Draft Final Report
on
A National Science Foundation (NSF) Sponsored Workshop:
A US-AFRICA RESEARCH AND EDUCATION COLLABORATION

Theme: “Promoting Research and Education in Power, Information Technology, and Environment”

Ralph J. Bunche International Affairs Center
November 5 - 6, 2003

Submitted by the Organization Committee Members
Dr. Joe Chow (Chair), Professor, Rensselaer Polytechnic Institute
Dr. James Momoh (Co-Chair), Program Director, NSF
Dr. Victor C.W. Dzidziienyo, Associate Dean, CEACS, Howard University
Dr. Kevin Tomsovic, Professor, Washington State University

December 2003
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People who contributed to the workshop organization

People who contributed to the report
Section 1

Summary of the Workshop and Recommendations for Future Activities
Summary

The US-Africa Research and Education Collaboration Workshop is an outgrowth of the biennial International Conference on Power System Operation and Planning (ICPSOP), which the National Science Foundation (NSF), a host of utility companies, and universities in the US and Africa have funded. Previous workshops, organized by Howard University, have led to collaboration in faculty exchange, recruitment of students, and joint research between US professors and African colleagues.

To allow these activities to achieve greater impacts in the science and engineering of power / energy, information systems, and human and social dynamics, a research and education collaboration initiative was started by the Division of Electrical and Communications Systems (ECS) at NSF. ECS grantees serve as co-PIs with several African researchers in order to broaden existing research and education activities. To kick-off these efforts, this NSF sponsored two-day workshop, under the theme “Promoting Research and Education in Power, Infrastructure and Environment”, cultivated the following objectives:

- Develop collaborative work between mathematics professors and engineers to develop robust modeling techniques and tools for analysis of large networks.
- Detail a roadmap for future collaborative research activities in power / energy, information systems technology, environmental and social dynamics, and education.
- Build collaboration between African and US researchers to allow greater understanding of power system performance in different environments.
- Establish a forum to increase Minority enrollments in engineering and international cooperation.
- Promote the NSF mission to prepare students to be globally engaged in the workforce of the 21st Century.

Each of the above addresses important forces that have important implications for future power systems research and education programs in the Engineering Directorate and especially in the Division of Electrical and Communications Systems (ECS) at the National Science Foundation.

The broadening of researchers across disciplines in the areas of computational intelligence, advanced system controls, social sciences, economics and environmental sciences, and the development of new education pedagogy, curricula, and test beds for different environments contributes greatly to the overall mission of NSF.

It is expected that this workshop will not only allow for vital research discussions, but serve as a catalyst for the convergence of multidisciplinary solution methodologies in science and engineering, and provide directions for advancing science and engineering collaboration between the US and Africa.
At the conclusion of the two-day workshop, a number of African participants traveled to their host universities to work on joint projects and lay out plans for future collaboration.

Conclusions and Recommendations

The workshop in Washington DC and the visits to the host universities initiated many involved discussions and yielded some general consensus on important areas for focus and development for further cooperation in research and education. The main points are summarized below:

Benefits to US from Cooperation

- There are areas of expertise with electric power systems that are more advanced in Africa. This includes the greater reliance on distributed generation technologies due to the weaker transmission links. It also includes particular operational experience in weakly meshed systems, such as, greater familiarity and experience with restoration procedures following a blackout or brownout.
- Africa has a large pool of manpower that is not being fully utilized. This includes a well-educated student population that is anxious to be involved in research.
- Previous international cooperation efforts have shown the great interest from US students in being involved in such projects. This is particularly so for underrepresented groups, including women and African-Americans.
- This cooperation is an opportunity to give students a different perspective on engineering issues, thus, enhancing their educational experience.
- Addressing the challenges faced by African nations in developing the electric supply system, may provide new perspective and ideas for US problems. For example, the successful development of distributed generation within Africa could be translated to the US. As another example, there are subsystems within the US, such as Alaska, that may have similar infrastructures.

Benefits to Africa from Cooperation

- The US is generally more experienced in the use and application of advanced technologies. This experience would be useful for engineering needed changes to the African power networks, such as, greater interconnection.
- The US has a more developed research and education infrastructure in the University.
- The US has more experience with the process of electricity deregulation.
General Recommendations and Considerations within the African Power Systems and for the Development of Research Cooperation

- There is a need for greater cooperation among African nations in both research and education that can be facilitated by cooperation with the US, perhaps through establishment of a joint center for research and education.
- There are numerous benefits to greater interconnection among the West African electric systems. These links may even benefit from either newer advance DC systems or more traditional AC links. Research is needed on the appropriate controls as weakly meshed systems are interconnected.
- It is important to allow competition in generation supply, such as from Independent Power Producers (IPPs).
- African universities need to be involved and visible in the decision-making process of regulatory changes to the electric supply system.
- Technology developments need to consider the special circumstances within various countries on the African continent. This includes focus on appropriate technology, such as, solar refrigerators or alternative technologies for irrigation pumps.
- There must be a business structure to encourage small and medium sized enterprises. Such business considerations should be integrated into engineering education.
- The process of deregulation must have a realistic roadmap that takes into consideration the existing infrastructure within Africa.
- The possibility should be explored in the manufacturing and development of small turbines and electrical machinery appropriate for Africa.
- Greater investment in, and application of, Information Technologies (IT) is needed both within the electric systems and the educational facilities. There are possibilities, such as the use of “thin” clients, for using less costly alternatives in the communication and computation infrastructure. More than just equipment, the technology gap among students must be bridged.
- The importance of the power system in critical aspects of the economy (agricultural, food processing, transportation) must be kept in mind.

Targeted Technology Areas for Research:

1. Power Systems
   - Interconnections and advanced transmission system technologies
   - Power system planning and economics
   - Deregulations and energy policies
   - Distributed generation and alternative generation technologies
   - Power system security, control, and optimization

2. Information Technology
   - Power system automation and energy management systems
   - Online and collaborative learning
Engineering applications of internet technology
Common language for internet applications

3. Environment
   Emission control
   Environmental policies
   Environmental sensors
   Reuse of public waste
   Energy efficiency

African University Infrastructure:

1. Form a joint research center or consortium for a group of universities, with each university focusing on the specific aspects of a few proposed targeted research areas.

2. Develop close industry and university relationship, in educating full time and part time (working in industry) students, and in joint technical work.

3. Support professors and students on exchange programs to universities in other countries.

4. Get access to electronic journals though local and external university libraries.

5. Encourage research personnel to submit papers to regional and international conferences and technical journals.

6. Provide/secure sources to obtain necessary research facilities (such as computers) to support advanced research. Develop cost effective means of providing computing facilities to students.

7. Focus on the development of young professors

Collaborations between US and African universities

1. Based on technical needs, US universities need to form alliances with specific African universities to develop expertise mutual to both parties.

2. Develop memorandum of understanding between the universities to enhance working relationship.

3. Write joint proposals to fund collaboration programs, allowing the exchange of professors and students.

4. Coauthor papers for journals and conferences
5. Promote under-represented groups of students and professors to participate in the collaboration activities.

6. Share teaching material and library resources as well as teaching pedagogy. Leverage on IT support. Develop remote, collaborative learning techniques.

**Potential Sources of Funding**

1. NSF – most of the US university activities would come from NSF, either under the international program or a special initiative.

2. USAid – it may be possible to support the activities of African university participants from USAid funds. This would be particularly welcome because of the difficulties in providing funds to the African participants for the local expenses in the US.

3. UNESCO – this organization has been cited by African participants as a dominant source of support in developing countries.

4. Private foundations – solicit funds from private foundations to support the travel for African participants.

**Roadmap and Milestones**

It must be first recognized that we are a small group of US and African university professors, who are trying to accomplish many tasks with limited resources. Our plan is to set up models of collaboration to motivate the formation of other US-African partnerships. Initially we propose a 5-year plan with two milestones.

**Milestone 1: August 2005**

The accomplishments include

1. Development of memorandum of understanding a number of African and US universities.

2. Mutual visits of professors and students between collaborating universities.

3. Establishment of several technical projects in the targeted research areas between the collaborating universities.

4. Development of an African testbed power system model for technical collaboration.

5. Joint development of courses and materials which can be accessed remotely.

6. Seminars conducted during the visits.
7. Coauthored papers submitted to conferences and journals.

**Milestone 2: August 2008**

1. Formation of an African university power system research consortium, with US affiliated members.

2. Development of industry support for the Consortium.

3. Establishment of additional funding for US professors to continue the exchange program.

4. Development of additional joint technical projects with African industry participation.

5. Development of a consortium website for internal communication and external access.

6. Double the number of students involved in the joint research program with emphasis on under-represented groups.

7. Dissemination of technical results to industry via courses and seminars.

8. Double the number of coauthored papers submitted to conferences and journals.
Section 2

Workshop Activities
The US-Africa Research and Education Collaboration Workshop was held at Howard University on November 5-6, 2004, and attended by over 50 people.

The first day of the workshop was devoted to presentations and discussion on the opportunities of US-Africa exchange programs and the framework of collaboration. The second day allowed the African participants to present technical challenges of concerns to them, and how they desire to move forward. The summary of these discussions has been given in Section 1.

The detailed records of the workshop are given in the Appendices. The workshop program is given in Appendix A. The presentations can be found on the Howard University Center of Energy Systems and Control (CESaC) web site http://www.cesac.howard.edu/ . The abstracts of the talks can also be found in Appendix B. A listing of the workshop participants are given in Appendix C.
Section 3

Host University Visit Activities
Summary Report on Visits to Washington State University

Participants

Washington State University
Prof. K. Tomsovic (Host – School of EECS)
Prof. A. Ford (Environmental Sciences)
Prof. A. Bose (Dean of College of Engineering and Architecture)
Prof. T. Fischer (Director School of EECS)
Prof. R. Olsen (School of EECS)
Prof. S. Roy (School of EECS)
Prof. V. Venkatasubramanian (School of EECS)
Dr. A. Dimitrovski (School of EECS)
M. Gebremicael (graduate student - EECS)
S. Bhowmik (graduate student - EECS)
Dr. R. Harder (Director of International Programs)

West Africa
Prof. T. Nwodo, Fed. Univ. of Sc. & Tech., Owerri, Nigeria
Prof. J. Ngundam, Univ. of Yaounde, Cameroon
Prof. R. Salawu, Univ. of Lagos, Nigeria
Prof. Mamadou Adj, Campus Universitaire - ESP Dakar
Prof. M. Momoh, Usman Danfodiyo University, Sokoto, Nigeria

Overview of Activities
This report outlines the various activities and accomplishments of the researchers visit to Washington State University under the National Science Foundation (NSF) Sponsored Workshop: A US-AFRICA Research and Education Collaboration.

Research and education overview with WSU faculty with the following presentations:
- Boeing partnership in Ghana
- E/M research in power systems
- Stochastic systems
- Real-time controls
- Non-linear dynamic systems
- Use of Matlab in instruction and research

Several sessions were held to familiarize visitors with various modeling and simulation tools, including:
- Vectorized Matlab loadflows
- Power system dynamic studies in Matlab
- Use of the Operator Training Simulator (OTS)
- Long term planning using Stella (a System Dynamics tool) and using Matlab

Computer hardware, software and data exchanges:
- Provided to Prof. Ngundam, Prof. Momoh and Prof. Nwodo:
  o Computer hardware loan
  o Matlab
  o Text book on System Dynamics
- Provided to all visitors:
  o OTS
  o Load flow in Matlab with several sample systems
  o Power system dynamic studies in Matlab with several sample systems
  o Models for studying long term dynamics in Stella and Simulink
  o Various other reference materials
- Data on power networks in West Africa provided to WSU

**Specific Project Discussions**
- Modeling the long term planning of the West Africa power network
  o Country by country interconnection plans
  o Load growth forecasts upper and lower limits
- Identified data needs
  o Better characterization of load growth trends by regions.
  o Description of the generation construction process – construction time, permit process and so on.
  o Models for the economic incentives to build new generation plants.
  o Approximate transfer limits between regions
- Research approach
  o All 5 researchers involved, begin by building simple models for long term planning as was done during WSU training session
  o Exchange data
  o Proceed to building more sophisticated models

**Approximate Time Line – Suggested by Tomsovic**
- Initial simple model development – Feb. 2004
- Exchange of data and discussions on approaches – May 2004
- Plan for subdividing work on models – Aug 2004
- More sophisticated models complete – December 2004
- Combination of different models – March 2005
- Running studies, debugging and documentation – December 2005

**Concerns Raised**
- Access to literature
-Completeness of data and adequacy of models
- Involvement and exchange of students

**Longer Term Plans**
- Development of more sophisticated models
- Distributed generation impacts
- Country by country specific conditions
- Exchange of researchers and students
Summary Report on Visits to University of Washington

Visitors from Africa:
Prof. Thomas C. Nwodo, Fed. Univ. of Sc. & Tech., Owerri, Nigeria
Prof. John Ngundam, Univ. of Yaounde I, Cam
Prof. Raifu I. Salawu, Univ. of Lagos, Nigeria
Prof. Adj Mamadou, Campus Universitaire - ESP Dakar
Professor Musa Momoh, Usmann Danfodiyo University, Sokoto, Nigeria

UW Attendees:
Prof. Chen-Ching Liu, Prof. Mark Damborg, Prof. Kai Strunz, Prof. Alexander Mamishev, Prof. Jacques Lawarree, Prof. Steve Olswang (Vice Provost of the UW), Mr. David Fenner (Director of International Programs and Exchanges), Mr. Sung-Kwan Joo, Mr. Guang Li, Mr. Xiao-long Yu, Mr. Gao Feng, MS. Yanfang Shen M.S. Sanaz Namdar, Dr. Jinho Kim (Visiting Scholar from South Korea), MS. Kerry Donk (ALSTOM)

Summary of NSF Project Discussions

A. Technical Subjects
It was decided that the technical subjects of the NSF project include (i) Market Optimization (social welfare) and (ii) Calculation of Available Transfer Capability (ATC) (between Nigeria and Cameroon (or Congo)).

It was also agreed that all five universities in Africa will provide test cases with African power system models for the project by Feb 29th, 2004 and UW will use the African power system model for test cases of the project and report the testing results by April 30th, 2004.

There are a number of interesting areas for future research, including the following areas:
- Reliability
- Distributed Generation (DG)
- AC/DC Interconnection
- Distribution/Transmission System Loss Reduction
- Power Consumption Monitoring

B. Library/Publication Access

Faculty and students in West Africa need to access the literature through the UW library. The following issues were raised in relation to library/publication access:
- Needs for computer HW/SW
- Licensing (IEEE Publications) and Funding from NSF for licenses
- UW library access
## C. List of Contact

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>University</th>
<th>E-mail &amp; Telephone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomas C. Nwodo</td>
<td>Professor</td>
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<td><a href="mailto:tomennwodo@yahoo.com">tomennwodo@yahoo.com</a>&lt;br&gt;Cellular: 08033237990</td>
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<tr>
<td></td>
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<td>Owerri (FUTO), Nigeria</td>
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<tr>
<td>E.N.C. Okafort</td>
<td>Ph.D. Student</td>
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<td>Owerri (FUTO), Nigeria</td>
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<tr>
<td>Obinna Obah</td>
<td>Ph.D. Student</td>
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<td>Owerri (FUTO), Nigeria</td>
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<tr>
<td>Damian Dike</td>
<td>Ph.D. Student</td>
<td>Federal Univ. of Sc. &amp; Tech.,</td>
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<td></td>
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<td>Owerri (FUTO), Nigeria</td>
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<tr>
<td>Papa Ibrahima</td>
<td>Ph.D. Student</td>
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<td>N/A</td>
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<tr>
<td>John Ngundam</td>
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<td><a href="mailto:jmnngundam@yahoo.co.uk">jmnngundam@yahoo.co.uk</a>&lt;br&gt;<a href="mailto:ngundam@polytech.uninet.cm">ngundam@polytech.uninet.cm</a>&lt;br&gt;<a href="mailto:ngundam@anl.gov">ngundam@anl.gov</a>&lt;br&gt;Office: 630-252-9682&lt;br&gt;Home: 630-985-0647</td>
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<td>Sunday Wilson Balogun</td>
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<td>Yanfang Shen</td>
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</tr>
</tbody>
</table>
African Visitors:
Prof. Thomas C. Nwodo, Fed. Univ. of Sc. & Tech., Owerri, Nigeria
Prof. John Ngundam, Univ. of Yaounde I, Cam
Prof. Raifu I. Salawu, Univ. of Lagos, Nigeria
Prof. Adj Mamadou, Campus Universitaire - ESP Dakar
Professor Musa Momoh, Usman Danfodiyo University, Sokoto, Nigeria
Prof. Ehile E. Etienne, Univ. of Abobo Adjame, Cote d'Ivoir (Not coming)

Agenda

Friday, November 7

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>2:30 PM</td>
<td>Chen-Ching Liu</td>
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<tr>
<td>4:00 PM</td>
<td>Campus Tour, Kevin Schneider to meet at the University Inn Lobby</td>
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<tr>
<td>5:30 PM</td>
<td>Dinner with Chen-Ching Liu</td>
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Saturday, November 8

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<td>8:45 AM</td>
<td>Welcome and Continental Breakfast</td>
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<tr>
<td></td>
<td>Location: EE Building, Room 403</td>
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<tr>
<td>9:00</td>
<td>Chen-Ching Liu:</td>
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<tr>
<td>9:30</td>
<td>Jacques Lawarree: Deregulation</td>
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<tr>
<td>10:00</td>
<td>Y. Shen: Market Optimization Problems</td>
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<td>10:30</td>
<td>Sanaz Namdar: Aspects of FACTS Placement and Control in Electricity Markets</td>
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<td>11:00</td>
<td>Jinho Kim: Maintenance</td>
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<td>11:30</td>
<td>Yu Xiaolong: Hybrid Plant of Renewable Stochastic Source and Multi-Level Storage for Emission Free Deterministic Power Generation</td>
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<td>12:00</td>
<td>Lunch</td>
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<td></td>
<td>UW Attendees: Sung-Kwan Joo, Jacques Lawarree, Jihho</td>
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Kim, Chen-Ching Liu, Shen, Guang Li, Kai Strunz, Gao Feng, Xiaolong Yu, Sanaz Namdar

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<tbody>
<tr>
<td>2:00</td>
<td>Kai Strunz: Blackouts: Causes and Consequences</td>
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<tr>
<td>3:00 – 5:30</td>
<td>Presentations by African universities</td>
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<td>6:00</td>
<td>Dinner at Ivar’s Salmon House</td>
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UW Attendees: Gao Feng, Jinho Kim, Guang Li, Chen-Ching Liu, Kai Strunz, Xiao-long Yu, Shen, Kerry Donk (ESCA)

Monday, November 10

<table>
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<td>Welcome and Continental Breakfast</td>
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<tr>
<td></td>
<td><strong>Location:</strong> EE Building, Room 303</td>
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<tr>
<td>9:00 – 11:00</td>
<td>NSF project discussions</td>
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<tr>
<td></td>
<td>UW attendees: Chen-Ching Liu, Guang Li, Sung-Kwan Joo</td>
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<tr>
<td>11:30 – 1:30</td>
<td>Luncheon</td>
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<td></td>
<td>UW Attendees: Mark Damborg, David Fenner, Gao Feng, Sung-Kwan Joo, Guang Li, Jinho Kim, Jacques Lawarree, Chen-Ching Liu, Alex Maminshev (will be late), Kai Strunz, Steve Olswang (Vice Provost of the UW)</td>
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</tbody>
</table>

Limo Pick Up Outside the EE Building at 1:45 Departure for Sea-Tac Airport
Summary Report on Visit To Iowa State University (ISU)

Participants

Iowa State University
Prof. V. Ajjarapu (Host – Department of ECPE)
Prof. J. McCalley (Department of ECPE)
Prof. V. Vittal (Department of ECPE)
Prof. G. Sheble (Department of ECPE)
Prof. R. Kumar (Department of ECPE)
Prof. V. Oscar (Department of Economics)
Prof. A. Somani (Chairperson of Department of ECPE)
Dr. T. Okishi (Associate Dean, College of Engineering)
Mr. Z. Zhou (Graduate student - ECPE)
Mr. X. Wen (Graduate student - ECPE)
Ms. P. Kohli (Graduate student – ECPE)
Mr. K. Fares (Undergraduate student - ECPE)
Mr. P. Shivam (Undergraduate student - ECPE)

Africa
Prof. George O. Anderson, Univ. of Botswana, Botswana
Dr. Tanimu Abubakar, Ahmadu Bello University, Zaria, Nigeria

Overview of Activities
Prof. Anderson and Dr. Tanimu from Africa visited ISU from Nov. 7-13, 2003 under the National Science Foundation (NSF) Sponsored Workshop: A US-AFRICA Research and Education Collaboration. ISU group discussed in detail the ways to involve African delegation in research, education and outreach aspects of this project. We came up with a road map with tasks and corresponding deadlines. This report highlights various components of this interaction.

The following Presentations are given to provide an Overview of Education and Research Activities.

• Dr. Ajjarapu
  – Presented an overview of ISU power group’s research
• Dr. Anderson
  – Presented South African Power Pool Structure
• Dr. McCalley
  – Presented ISU’s NSF EPNES project
• Mr. Weyer (Alliant Energy)
  – Gave a seminar on Distributed Resources

Hands on Sessions were held to familiarize visitors with various modeling and simulation tools, including:

• Power World
- Power flow, OPF, Visualization
- Dymola
  - Power Electronics Simulation Software
  - Real time control Demonstration
- Web Based Continuation Power Flow
  ---ISU software: Can be Accessed From a Remote Location

The Following Table Provide Specific Tasks

<table>
<thead>
<tr>
<th>Task Definition</th>
<th>Approximate Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Describe Respective African System Structure with respect to:</td>
<td>January 31st, 2004</td>
</tr>
<tr>
<td>- Economic Dispatch and Markets. How it is done at present?</td>
<td></td>
</tr>
<tr>
<td>- Transmission</td>
<td></td>
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<tr>
<td>- Organizational Chart</td>
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</tr>
<tr>
<td>2. Course Development (Economic Systems for Planning in Electric Power)</td>
<td>First Draft: June 1st, 2004</td>
</tr>
<tr>
<td>- Prepare one 50 minute lecture :Each from Nigeria and Botswana</td>
<td>Final Draft: August 1st, 2004</td>
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<tr>
<td>- The material should include some level of visible notes.</td>
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<tr>
<td>3. Specify African Testbed for Each Country. It should include:</td>
<td>June 1st, 2004</td>
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<tr>
<td>- A One Line Diagram</td>
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<tr>
<td>- Static Data (e.g. power flow..)</td>
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<tr>
<td>- Dynamic (e.g. excitation control)</td>
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<tr>
<td>- Economic (cost and market data)</td>
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<tr>
<td>- Sequence of existing control to respond to an emergency.</td>
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<tr>
<td>4. Identify persons from each country to be involved in EPNES project with</td>
<td>January 31st, 2004</td>
</tr>
<tr>
<td>expertise in each one of the following areas: power, control and power</td>
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<tr>
<td>system economics. This facilitates to implement control techniques</td>
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<td>developed in this project on African Testbed</td>
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<tr>
<td>- Nigeria: Dr. Tanimu identifies these three persons</td>
<td></td>
</tr>
<tr>
<td>- Botswana: Dr. Anderson identifies the control and economics persons</td>
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</tbody>
</table>
5. Identify departmental and university infrastructure available in collaborating countries to carry out this project.
   • List the power system software/hardware available
   • Indicate the technologies available at the respective countries to interact with ISU EPNES group (e.g. video conferencing facilities, internet connection and bandwidth..)
   January 31st, 2004

6. Dr. Anderson prepares a draft version of memorandum of understanding for further collaboration.
   June 1st, 2004

7. Plan for mutual visits
   Two participants (one from Nigeria and Dr. Anderson from Botswana) will visit ISU at a date to be fixed (Tentatively July-August 2004)

Accomplishments
• Acquainted with advanced tools that can be applied for both power systems and power electronics in research and education
• African participants understood their role in EPNES NSF ISU proposal.
• Established logistics for participating in the EPNES project.
• Learned web based power system simulation tool that can be accessed from a remote site
• African delegation, through the interaction with ISU power group learned:
  – Recent advances in power system security and de-regulation.
  – The usefulness of weekly power seminar with participation of experts from industry
• Proposed a road map for collaboration with detailed tasks and time frames.

Long Term Plans
• Study the feasibility of exchange of undergraduate and graduate students between Africa and ISU.
• Expand the scope of collaboration with larger number of African Universities and accordingly plan for future course of action with respect to funding
  – As a part of this, explore the possibility of GRID computing for African context.
Summary Report on Visits to University of Missouri - Rolla

- Literature Survey – A detailed survey of the state art in reactive power and voltage control and other areas relevant to Nigerian grid was carried out. Over 70 papers reviewed.

- Seminar presentations delivered by UMR graduate students working in computational intelligence with applications in power systems and other nonlinear problems to Dr. Aliyu.

- The power system simulation software -PSCAD was reviewed for Dr. Aliyu.

- Dr. Aliyu attended a PhD defense seminar in Electrical Engineering.

- Dr. Aliyu gave an IEEE seminar at UMR entitled “Adaptive Load Frequency Control of Interconnected Hydro and Thermal Areas using Unsupervised Learning Neural Network” based on current research activities at ATBU. The seminar was well attended by UMR faculty and students.

- Dr. Aliyu had meetings with the following people at UMR: -
  o Chair of the Electrical and Computer Engineering – Dr. Kelvin Erickson.
  o Dean of School of Engineering – Dr. Robert Mitchell.
  o Director for International Affairs – Ms. Jeanie Smallwood.
  o Informal meeting with the Nigerian UMR faculty and students.

- The plan of work outlined in the NSF International proposal was reviewed and milestones planned out.

- The proposal for the new course on Computational Intelligence to be offered in UMR in Winter/Spring 2004 was reviewed and course syllabus shared.

Plan of Work Statement

- Development of new course on Computational Intelligence – WS2004 in the USA. To be introduced as part of current courses in ATBU next year.

- Nigeria grid data to be supplied to UMR by November 2003.

- PSCAD model for Nigeria grid to be developed in the first half of 2004.

- ATBU to acquire PSCAD software by February 2004.
• Implement computational intelligences to carry out reactive power and voltage control at different levels on an IEEE benchmark systems and Nigerian grid (March 2004 to August 2005).

**Planned Visits**

• Dr. Venayagamoorthy to visit ATBU, Nigeria in March 2004.

• Dr. Aliyu to visit UMR, USA in June 2004.

• Dr. Aliyu to attend 2004 PES meeting, June 6 – 10, 2004 in Denver, USA.

• Dr. Venayagamoorthy and a graduate student to visit ATBU in October 2004.

• Dr. Bakare to visit UMR, USA in March 2005.

• Dr. Venayagamoorthy to visit ATBU, Nigeria in June 2005.

• Dr. Venayagamoorthy, Dr. Aliyu and Dr. Bakare all to meet at the International Conference on Power Systems Operation and Planning 2005 in Durban, South Africa, August 14-17, 2005.

**Dissemination of Results**

• IEEE and IEEE PES General Meetings

• IEEE Transactions

• Seminars at the UMR, USA and ATBU, Nigeria.

• Tutorials at IEEE Conferences.

• Doctoral and Master’s Thesis and Dissertations.

• Internet Websites.

**Long Term Plans**

• Establish collaboration between the various departments and schools of University of Missouri-Rolla, USA and Abubakar Tafawa Balewa University, Bauchi, Nigeria.

• Have student and Faculty exchanges for a semester or two. Students should be able to transfer undergraduate and graduate level credits from one university to the other.
Summary Report on Visits to Howard University

US – Africa Universities Research and Education Collaboration
Nov 5-14, 2003
Howard University Group Summary

List of participants

1. US Participants

1a) Howard University
Professor Johnson (Dean and PI)
Professor Victor Dzidzienyo (Host – Associate Dean, CEACS)
Professor James A. Momoh (Director, CESaC, on leave at NSF)- project coordinator
Professor Peter Bofah (Acting Assistance Director, CESaC)
Professor Philip Fanara, Jr. (School of Business)
Professor L. Jide Iwarere (School of Business)
Ayodele Ishola-Salawu (Graduate Student, CESaC)

1b.) University of Maryland, College Pack
Professor Eyad Abed (Electrical & Computer Engineering Dept.)

2. Africa
Professor Philip Kuale (University of Benin, Benin City, Nigeria)
Professor Ebenezer Jackson (Kwame Nkrumah Univ. of Sc. & Tech., Kumasi, Ghana)
Dr. Joseph Ekeh (Ambrose Alli University, Ekpoma, Nigeria)
Dr. Innocent Davidson (University of Natal, Durban, South Africa)

Summary of joint research collaboration

The Howard team had a series of presentation of papers, discussions and brainstorming sessions during the visit. Several decisions were arrived at which will form the road map and hence the plan of action for executing the research and educational goals. The summary of the outline is as follows:

Educational components involving students research experience. Amongst the issues raised are the needs for:

1.) Course Development: Power System Economics with Distributed Generation,
Introduction to power system model, Power systems, Distributed Power systems,
Reliability of Power systems, Environmental Power systems concepts, Price Theory for the Electricity Market, and Introduction to Linear Power systems

2.) Tool Development and Training
Dissemination of information by publication
Publish Papers and present work at conferences
3. The Special Guest Lectures on Electricity Marketing.
Participants also received lectures on:
Market Microstructures and Electricity Pricing, Basic Notions
Congestion influence on bidding strategies in an electricity market
On transmission congestion and pricing
Transmission congestion management and pricing

4.) Project Description and Review of Literature.
The research activities at the center were discussed to update collaborators with new research direction such as
Electric Power Network Efficiency and Security (EPNES) project and the Photovoltaic project sponsored by the NREL.

5. Review of Locational Marginal Prices (LMP)
The LMP attempts to find the optimum price of supplying an additional MW load at each location (or bus) in the system. The brief overview of the LMP is as follows:

i.) LMP for day (days) ahead of market
ii.) LMP for hour a-head market which must take into account the starting requirements of DG’s
iii.) Real time LMP Aggregated LMP.

6. Task Definitions for Participants
The milestone of activities proposed for the collaborative research defined by the group is presented in table 1 below

<table>
<thead>
<tr>
<th>Task Definition</th>
<th>Approach</th>
<th>Approximate Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Data Collection: NEPA, GHANA and US</td>
<td>Faculty staff, Students to Contact, Industries for Data</td>
<td>December, 2003</td>
</tr>
<tr>
<td>2. DG Data: Fuel cost and Pricing - Nigeria and Ghana</td>
<td>Faculty staff, students to contact Gas supply Companies and Billing Rates of cost and current prices respectively</td>
<td>February, 2004</td>
</tr>
<tr>
<td>3. Modeling 1 &amp; 2 with DC, FACTS -Howard</td>
<td>Faculty staff and Research students to develop models</td>
<td>February, 2004</td>
</tr>
<tr>
<td>4. Base Case Studies of 1&amp; 2</td>
<td>Faculty staff and Research</td>
<td>March, 2004</td>
</tr>
<tr>
<td>5. Formulation of LMP with DG, FACTS and Congestion Constraints - Howard</td>
<td>Faculty staff and students</td>
<td>March, 2004</td>
</tr>
<tr>
<td>6. Evaluations Techniques for solution of LMP, -LP, -DC, NLP-AC, ADP, (Interior paint method) - Ghana, Nigeria and Howard</td>
<td>Faculty staff and students</td>
<td>July, 2004</td>
</tr>
<tr>
<td>7. Implementation: Program Development, Define scenarios or Riddles -</td>
<td>Faculty staff. Staff using computing techniques</td>
<td>September, 2004</td>
</tr>
</tbody>
</table>
Howard

8. Simulation studies - All participants
   Graduate students supervised by Faculty staff
   October, 2004

9. Comparison of Results All participants
   Graduate students
   December, 2004

10. Study 5-9 with Environmental Constraints Howard
    Faculty to liaise with Government Agents in Environmental matters
    February, 2005

11. Do Cost-Benefit Ratio Howard
    Graduate students and supervision
    June, 2005

12. Final Report and papers All participants
    Graduate student and supervisor which could include thesis
    August, 2005

13. Education Pedagogy Course - Howard develop the course and all participants testing the course
    Faculty staff assessment of the Course. Student activities next year
    Spring 2004

7. List of Research team members and contact address
The list of participants in the collaboration with Howard and the African colleagues and students are shown below.

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>University</th>
<th>E-mail &amp; Telephone</th>
</tr>
</thead>
</table>
| Kuale Philip K.        | Professor              | University of Benin, Benin City, Nigeria | C/o Dr. C. Anyaeji
                        |                        |                                 | [dr.anyaeji@hotmail.com](mailto:dr.anyaeji@hotmail.com) 234 80 233 96 406 (GSM) 234 052 602498 |
| Mr. Jacob Tsado        | PhD student            | University of Benin, Benin City, Nigeria | N/A                                       |
| E.A. Ogunjo           | M.Sc. Student          | University of Benin, Benin City, Nigeria | N/A                                       |
| Abdulahi Musa         | M.Sc. Student          | University of Benin, Benin City, Nigeria | N/A                                       |
| Joseph. C. Ekeh       | Associate Professor    | Ambrose Alli University, Ekpoma, Nigeria | [Engr.ekeh@yahoo.com](mailto:Engr.ekeh@yahoo.com) c/o Prof. Kuale 234 80 233 96 406 (GSM) |
| Ebenezer Jackson      | Professor              | Kwame Nkrumah Univ. of Sc. & Tech., Kumasi, Ghana | [jacksonea@yahoo.com](mailto:jacksonea@yahoo.com) 011-233-51-60-255 011-233-20-81-63-911 |
| Dean James H Johnson  | Professor              | Howard University, Washington DC, USA | 202 806 5350                              |
| Dr. Yaoyu Wang        | Post Doc.              | Howard University, Washington DC, USA | [ywang@howard.edu](mailto:ywang@howard.edu)202-806-5350 |
| Garfield Boswell      | Ph.D Student           | Howard University, Washington DC, USA | N/A                                       |
| Julan Feng            | Ph.D Student           | Howard University, Washington DC, USA | N/A                                       |
8. Conclusion and strategy for achieving results between the collaborating institutions.

The research direction for the collaboration was defined. The specific assignment for each participating member was defined. A milestone activities and monitoring scheme was designed by the members. Specifically the following activities are suggested for the members to undertake upon reentry:

- Recruitment of qualified students for the research projects
- Training of research members in computational tools such as Mat lab, DISREL, Lab View and the collection of data for power system network studies.
- Development of literature review, in DG options and Locational pricing papers for possible publication with Howard research team
- Maintain contact relationship via Ethernet and telephone of visits during

Finally, it is suggested that every upon reentry the participants should engage their home government to fund research more generously and promote this worthwhile initiative.
<table>
<thead>
<tr>
<th>Day</th>
<th>November 10-14, 2003</th>
<th>US-Africa Collaboration</th>
<th>Howard University Group Time Table During the research visit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MONDAY</strong></td>
<td>November 10</td>
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<tr>
<td></td>
<td><strong>MORNING SESSION</strong></td>
<td><strong>AFTERNOON SESSION</strong></td>
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<td></td>
<td>9:30 – 11:30</td>
<td>11:30 – 1:00</td>
<td>2:30 – 3:30</td>
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<td>3:30 – 5:30</td>
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<tr>
<td></td>
<td>CESaC Overview</td>
<td>HU EPNES Overview</td>
<td>Evaluation of Tools</td>
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<td>- MatLab</td>
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<td>- Etc.</td>
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<td></td>
<td></td>
<td>Lunch</td>
<td>Free Time &amp; More Tools</td>
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<tr>
<td></td>
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<td></td>
<td>(Identify Tools / Hardware needed for research)</td>
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<tr>
<td></td>
<td></td>
<td>Robert / Salawu</td>
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<td>3:30 – 5:30</td>
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<tr>
<td><strong>TUESDAY</strong></td>
<td>November 11</td>
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<tr>
<td></td>
<td>Background of Exchange Project (Brainstorming Session)</td>
<td>Materials / Survey of Exchange Project</td>
<td>Theory of Locational Marginal Pricing (LMP)</td>
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<td></td>
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<td>- Simulation</td>
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<td>- Geste Lecture</td>
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<td></td>
<td>Lunch</td>
<td>Brain Storming Session</td>
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<td></td>
<td>Development of Statement of Work</td>
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<td></td>
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<td>Dr. Momoh / Dr. Wang</td>
<td>Dr. Momoh</td>
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<td>9:30 – 10:30</td>
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<td>2:30 – 4:30</td>
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<td></td>
<td>4:30 – 6:30</td>
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<tr>
<td></td>
<td>Lecture on Economics and Public Perception</td>
<td>Lecture by Dr. Abed from the University of Maryland</td>
<td>Lecture by Dr. Abed from the University of Maryland</td>
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<td>Dr. Jide Iwarere</td>
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<td>4:00 – 5:30</td>
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<td><strong>WEDNESDAY</strong></td>
<td>November 12</td>
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<td><strong>MORNING SESSION</strong></td>
<td><strong>AFTERNOON SESSION</strong></td>
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<td>3:30 – 5:30</td>
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<td></td>
<td>Summary / Video Conference at NSF or teleconference at HU (will require Securing PIN # in advance if at HU).</td>
<td>ICP SOP 2005 meeting</td>
<td>CESAC Research / Staff Meeting</td>
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<td>- Future work</td>
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<td>- Draft schedule</td>
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<td></td>
<td>1. Dr. Bofah</td>
<td>Joint EPNES/Collaborative group meeting</td>
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<td>2. Dr. Fanara</td>
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<tr>
<td><strong>THURSDAY</strong></td>
<td>November 13</td>
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<td><strong>MORNING SESSION</strong></td>
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<td>Visit to the Museum</td>
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<tr>
<td><strong>FRIDAY</strong></td>
<td>November 14</td>
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<td><strong>MORNING SESSION</strong></td>
<td><strong>AFTERNOON SESSION</strong></td>
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<td></td>
<td>Summary / Video Conference at NSF or teleconference at HU (will require Securing PIN # in advance if at HU).</td>
<td>CESaC Staff and Students</td>
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</tbody>
</table>

**MORNING SESSION**: 9:30 – 11:30

**AFTERNOON SESSION**: 2:30 – 3:30

**Lunch**: 11:30 – 1:00

**Dinner**: 6:00 – 8:00
Section 4

Reports and Comments by African Participants
REPORT ON THE USA – AFRICA RESEARCH AND EDUCATION COLLABORATION – submitted by Professor George O. Anderson, Department of Electrical Engineering, University of Botswana, Botswana

I wish to sincerely express my gratitude to Professor James Momoh and Professor Joe Chow for inviting me to participate in the USA – Africa Research and Education Collaboration. The workshop was well organized. Participants had the opportunity to meet and listen to some of the members of NSF, as well as distinguished personalities, including those from Energy Department.

PHASE 1, 5 & 6 November 2003

LOGISTICS

Accommodation: The accommodation was excellent

Venue: The different venues for the workshop were perfect

Transportation: The transportation to and from the venue was excellent

Boarding during the workshop: Provision of breakfast snacks and lunch and tea breaks at the workshop was necessary and adequately provided for.

Per-diem: The per diem was adequate, but could have been given out in advance. We were, however, informed of the practice in the Universities concerning per-diem.

PRESENTATIONS

The presentations were in accordance with the programme. However we run against time due to unforeseen circumstances. The summary at the end of the two – day workshop could therefore not be adequately captured. The presentation on the Research and Education road map was precise and clear and that took us to phase 2 of the workshop.

COMMENTS

1. All presentation should preferably be by Power Point
2. The presentations should be received at the venue at least a week before the start of the workshop
3. Participants should be given the option to select from a pool of identified research topics for presentation
4. Ample time should be given for each presentation and questions. Perhaps three sections instead of two could be appropriate depending on the number of the number of power point materials received before the program is prepared
5. To sustain collaboration and avoid duplication, each of the designated universities should be given specific research topic and particular area to collaborate with the African Universities in Education. I am not sure if this is currently the practice
6. Memorandum of understanding (MOD) must be concluded between the collaborative Universities/Faculties. The MOD will facilitate collaboration in research, student exchange, staff visits, and joint programs beneficial to both parties.

7. One day should be set aside purposely for site seeing to acquaint foreign participants with the environment where the workshop is held.

8. Any material/equipment to be offered to the participants for the project, should be made available to the them before departure for their home countries.

PHASE 2, 7 to 13 November 2003

Visit to IOWA State University

I wish to thank Professor V. Ajjarapu of ISU and the colleagues involved with the NSF project for the hospitality accorded the African team. There were interactions between the participating teams, also interaction with some of the power systems graduate students, and some Professors in specialized areas and distinguished personalities. We had access to the laboratory facilities, and demonstration by the application of software in solving power system problems. A program of activities was prepared and enabled us to spend the time at ISU fruitfully.

At the last day of our visit, a discussion took place between the US team (Ajjarapu, MacCalley, Ratnesh, Oscar) and the African team (Anderson and Abubakkar). We brainstormed through the EPNES project “Planning Reconfigurable Power Systems Control for Transmission Enhancement with Cost recovery”.

We came up with a road map indicating various tasks and corresponding time frame for EPNES project as indicated in the report by Professor V. Ajjarapu of Iowa State University.

To improve and sustain this collaboration, a memorandum of understanding (mou) is to be signed by the ISU, Faculty of Engineering and the University of Botswana, Faculty of Engineering. The MOU will facilitate all activities of mutual interest in the collaboration project(s).

It is envisaged that technical papers from research activities will be published in reputable journals.

PHASE 3, 14 November 2003

The radio conferencing session on 14 November 2003 enable the African participants to be abreast with what activities took place in other Universities. It was a healthy exercise that should be continued in future.
I propose that radio conferencing facilities be located at the University of Botswana, at one of the northern Universities in Nigeria, and two in two of the southern Universities in Nigeria. Radio conferencing is proposed to take place at least once a year depending on the progress of activities.

I wish once more to sincerely thank Professor James Momoh for the invitation and sumptuous lunch that we enjoyed at the last day of the deliberations.

(Professor Ajjarapu at ISU promised to send me my computer, but I am yet to receive from him. A word from you to him will be appreciated. Thank you).
PARTICIPATION AT THE WORKSHOP ON US-AFRICA RESEARCH AND EDUCATION EXCHANGE SPONSORED BY THE US NATIONAL SCIENCE FOUNDATION (NSF), NOVEMBER 4-14, 2003

By

John M. Ngundam, PhD., DIC
Professor of Electrical Engineering
Ecole Polytechnique, Universite de Yaounde I
Yaounde, Cameroon

PERSONAL PARTICIPATION

The above workshop took place at Howard University although the NSF as indicated above sponsored it. The participants were drawn from twenty universities/organisations from the African side and seventeen universities/organisations on the American side. Apart from the opening ceremonies with its speeches, there were scientific/research presentations on the workshop’s main theme of Promoting Research and Education in Power, Infrastructure and Environment from selected participants.

All took place in an intensive two-day activity, which I attended. Apart from making a presentation on the research activities and results of the Automation and Control Laboratory (ACL), which I head, of the School of Engineering at the University of Yaounde I, I made contributions to discussions in the plenary and other sessions. A copy of my presentation was delivered to the workshop secretariat.

The workshop broke off after two days and some of the African participants took trips to five US universities participating as host universities in the collaborative project for now. Among four other colleagues from Nigeria and Senegal, my group flew to Seattle for the first leg of what you might call the field part of the workshop. At the University of Washington, Prof. Chen-Ching Liu arranged to have some of his colleagues and graduate students present ongoing research work of interest to the goals of the collaborative project. The presentations included:

- Blackouts in North America: Causes and Consequences
- Hybrid Plant of Renewable Stochastic Source and Multi-level Storage for Emission-Free Deterministic Power Generation
- Global Optimization in an Electricity Market Environment
- Electricity Deregulation
- Introduction to Electricity Markets in Korea

The five members of the African delegation including myself also made presentations on our research activities and institutions after faculty and students of the University of Washington.
After presentations and visits to sites in the Seattle area, we sat down to discuss the areas of research collaboration of interest to both parties. Agreement was reached on the four broad areas following:

- Electricity Market Optimisation in Deregulated Systems
- Available Electricity Transfer Capability (Network Planning)
- Interconnection of Central and West African Networks
- Engineering education and student/research exchange programs

African colleagues agreed to make required data for the above studies available to all by end of February 2004.

The group of five left for Pullman in the evening of Monday November 10 2003. The following day, at Washington State University, Professor Kevin Tomsovic, some of his colleagues and two graduate students presented selected ongoing research projects relevant to the collaborative project. The following were presented:

- Power Systems Analysis Tools at WSU
- Stella Software for Dynamic Modeling of Environmental Systems
- Flexible AC Transmission Systems and Systems Control
- The use of MATLAB for Modeling in Power Systems

Again, the members of the African delegation presented their research activities and institutions. At the end of these presentations, the five members of the African delegation had some hands on training on the use of the software tools used in the above research projects at WSU.

The delegations from Nigeria and Cameroon were provided with computers, books and CDs before they left for Washington DC.

IDEAS ON FUTURE COLLABORATION

Evidently, the main goal of the NSF initiative is to help African countries to better plan and run energy systems on the African continent. Along with that also go better environmental management policies. These objectives may be hard to meet if African governments do not complement the efforts of the US through the NSF. It is important to understand from the side of the US that in many countries universities and research laboratories depend on government money to function. In many cases money for teaching programs is not available or is inadequate. Consequently, the quality of engineering education leaves a lot to be desired. Funding of research is therefore considered as a luxury. The idea behind the collaborative project is sound, necessary and of the utmost importance if these countries must develop industrially and socially. The US through the various channels of contact with the African countries involved should seek to encourage these governments to support the collaborative project with counterpart funds for equipping laboratories, for postgraduate students support (stipends, travel to collaborating...
US universities, books etc.). I already talked about the importance of the objective of this project. There is a lot and a long way to go. The problem is being able to sustain the momentum that has been created not just for the sake of doing so but for the sake of creating the momentum for development in the region.

US universities involved in the project should seek to strengthen African university laboratory capabilities by approaching US companies doing business on the continent. If these companies could be convinced to see their own interests in supporting the program, they just might well be willing to support the NSF initiative.

The technical areas covered in the Washington workshop look good enough. However, aspects of industry and power/energy sector restructuring (economics, legal, sociological etc.) in particular should be given as much importance as well. This also suggests that we should seek to include these areas in new engineering courses to be developed within the framework of this project.

I would like to see us change the background of the engineer on the African continent to give graduates the skills required not only to successfully run power/energy industries and manage the environment sustainably but also to be able to become better consultants and supervisors of new infrastructure under development. At the moment, engineers either do not have adequate skills to undertake that function. If they do, they may in most cases not have the ethical and moral character to do a better job of it. Africa ends up paying too much for sub-standard infrastructure. We have to think of a way of taking this aspect on board this project. It is indirectly linked to the objective of the project.

By
Professor Thomas Nwodo
Professor of Electrical Engineering
Federal University of Science and Technology
Owerri, Nigeria

A prelude to the main workshop on US-Africa, Research and Education collaboration was the Applied Mathematics Workshop for Power System Engineering in Washington DC. This very useful and valuable workshop presented and discussed papers in Artificial Intelligence, Control Theory, Voltage Stability, Optimization Techniques, etc, on Nov. 3-4, 2003.

The main workshop on the US-Africa Research and Education Collaboration kicked off on Nov. 5, 2003, with a welcome address by Prof. Chow and introduction of the Theme and Objectives of the workshop by Prof. James Momoh. The workshop theme is: “Promoting Research in Power, Infrastructure and Environment which nurtures the following objectives:

- Developing collaborative work between Mathematics professors and engineers to develop robust modeling techniques and tools for analysis of large networks.

- Building African collaboration with US researchers to build further understanding of different power system case studies.

- Establishing priorities to increase Minority in engineering and increase international co-operation.

- Promoting the NSF mission to prepare students to be globally engaged in the workforce of the 21st Century.

- Developing a road map for future research activities in power/energy, information systems technology, environmental and social dynamics, and education pedagogy.

Guest speakers and speakers from US discussed various aspects of the theme and the impact the objectives have for future power systems research and education programs. Participants from Africa made their contributions during the break-out sessions on Research and Education Road Map.

My contribution focused on the application of gas turbine technology in the exploitation of natural gas for power generation because it is the cleanest of all fossil fuels and it is in abundance in Nigeria and Cote de’Ivoire. The combined cycle gas turbine technology is
recommended to independent power producers (IPPs) because of high efficiency, compactness relatively low cost and short construction time. The technology is appropriate for distributed generation (DG) for both developed and developing economics.

There is need for university undergraduates in Power System Engineering to acquire skills in the design, production, installation and operation of gas turbine plants as well as knowledge of power economics.

During our visits to Washington University in Seattle and the Washington State University in Pulman, the African participants were exposed to modern research tools in power system engineering in a deregulated utility environment and the importance of research in alternative systems, especially hybrid systems. The impact of power economics and the environment in the planning and operation of modern power systems and future power systems is of great interest to researchers. Research topics for collaborative work between US and African researchers were identified and target dates fixed for implementation.

The African participants returned to Washington DC in Nov. 13, 2003 to attend a wrap up meeting at Howard University on Nov. 14, 2003 to develop a communiqué for the workshop before returning to their home countries.

The workshops organizations were super but there is need for the African co-PIs to have some cash for traveling expenses, data collection, phone retire before the expiration of the NSF contracts.

Since most of the African co-PIs lack computers in sufficient quantities there is need for each of them to have a complete computer work station (PC, monitor, keyboard, mouse and printer).

My vice-chancellor at FUTO, Nigeria has been fully briefed on the workshops and the good working relationship and co-operation between US and African researchers. He sends his thanks and deep appreciation to the NSF, the Presidents of Howard University, Washington University, Seattle, and Washington State University, Pulman, and Prof Joe Chow and Prof. James Momoh.
I wish to express my gratitude to the organizers of the US-Africa collaborative research workshop for extending the invitation to me and providing the necessary financial support that covered travel, accommodation and limited out-of-pocket expenses. Without the concerted effort made by the organizers that facilitated the issuance of visas to the Nigerian participants, some of us would have been denied the opportunity to benefit from the knowledge rich workshop. Being the first workshop of its kind, naturally there is room for improvement. It is in this respect that I forward my comments so that future workshops would be better organized to achieve maximum benefits. But by and large, I came back from the workshop better equipped to pursue the NSF supported collaborative research activity between University of Missouri at Rolla (UMR) and Abubakar Tafawa Balewa University (ATBU), Bauchi-Nigeria.

ACTIVITIES DURING THE TWO-DAY WORKSHOP

1. I attended all the sessions during the two-day workshop and participated during the discussions that followed the various presentations. I also took maximum opportunity to interact with some of the US researchers to exchange mutually beneficial ideas.

2. I presented my own contribution during the second day of the workshop during which I outlined our research activities at ABTU that recommended us to enter into collaborative research work with UMR for the furtherance of knowledge and academic scholarship.

3. Dr. Kumar of UMR, the US Principal Investigator and myself discussed at length the short, medium and long-term modus operandi for the collaborative research work.

COMMENTS ON WORKSHOP

- The two days scheduled for the workshop would have been sufficient, if only the allotted times to various presenters were strictly adhered to. Perhaps future
workshop should ensure time discipline by presenters through wider use of power point presentations and optimum use of parallel sessions.

- In as much as possible, opening ceremony should be scaled down to save time for more serious business of the workshop.
- The theme of the workshop was not clearly understood by the participants with several off target contributions.
- Expected contributions by the African participants by the sponsoring body should be clearly spelt out in future to avoid infringement as was observed during the workshop.
- The organizing committee of the workshop should, in future, endeavor to meet the minimum expectations by the African co-investigators, which are provided for by the sponsoring body.
- There was this perception that the African participants were treated as very junior partners in the collaborative research workshop and should be mitigated in future.

**ACTIVITIES AT THE HOST UNIVERSITY**

1. The activities lined up for me at my host university, UMR, by Dr. K. Venayagamorthy were academically rewarding and very beneficial as summarized below.

   - We jointly carried out literature survey on the state-of-the-art in reactive power and voltage control relevant to our collaborative research work with over 70 papers reviewed.
   - I attended presentations by graduate students of Dr. Venayagamorthy on Computational Intelligence Techniques as well as a PhD defense seminar in EE so as to synchronize our mutual research interest at EE, ATBU.
   - We reviewed PSCAD and Mathlab 6.0 packages as well as computer hardware needed for the research work in Nigeria.
   - I delivered an IEEE seminar at UMR to UMR faculty and students entitled: ‘*Adaptive Load Frequency Control of Interconnected Hydro and Thermal Areas using Unsupervised Learning Neural Network.*’
   - I held meetings with the Chair of the Electrical and Computer Engineering, Dean of School of Engineering and Director for International Affairs on the possibility of linkage with ATBU.
   - We reviewed the work outlined in the NSF International proposal.
   - We evolved a work plan with deadlines that cover data acquisition on the Nigeria grid system; acquisition of PSCAD software at ATBU; Simulations studies at ATBU and UMR; and Introduction of New Course on Computational Intelligence at ATBU for graduate students.
   - We reaffirmed our full commitment to its success to serve as a model to achieving maximum exchange of knowledge with wider impacts on the quality of education through mounting of new courses for undergraduate/graduate students of both institutions.
   - We also brainstormed on the transfer of know-how to achieve maximum cost-effective service delivery by electric utilities of US and Nigeria.
COMMENTS ON ACTIVITIES AT HOST INSTITUTION

- The activities at my host university were most rewarding academically and therefore commended for retention in future workshop. It should be stressed that without the visit to the host, the African participants will lose sight of the focus of the collaborative research initiative.
- Activities at the host university should be designed, so that each participant will immediately see the dividend of the collaborative research work.

IDEAS ON FUTURE COLLABORATIONS

Future collaborations should:
1. Consider and formalize counterpart funding by the home countries or universities of the participants for the sustenance of the collaborative research work. Organizations like USAID, African-American Institute, etc might be more favorably disposed towards funding such collaborative research work.
2. Focus more on young academics that successfully completed their doctorate degrees in the participating universities but need exposure to state-of-the-art techniques in their areas of specializations.
3. Continue to explore technical areas, education issues that are mutually beneficial to US and Africa. There is no doubt that energy and information technology will remain topical into the foreseeable future.
4. Aim at objectives that are realizable, pragmatic and, above all, capable of achieving maximum benefits and impacts for US and Africa in terms human development through knowledge exchange.
Appendix A

Workshop Program
A National Science Foundation (NSF) Sponsored Workshop:
A US-AFRICA RESEARCH AND EDUCATION COLLABORATION

Theme: “Promoting Research and Education in Power, Information Technology, and Environment”

Ralph J. Bunche International Affairs Center
Howard University
2218 Sixth Street, NW
Washington, DC 20059

November 5 - 6, 2003

Organization Committee Members
Dr. Joe Chow (Chair), Professor, Rensselaer Polytechnic Institute
Dr. James Momoh (Co-Chair), Program Director, NSF
Victor C.W. Dzidziienyo, Associate Dean, CEACS, Howard University
Dr. Kevin Tomsovic, Professor, Washington State University
A National Science Foundation (NSF) Sponsored Workshop:

A US-AFRICA RESEARCH AND EDUCATION COLLABORATION

OVERVIEW: The US-Africa Research and Education workshop is an outgrowth of the biennial International Conference on Power System Operation and Planning (ICPSOP), which the National Science Foundation (NSF), a host of utility companies, and universities in the US and Africa have funded. Previous workshops, organized by Howard University, have led to collaboration in Faculty exchange, recruitment of students, and joint work between US professors and African colleagues.

To extend the activities and achieve the intellectual merits and broader impacts of science and engineering in the power / energy, information systems, and human and social dynamics, a research and education collaboration initiative was started by the Division of Electrical and Communications Systems (ECS) at NSF. ECS grantees serve as co-PIs with several African researchers. To kick-off the research activities, this NSF sponsored two-day workshop, under the theme “Promoting Research and Education in Power, Information Technology, and Environment”, nurtures the following objectives:

- Developing collaborative work between Mathematics professors and engineers to develop robust modeling techniques and tools for analysis of large networks.
- Building African collaboration with US researchers to build further understanding of different power system case studies.
- Establishing priorities to increase Minority in engineering and increase international cooperation.
- Promoting the NSF mission to prepare students to be globally engaged in the workforce of the 21st Century.
- Developing a roadmap for future research activities in power / energy, information systems technology, environmental and social dynamics, and education pedagogy.

IMPACTS: Each of these driving forces has implications for future power systems research and education programs in the Engineering Directorate and especially in the Division of Electrical and Communications Systems (ECS) at the National Science Foundation.

The broadening of researchers across disciplines in the areas of computational intelligence, advanced system controls, social sciences, economics and environmental sciences, and the development of new education pedagogy, curricula, and test beds for different environments will improve the contributions to the overall mission of NSF.

It is hoped that this workshop will provide information and content of high intellectual merits, serve as a catalyst for the convergence of multidisciplinary solution methodologies in science and engineering, and provide directions for advancing science and engineering collaboration between the US and Africa.

Dr. James Momoh, Program Director
Electrical and Communications Systems Division (ECS)
National Science Foundation
Tel: 703 292-8339; Fax: (703) 292-9147; Email: jmomoh@nsf.gov
Wednesday, November 5, 2003

7:30 am  Bus leaves Hotel for Howard University

VENUE: Ralph J. Bunche International Affairs Center (8:00 am – 12:00 pm)

8:00 – 8:30  Coffee and Refreshments

8:30 – 9:15  Welcome and Introduction
  - Dr. James A. Momoh
    Program Director, NSF
  - Dr. Joe H. Chow
    Professor, Rensselaer Polytechnic Institute

9:15 – 10:15  Keynote Speakers
  - Dr. Esin Gulari, Program Director, Division of Chemical & Transport Systems (CTS), NSF
  - Dr. Elbert L. Marsh
    Senior Advisor to the Assistant Director for Engineering, NSF
  - Dr. James H. Johnson, Jr.
    Dean, College of Engineering, Architecture, and Computer Sciences (CEACS), Howard University, Washington DC

10:15 – 10:30  Break

10:30 – 12:00  NSF US-Africa Sponsored Research and Education Collaboration
  - Engr. Foluseke A. Somolu
    President, Nigerian Society of Engineers (NSE)
    An Overview of recent US-Africa Workshop Activities
  - Dr. Chen-Ching Liu
    Professor and Associate Dean, University of Washington, Seattle
  - Dr. Kevin Tomsovic
    Professor, Washington State University, Pulman
  - Dr. Venkataramana Ajjarapu
    Associate Professor, Iowa State University, Ames
  - Dr. Ganesh Kumar Venayagamoorthy
VENUE: Howard University Blackburn Gallery Lounge (12:00 pm – 8:45 pm)

12:00 pm – 1:15 Luncheon with Guest Speaker
Mr. John Casazza, President, American Education Institute (AEI), USA
Topic: “Building Power Grid in Developing Countries”

Break Out Sessions - Research and Education Road Map

SESSION 1A

1:30 – 3:30 Research and Education Issues: Power System Planning and Development, Power System Control and Applied Mathematics Applications

Session Chair: Dr. Kevin Tomsovic Washington State University, USA
Rapporteur: Dr. Innocent Davidson Univ. of Natal, Durban, South Africa

Session Members
- Dr. George O. Anderson, University of Botswana, Gabarone, Botswana
- Dr. Karen Butler, Texas A&M, USA
- Dr. Joseph C. Ekeh, Delta State University, Ekpoma, Nigeria
- Dr. Ram Adapa, Electric Power Research Institute (EPRI), USA
- Dr. Ebenezer A. Jackson, Kwame Nkrumah Univ. of Sc. & Tech., Ghana
- Dr. John Ngundam, University of Younde, Cameroon
- Mr. Floyd Galvan, Entergy Corporation, USA
- Engr. Foluseke A. Somolu, Nigerian Society of Engineers (NSE), Nigeria
- Dr. Joe Chow, Rensselaer Polytechnic Institute, USA
- Dr. Eyad Abed, University of Maryland, USA
- Dr. Venkataramana Ajjarpal, Iowa State University, USA
- Engr. Alex Amakom, Ministry of Power & Steel (Energy), Nigeria
- Dr. Thomas C. Nwodo, Federal Univ. of Science & Technology, Owerri, Nigeria
- Dr. Chuks Erasmus Ogbuobiri, Ezak Associate Limited, Portland, USA

SESSION 1B
1:30 – 3:30  Research and Education Issues: Alternative Energy, Emerging Technologies, Environmental Issues, and Information Technology Research

Session Chair:  Dr. Chen-Ching Liu  
University of Washington, USA

Rapporteur:  Engr. John Ayodele  
General Manager (Transmission), West African Power Pool, NEPA, Nigeria

Session Members
- Dr. Philip A. Kuale, University of Benin, Nigeria
- Dr. Paul Werbos, National Science Foundation (NSF), USA
- Mr. John Chandler, President of Total Service Solutions (TSS), Inc., USA
- Dr. Musa Momoh, Usman Dan Fodio University, Nigeria
- Dr. Anil Pahwa, Kansas State University, USA
- Dr. Ganesh K. Venayagamoorthy, University of Missouri-Rolla, USA
- Dr. Pragasen Pillay, Clarkson University, Potsdam, NY, USA
- Dr. Ehile Ehouan Etienne, University of Abobo Adjame, Cote d’Ivoire
- Dr. Mani Aniebonam, George Washington University, USA
- Dr. Olorunfemi Ojo, Tennessee Technological University, USA
- Dr. Usman O. Aliyu, Abubakar Tafawa Balewa University, Nigeria
- Dr. Peter Bofah, Howard University, USA
- Dr. Raifu I. Salawu, University of Lagos, Nigeria
- Dr. Johnson A. Asumadu, Western Michigan University, USA
- Dr. Mamadou Adj, Campus Universitaire – ESP Dakar, Senegal
- Dr. Isaias Barreto da Rosa, Jean Piaget Univ., Cape Verde

3:30 – 5:15  NSF PANEL SESSION

Moderator – Dr. James A. Momoh, Program Director, Division of Electrical and Communications Systems (ECS), NSF

- Dr. Radhakishan Baheti, Program Director, Division of Electrical and Communications Systems (ECS), NSF

- Dr. Elizabeth E. Lyons, Program Director, Office of International Science and Engineering (ISE), NSF

- Dr. Vicki B. Booker, Program Director, Engineering Education and Centers (EEC), NSF

- Dr. Dan Newlon, Program Director, Division of Social, Behavioral, and Economic Sciences (SBE), NSF
- **Dr. Marvin Goldberg**, *Program Director*, Division of Physics, NSF

- **Dr. Marshall M. Lih**, *Senior Engineering Advisor*, Bioengineering and Environmental Systems (BES), NSF

5:15 – 5:30 Coffee Break
5:30 – 6:30 Break-Out Session Reports
7:00 – 8:30 Dinner, Guest Speaker
8:45 pm Bus leaves Howard University for Hotel

**Thursday November 6, 2003**

7:30 am Bus leaves Hotel for Howard University

*Venue: Ralph J. Bunche International Affairs Center (8:00 am – 11:00 am)*

8:00 – 8:30 Coffee Break

**SESSION 2A**

8:30 – 10:00 Research Activities of Interest for Future International Collaboration

**Session Chair:** Dr. Karen Butler, Texas A&M, USA

**Rapporteur:** Sir Joachim J. MacEbong, Nigerian Society of Engineers (NSE), Nigeria

**Session Members**
- Dr. Anil Pahwa, Kansas State University, USA
- Dr. Innocent Davison, University of Natal, Durban, South Africa
- Mr. Floyd Galvan, Entergy Corporation, USA
- Dr. Eyad Abed, University of Maryland, USA
- Dr. Philip A. Kuale, University of Benin, Nigeria
- Dr. Emmanuel Glakpe, Howard University, USA
- Dr. Arunsi Chuku, Tuskegee University, USA
- Dr. John Ngudam, University of Yaounde, Cameroon
- Dr. Phillip Fanara, Jr., Howard University, USA
- Dr. Kevin Tomsovic, Washington State University, USA
SESSION 2B

10:00 – 11:00 | International Representatives’ Forum

**Coordinators:** Prof. Victor C.W. Dzidzienyo, *Associate Dean*, CEACS, Howard University, USA

Dr. Chen-Ching Liu, *Professor* and *Associate Dean*, University of Washington, USA

**Representation:**
- US Department of Energy (DOE)
  - **Ms. Vickie Bailey** (Invited)
    *Assistant Secretary for Policy and International Affairs*

- Participating African Countries – Ambassadors represented by:
  - **His Excellency Mr. A.O. Soyombo** (Invited)
    *Charge D’Affaire*
    Embassy of the Federal Republic of Nigeria, USA

  - **Her Excellency Ms. Barbara Masekela** (Invited)
    *Ambassador*
    Embassy of the Republic of South Africa, USA

**VENUE:** Howard University Blackburn Center *(11:15 am – 2:30 pm)*

11:15 – 12:30 pm | Working Lunch with Selected Presentations on Research Activities and Experiences

12:30 – 2:30 pm | Workshop Report Organization & Writing

**Facilitators:**
- Dr. Joe Chow, *Professor*, Rensselaer Polytechnic Institute (RPI), Troy, NY
- Dr. James A. Momoh, *Program Director*, National Science Foundation (NSF), VA

**Coordinators:**
- Dr. Chen-Ching Liu, *Professor and Associate Dean*, University of Washington, Seattle, WA
- Sir Joachim Joe MacEbong, *Secretary*, Nigerian Society of Engineers (NSE), Nigeria

**Writing Team:** All Session Chairs and Rapporteurs

**VENUE:** Ralph J. Bunche International Affairs Center *(2:30 pm – 4:00 pm)*

2:30 – 3:30 | Summary Session and Presentation of Action Items by:
Dr. James A. Momoh  
Program Director, NSF

Dr. Joe Chow  
Professor, RPI

3:30 – 3:45  Photo Session

4:00 pm  Adjournment!

Post Workshop Activities
November 7 – 14, 2003

Schedule of visits to universities

**Friday, Nov. 7-13**  
**Travel from Washington DC to Host Universities**  
Visitors to UW and WSU, Iowa State, Howard University and University of Missouri Rolla; (Local arrangements by the host university)

**Thursday, Nov. 13**  
**Travel from Host Universities to Washington DC**

**Friday, Nov. 14**  
*Visit summary and follow up action/ via videoconference*

Return trip to home countries
Acknowledgments from NSF

The National Science Foundation, the Division of Electrical and Communications Systems (ECS) wishes to thank all members of the local committees at Rensselaer Polytechnic Institute (RPI) and Howard University for coordinating and hosting this premier workshop, which serve to promote research and education in power, information Technology, and environment.
Appendix B

Workshop Presentation Abstracts
EVALUATION OF PHOTOVOLTAIC POWER SYSTEMS IN GHANA

Ebenezer A. Jackson,
School of Engineering,
KNUST, Kumasi, Ghana
Email: jacksonea@yahoo.com

Iloabachie, Issomme
Department of Electrical Engineering,
KNUST, Kumasi, Ghana

Generation of electricity from solar could be a viable cost effective renewable energy option for electrifying very remote isolated rural communities with low electrical energy demand. In the past four years, many governmental and non-governmental projects have been undertaken to provide solar photovoltaic power to remote areas that do not have access to the national grid. The availability of solar electricity in these communities has had very significant improvement in the lives and social well being of the people concerned.

Services provided by most of the installations include Solar Home Systems for lighting and TV/Radio operation, Solar Hospital Systems for vaccine refrigeration, Street Illumination etc. Some of the systems are performing satisfactorily, whilst others are not due to poor maintenance, neglect and sub-standard charge regulators.

This paper presents and analyzes the status and performance of solar installations in Ghana, discusses the setbacks and gives suggestions on how to improve on the existing systems.

PHOTONIC SWITCHING OF HIGH-SPEED SILICON CARBIDE (SiC) HIGH POWER DEVICES UTILIZING LASERS AS OPTICAL SOURCES

Dr. Johnson Asumadu
Western Michigan University, Kalamazoo, Michigan, USA.

The objective of this work is to use lasers (as optical sources) to activate high-speed silicon carbide (SiC) power electronics switching devices with photons not electrons in order to eliminate the need for small electronic drivers and control circuits, provide isolation, and immunity to electromagnetic noise and therefore relax the need for magnetic shielding. The doped (with electrons/holes) polytypes of SiC are able to absorb photon fluxes to re-create the electron-hole pairs.

Therefore, the overall goal of this project is to study in detail the characteristics and develop new modulation techniques for continuous switching duty cycle and pulsed...
modulated laser pulses, perform detailed static/dynamic characteristics and obtain performance measurements of SiC power devices using lasers as optical sources, and design new optical activation drivers for power electronics circuits that have already been optimized for silicon (Si) and gallium arsenide (GaAs) power devices.

**PRESENTATION AT THE US-AFRICA WORKSHOP**

Engineer F. A Somolu  
Nigerian Society of Engineers  
Lagos, Nigeria

“In the beginning was the word. And the word was with God. And the word was God (John 1 verse 1).” Similarly, in the beginning was the dream. And the dream was with Professor Momoh. And the dream was Professor Momoh. This presentation is about how Professor Momoh's dream and work, beginning with a workshop conducted for NEPA engineers in Nigeria while on holidays in 1989, has culminated in the USA-Africa Power Education and Research Collaborative Program.

**SOUTHERN AFRICA POWER POOL – IMPACT ON THE BOTSWANA POWER CORPORATION**

G. O. Anderson  
Electrical Engineering Department, University of Botswana,  
Gaborone, Botswana  
Anderson@mopipi.ub.bw

The Botswana Power Corporation (BPC) has traditionally been meeting the national electricity demand through generation at Morupule power Station (120MW s.o.) and importing from neighbouring utilities, especially ESKOM of South Africa

Imported power has for a long time been based on long-term bilateral contracts. The contracts themselves have evolved in nature from customer captive, to co-operative and now to competitive ones.

In this paper, electricity trade in Southern Africa Power Pool (SAPP) is considered, and that includes a portion of highly competitive short-term energy market (STEM). ESKOM has only freed BPC to trade 25% of its requirements in this market, because of an agreement that runs until 2007.

The paper gives details of bidding and delivery at STEM and at the Bulletin Board. Savings against bilateral costs are also presented. A 25% of import power is applied to trade at STEM for the first hour of 25 January 2002. The savings stand at ZAR 1498.95 / hr. The same procedure is applied to obtain STEM total savings for the month of December which equal ZAR 1 223 257.20
The paper proposes that the bilateral agreement with ESKOM should be renegotiated with the view to requesting ESKOM to free more of BPC power imports to be traded at STEM. Such an agreement will allow BPC to boost its profit margin considerably.

**ISU -AFRICA RESEARCH AND EDUCATION COLLABORATION**

V. Ajjarapu  
Iowa State University (ISU), USA  
vajjarap@iastate.edu

The aim of the presentation is to discuss ways to build African collaboration with ISU researchers and to develop a road map for future research activities in power/energy, information systems technology, environmental and social dynamics, and education pedagogy. It started with various educators (Africa as well as ISU) involved in this project. Possible topics for collaboration under NSF electric power network and efficiency (EPNES) are discussed. The medium of interaction for collaboration is also presented. ISU web based simulation tools and other free software available for public use are discussed. In particular web based continuation power flow developed at ISU to study voltage security is presented. Finally the talk concluded with activities planned for African delegation visit to ISU during November 7-13, 2003.

**SELF-HEALING POWER SYSTEMS**

Dr. Karen L. Butler-Purry  
Department of Electrical Engineering  
Texas A&M University  
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Self-healing is becoming a desired feature of power systems to enable them to automatically respond to threats, material failures, and other de-stabilizers as a mechanism to increase reliability. Self-healing can take the form of preventive or restorative/corrective strategies. This presentation discusses previous efforts by the author’s research group in the development of self-healing methodologies for shipboard power systems, both preventive and restorative. A restorative methodology is discussed in this presentation along with an illustration of the method’s application to a shipboard power system computer model. These new self-healing methods have high potential for adaptation to isolated terrestrial power systems such as those found in some places in Africa, as well as large interconnected power systems using a distributed approach.

**NIGERIAN GOVERNMENT’S INCENTIVES TO INDEPENDENT POWER PRODUCERS**
Professor R.I. Salawu

Department of Electrical Engineering
University of Lagos
Lagos, Nigeria

A) Government Incentives to Emergency Power Producers (EPP)
- Government to pay for energy produced and installed capacity
- And to provide gas at Egbin and diesel in Abuja.

Now Government spends N1.4 billion monthly on the three EPPs – one at Egbin in Lagos and two in Abuja.

B) In Areas of Educational Development, the collaboration effort will;
- Afford academic staff and students the opportunity to interact with one another, provide for staff and student exchange,
- Bring about development and acquisition of infrastructures such as online centers where people can interact.
- Develop new programs especially for new technologies such as GSM, biometrics, prepaid charging for power, security etc.
- Develop and acquire application software for use by staff and students within the group.

THE APPLICATION OF GAS TURBINE TECHNOLOGY IN THE EXPLOITATION OF NATURAL GAS (A STRATEGIC PRIMARY ENERGY RESOURCE) IN THE WEST AFRICAN SUB-REGION

T. C. NWODO and R. N. EKE
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This paper presents a brief summary of the rich, vast and great potential for natural gas reserve in the West African Sub-region. The various steps already taken to utilize these resources and the fact that due to environmental constraints, the desire for a clean energy and the derivable advantages, the gas turbine technology using natural gas has greater prospect in the sub-region. Also, we briefly reviewed the need for training/partnership leading to the acquisition of Gas Technology.

PREDICTIVE THERMAL CIRCUIT RATINGS TECHNOLOGY

Dr. Rambabu Adapa
Improving the transmission capacity of existing power delivery equipment is an effective method of meeting increased power demand without costly capital investments. However, maintaining system reliability while increasing transmission capacity presents challenges. Transmission companies will benefit from predictive rating technologies for equipment that enable increased power flow while supporting system reliability and assuring public safety.

INTRODUCTION
In 1993, EPRI initiated a project to develop and field-test software to support real-time thermal monitoring of transmission circuits, which resulted in the DTCR (Dynamic Thermal Circuit Rating) and PTLOAD (Power Transformer LOADING) software programs, intended for use by operators and substation engineers, respectively. DTCR provides an effective method of calculating dynamic ratings of lines, cables, and transformers every ten minutes based on the line current, ambient temperature, sag, tension, conductor core temperature, solar emissivity, and wind speed. However, the program does not support the prediction of the equipment’s future thermal circuit ratings, which would benefit transmission companies by supporting effective planning for day-to-day operations.

The dynamic rating methodology of DTCR can be extended to predictive thermal circuit rating through the application of neural network technology. The software is “trained” using two to three years of available line-rating data, as well as weather, wind, and load forecast data available at the utility sites, to estimate the future thermal circuit ratings of equipment for the next hour, day, or several days. These predictive thermal circuit ratings will enable effective scheduling of generator capacity, fuel purchases, and power transactions to efficiently and economically meet load demands.

PROJECT SUMMARY
In this project, EPRI proposes to develop a predictive thermal circuit rating methodology and software based on neural network technology. EPRI will determine the requirements for interfacing with weather, wind, and load forecast data; identify neural network training requirements for use of historical thermal circuit ratings; and identify any incremental training requirements. The resulting predicted thermal circuit ratings will be compared against the actual ratings to determine the accuracy of the predictions, and enable systemic improvements to minimize prediction errors.

To the extent possible, the project will leverage the feed-forward, three-layer neural network technology embedded in EPRI’s artificial neural network short-term load forecaster (ANNSLTF). The predictive thermal circuit rating system will be devised to ensure compatibility with a range of weather, wind, and load forecasting data and software, including company-specific, statistically-based forecasting systems and subscription services.

Because the predictability of circuit rating varies with the type of power equipment in use
and the causes of high electrical load, the participation of several funders is required to ensure the development of an accurate methodology and associated software tools. Participating companies will receive first-hand information about predictive thermal circuit rating technology and implementation software. As a result, participating companies will be better able to operate transmission systems at maximum thermal capacity in hour-ahead, day-ahead, and week-ahead scenarios.

The project will answer such questions as:
- How can the thermal circuit ratings of a transmission corridor be predicted?
- What data inputs are necessary to accurately predict the thermal circuit ratings?
- How much past thermal circuit rating data is required to sufficiently train a neural network?
- Will the neural network require incremental training to predict thermal circuit ratings?
- How can the accuracy of the predictive thermal circuit ratings delivered by the program be improved?

**NSF Sponsored US-Africa Research and Education Collaboration,**

*Promoting Research and Education in Power, Information Technology and Environment*

**Innocent E. Davidson, PhD**
University of Natal, Durban
University of Durban-Westville, Westville
South Africa

Outline of Presentation:
- Introduction
  - Overview of SA Power Infrastructure
  - SA ESI/EDI Restructuring/Challenges
  - New Initiative – T&D Graduate Program
  - Research Activity/Focus

- Highly educated and sophisticated population
- Highly developed technology
- Rich modern and highly productive agricultural base
- Rich base of energy-bearing materials
- Abundant supply of non-energy bearing materials

“Success is not an event but a response to life”

SA Power Infrastructure
- Nominal generating capacity: 39 154 MW from 20 power stations
- Eskom (the world’s 5th largest electric utility) supplies over 95% of SA electric power.
- Plant portfolio: 34 882 MW coal fired, 600 MW hydroelectric, 1930 MW nuclear, 1400 MW pumped storage, 342 MW gas turbine (oil fired)
- System Peak Demand: 32000MW
- Two-thirds of the national power capacity is concentrated in just 10 base load coal-fired power stations
- Spare capacity to be eroded in 2007
- Population: 42 million, 70% grid connected, 30% off-grid

SA ESI/EDI Restructuring/Challenges
- Deregulation of SA ESI – Jan 2003, NER
- Generation: Full competition
- Transmission Grid/ISO: Government-owned company
- EDI (distribution, supply/retail) - restructured into 8 REDS
- Privatisation

New Initiative – T&D Graduate Program
- Recognition of the changing environment/problems of the industry
- Need for a qualitatively different graduate program in electric power systems
- Industry-focus, multi-disciplinary in approach
- Joint effort between industry (Eskom), and academia (UND/UND)
- Transmission & Distribution Research and Training Institute (TDRTI)

Background
- Major expansion of the transmission and distribution network (SA and Africa)
- Shortage of skills in this area
- Industry need for graduates who can add value to business with minimum amount of training
- Huge gap between academia and industry
- Development of an industry focussed graduate program in T&D Engineering

Why UND/UDW
- Good relationship with industry (Eskom)
- Success story HVDC centre - 35 MSc students, 2 PhD, THRIP excellence awards 2001/2002 consecutively
- National/global trend: Move towards industry focussed programs
- HVDC, HVAC, Distribution engineering skills
- Facilities, UDW-HVDC, VRTC, UND-HVAC
- Merger of UND/UDW in 2004 (University of KwaZulu-Natal)

Structure of Graduate Program
Compulsory Courses:
Research methodology, Project Management, Utility Management, Power Systems Engineering

Specialist Streams
- Planning
- Design
- Protection
- Performance & Maintenance
- Systems Operations
- Power System Economics

Research Activity/Focus (Dr IE Davidson):

Power system analysis, economics and computing

Focus:
- Modelling and analysis of distributed power system dynamics and economics
- The underlying research philosophy is to align research activity to meeting local needs
- Providing solutions to problems facing local industry, business enterprises and society, such as cost-effective electricity supplies, sustainable development of communities
- Matching international intellectual standards for education and technical scholarship.

Research Projects
- The global trend of reform in the power sector has seen an upsurge in autonomous and distributed power systems involving the integration of renewable energy resources in hybrid notation in small and medium scale into grids, at transmission, distribution or reticulation level.

- A project has therefore been initiated in the area of power systems analysis, economics & computing, with special emphasis on the effects of power
sector deregulation: electric power network loss optimisation, ESI structure, deregulation management, electricity market and tariff design.

- This activity involves both the technical and economic aspects of power network planning and operation, DER modelling, dynamics and performance analysis for stand-alone and grid-connected schemes.

- This initiative has received endorsement locally from electric utilities and the national electricity regulator.

- A major industry-funded research project is in progress, ‘Spatial Modelling of a Photovoltaic Fuel Systems for Localised Load Management’.

T&D Industry-funded Research Projects: Other industry funded projects for 2004 include

- Reticulation data capture techniques
- Electrification LV drop estimation using summary data
- LV losses in rural networks
- Reticulation network planning alternative evaluation
- Distribution Generation and Network Losses Minimization (IED)
- Measuring moisture on kiln dried poles
- SWER earth designs- risk versus benefit
- Use of Repeater Fuses on SWER Networks
- Replacement of the Steel Core in ACSR Conductors
- Zinc air batteries for dc systems
- Distribution Line Carriers for MV Lines
- Live Line Stringing of Earth Conductors (GW and/or OPGW)
- Contextual Alarm Processing Investigation

Transmission and Distribution Research & Training Institute (TDRTI)

The vision: To develop skills and build technical capacity in the advancement & application of scientific and engineering knowledge associated with the generation, transmission, distribution and utilization of electric power in the African continent, in line with NEPAD, and with the full support of the US-Africa Forum

Discussion of Activities & Experiences

Preamble
As the South African delegate, assigned to visit Howard University and the University of Maryland, both Dr Eyad Abed and Dr James Momoh as hosts conducted me around facilities and on-going research projects undertaken both in their direct research work as well as activities supervised by other colleagues within their programs or institute.

Collaborative Research
The hospitality and time commitment made by these leaders of research and their support staff to make my stay productive is highly appreciated and most valued. Key discussions
for possible collaboration were carried out with Dr Karen Butler-Purry of Texas A & M University in the area of ‘Distributed Generation’, and Dr Eyad Abed in the area of Computer Visualization, with specific application to the Electric Power industry. These potential areas of mutual activity will be explored further under the US-Africa Collaboration in Research and Education Program.

**ICPSOP 2005**
The last and extremely important activity was the planning of the 6th edition of the International Conference on Power Systems Operations and Planning, due to take place in Durban, South Africa, from 14-17th August 2005. Planning meetings were held with US delegates under the leadership of Dr Momoh, and a concrete plan of action and mutual commitment towards the conference was solidified.

**Workshop (5 – 6th November)**
The preceding workshop articulately expounded on the activities of the NSF, NSF sponsored researchers and their activities, and highly valuable presentations from various perspectives of research, industry, education and a blend of history.
Appendix C

Workshop Participants
NATIONAL SCIENCE FOUNDATION (NSF) SPONSORED WORKSHOP
US-AFRICA RESEARCH AND EDUCATION COLLABORATION
Venue: Center for Energy Systems and Control (CESAC), Howard University,
Washington DC 20059.
Period: November 5-7, 2003

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