College of Engineering & Computational Sciences
Department of Electrical Engineering

COLORADOSCHOOLOFMINES
ELECTRICAL ENGINEERING

EPRI
GridEd Undergraduate Design Project
GridEd Affiliate Universities
2017 GridEd Student Design Project Proposal

Final Report

Project Title

Advancement in Electric Drives and Motor Design as Applied to the Steel Industry and Electrical System Design Calculations

Submitted By:
Dr. P.K. Sen, PE, Fellow IEEE
Professor of Electrical Engineering
Colorado School of Mines
Golden, CO 80401
psen@mines.edu,
(303) 519-3467 (Cell), (303) 384-2020 (Office)

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$ 5,000 (Five Thousand Dollars)

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Executive Summary:

Iron and Steel is an energy intense industry. In recent years they spent a great deal of resources in reducing the energy intensity and improve overall energy efficiency. The techniques include cogeneration, waste heat recovery, process improvement and application of the variable frequency drives, etc. However, little information is available about how large motors and drives are selected? Electric motors, in particular induction motors, are the workhorse of the industry. Steel industry, on the other hand still utilizes large DC motors. Improper selection of large motor drives system cause failures which cost millions of dollars in loss of production.

A lot has changed in the design (both at AC LV and MV and DC) of large motors and drives in the past few decades with the advancement of power electronics and control. This design project focusses on bringing the state-of-the-art in design and application issues of large motors, both DC and AC. An excellent understanding of the motor performance that includes torque-speed characteristic, speed control, coordination with the drive, energy efficiency, and reactive power demand, costs of electricity in running the plant, voltage drop, and power quality is essential. Many unwanted system conditions could be avoided in the design and procurement stage by proper selection of motors and drives. That is the primary thrust of this design project.

This design project required one field trip to the plant for data collection, and discussions with the plant operations and maintenance personnel. This was done in February, 2017. The 2nd semester was utilized in checking the existing design, perform design calculations.

The major task successfully completed is to introduce future electrical engineers about the iron and steel industry needs in the form of Senior Capstone Design. A team of five students (bio-sketch attached) visited the ArcelorMittal Burns Harbor plant and studied two Hot Rolling Mills electrical distribution systems and electric motors and drives in details. They performed the system adequacy study and made specific recommendations for the plant upgrade and operation.

The Senior Design Team made a number of presentations to a wide variety of audience (students, researchers and industry guests) including Poster Presentation at the Senior Design Fair at Mines, local (Denver) Chapter of IEEE PES/IAS Society meeting and a couple of papers were presented by (PI) Dr. Sen at the 2017 AIST Annual Technical Conference in Nashville in May, 2017.

The budget was spent in traveling to the ArcelorMittal Burns Harbor plant (five students plus Dr. Sen, PI) for 2.5 days and attending the AIST Annual Meeting in Nashville by Dr. Sen to present two technical papers and attend other meetings. Dr. Sen also attended the EPRI GridEd Technology Transfer Workshop for Affiliate Universities in Dallas, Texas on April 9-11, 2017

Acknowledgements

The "Team" acknowledges graciously the support from the EPRI GridEd initiatives for Affiliate Universities, and AIST Foundation, in particular, to James Hendrickson (and others at the plant) from ArcelorMittal to support this project and help during this project including the field trip.

1.0 Introduction

The proposal titled "*Title: Advancement in Electric Drives and Motor Design as Applied to the Steel Industry and Electrical System Design Calculations*" was jointly funded by the EPRI GridEd support and the AIST Foundation.

The number of participants as originally proposed changed (from two to five) to accommodate more undergraduate students. The "team" consists of one full-time (tenured) senior professor, two graduate students and five undergraduate students as follows:

1. **Dr. P.K. Sen**, PE, Fellow IEEE, Professor of Electrical Engineering (PI)
2. **Supriya Tawde and Yaswanth Nag Velaga**, Graduate Students, Major Focus Area "Energy Systems, Electric Power, Machines and Renewable Energy."
3. **Five Undergraduate Students**, Brittany Kelly, Colin Hovden, Kenny Larson, Matt Renwick and Adam Shreck, Majoring in, "Energy Systems, Machines and Power.'

Based on the initial meetings, interests and manpower availability, this project is divided broadly in two separate efforts. Graduate students worked on independent studies related to the advancement in design and applications, whereas, the undergraduate students worked for the two-semester long Capstone Senior Design in the analysis and design.

2.0 Proposal Summary, Tasks and Deliverables

The key purpose of this proposal was to educate and train future electrical engineers about the advancement in design, analysis, protection and applications. This is an essential component of the industry and often doesn't get the much needed attention. Proper selection, operation, maintenance of these motors and drives are the workhorse of the industry.

Description of the Work Performed:

This Capstone Senior Design Project is divided into multiple tasks:

1) **Task No. 1**: Educate the students to the iron and steel industry needs including the big picture, manufacturing process, energy needs with a special focus on motors and drives.
2) **Task No. 2:** Students focus on motors and drives, understand the key aspects including losses and efficiency, power factor, torque-speed characteristic, starting, DC vs. AC drives, insulation and temperature rise, mechanical aspects, protection requirements and application of variable frequency drives and energy savings, etc.

The two Tasks mentioned above are completed by the end of the first semester.

3) **Task No. 3:** This includes the only trip to the plant for 2.5 days for data collection, meeting various people, understand the big picture of steel making. Dr. Sen accompanied the team. Students perform an in-depth study of a sub-system (rolling mills) to see the process requirements, sizing of motors and drives.
4) **Task No. 4:** This task involves the writing of the technical report, papers and a PowerPoint presentation. This includes research on motor life expectancy, applications of high (energy) efficiency motors, economic analysis for loss evaluations.

These two tasks are performed in the second semester. The undergraduate students successfully complete the Capstone Senior Design Project and graduated.

The graduate students, however, are continuing the work.

5) **Task No. 5:** This requires advanced research. It focuses on reliability aspects to design and applications including the applications of variable speed drives.

Project Deliverables and Expected Outcome:

The list below provides all the deliverables accomplished during the project.

(1) Brittany Kelly, Adam Shrek, Kenny Larson, Matt Renwick and Colin Hovden, "Electrical System Study for a Heavy Industrial Plant: Steel Plant – A Case Study," **Capstone Senior Design Project**, Colorado School of Mines, Golden, CO, May 2017.

(2) Sen, P.K., "Advancement in Electric Drives and Motor Design as Applied to the Steel Industry," **AIST Annual Conference**, Nashville, TN, May 9, 2017.

(3) Sen, P.K., "High-Efficiency Motor Design and Performance Evaluation: An Application Guideline," **AIST Annual Conference**, Nashville, TN, May 9, 2017

(4) Sen, P.K., "Energy Efficiency and Economic Evaluation of Induction Motors," ArcelorMittal, February 21, 2017

Presentations:

(1) **IEEE Denver Section, PES/IAS Chapter Society Meeting**, November 17, 2016 and April 20, 2017, Dr. P.K. Sen Senior Design Award Competition, Final Presentation, Attended by 40 local area industry guests, students from two other local universities:. Winner of the Best Presentation Award.

(2) Two presentations for the **Senior Design Class** and (**Poster Paper**) in the Senior Design Fair (attended by hundreds of industry guests, faculties and students) in April, 2017.

(3) Presentation for the Class EENG 481: Analysis and Design of Advance Energy System

(4) ArcelorMittal, Burs Harbor, "Burns Harbor Steel Plant – System Study," February 20, 2017. Attended by engineers and technical personnel.

The work is being continued and it is expected to have a technical paper for possible presentation and publication at an IEEE Conferences.

3.0 Expenditure of the Total Project Cost

The approximate expenses breakdown of the project is given below:

1) Travel for the PI to attend the AIST annual conferences Attend the Meeting and Presentations	$1,758.00
2) Travel for the Students to attend the plant visits Data Collection, Familiarization, etc.	$3,085.00
3) Incidental Cost: Materials and Copying, Reports, etc. Refreshments for Class Presentation	$ 157.00
Grand Total:	$5,000.00

This is partially supported by the AIST Foundation and EPRI GridEd initiative.

Notes:

1) Dr. Sen (PI) gave all his time (estimated at 120.00hrs.) at no cost to the project as a cost sharing. This is estimated in excess of $10,000.00 in time and labor. The time was used to prepare lecture materials, PowerPoint slides, attend meetings, project coordination and communication, reporting and the final project report.
2) Time (many hours) donated by ArcelorMittal in assisting in the project during the plant visit, discussions and communications

4.0 Students' Participation throughout the Project toward Building Interest in the Electric Power and Energy Industry

The sole purpose of this project is to expose, educate and train young engineers for future workforce. The students did the following tasks either individually and/or collectively:

1) Understands the broad pictures, needs and challenges in the steel or related industry.
2) Extensive reading and perform independent research.
3) Make plant visit, interact with technical personnel, in data collection, see the plants in operation, discuss with the maintenance, operational personnel, and the management.
4) Write report, prepare PowerPoint presentations, and present.
5) Understand the process requirements and coordinate with the process engineers.
6) Read one-line diagrams and perform system studies.
7) The undergraduate students did a Senior Capstone Design project and a report was prepared. A final poster paper 9s being done at this time.

5.0 Conclusion

Dr. Sen would like to continue his association with the EPRI GridEd as an Affiliated University, AIST Foundation and the Iron and Steel Industry and other related professional societies, participate in working groups, attend meetings and present technical papers at the annual conferences and meetings, conduct workshops for electrical technical personnel and meetings on demand, provide technical leadership in his areas of expertise. He has made that commitment. The students will be encouraged to continue to be active members of the professional societies and promote the needs of the industry. They should be taught to continue to develop deeper knowledge, understand the bigger picture of the industry and be future leaders in the industry.