UK ENERGY RESEARCH CENTRE

Microgrids Book Stakeholder Meeting

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Kythnos Bay Hotel, Kythnos Island, Greece

Workshop Report

UKERC/MR/MP/2008/006

Recorded by:
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Edited by:
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Event organised and sponsored by:

UKERC
The meeting place

This document is a report by the organiser of a technical meeting set up as part of UKERC's research programme. It is believed to be an objective record of the meeting but has not been separately reviewed by the participants

THE UK ENERGY RESEARCH CENTRE

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UKERC also acts as the portal for the UK energy research community to and from both UK stakeholders and the international energy research community. The National Energy Research Network (NERN), supported and facilitated by UKERC, acts as an umbrella network for energy researchers across all disciplines. The UKERC Meeting Place, based in Oxford, is a key supporting function of UKERC that aims to bring together members of the UK energy community and overseas experts from different disciplines, to learn, identify problems, develop solutions and further the energy debate.

Core Organising Team

Hiroshi Asano, CRIEPI and the University of Tokyo
Nikos Hatziargyriou, National Technical University of Athens
Carlos Hernandez Aramburo, Imperial College London
Karyn John, UKERC Meeting Place
Chris Marnay, Berkeley Lab
Afzal Siddiqui, University College London
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Executive Summary

Introduction

This workshop brought together 74 experts including policy makers, advisors, and scientists to provide a neutral forum, under Chatham House rules, for full and frank dialogue to provide critical comments and insights to ensure the most important issues in microgrids have been addressed in the developing book. This was an opportunity for the book authors to present an annotated outline of their chapters for a Microgrid book to be published by Springer-Verlag later in 2008. The aim of the workshop was to gather feedback and possibly further contacts to ensure the microgrids book is rigorous and complete. The workshop outputs will provide a compilation of significant comments to be incorporated in the book, and potentially identification of new research collaborations.

Workshop Process

To address the aim, each chapter author presented a 10-minute summary of his chapter. This was followed by a five-minute critique by an invited discussant. Comments were invited from the floor for a further 15-minute period. Professor Gary May provided an overview of research in this area at the end of the workshop. The workshop was opened by an invited chair, Professor A.P. Sakis Meliopoulos of the Georgia Institute of Technology. Professor Meliopoulos offered final concluding remarks.

Key Messages

Three key issues were identified in the discussion as important messages for the authors:

1. Specify the target audience, and tailor the book accordingly;
2. Improve the integration of chapters;
3. Provide a strong storyline throughout the book, which makes the case for microgrids.

Organisation of the report

The report begins with a backgrounder explaining the rationale for the workshop. The organisation of the book is explained, together with an abstract of its purpose. This is followed by a summary of each author's presentation, comments by the corresponding discussant, and a summary of the group discussion following each chapter. The final closing remarks are presented. Appendix 1 is the annotated outline by the chapter authors. Appendix 2 is the workshop programme, Appendix 3 gives a short biography of the principals involved in this meeting, and Appendix 4 lists participants, affiliations and email addresses.

Throughout the report, spellings have been standardised, abbreviations spelled out and punctuation inserted where it may help to clarify meaning.

Contents

Microgrids Book Background

By Afzal Siddiqui

The objective of the microgrids book is to bring together current thinking and evidence on microgrids vis-à-vis the role of microgrids in confronting the global energy predicament and to disseminate this to policy-makers, academics and other interested stakeholders through publication of a book and an executive summary specifically for policy-makers.

The UKERC Meeting Place support enabled an international and multi-disciplinary team of researchers to work on this book, which outlines the concept of microgrids from both theoretical and practical perspectives. A microgrid is a grouping of energy sources and sinks that is connected to the central grid, but can function autonomously from it. Since the existing central grid is in many ways unable to cope with increasing consumption of electrical energy and ever more demanding expectations for high reliability and power quality, the microgrid has been proposed as a means to tailor local electricity service to local requirements. Microgrids can potentially provide an alternative expansion path for electrification in both developing and industrialised countries. In the proposed book, the electrical engineering theory and the power system architecture of microgrids will be outlined. It will also present an economic model that guides investment and operation of the distributed energy resources that will compose such entities. The planned research output, therefore, is an engineering and economic treatment of microgrids that will not only provide a resource for other researchers in this area, but also assist policymakers in determining the benefits of microgrids as part of a wider energy system. The proposed book will take an international perspective with case studies from multiple countries to account for the diverse paths along which microgrids have evolved.

The book will have the following chapters:

1. Introduction: this will provide a summary of the development of the traditional central electricity grid, discuss its drawbacks, and then outline the emergence of the microgrid as an alternative paradigm
2. Distributed Energy Resources (DER): the technical and economic characteristics of small-scale on-site generators, heat exchangers, absorption chillers, and related DER equipment will be discussed
3. Power System Architecture: the design of microgrids from an electrical engineering perspective will be outlined along with a discussion on the reliability of microgrids
4. Engineering-Economic Analysis: the investment in and operation of DER from a customer's perspective will be examined in order to indicate the economic and regulatory conditions under which microgrids are beneficial
5. Prospects for Microgrids: social, economic, regulatory, and technical challenges to microgrids will be discussed along with potential for their installation
6. Site-Specific Case Studies: the performance of installed microgrids in various countries will be analysed to identify the critical factors in their success and to provide perspective on the diverse ways in which microgrids have evolved

7. Summary: the main economic and regulatory issues will be recapitulated along with a discussion of the social benefits that microgrids can provide

Since there is no combined engineering and economic treatment of microgrids, this work is filling an important gap in the area. Indeed, the unique feature of this work is that it will strive to bring together the varying perspectives on microgrids. First, it will serve as a resource for students and researchers in this increasingly important field. Second, it will provide policymakers with a framework in which to assess the benefits of microgrids. We believe that such treatment of an emerging paradigm is essential in documenting the research advances and open questions.

The intended target audience is energy researchers and policymakers who are exploring the viability of microgrids in a variety of applications, from urban environments to rural electrification programmes. The proposed work will provide researchers and policymakers with a resource on the engineering and economic aspects of microgrids, along with a discussion of the regulatory and technical challenges that they face.

Welcome and Introductions

Chair A.P. Sakis Meliopoulos welcomed participants and explained the process for the workshop. Sakis provided an overview of microgrids and explained that the benefits include environmental sustainability and a mechanism for incorporating renewables into the grid. Sakis discussed the issue of interdependency, explaining that our utilisation of energy is divided into three main categories:

- Electric power utilities
- Transportation
- Industry

Regarding the current microgrids book project, this explores the development/deployment of microgrids and establishes terminology. Sakis invited participants to contribute their research and ideas at this workshop and in the future. He then outlined the process and explained that each chapter author would present for 10 minutes, followed by a 5 minute response from an invited discussant. There would be 15 minutes for audience feedback after each chapter/discussant presentation.

Sakis acknowledged the project participants and invited Carlos Hernandez to present Chapter 2.

Chapter 2: Distributed Energy Resources

By: Carlos A. Hernández Arámburo
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Carlos noted that the chapter begins with a section on power electronics and then goes on to explain the basic operating principles which are:

- Storage
- Combined Heat and Power
- Absorption chillers and solar thermal

The chapter closes with some topics related to demand side management.

Overall, this chapter serves as a preamble to Chapter 3 and design aspects, as well as economic aspects in Chapter 4 and Chapter 5.

Discussant: José Maria Oyarzabal*, Labein Tecnalia*
José posed several issues/questions following Carlos' presentation:

- The issue in power electronics is in the control, not the technology;
- Power electronics are not a major technology. The sources and the capacity of power electronics is limited. The question is, is it a major technology?
- Regarding electricity production, is the microgrid a kit?
- Does power system storage on a large scale work
- Are heat and electricity linked into the microgrid or not?

- Agree with Carlos that demand side management is really consumer demand response.

Discussion

- Disagree that power electronics not a major technology. It has made the microgrid concept possible. Would definitely include power electronics in the book.
- The demand side management issues should be included in the book, but the resources chapter may not be the best place for that.
- Regarding the structure of the book: please add your definition of microgrids to the book, and give a brief summary of the electrical structure. What kind of grid is it?
- Where is hydro in terms of resources?
- Please be more clear about what you mean when you say control.
- Where will you be discussing safety?

Afzal provided an overview of Chapter 1 for participants, as this will not be explicitly presented during the workshop. Chapter one will give a broad overview of how the existing power system developed, the pros and cons and the evolution of microgrids. The specific comments provided so far are exactly what we are looking for.

- Who is the audience for this book? This needs to be clarified and the book structured in response.

Afzal and Chris clarified the intended audience. The aim was to take an interdisciplinary approach that would be of interest to policy makers and academics, with case studies for practitioners. Chris made two points. First, there wasn't a particular audience in mind, though we did want it interdisciplinary and general – we are open to suggestions. The book is intended as a treatise/manifesto for microgrids, and therefore needs to make the case to a broad audience. Second point, regarding definition of a microgrid: the authors don't want to be too specific on what a microgrid is. The defining principle would be that the microgrid is of benefit to the local participants.

- Perhaps use title distributed energy generation and distribution
- Need to incorporate the concept of integrated energy systems
- Need to involve the utilities in these discussions (the enemy)
- Regarding audience, each chapter will have a different audience. As a specialist in a certain field (eg. Power electronics), skip that chapter – read the others.
- Concerned the book is just a collection, without coherence
- Need to push the systems aspect – how do the different components interact
- Focus on the inter-relationships, rather than the gritty details
- In the introduction, a key issue should be the coordinated control of all resources and their ability to perform as a single entity and join distributed control.
- The different needs of the developing and industrialised world should be considered, and money will go to the issues of the west, rather than remote sub-Saharan Africa countries

- Black box issue – won't put this into the public domain without confidence it works in the real world
- Suggest naming chapter two Microgrid Components, and then divide into distributed energy resources for first half, followed by a description of the control and control layers.

Chapter 3 – Power System Architecture and Control

By: Nikos Hatziargyriou
Click here
http://www.ukerc.ac.uk/Downloads/PDF/Meeting%20Place/Events/2008/0608Microgrids/Hatziargyriou.pdf

to access the powerpoint slide presentation

Nikos acknowledged the contributions to this chapter from Nick Jenkins at the University of Cardiff, Joao Lopes and Carlos Moreira at the University of Porto, Aris Dimeas from the National Technical University of Athens, and Janaka Ekanayake from the University of Manchester.

This chapter deals with power system architecture and control, the microgrid operational and control architecture, and controlling frequency and voltage through the local controllers and then the coordinated control, energy management, protection and safety. The chapter will discuss existing methods and practices, transference to microgrids, and possible solutions developed to date.

More specifically, the chapter deals with:
- Technical issues associated with the operation and control of microgrids;
- Different levels of microgrid control, from primary to secondary levels;
- How to coordinate large numbers of distributed sources with the possibility of conflicting requirements (often resolved through distributed control);
- Architecture, regarding participation in control of the overall as well as islanding;
- Different types of networks: AC or DC, fixed or variable, - can the frequency and strict voltage regulations be relaxed to accommodate microgrids which

Nikos continued by going into detail by describing a typical microgrid.

The last part of the chapter deals with protection and safety. There are differences between traditional distributed systems and microgrids – we will look at the existing protection philosophies. One notable problem is fault currents of different micro-sources. Switching from interconnected to island mode significant changes to capabilities may occur. Fault current levels will vary depending on the number of interconnected generators.

Discussant – Thomas Degner, Institut für Solare Energieversorgungstechnik

Generally, chapter is valid, advanced, structured and feel it covers all important aspects and especially looks at the state of research.

Specific comments:

- Expanded or generalised in some parts
- Following the discussion on chapter 2, it is important to define, particularly regarding technical issues
- The first part of the chapter on power system architecture and control, state clearly that you have microgrids in mind, even though applicable in other areas.
- In some part of the network, we are talking about islanding (not quite right)
- Different control aspects, important that in previous chapter we get information on capabilities of distributed energy resources - how can DER contribute to the operation of the network – not just energy but other network resources.
- How generators can support network operation
- Also state there may be others not mentioned here
- 3.5 energy services – use concept of microgrid controller. What is the operator of this controller? This is a technical chapter, but need to understand different functions of the controller and does this fit with the interests of the operator
- Definition of the microgrid controller. Distinction of the Virtual Power Plant and the microgrid
- 3.7 protection. Again important to know which we are talking about. Extend the challenges of protection for the islanding situation as well
- Fly wheels are introduced as one source for fault current contribution, but more discussion needed on this.

Discussion

- In 3.3 there's diagrams. Main point is 3.4.2 coordinated voltage control: I like the idea of accepting in voltage
- Centralised we find the global optimum. On decentralised view, smaller units, distributed agents, less costly communication and decision based locally.
- Don't forget we have synchronous and asynchronous generators as well.
- Great chapter
- Most of distributed generators are much larger, medium voltage. What we are finding is depending on physical location, protection and voltage aspects are very different. We're seeing Tx actually influences Dx in terms of ability to manoeuvre voltages. Going non-traditional way to reduce costs. Our first 100 distributed generators will go on wireless. Protection – we give challenge to academics.
- ON protections, we agree with what's been said. There's a locus on how the short-circuit will operate. Huge locus and relays must be adaptive enough to sense it. My question for this chapter: what change to infrastructure would be required to address and implement distributed generation? What is the paradigm shift needed to accommodate this?
- The Argument for adoption needs to be better made.
- Lack in literature is how microgrids are feasible. How do you improve reliability, environmental attainment targets, how do you improve operational cost and efficiency. Policy-makers are the correct audience.

- Engineers are driven by regulation, but I don't make regulation – this is where we need the policy makers on board
- Need to put more emphasis on the societal argument – think about re-ordering the book.
- You need to sell to me better – I'm your audience (engineer). I need an implementation roadmap.
- Add an appendix – range of standards that would touch on your interest area. Look for those opportunities to find areas and get consist and get them to conform.
- Include an appendix with range of international standards
- Forest level view for policy-makers, and for engineers, provide compelling reasons as to 'why microgrids' before providing the implementation roadmap.
- Why don't you add a chapter at the beginning on the role of microgrids in a smart grid to address these issues. Not just a page in the introduction.
- A lot in this chapter has to do with modernisation of the grid: smart grid, etc. The work of the microgrid community has cross-fertilisation of grid work modernisation. This is a significant development.
- Where we are coming from, we are subject to regulatory pressures. But we also have a government saying shut down coal fired plants. Most of our assets are 40 years plus. What do we change to when we retire them? Landline versus cellular. There is an internal business driver.
- The Japanese doing a lot on control and architecture. Ask for response.
- Need more on advance control and energy concepts and methods
- Important to point out optimisation and potential of advanced control concepts to improve microgrid performance
- Comparison of diverse controls, what other methods are there and how can they be applicable in this system
- Also what kind of multi-criteria optimisation techniques are there – lots published on this and a literature review would help.
- Time series prediction can be integrated into energy management and advance control concepts – potential for great improvement.
- For either chapter 2 or5, communicate advanced policies that are relevant to smart grid deployment and DER in particular - don't want to put all on old stuff
- For denmark and Sweden – the ability to deal with blackout situations an issue. Today, it is free for a utility to have a blackout. This will not be the same in the future after the big storms in Sweden, this is the pressure for the utilities from societies.

Chapter 4 – Private Benefits and Costs of Microgrids

Afzal Siddiqui
Click here
http://www.ukerc.ac.uk/Downloads/PDF/Meeting%20Place/Events/2008/0608Microgrids/sidiqui.pdf
for Afzal's PowerPoint presentation

This chapter identifies certain quantifiable benefits from the development of microgrids:

- Lower energy bills
- Higher energy efficiency
- Potentially lower carbon dioxide emissions;
- Power quality and reliability (PQR), which is more difficult to quantify

The framework for analysis is DER-CAM (Distributed Energy Resources Customer Adoption Model), developed at Berkeley Lab. It is an optimisation tool that enables analysis of incentives for installing and operating onsite generation and CHP technologies from a microgrid. Assumptions are that the microgrid is operating semi-autonomously and is cost-minimising.

DER-CAM provides answers to:

- Which technologies should be selected?
- What is the appropriate level of installed capacity to minimise costs?
- How should the technologies operate so as to minimise the energy bill while meeting all end use requirements?

DER-CAM tells you which technologies to install, how to operate them optimally, and shows any change in the situation from the adoption of on-site generation.

Energy flows are key to how DER-CAM operates, and Afzal provided an example. The complexity of energy flows is dealt with compactly using DER-CAM. This is a mixed-integer linear program, and its objective function is to minimise the annual energy costs, consisting of all costs of purchasing energy, amortised technology costs, operation and maintenance expenses, all subject to a variety of constraints.

Consideration must be given to:

- Input requirements;
- Tariff structures;
- Accurate technology cost and performance data;
- Capital and operating and maintenance costs;
- Capacities;
- Heat rates;
- Amount of waste heat captured;
- Storage efficiency;
- Regulatory information;

Afzal gave an example of a San Francisco hotel (will appear in the journal IEEE Transactions on Power Systems).

Since DER-CAM is a purely deterministic model, it does not account for stochastic electricity or fuel prices. Other limitations include engineering/infrastructure especially in developing countries, and localised environmental impacts as well as an inability to account for more “qualitative” benefits resulting from more tailored PQR.

This chapter will show the private benefits from microgrids with DER-CAM as the framework of analysis.

Discussant - Hideharu Sugihara*, Osaka University*

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for the presentation

First point is the possibility of combining several types of customers in DER-CAM

Second point is the evaluation of a PQR benefit. Difficult to do this quantitatively, so a few comments on this:

- Reliability improvement: there are two types of distributed generators in microgrids. One is system operator owned and the other is customer owned. The latter likely uncontrollable resources, so we have to evaluate the reliability indices in microgrids.
- Next, it is necessary to install another distribution line and other control equipment in the microgrid so important to evaluate the cost benefit analysis.

Discussion

Question: You mentioned you are not using DER-CAM stochastic analysis or uncertainty of fuel prices. Don't you think it gives an advantage to renewables for microgrids?

Afzal: The problem is when we don't have exposure to fuel price risks, then we end up building a larger system than if we were exposed to fuel price risk. If we did have stochastic fuel prices, it would give an advantage to renewables as they're not susceptible to that risk. Yes, DER-CAM as deterministic is more biased to fossil fuel based technologies than if we had the fossil fuel price evolving randomly.

- This chapter is flipped upside down. I'd put more time to the issues and their interrelationships, with DER-CAM as an example at the end.
- PQR a major driving point that hasn't been dealt with yet.
- A key feature of microgrids is ability to operate in interconnected and islanded modes – would like to see the associated costs and benefits of islanding in this chapter.
- Fundamental remark of this chapter – you're always trying to optimise – for whom? For grid operators, need to know optimal penetration. Multiple stakeholders. So you're dealing with a moot objective problem. Need general discussion on finding optimal.
- Also need to deal with a stochastic approach for finding optimal. See Strathclyde, others.
- Need to discuss constraints of the electricity grid. Don't make same error as wind, where grid doesn't accept anymore.
- Most part of chapter is for DER-CAM. Good model. But there are lots of other models, why did you choose DER-CAM as an example. Also, DER-CAM optimises for CHP, not microgrid

- Information in this chapter should be beneficial to those who want to implement a microgrid. I think that such information should be included in this chapter and should be placed first in the chapter.

Chapter 5 – Societal Benefits and Costs of Microgrids

This chapter emphasises wider society benefits of microgrids through non-technical economic policy issues. One goal of this book is to provide a general policy case for microgrids – a 'broad, world-wide manifesto'.

This chapter is future-focused, both from a developed and developing country perspective.

Three costs and benefits aspects are identified:
1. Is it big – are microgrids important with potential for significant impact?
2. From a public policy perspective, the market likelihood: Can external costs and benefits be internalised?
3. Tractability: calculation of benefits.

Questions for the audience:
- Are there others who would be interested in contributing to this chapter?
- Is the approach taken reasonable?
- How should we approach quantification, and is this possible?
- What other relevant literature is available, particularly non-English literature?

Discussant

Iain MacGill, Centre for Energy and Environmental Markets, University of New South Wales, Australia

As a general observation, engineers make good economists. Also taught not to trust the models. I think harder to make case to write books, because in their general form, expensive and limited access. Hard to sell to students when cost hundreds of dollars. When they work well, they provide a coherent set of information and a valuable resource.

Books for policy-maker very difficult – and they rarely buy books.

Key point of underlying principle of markets is people pursing own private interests and therefore provide best for society. This isn't the case with energy. With energy, we have a market design and policy problem. For policy-makers, you need to make a compelling case for microgrids, which has not yet been made. Is it a social welfare case? This must be the critical path of the book.

In terms of Chris' structure

In 5.1

- Looking at what's there. The history of the centralised paradigm. Important to talk about the future and associate challenges, but noting it is doing new things quite well, such as wind power into our electricity. Challenges emerging, of course.
- The electricity history is a history of externalities. Tightly bound, directed and herded by government. Far important to leave to market forces.
- One thing that needs to be covered is electricity restructuring. Restructuring should be positive for DER resources if they offer value, and should bring end-users more closely into the industry.
- This has a theoretical basis – end-users are the only who get value through the energy services provided.
- Lots of practical basis. Industries around the world have been built for centralised control. They would argue case has not been made.

In 5.2

- Social cost and benefit framework. Limitations, but powerful way of looking at these issues.
- DER is a wide range of technologies, so hard to bundle them into what they do.
- Value of DER versus value of control

- Ideally with CBA, especially externalities, too hard to calculate so lets create a market and policy framework that lets them emerge and internalise.
- Benefits literature review – Chris says most important section. I would say not the case. Also need to look at the cost literature. If DER takes off, there will be a lot more cost literature.
- The case study approach – you will get good ideas and numbers, but can't apply across the board
- Literature review – my view is that this literature is under challenge and rightly so. Claims don't bear out in practice.

In 5.4 List of barriers

- Standard set of electricity barriers. This is a design question. Some industries take very different approaches to pick up temporal, spatial, etc. dimensions. The unfinished business of utilities to work better with end-users.
- This is something we should be doing anyway. What DER can we tap into. We do know there's load. We don't know about CHP, micro-turbines, etc.
- The example of cooking came up, but what about air conditioning, etc. Electricity restructuring should be picking this up anyways.
- Missing in 5.4 – if you want to address this to policy-makers, you'd better have something they can do. Should be part of a policy document

Discussion

- Existing utility work – paper on Agent based distribution automation. DG assisted reconfiguration. Massive room for improvement. See this paper for suggestions on improvement (from IRAF conference last year)
- We're not sitting still – multiple island restoration. Stability work we did, which showed grid-disconnected doesn't work. Grew internally to system restoration. Another illustration of massive improvement. A compelling reason. Franshise monopolies – calls for rate-basing. Don't wait for markets – rate-basing. Send me better models and show me how they work, because they don't work.
- The nature of deregulation itself – often find de-optimisation of wires based on cost benefit analysis of proponent.
- The customer pays – through rate based or cost saving. Where should cost benefit lie for society.
- I would add to Chris' list – retail, and analyse for cost avoidance, capital avoidance and line losses. We tend to law of averages, but averages don't work – need local, local, local.
- Reliability versus power quality, DG provides reliability, customers want flexibility for seeing power quality going down. Don't have information on islanding re this.
- When we talk about wind, I'm confused as we don't use the transmission for wind – connect at the distribution level.
- MIT, paper in 1974. Book in 1988. Read this paper.

Chapter 6 – Site-specific case studies

Hiroshi Asano, Central Research Institute of Electric Power Industry, University of Tokyo
Click here
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for Hiroshi's powerpoint presentation.

Chapter 6 focuses on site-specific case studies of microgrids in various regions. Hiroshi has outlined preliminary results from case studies in Japan, the U.S. and Europe, and is in need of further case studies from emerging and developing economies.

The case studies intend to demonstrate the technical feasibility of microgrids within interconnected and islanded modes. Quantification of economic and environmental benefits is required, as currently commercialisation based on economics is not feasible.

Hiroshi provided several case studies from Japan.

The biggest problem with this chapter is data. This chapter will include generalisations from the case studies, and quantitative performance of installed microgrids. A comparison of the diversity of microgrids installations will be given.

Hiroshi concluded by introducing the Japanese team and individuals who led on each case study.

Discussant – Ryoichi Hara*, Hokkaido University*

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to view Professor Hara's powerpoint presentation.
Professor Hara made the following points:

- Each demonstration project in Chapter 6 has its own targets and objectives;
- Comparison between the case studies difficult, given the differing targets and objectives;
- A common measure to compare the case studies is needed;
- Important to indicate the future vision of microgrids through presentation of these case studies;
- Data and results from various demonstration projects is required on a worldwide basis – it would be helpful to have assistance on this from this audience;
- Case studies on combined heat and power would be important.

Discussion

- US case studies – mini and micro grid applications. We're also wrestling with going from information to usefulness. Happy to share data.
- Comparative indicators are required as Professor Hara mentioned. Environmental, economic, technical and social issues indicators are required. We have similar issues so opportunities for exchange.
- Need to think about when a book is report. Series of reports less formal. This looks like a collection of papers, and not an integrated book aimed at policy makers and non-technical specialists. Who is your target audience? This looks more like a research book than one for policy makers.
- I coordinate an ongoing European project. Installing 3 small microgrids within FP6. Morocco, Tunisia and Egypt. Finishing final design of the systems. The one in morocco is introduction of hydrogen production. The one in Tunisia is more simple one and the one in Egypt – inclusion of water desalinisation is the innovation and may be used as alternative form of storage. Not just technical feasibility, but social and economic issues as well. In these cases, installations are all in remote areas. Poor people cannot afford to pay for their electricity. This has to be investigated – major aspect. Would be good to include as case studies in your book.
- How was case study selected? Random? Based on energy resource? Are you trying to demonstrate something. What worked and what didn't work. What were complications, challenges that you faced. Tie into other chapters. Voltage source and controls. Did it work or did you switch along the way.
- Just showing what works. Previous comments would be useful. What was learned from the case studies. Linked to this, link the case study to economic analysis chapter. Engineers have distrust of the economic analysis. Do the economic analysis now and then see if it works. This integration would be really useful.
- Link this chapter to the previous three. Also links to the third chapter. Use common criteria for evaluation.

- Have two more legs in the diagram – economic development and the DER checklist.
- 7 studies in Ontario. After 5 years, those that were doing well have suddenly become uneconomical. What is the longevity of the study period? When do you say you are successful – at the end of the project or after 5 years, longer?

Georgia Institute of Technology – Research Overview

Gary May, Lead Discussant
Click here
http://www.ukerc.ac.uk/Downloads/PDF/Meeting%20Place/Events/2008/0608Microgrids/MAy.pdf
to view Gary's powerpoint presentation

Gary gave and overview of energy initiatives at the Georgia Institute of Technology.

Concluding Remarks

Sakis thanked the authors, organisers and participants for their contributions to this meeting. A record of the meeting will be written by UKERC, and a transcription of the meeting will be provided to chapter authors.

The Annotated Chapter Outlines can be accessed
http://www.ukerc.ac.uk/Downloads/PDF/Meeting%20Place/Events/2008/0608Microgrids/abstracts.pdf

here.

Appendix 1: Workshop Programme

Sunday 1 June 2008

08:00 **Registration and Refreshments**

08:30 **Welcome by the Chair**
Sakis Meliopoulos, *Georgia Institute of Technology*

08:45 **Overviews of Chapters 2 - 6**

Five Chapter presentations consisting of a 10 min summary by its lead author, followed by a 5 min critique by a discussant and 15 min of open-mike audience feedback.

Chapter 2 – **Distributed Energy Resources (DER)**
Lead Author: Carlos A. Hernández Arámburo
Discussant: José Mª Oyarzabal, *LabeinTecnalia*

09:15 Chapter 3 – **Power System Architecture and Control**
Lead Author: Nikos Hatziargyriou
Discussant: Thomas Degner, *Institut für Solare Energieversorgungstechnik*

09:45 Chapter 4 – **Private Benefits and Costs of Microgrids**
Lead Author: Afzal Siddiqui
Discussant: Hideharu Sugihara, *Osaka University*

10:15 Chapter 5 – **Societal Benefits and Costs of Microgrids**
Lead Author: Chris Marnay
Discussant: Iain MacGill, *University of New South Wales*

10:45 Chapter 6 – **Site-Specific Case Studies**
Lead Author: Hiroshi Asano
Discussant: Ryoichi Hara, *Hokkaido University*

11:15 **Research Overview by Lead Discussant**
Gary May, *Georgia Institute of Technology*

11:30 **Concluding Remarks by the Chair**

Appendix 2: Background on the principals

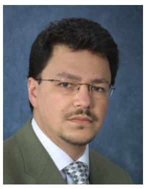
AP Sakis Meliopoulos obtained a Diploma in Electrical and Mechanical Engineering from the National Technical University in Athens, Greece in 1972 and a Master in EE (1974) and a Ph.D. degree (1976) from the Georgia Institute of Technology in Atlanta, Georgia, USA, where he is currently a full professor. He is a Fellow of the IEEE, holds 3 patents, he has published two books, a chapter in the Standard Handbook for Electrical Engineers and over 200 technical papers.

Gary May received the B.S. degree in electrical engineering Georgia Tech (1985) and the M.S. (1987) and Ph.D. (1991) degrees in electrical engineering and computer science from U.C. Berkeley. He is currently a Professor and Steve W. Chaddick School Chair of the School of Electrical and Computer Engineering at the Georgia Tech. He was Editor-in-Chief of *IEEE Transactions on Semiconductor Manufacturing* from 1997-2001, was a National Science Foundation "National Young Investigator," and a National Science Foundation and an AT&T Bell Laboratories graduate fellow.

Afzal Siddiqui is a Lecturer in the Department of Statistical Science at University College, London. His research interests lie in investment and operational analysis of electricity markets. In particular, he focuses on distributed generation investment under uncertainty, optimal scheduling of distributed generation, real options analysis of renewable energy technologies, and demand response. He holds the following degrees in industrial engineering and operations research: a B.S. from Columbia University, New York, an M.S. and a Ph.D. from the U.C. Berkeley.

Hiroshi Asano received the B.Eng., M.Eng. and D.Eng. degrees in Electrical Engineering all from the University of Tokyo. Currently, he is a Senior Research Scientist with the Central Research Institute of Electric Power Industry (CRIEPI). His main research interests include integration of distributed energy resources, power system economics, demand-side management, systems approaches, and transmission pricing. From 1988 to 1989, he was a Visiting Scholar Stanford's Energy Modeling Forum, and he has twice served at the University of Tokyo, from 1993-95 and from 2005-08.

Nikos D. Hatziargyriou is Exec. Vice-Chair and Deputy CEO of the Public Power Corporation of Greece and professor at NTUA. His research interests include dispersed and renewable generation, dynamic security, power system analysis, and artificial intelligence techniques in power systems. He is a senior IEEE member, a member of CIGRE SCC6, and of the Technical Chamber of Greece. He has a Diploma in Electrical and Mechanical Engineering from NTUA, and MSc and PhD degrees in Electrical Engineering from UMIST, UK.



Carlos A. Hernández Arámburo is a lecturer in the Control & Power Research Group at the Department of Electrical Engineering, Imperial College London. His professional interests include the application of power electronics in power systems, and the integration of distributed energy resources into the grid. He received the B.Sc. and M.Sc. degrees from the Universidad de las Americas, Puebla, Mexico, in 1994 and 1998, respectively; and the Ph.D. degree from Imperial College London, U.K., in 2003.

Chris Marnay is a Staff Scientist in the Technology Evaluation, Modeling, and Assessment group within the Energy Environmental Technologies Division of Berkeley Lab. He leads work on economic and environmental modeling of microgrids. He specializes in problems concerning likely future adoption patterns of local energy conversion, especially those involving commercial building use of heat activated cooling, and renewables. He has an A.B. in Development Studies, an M.S. in Agricultural and Resource Economics, and a Ph.D. in Energy and Resources, all from the U.C. Berkeley.

APPENDIX 3: Workshop Attendee List

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