

# Optimization Methods for Enhancing Real-Time Voltage Stability

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*ABSTRACT: The research activity includes Faculty, Graduate and Undergraduate students at Howard University (HU) in Partnership with University of Benin (Uniben). The collaboration program consists of research activity between the two schools as well as seminars and tutorials on special topics related to the project. The Supplementary award allows HU to expand on the original grant to utilize real life test systems of recorded voltage collapse on Power Holding Company of Nigeria (PHCN) systems, which is readily available at the University of Benin. The recorded systems are gathered using Phasor Measurement Unit (PMU) systems inspired at Uniben processed and sent to HU Center for Energy Systems and Control (CESaC) research center for further processing and evaluation to test new voltage stability indexes. The HU/Uniben team will test the real time voltage stability control algorithm being developed as part of the original award within the grant period. As part of the education experience joint seminars in Distributed Generation or IPP or Loss Managed of transmission by University of Benin Professors/PHCN staff will be given to participate on the project. In addition, Professor Momoh has included some of the inception of the Program launch off tutorial lectures on Voltage Stability indexes reviews, optimization techniques and adaptive dynamic programming concepts for real time control and operations. To ensure that the research team is properly equipped to undertake the research, lecture notes internet/telephone exchange between the PI and the research team is emphasized. To ensure that the students participants experience are positive, the PI and the Co-PI at Uniben have put together a monitoring scheme that includes healthcare, security, and time management and adjustment strategies. A well-prepared student host's guesthouse properly equipped with e-mail services and easy access to University Library, Laboratories, and Professors are in place for the long-term stay by the team. The long stay, which is on the second trip to Uniben is scheduled for May through July 2007 and will include two of the students so that we can complete the on-site activities of the supplement award.*

## INTRODUCTION

The Center for Energy Systems and Control (CESaC) within the College of Engineering, Architecture, and Computer Sciences (CEACS) at Howard University is currently funded by NSF under Supplement Grant Award No. ECS-0601636. The title of the project is “Optimization Methods for Engineering Real Time Voltage Stability” for the NSF International Research and Education in Engineering (IREE) program.

#### **Summary of Work Being Carried out under NSF Award**

The research work involves development of a real time measurement for voltage stability assessment and control. This scheme proposed is based on development using real time system parameters to compute voltage stability margin. Given these margins a real time advanced optimization control scheme is needed to mitigate the voltage problems.

The scheme is being tested using different test cases and issues of robustness, sensibility and scalability to practical systems as part of the research thrust.

To promote the broader impact of the research, new education modules stemming from Phasor Measurement Unit (PMU), State Estimation (SE) and Adaptive Dynamic Programming (ADP) techniques and their application to stability assessment is to be developed. Involvements of undergraduate and graduate students are needed to ensure that the future workforce and underrepresented groups emerge in the competitive Power Industry.

#### **The Reasons/Rationale for International Cooperation Carried Out Under IREE**

The proposed research approach is unique based on the need for real time versus detection and prevention. However, for us to justify its value/practicality, real time data and practical load model and uncertainties, which are obtained in real life situation, are important for valuating the proposed integration algorithm.

Knowledge of social technical constraints in a rapidly growing power industry with injection of Independent Power Producers (IPP) and new and old evacuation plan is absent in the US. This situation is different in Nigeria; according to findings, several Independent Power Producers (IPPs) are being built around Uniben. New transmission line for evacuation of power and news loads is being added without adequate data planning studies.

The proposed scheme will therefore be tested for robustness, scalability and its ability to facilitate the ability to predict and adaptively overcome vulnerability of typical US Power systems.

The value of this scheme will be an improvement in the quality of supply and increase in the reliability and cost effectiveness of power and corrective schemes much needed in the Energy Management Systems (EMS) of the future.

The educational experiences of our students are currently limited to US Utility Networks, study habits and lack of understanding global competitiveness. We anticipate through cultural exchange, the exposure to the rigor of the Power Program at Uniben, the availability of real life data and opportunity for sustained interaction and collaboration with different professors in Systems Engineering, Economics, and Manufacturing and Power Systems will facilitate the interdisciplinary problem solving capability for our students.

#### **Anticipated Research and Education Outcomes**

We expect that the research outcome will lead to a well-tested algorithm for real-time voltage margin competition using SE and PMU for measurements. The use of new optimization techniques capable of handling productions and adaptive control such as ADP and/or hybrid of classical optimization and intelligent system developed will serve as a model for dynamic voltage constraint Optimal Power Flow (OPF) with locational pricing as constraints.

#### **Education Outcome**

The research results will enhance the thesis and dissertation effort of our students. The interaction with Uniben faculty and students and Power Holding Company of Nigeria (PHCN) staff will provide our facility students with new problem solving schemes, hands on exercises and ability to handle intellectual work in an environment with uncertainty in the data and dynamically changing model.

This experience, which is part social, part cultural, and part technical collaboration with facilitate teamwork, leadership and innovation in development of future schemes for ensuring secured Power Systems.

#### **Information about Host Laboratory**

The University of Benin is one of the well-funded government institutions in Nigeria with substantial private endowment from the oil industry and IPP developers. It is situated in an ideal place being close to Power Holding Company of Nigeria (PHCN) Transmissions and Distribution units.

The College of Engineering at the University is also highly renowned among the West African Engineering Schools. The Power Simulation and Machine Laboratory are superb. They are equipped with DC/AC machines measuring devices, High voltage testing labs and interfaces with real time measurements devices.

The PMUs obtained from the grant are installed within the simulation laboratory for real time measurement. The simulation is equipped with computers. Email services and on-line printing options are available to students.

#### **Name of Travelers**

The following are names of project participants that will travel to Uniben and engaged in the research and education activities of the IREE program.

- Professor James A. Momoh, Ph.D., FIEEE (Principal Investigator)
- Mr. Garfield Boswell (Ph.D. Candidate)
- Mr. Paul Booker (Undergraduate Student)

#### **Dates of Travel (to Uniben)**

- Kick-Off Meeting : March 23 - 26, 2007
- Major Research Activities : May 31 - July 13, 2007

## **RESEARCH ACTIVITIES AND ACCOMPLISHMENTS OF THE INTERNATIONAL COOPERATION**

### **Program of Research Carried Out in IREE**

The research program undertaken will be divided into the following phases:

#### Phase 1

Acquisition of literature and background information on Phasor Measurement Unit (PMU), Voltage Stability, State Estimation (SE), and Adaptive Dynamic Programming (ADP). This information is utilized in developing tutorial for participating students and faculty at Howard University and the University of Benin (Uniben). The PI does the program. This background is necessary to introduce the problem to students.

#### Phase 2

This phase of the work involves development of the statement of work between Howard University and the host institution, Uniben, and development of discussions with participants on the project.

#### Phase 3

Installation of the Phasor Measurement Unit (PMU) hardware, MATLAB simulator, and State Estimation program for data collection, processing, and analysis. The data collection from Power Holding Company of Nigeria (PHCN) is an integral aspect of the research work in this phase to be used for voltage stability studies and control.

#### Phase 4

Development of software architecture design for Voltage Stability Margin (VSM) using measurements from PMU, Optimal Power Flow (OPF) based on Adaptive Dynamic Programming (ADP), and Locational Marginal Price (LMP) computations using new adaptive dynamic constraint construction.

#### Phase 5

Implementation of the algorithm that involves testing, and validation using real-time power system data and available testbeds.

#### Phase 6

The last phase of the project is the development of reports, joint publications and paper presentations at conferences in Nigeria and the US in July and October of this year, respectively.

### **How the work on site is related to NSF Award**

This research activity, under the NSF sponsored IREE Grant for real-time voltage monitoring and control, has been extended for testing using real system data from University of Benin and also extended for real-time control and Pricing using the Locational Marginal Price (LMP) computation technique. Thus, the work under this cooperation is directly impacting NSF ECS-0601636.

### **A Substantive Description of the General Interaction between Researcher and Host Laboratory during the IREE**

The IREE has presented research between Howard University (HU) and the University of Benin (Uniben). The capability of the laboratory for real-time data gathering and processing has made the real time stability of margin a possible goal. The interaction between graduate Uniben faculty and students has helped to improve the quality of research through constant feedback and monitoring of research activity done by the PI.

Overall, we are expecting increased interactions between HU and Uniben students during the project execution. The interactions will involved a daily log on research procedure of data collection and analyses, time usage, regular reporting and presentations of significant results for discussions and feedback. Weekly or bi-weekly meetings as well as seminar sessions are planned as part of the cooperation to ensure that the proposed goals are met.

### **Research Schedule**

The proposed schedule for the IREE program of activities between HU and Uniben to meet the proposed research and education activities is presented in Table 1.

Table 1 Proposed schedule for the Howard University-Uniben IREE Project

<b>Period</b>	<b>Planned Research and Education Activities</b>
March 2007	Background and Statement of activities work
April – May	Phasor Measurement Unit (PMU) studies
May – July	Research, team visit Activity/Seminars
July – August	Paper development, and Report/Thesis writing

### **Photographs of IREE**

The first meeting involving the lead and host university has been scheduled to begin on May 31, 2007 and extending for 6 weeks. Photographs of all project activities will be provided in subsequent reports.

## **BROADER IMPACTS OF THE INTERNATIONAL TRAVEL**

### **Supplement Promotion of Diversity**

This supplement to NSF ECS Grant No. 0601636 has been a source of funding to promote diversity. The HU participants from underrepresented groups are taken from undergraduate and graduate students pools. The collaboration with other designees (economy, manufacturing, and system engineering) has helped to promote diversity of expertise in undertaking this project.

The interaction with other cultures and backgrounds has helped to improve the opportunity for exposing students to the value of collaboration in the performance of this project.

### **Ways in which the Supplement Expand the Original Scope of the Current Award**

The supplement has helped to improve the intellectual and broader impacts of the original award by:

1. Contributing to the increase scalability of the proposed algorithm
2. Demonstrating capability of the scheme using real life system
3. Increasing the fundamental knowledge of the science, technology and design by using PMU/SE for real-time data collection and Adaptive Dynamic Programming (ADP) for prediction and control.
4. Teamwork with other cultures by Howard University team with the participants at the University of Benin has helped to teach the value of teamwork.

### **HU Travel Fosters Closer Future Collaborations**

The travel undertaken has helped to facilitate future collaborations between Howard University and the University of Benin. Also, the following has resulted from the initial collaboration activities to date:

1. Mutual understanding of the capability and availability of resources at the University of Benin and Howard University bringing about an appreciation for culture, language and respect for engineering professors.
2. Ability to leverage on new power developments in Nigeria (including modeling, analysis and development) of advanced control scheme from Howard University research team.
3. Exchange of ideas and sustainability of long-range research and education that will promote US leadership in research and education.

### **Citizen/Permanent Resident International Perspective**

The opportunity for the researchers to engage in this partnership has helped to achieve several quantifiable goals:

1. Appreciation of students and faculty's passion for science and technology in Africa and commitment to the research activities to ensure project completion.
2. Love for their country to be one of the leading economies in the 21st century.
3. The entrepreneurial spirit of students and faculty to use homemade materials to achieve some technology progress.
4. Opportunity to transfer research results towards development of secure national power infrastructures.

## **DISCUSSION AND SUMMARY**

### **Summary of Most Significant Accomplishments of IREE to date**

Since the IREE is still ongoing, we summarize having only our initial appreciation for the program according to our accomplishments today.

1. Develop a viable program of strength which excite our students/faculty at HU and UNIBEN
2. The Kick-off meetings have lead to successful and hands-on use of PMUs, SE, and ADP and voltage stability indexes.
3. The design of algorithm for real time vision and ADP for control is completed. Understanding of the use of LMP using ADP is on. The implication is on going and will be completed during our stay by HU students at UNIBEN. The team will complete seminar and project writing at the end of the visit.

### **Recommendations for Best Practice of IREE**

Our experience with IREE Program will be delightful and hopefully from our work, we will develop a best practice scheme to assist in transformed research and evaluation in the Power Infrastructure.

## **ACKNOWLEDGEMENTS**

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The title of the project is “Optimization Methods for Engineering Real Time Voltage Stability” under NSF Supplement Award No. ECS-0601636.

## **REFERENCES**

Developed Publications (Thesis, Tutorials, and Presentations):

1. James A. Momoh, “Next Generation Optimization and Marginal Costing,” Tutorial No. 3 on Adaptive Dynamic Programming (ADP), *International Conference on Power System Operation and Planning (ICPSOP)*, Cape Town, South Africa, Jan. 22-25, 2007.
2. James A. Momoh, “Framework for Voltage Stability Security using Phasor Measurement Unit (PMU),” presented at the University of Benin, Benin City, *International Research and Education Engineering (IREE) Workshop*, March 20-23, 2007.

## BRIEF BIOGRAPHIES OF RESEARCHERS

**James A. Momoh** (M'76–SM'89–F'99) received the B.S.E.E. degree from Howard University, Washington, D.C., the M.S.E.E. degree from Carnegie Mellon University, Pittsburgh, PA, the M.Sc. degree in systems engineering from the University of Pennsylvania, Philadelphia, and the Ph.D. in electrical engineering from Howard University, in 1975, 1976, 1980, and 1983, respectively. He is a former Program Director in the Engineering Directorate of the Division of Electrical Communication and Systems (ECS) at the National Science Foundation (NSF) in Arlington, VA.

He is also former Chairman of the Electrical Engineering Department at Howard University, and is the Director of the Center for Energy Systems and Control (CESaC) at Howard University. His research interests include power system reliability and power system optimization, automation and intelligent systems, and economics and risk assessment in a deregulated power system environment.

He is currently developing an interdisciplinary research and education program in power, economics, regulation, and environmental adaptive systems. Dr. Momoh has received several awards/honors including the 1987 Presidential Young Investigator Award, and was the recipient of the 1989 ASEE Excellence Educator.

**Garfield Boswell** (Student Member, IEEE) received a BSEE (1994) from University of the West Indies (UWI). He also received his MSEE (1999) from Howard University, where he specialized in energy and power system optimization, and controls. He was a teacher at Belair High School during 1994-1996 and is a private contracting engineer for WelloMed Limited in Jamaica. He is currently working on his PhD at Howard University and his research interests lie in the areas of power system operation, planning, optimization, and market design.