	2	0.3137	0.319	1.68
9	9	18	5	1	5	1.8	0.2476	0.26	4.98
10	10	20	5	1	5	2	0.2005	0.194	3.24

Department has increased steadily since 2018-19. It is mentioned in a column chart in Fig. 4.

### 2. Improvement in students' performance due to laboratory development and Industry Institute Interaction

The impact of utilizing the numerical protection laboratory which is developed under III is also observed in the academic performance of the students in the course of Power System Protection. The grading system is used in the results of the students. Grades are given from AA to DD with weights from 10 to 4 respectively. The grade point average is a parameter to evaluate the collective performance of the students in a particular course. It is calculated by summing up the product of the number of students in each grade and the weight of that grade and then dividing by the total number of students. Thus the impact of the initiatives of laboratory development and industry-institute interaction are validated by various performance checks. The improvement in the Grade Point Average (GPA) for the course "Power System Protection" is shown in Fig. 5.

### 3. Improvement in student placement due to laboratory development and Industry Institute Interaction

Due to the increased interaction with industry and also utilizing the lab experiments developed in the course curriculum, the number of companies coming for the placement has increased in the last four years. The performance of the students in the campus placement has increased for the EE Department. The improvement in terms of the number of students placed is depicted in Fig. 6.

## 5. Conclusion

The paper discusses the development of numerical protection laboratory with sponsoring and technical support from ABB India Ltd. Hardware simulation of transmission line protection is achieved on a double section radial feeder by a numerical relay REF615. Various protective situations have been realized in the tenure of the project to fully utilize the multiple features of the relay. This helps in improving the teaching efficacy of the institute as students can experiment on the latest and relevant protection relay used in the field. The improvement in the outcomes of this project is validated in terms of the number of companies providing industrial projects, students' academic performance, and student placement. There is a significant improvement in all these performance parameters.

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