Models of Undergraduate Research

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What is undergraduate research?

“… universities should treat learning as not yet wholly solved problems and hence always in research mode” W. von Humboldt, 1810

Reflect on what do you think is undergraduate research
Agenda

- Introduction
- What is undergraduate research (UR)?
- Motivations for UR depending on institution
- Some models of UR
- Examples
Introduction

- Perspectives on education
  - Does education only entail teaching?
- Balance among our various responsibilities as educators
  - How to deal with the various constraints with regards to teaching and research and service?
Introduction

- RESEARCH AND EDUCATION ACTIVITIES:
  Equal weight?

- RICH FELDER:
  “The Myth of the Superhuman Professor”

- ERNEST BOYER’S SCHOLARSHIP MODEL:
  > Integration
  > Application
  > Discovery
  > Teaching
Boyer’s Scholarship

- **Discovery**: Build new knowledge through traditional research (Publishing, producing and/or performing creative work, creating infrastructure)

- **Integration** Interpret the use of knowledge across disciplines. Preparing a comprehensive literature review. Writing a textbook for use in multiple disciplines. Collaborating with colleagues to design and deliver a core course.
Boyer’s Scholarship

- **Application** Aid society and professions in addressing problems. Serving industry or government as an external consultant. Assuming leadership roles in professional organizations. Advising student leaders, thereby fostering their professional growth.

- **Teaching** Study teaching models and practices to achieve optimal learning. Advancing learning theory through classroom research. Developing and testing instructional materials. Mentoring graduate students. Designing and implementing a program-level assessment system.
UR: LOOKING FOR A BALANCE

- Research
- Teaching
- Service

- Research
- Teaching
- Service
Carnegie Classification of Academic Institutions (before 2005)

- **Research universities I** 50 or more doctoral degrees, and at least $40$ million or more in Federal research support
- **Research universities II** between $15.5$ million and $40$ million in Federal research support per year
- **Doctorate-granting I** (at least 40 PhDs in 5 disciplines), **II** (20 or more doctoral degrees in one discipline or 10 in 3)
- **Master’s (comprehensive) universities and colleges I** At least 2,500 students), **II** (between 1,500 and 2,500 students)
- **Baccalaureate (liberal arts) colleges I** (highly selective, primarily undergraduate colleges) **II** (less restrictive)
- **Associate of arts colleges**
- **Professional schools and other specialized institutions**
Carnegie Classification of Academic Institutions (2005)

- **Doctorate-granting universities** (at least 20 PhDs per year): very high research activity, high research activity, and doctoral/research universities.
- **Master’s colleges and universities** (at least 50 master’s degrees and fewer than 20 doctoral degrees per year)
- **Baccalaureate colleges** (fewer than 50 master’s degrees or 20 doctoral degrees per year)
- **Associate’s colleges** (2 year institutions)
- **Special focus institutions** (single field or a set of related fields)
- **Tribal colleges**
What is Undergraduate Research?

“An inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline”

Council for Undergraduate Research

- Do you agree with this definition?
- Is it possible to perform this type of UR in your institution?
What is Undergraduate Research?

“A broad definition of the undergraduate as researcher to describe student engagement at all levels in research and inquiry into disciplinary, professional and community-based problems and issues”

University of Gloucestershire, UK
STUDENTS AS PARTICIPANTS

Research-tutored | Research-based

Research-led | Research-oriented

STUDENTS AS AUDIENCE

Curriculum design and linking research and teaching

Source: Healey and Jenkins, 2008
Advantages of Undergraduate Research

- **Students:** advanced knowledge and improved critical thinking skills. Turn them from passive to active learners.
- **Faculty:** expanded scope of their research group and training of potential graduate students.
- **Institution:** improved educational experience for students.
Motivations for Undergraduate Research

- At Doctorate-granting universities
  - Comply with teaching objectives of funding agencies’ RFPs
  - Effective way of integrating research and teaching
  - Mentoring opportunities for graduate students
Motivations for Undergraduate Research

- At Master’s colleges and universities
  - Begin training of potential graduate students
  - Foster graduate education among undergraduates
  - Comply with teaching objectives of funding agencies’ RFPs
  - Effective way of integrating research and teaching
  - Mentoring opportunities for graduate students
Motivations for Undergraduate Research

- At Baccalaureate colleges, special focus institutions and Tribal colleges
  - Improved learning experience for students
  - Opportunity for faculty to perform research
Motivations for Undergraduate Research

- At Associate’s colleges, special focus institutions and some tribal colleges
  - Provide basic research skills to students
  - Improved learning experience for students
Models for Undergraduate Research

- UR in undergraduate courses
- Undergraduate students in graduate courses
- UR as part of research projects
- Institutional UR programs
- Agency-sponsored UR programs
- UR as part of long-term research projects
UR in undergraduate courses

- Group or individual research projects
  - Written report
  - Oral Presentations: Open to public, turned to service
  - Class publication

- Assigned reading of technical literature
  - Written summaries, short presentations
Undergraduate students in graduate courses

- Group or individual research projects
  - Written report
  - Oral Presentations: Open to public, turned to service
  - Class publication
  - Peer-reviewed conference papers
- Assigned reading of technical literature
  - Written summaries, short presentations
- Case studies
UR as part of research projects

- Student becomes part of a professor’s research group
- Mentoring from professor and from graduate students
- Training in research skills useful in their careers or graduate school
Institutional UR programs

- IAP is an example of programs that Departments or Institutions establish to provide UR opportunities.
- At UPRM, there are several examples: Institute for Community Development, Institute for Undergraduate Research, Science on Wheels among others.
Research Centers such as the NSF Center for Power Electronics Systems (CPES) provide many opportunities for UR

- Be part of Center-sponsored research projects
- Formal Research Experiences for Undergraduates (REU)
  - Internal and External
  - Example: UPRM’s REU with students from PUPR
Agency-sponsored UR programs

- Agencies such as NSF and NASA have formal undergraduate research programs
- For example, the NSF’s Louis Stokes Alliance for Minority Participation (LSAMP) provides funding for student stipends and research materials for UR.
  - The Puerto Rico LS-AMP is run by the CRSE, and in its fourth stage included a more structured Mentoring experience for participating Faculty and students
Examples of Implementing UR

- “Student as a Scholar” from the first to final year. Requires a fundamental shift in how the curriculum is planned and structured (from teacher to learner-centered).***
  - However… Humboldt in 1810 discussed how research and teaching had to go together in a university setting....

- Affinity Research Groups

*** Source: D. Hodge, *Student as a Scholar Conference*, April 2007
Two Personal Examples

- Living in Chaos: My first undergraduate research mentoring experience
- Fighting the Establishment: An outstanding undergraduate (an eventually graduate) researcher

*My two-cents*: No one-size-fits-all. Try new things but be yourself. Adapt strategies to your circumstances, and enjoy whatever you do.
The Scholarship of Teaching and Learning (SoTL) presents alternative integrations. Look for Elton’s paper (references) for more information on SoTL.
Boyer’s Model Applied

Boyer’s Model Applied to Proposed Research

Research Phases

Simulation & Analysis (years 1-4)

Testing & Validation (years 1-5)

System Issues (years 3 – 5)

Integration

Application

New knowledge

Research Goals

• Interface Saber & ATP
• Library of models
• Power quality indices

• Alternate Sources: PV
• Power quality of PV system
• Validation of models
• Interconnection tests

• Visit to CERPD (Glasgow)
• PV impact on power quality
• DG impact on nearby loads
• Validation of P1547
• Application to actual system: Puerto Rico Power Authority
POWER ENGINEERING EDUCATION

- ENGINEERING EDUCATION CRISIS
- RENOVATION EFFORTS
  - U.S. & local
- CHANGE IN THE EDUCATIONAL PARADIGM
SCHOLARSHIP OF TEACHING

- Undergraduate research in power quality
- Courses on power quality, energy conversion, and power electronics
- Power quality laboratory modules
- Demonstrations
- Caribbean Colloquium on Power Quality
- Energy Systems Seminar Series:
  - Distributed generation, alternate energy sources, social and ethical implications in power engineering, industry presentations
Final Thought

“We are all researchers now… Teaching and research are becoming ever more intimately related… In a ‘knowledge society’ all students – certainly all graduates – have to be researchers. Not only are they engaged in the production of knowledge; they must be educated to cope with the risks and uncertainties generated by the advance of science” (Scott, 2002)

From
http://www.northumbria.ac.uk/sd/central/ar/lts/researchandteaching/
SOME USEFUL REFERENCES

- Council on Undergraduate Research http://www.cur.org
  www.beacademy.ac.uk/assets/York/documents/events/conference/2008/Mick_Healey_Alan_Jenkins.doc
- Student as a Scholar Conference, April 2007, CA.
  http://www.aacu.org/meetings/undergraduate_research/index.cfm
- Undergraduate Research Centers http://urc.arizona.edu/
- Rich Felder’s Website http://www.ncsu.edu/felder-public/RMF.html
- FIE Conferences http://fie-conference.org/
- L. Elton’s paper on the Scholarship of Teaching and Learning,
DEVELOPMENT OF TOOLS FOR THE STUDY OF CHAOTIC BEHAVIOR IN POWER ELECTRONICS

Eduardo Colón      Uriel Contreras      Félix Rodríguez
Students

Dr. Efraín O’Neill Carrillo
Advisor
OBJECTIVES

COMPLETE A LITERATURE REVIEW
SIMULATE POWER ELECTRONICS DEVICES
ANALYZE VOLTAGE AND CURRENT FROM SIMULATIONS
IDENTIFY CHAOTIC COMPONENTS IN POWER ELECTRONICS CIRCUITS
DETERMINE HOW TO MINIMIZE OR CONTROL THE IMPACT OF CHAOS IN THE DEVICES
PROVIDE A TEACHING TOOL TO DEMONSTRATE POWER ELECTRONICS PRINCIPLES
POWER ELECTRONICS

DEFINITION
ENERGY PROCESSING
CONVERTER TOPOLOGIES
NONLINEAR PROBLEMS
CHAOS
WHAT IS CHAOS?

CHAOS OCCURS IN NONLINEAR SYSTEMS
SENSITIVITY TO INITIAL CONDITIONS IS A CHARACTERISTIC OF CHAOS
NOT STOCHASTIC BUT DETERMINISTIC PHENOMENON
IRREGULAR, NON-PERIODIC, BOUNDED BEHAVIOR
POSSIBLE TO IDENTIFY CHAOS FROM MEASUREMENTS
LYAPUNOV EXPONENTS: MEASURE SENSITIVITY TO INITIAL CONDITIONS (DIVERGENCE OF NEARBY TRAJECTORIES)
EXAMPLE OF A CHAOTIC SYSTEM

ATTRACTOR FROM STATE EQUATIONS

\[
\begin{align*}
X &= -aY + rZ \\
Y &= -bZ + X \\
Z &= X
\end{align*}
\]

ATTRACTOR FROM RECONSTRUCTED STATES
MODELING TOOLS AND PROGRAMS

SPICE

ELECTRONIC WORKBENCH

MATLAB

FORTRAN
CHAOS IN AN RLD CIRCUIT

R-L-D Circuit

R1

L1

6mH

D1

D1N3063

V1

2.2

DIODE CURRENT

DIODE VOLTAGE

INPUT VOLTAGE
BOOST CONVERTER

DISCONTINUOUS MODE

“IDLING” INTERVAL OPERATION
CHAOS IN BOOST CONVERTER

VCOM <= VSAW-TOOTH: SWITCH OFF

VCOM >= VSAW-TOOTH: SWITCH ON

CHAOS CAUSED BY PWM SWITCHING REGULATORS
CONTINUOUS MODE OPERATION
PWM CONTROL
CHAOS IN BUCK CONVERTER

SWITCHING STATES
VALUES OF INPUT VOLTAGE
BUCK ATTRACTOR
LYAPUNOV EXPONENTS

WOLF’S ALGORITHM: ESTIMATE LARGEST LYAPUNOV EXPONENT

\[ \lambda_1 = \frac{1}{t_M - t_O} \sum_{k=1}^{M} \log_2 \frac{L'(t_k)}{L(t_{k-1})} \]
LYAPUNOV EXPONENTS

THE LYAPUNOV EXPONENT PROVIDES A QUANTITATIVE DESCRIPTION OF CHAOTIC BEHAVIOR

A POSITIVE LYAPUNOV EXPONENT IS AN INDICATION OF SENSITIVITY TO INITIAL CONDITIONS (I.E., CHAOS)

THE LARGEST LE CALCULATED FROM CONVERTER CURRENTS WAS POSITIVE
MITIGATION TECHNIQUES

REDUCE SWITCHING FREQUENCY

MINIMIZE FLUCTUATION CURRENT

AVOID PROTECTIVE MODE

TESTING COMPONENTS
BENEFITS FOR THE STUDENT

LEARNED HOW TO MODEL POWER ELECTRONICS CIRCUITS
ACQUIRED KNOWLEDGE OF CHAOS THEORY AND ITS APPLICATIONS IN ELECTRICAL ENGINEERING
IMPROVED PROGRAMMING SKILLS
DEVELOPED EXPERTISE IN SEARCHING PROFESSIONAL JOURNALS AND CONFERENCE PUBLICATIONS
BECAME FAMILIAR WITH TECHNICAL WRITING AND PRESENTATION TECHNIQUES
A TRUE TEAM WORK EXPERIENCE
CONCLUSIONS

DEVELOPED SIMULATIONS FOR POWER ELECTRONICS DEVICES USING SPICE AND ELECTRONIC WORKBENCH
DEVELOPED PROGRAMS FOR THE STUDY OF CHAOTIC BEHAVIOR
COMPLETED LITERATURE REVIEW ON CHAOS IN POWER ELECTRONICS
STUDIED CHAOS IN CURRENT AND VOLTAGE TIME SERIES FROM SIMULATIONS

FUTURE WORK

CHAOS IS A TRULY EXCITING FIELD - THAT’S WHAT NATURE REALLY IS !!!
Distributed Generation

Doeg Rodríguez-Sanabria
Efraín O’Neill-Carrillo

POWER ENGINEERING @ UPRM
Energizing the Future

ES³
Energy Systems
Seminar Series
What is Distributed Generation (DG)?

- Small-scale power generation technologies located close to the load being served. Thus, connected to the distribution level
- Connected close to served loads
- Typically 10MW capacity or less
- Can also be called generational distributed resources (DR), Distributed generation (DG), distributed energy resources (DER) or dispersed power (DP)
Types of DG

- Photovoltaic cells
- Microturbines
- Fuel Cells
- Wind turbines
A future with DG
Reasons for installing DG

- Increased power quality and grid security
- Provide more reliable service
- Allow for custom power applications
- Mitigation of generation deficit
- Approximately 20% of all new generation by the year 2010 will be DG
Economics of DG

- Capital cost
- Fuel cost
- Operation and maintenance costs
- Efficiency
- Operating mode (hours) / Energy profile support
- Power quality
- Siting / environmental and other costs
Why is DG better? Is it cheaper?

- Economics is not the only driver for DG
- Power quality and integrity are major drivers for DG - energy managers.
- Emerging Technology DGs offer lower maintenance costs than conventional gen
- Improvement in environmental performance.
- Operating hours - base load Vs. peak shaving / standby
- Shelter from high volatility in electricity prices
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<tbody>
<tr>
<td>Size</td>
<td>30kW - 6+MW</td>
<td>30kW - 6+MW</td>
<td>30-400kW</td>
<td>0.5 - 30+MW</td>
<td>100-3000 kW</td>
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<tr>
<td>Installed Cost ($/kW)</td>
<td>600-1000</td>
<td>700-1200</td>
<td>1,200-1,700</td>
<td>400-900</td>
<td>4,000-5,000</td>
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<td>Elec. Efficiency (LHV)</td>
<td>30-43%</td>
<td>30-42%</td>
<td>14-30%</td>
<td>21-40%</td>
<td>36-50%</td>
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<tr>
<td>Overall Efficiency</td>
<td>~80-85%</td>
<td>~80-85%</td>
<td>~80-85%</td>
<td>~80-90%</td>
<td>~80-85%</td>
</tr>
<tr>
<td>Total Maintenance Costs ($/kWh)</td>
<td>0.005-0.015</td>
<td>0.007-0.020</td>
<td>0.008-0.015</td>
<td>0.004-0.010</td>
<td>0.0019-0.0153</td>
</tr>
<tr>
<td>Footprint (sqft/kW)</td>
<td>.22-.31</td>
<td>.28-.37</td>
<td>.15-.35</td>
<td>.02-.61</td>
<td>.9</td>
</tr>
<tr>
<td>Emissions (gm / bhp-hr unless otherwise noted)</td>
<td>NO\textsubscript{x}: 7-9 CO: 0.3-0.7</td>
<td>NO\textsubscript{x}: 0.7-13 CO: 1-2</td>
<td>NO\textsubscript{x}: 9-50ppm CO: 9-50ppm</td>
<td>NO\textsubscript{x}: &lt;9-50ppm CO:&lt;15-50ppm</td>
<td>NO\textsubscript{x}: &lt;0.02 CO: &lt;0.01</td>
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DG’s Pros & Cons

Positives

• Growth prospects are solid across all technology types
• Potential benefits to grid, air quality, energy sector, job market, and manufacturing sector, and end users just being recognized
• New legislation, agencies, incentive programs present prospects for growth

Negatives

• Inconsistent and conflicting policies coming from various State entities
• Tariff structures that thwart or inhibit development
  – standby charges, demand charges, exit fees
• Complex vs simplified compliance requirements
  – many jurisdictions, lack of standardization
• Incumbent utilities slow to embrace private ownership
• Lack of strong DER industry trade / advocacy group
Possibilities or uses of DG

- Voltage regulation services
- Network stability services
- Mitigation of energy imbalances
- Increase of service reliability
- DG sitting can be included in DN expansion plans
Impacts of DG sitting

- Feeder dependence for voltage regulation
- Modification of network voltage level profiles
- Transformer tap setting conflicts
- Multiple fault currents
Impacts of DG sitting

- Increased fault current due to DG current injection

- Flicker caused by DG units may cause “regulator hunting”

- Possibility of harmonic current injection by PE interfaced DG
Rural Distribution Feeder - 13.2kV

500kW DG Unit

Substation 13.2kV / 22MVA

To trans. grid
Voltage profile impact

Voltage Profile

Voltage Level (pu)

1 2 3 4 5 6 7 8 9 10 11

Nodes

Profile-No DG
Profile-DG
Fault event 1-Line-Ground

Fault 50% Distance
Fault Current Increase

Increased Fault Current

Node 7 Injection

Current Mag. (pu)

Without DG

With DG

0.68249

1.56768

0 0.5 1 1.5 2

Fault Current Increase
Multiple fault currents

Fault 50% Distance
Multiple Fault Current Creation

![Multiple Fault Currents Graph](image)

- **Node 2 Injection**
  - Without DG: 0.00148
  - With DG: 0.71747

- **Node 6 Injection**
  - Without DG: 0.71747
  - With DG: 0.93463

Legend:
- **Node 2 Injection**
- **Node 6 Injection**
Future Work

- Transient response of DG units in presence of faults
- ATP modeling of DG units
- Creation of Educational modules
- Creation of updated protection schemes for DN featuring DG
- Propose DG interconnection for use in local power systems