

ND ENERGY STUDENT RESEARCH FELLOWSHIP FINAL REPORT

STUDENT NAME:	Nayara Aguiar
FACULTY ADVISOR:	Vijay Gupta
REPORT PERIOD:	January 2019 – December 2019
PROJECT TITLE:	Electricity Market Design to Increase Integration of Renewables in the Power Grid
CONNECTION TO ND ENERGY'S RESEARCH AREAS (CHECK ALL THAT APPLY):	<input checked="" type="checkbox"/> Energy Conversion and Efficiency <input type="checkbox"/> Sustainable and Secure Nuclear <input checked="" type="checkbox"/> Smart Storage and Distribution <input type="checkbox"/> Transformation Solar <input type="checkbox"/> Sustainable Bio/Fossil Fuels <input type="checkbox"/> Transformative Wind

MAJOR GOALS AND ACCOMPLISHMENTS:

List your major research goals and provide a brief description of your accomplishments (1-2 sentences). Indicate the percentage completed for each goal. Please use a separate sheet to share additional details, technical results, charts, and graphics.

MAJOR RESEARCH GOALS	ACTUAL PERFORMANCE AND ACCOMPLISHMENTS	% OF GOAL COMPLETED
1. Analyze different energy sources that can provide flexibility to the grid	I analyzed both natural gas power plants (NGPPs) and battery storage systems as providers of flexibility. I showed that these energy sources can enable higher levels of renewable integration in the power grid by setting aside some energy that can be used in case of renewable shortage.	100%
2. Design market mechanisms through which flexible energy sources can offer flexibility to renewable generators	I designed a real options market in which NGPPs offer to reserve some fuel to be used in case of renewable shortage, while renewable generators purchase the right to request use of that reserve if needed. This market is realized through bilateral contracts, and my studies confirmed that (i) they are economically viable for both the renewable generator and the NGPP, and (ii) they lead to an increase in renewable participation in the market. Similar results were achieved for a single bilateral contract between a renewable generator and a battery energy storage.	100%
3. Analyze how network congestion affects the mechanisms designed	I performed numerical case studies which consider network congestion. The results show that the feasibility of the contracts proposed depends on the relative position of the renewable and the flexible energy source in the network. For example, if the renewable generator is located at a node with a low energy price, then this generator will set an upper bound on the contract price that may be too low for the flexible source to accept. Further analysis will be needed to characterize analytically how these contracts should be priced in the presence of network congestion.	80%

RESEARCH OUTPUT:

Please provide detailed information below regarding any output resulting from your research project.

CATEGORY	INFORMATION
EXTERNAL PROPOSALS	(Sponsor, Project Title, PIs, Submission Date, Proposal Amount)
EXTERNAL AWARDS	(Sponsor, Project Title, PIs, Award Date, Award Amount)
JOURNAL ARTICLES	(Journal Name, Title, Authors, Submission Date, Publication Date, Volume #, Page #s) <ol style="list-style-type: none"> 1. N. Aguiar, and V. Gupta, "An Insurance Contract Design to Boost Storage Participation in the Electricity Market", In <i>IEEE Transactions on Sustainable Energy</i>, Submitted December 2019 (Under review). 2. N. Aguiar, V. Gupta, and P. Khargonekar, "A Real Options Market-Based Approach to Increase Penetration of Renewables". In <i>IEEE Transactions on Smart Grid</i>, Accepted September 2019. 3. D. D'Achiardi, N. Aguiar, S. Baros, V. Gupta and A. M. Annaswamy, "Reliability Contracts Between Renewable and Natural Gas Power Producers". In <i>IEEE Transactions on Control of Network Systems</i>, vol. 6, no. 3, pp. 1075-1085, Sept. 2019.

BOOKS AND CHAPTERS	(Book Title, Chapter Title, Authors, Submission Date, Publication Date, Volume #, Page #s)
PUBLIC PRESENTATIONS, SEMINARS, LECTURES	(Event, Presentation Title, Presentation Date, Location) 1. ND Energy Postdoc and Grad Student Luncheon, “A Flexibility Market-Based Approach to Increase Penetration of Renewables in the Power Grid”, October 2019, University of Notre Dame.
AWARDS, PRIZES, RECOGNITIONS	(Purpose, Title, Date Received)
INTERNAL COLLABORATIONS FOSTERED	(Collaborator Name, Organization, Purpose of Affiliation)
EXTERNAL COLLABORATIONS FOSTERED	(Collaborator Name, Organization, Purpose of Affiliation) 1. Dr. Anamika Dubey, Washington State University, develop research focused on how to price flexibility from distributed loads.
WEBSITE(S) FEATURING RESEARCH PROJECT	(URL)
OTHER PRODUCTS AND SERVICES (e.g., media reports, databases, software, models, curricula, instruments, education programs, outreach for ND Energy and other groups)	(Please describe each item in detail)

MAJOR GOALS AND ACCOMPLISHMENTS
(Additional Details, Technical Results, Charts and Graphics)