Sustainable Energy Distribution Systems: Planning Methods and Models

Project description

2002-06-11

PART 1: The KMB project

1 OBJECTIVES

1.1 The main objectives in the project are the two following:

- Develop methods and models that allow several energy sources and carriers to be optimally integrated with the existing electric power system. Particular emphasis is placed on distribution systems and integration of distributed energy sources, from a technical, economical and environmental point of view.
- Develop a scientific knowledge base built on a consistent framework of terminology and concepts for mixed energy systems, in the field of planning methods and models. This will be a cornerstone for the curriculum 'Energy and environment' at The Norwegian University of Science and Technology (NTNU). Also, develop a scientific competent staff for the curriculum.

Mixed energy distribution systems are illustrated in Figure 1. A mixed energy distribution system means (in this context) a local (regional/local) energy system with different energy carriers (electricity, district heating, natural gas, hydrogen) and a mix of distributed energy sources and end-uses.

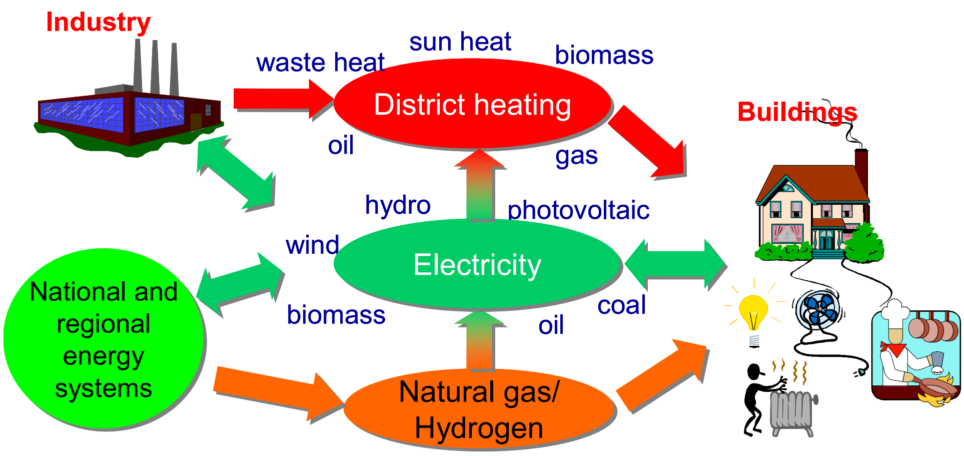

Figure 1: A mixed energy distribution system

The project will be conducted at Department of Electrical Power Engineering at NTNU in co-operation with SINTEF Energy Research. The department works closely on the curriculum Energy and environment with Dept. of Refrigeration and Air Conditioning, Dept. of Thermal Energy and Hydropower and Dept. of Applied Mechanics, Thermodynamics and Fluid Dynamics at NTNU, as well as Institute for Energy Technology (IFE). International partners in the project will be University of Porto and the associated research institution INESC, and Helsinki University of Technology and the associated research institution VTT. The Norwegian regulatory body, the Norwegian Water Resources and Energy Directorate (NVE), is working on a set of regulations concerning energy systems planning, and NVE is therefore an important partner in the project.

1.2 Develop new planning methods and models

The project will contribute to the development of new knowledge and competence through PhD studies within selected areas such as:
- Load and customer modelling
- Quality and reliability of service
- Environmental impact/life cycle analysis
- Multi-criteria decision support

These are core areas for system planning and new aspects are introduced when applied to mixed distribution systems, figure 1.

1.3 Develop a scientific knowledge base

The following targets are defined to reach this objective:
- Lay the foundation for new courses at MSc and PhD level
- Establish a consistent planning framework (terminology, concepts, general methodology etc)
- Establish a platform/toolbox/lab for simulation, visualization and demonstration of methodologies and technologies
- Contribute to student projects and thesis works
- Establish a multi-disciplinary network and competence environment of scientists/ teachers at NTNU within the area of energy systems planning

The development of the scientific knowledge base will be built on existing planning methodology and will be further developed in coordination with ongoing projects at the Norwegian scientific partners.

1.4 The project's roles

The project will play a variety of roles mentioned below, where the two roles 'Scientific coordinator' and 'Scientific meeting place' should be emphasized. Through these two roles the project will contribute to competence building in general as well as network building (Norwegian and international) within the area of energy systems planning.
- Producer of new knowledge and competence within the area of mixed energy distribution systems planning
- Organizer for educational use at NTNU of planning methods and models developed at the Norwegian scientific partners
- Organizer for integration of new energy technology models into the planning framework
- Scientific meeting place for students, scientists and industry related to energy systems planning
- Pool for student projects and thesis works related to energy systems planning
- Scientific coordinator for research projects related to planning methodology and mixed energy distribution systems
- Disseminator of knowledge through a variety of publications and course material

1.5 Main products

The main products from the project related to energy distribution systems planning are as follows.
- Qualified personnel for the curriculum Energy and environment and the industry
- New courses: MSc, PhD, post graduate etc
- Scientific knowledge base for the curriculum Energy and environment
- Consistent planning framework
- Demonstration and simulation toolbox/lab/platform
- New models and knowledge (up to 4 PhD)
- Multi-disciplinary network and competence environment for energy systems planning at NTNU
- Publications
- Spin-off: New co-operation, new projects, Norwegian and international networks etc

2 Frontiers of knowledge and technology

2.1 Status and background

Development of the hydroelectric power has had a major influence on the energy system development in Norway in general and on the electric power network and supply in particular. Therefore, in Norway the hydropower system and the existing electric power network will continue to be a backbone of the energy supply system. However, we will see a more mixed energy distribution system in the future, internationally as well as in Norway. The challenge is then to find optimal ways for integration of future energy sources and different energy carriers with the electric power network.

Planning of mixed energy distribution systems comprises development, operation and maintenance of the infrastructure as well as the integration of distributed energy sources and multiple energy end-uses. Information and communication technologies (ICT) are becoming more and more important parts, particularly in the operation of the energy system. Objectives and tasks in the planning process can briefly be summarized as:

- To cover supply duties with acceptable quality of supply and to contribute to effective energy markets.
- Specify infrastructure and mix of energy sources and carriers to minimum cost and acceptable environmental impact.
- Specify interplay between the infrastructure and demand side management.

2.2 Existing planning methods: Focused on particular areas and aspects

Research institutions and energy utilities have together a quite comprehensive knowledge and experience within various aspects of energy systems planning. Department of Electrical Power Engineering has together with SINTEF Energy Research (former EFI) over some years developed models and tools for electrical power systems planning, covering generation (supply), power networks, electricity markets and end-use. Some examples are 'EFI's Multi-area Power-market-Simulator (EMPS)'[1], 'Samlast'[2] which integrates market simulations with load-flow analysis, the network information system 'NetBas'[3], 'USELOAD'[1], 'EFI-ENERGI'[4] and 'Handbook for power network planning'. Department of Refrigeration and Air Conditioning has developed a tool for calculation of heat load and energy consumption: 'HeatQuick'.

Different research groups are working on specialized fields of energy technologies and planning aspects. However, this knowledge is piecewise and fragmentary and does not come together in a framework with consistent terminology and concepts that meet the needs of planning future energy systems. The future systems include multiple energy sources and carriers, and planning has to put adequate emphasis on technological issues, end-user quality aspects as well as economy and environmental impact.

2.3 New challenges

The new MSc curriculum at NTNU, 'Energy and environment' has energy planning methods and models as an area of vital importance. This program will produce candidates that are going to be key personnel in the future energy sector in Norway and as such responsible for planning and operation of this sector. There is an urgent need for further development of scientific based methods and models giving them knowledge and tools to do a qualified job. This development will of course be based on the pool of existing knowledge and experience, but there are some important new areas and aspects that are not adequately covered by existing methods and procedures.

The conditions for management of energy systems is changing quite fast in many countries due to different aspects, such as de- and re-regulation, business restructuring, multi-utility management etc. Therefore, it is believed that the importance and usefulness of developing a new planning framework for mixed energy distribution systems, taking into account the changing conditions, is relevant for the international research community and for education on MSc and PhD level. Planning of mixed energy distribution systems will in the future be characterized by:

- Increasing use of distributed generation
- Increasing use of information and communication technologies
- Regulations and constraints applied particularly on infrastructure, and interplay with demand side management
- Open energy markets
- Multi-utility management
- Uncertainties (technical, political, economical) and risk evaluation
- Multiple criteria and multiple agents behind decisions

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[1] EMPS and USELOAD: More information on http://www.energy.sintef.no/produkt/uk_index.asp
[2] Samlast: More information on http://www.energy.sintef.no/avd/Energisystemer/uk_index.asp
[3] NetBas: More information on http://www.powel.com/produkter/netbas/NIS_Losning/
[4] EFI-ENERGI: More information on http://www.energy.sintef.no/prosjnyt/prognose/ (in Norwegian)

The proposed project is addressing these challenges and seeks international co-operation and expertise in particular areas.

3 Research tasks

The project is organized in two main research tasks. In addition to the PhD studies focused on particular problem areas (section 3.2) a task called ‘Building a scientific knowledge base’ is proposed. This task is described in section 3.1 and Ch. 4.

3.1 Building a scientific knowledge base for planning methods, models and tools

This task can be broken down in two parts. The first part has main emphasis on conceptual elements: to define a consistent planning framework for mixed energy systems, including the new aspects and issues underlined in section 2.3. The second part emphasises the experimental approach using simulation models to explore scenarios, demonstrate and visualise planning methods and models.

3.2.1 Development of a consistent planning framework for mixed energy distribution systems

Define the planning process, elements, aspects and parameters involved etc.
- Terminology
- Concepts
- Methodology
- Data basis (Information modelling: Structures, attributes etc)
- Handling of risks and uncertainties etc.

The product from this activity will be an extended concept/foundation for planning of mixed energy distribution system. It is believed that this will be very useful, particularly for energy utilities responsible for local and regional energy systems planning.

3.2.2 Development of a software toolbox environment for simulation and demonstration

- Define the contents and the platform(s)
- Organize models, methods, tools for energy distribution systems and distributed energy sources
- Organize examples/cases
- Establish the database (structures, functions, interfaces etc)

The product from this activity will be a collection of methodological elements developed in this project and elsewhere. It is believed that this will be very useful for the research community as well as for educational purpose.

3.2 Development of specific planning methods and models (PhD studies)

These doctoral projects are addressing areas particularly important for energy distribution systems planning, focusing on modelling issues, customer concerns, environmental impact, risk management and decision aid.

3.1.1 Load and customer modelling of combined end-use, including heating/cooling and electricity specific consumption

Current and future load is one of the basic assumptions for the planning process. A variety of different factors will influence future end-use (electricity specific and heat/cooling), such as: An open and restructured energy market, network monopolies, new technologies, international agreements on emissions and quota, political and environmental motivated tax policy initiatives, prices and user preferences. Therefore, prediction of future load pattern is not a trivial task and includes a considerable part of uncertainty. The load modelling will have to consider such factors, and focus on:
- Power and energy, load profiles and stochastic variations

- Individual customer load and upstream aggregation
- Categorization of different types of load and the interplay between them

3.2.2 Quality and reliability of supply

Society as well as individuals depends on quality and reliability of power and energy supply for almost any activity. For electric power systems there is a rather long tradition for maintaining quality and reliability, and research activities are continuously making progress. The challenge here is to develop concepts and indices, component and system models adequate for a mix of energy supply sources and carriers and the interplay between them on the customer side.
Quality and reliability aspects:

- Technical: voltage, temperature, pressure etc.
- Comfort and flexibility
- Controllability
- Availability, and ability to supply with sufficient quality

3.2.3 Environmental aspects and consequences

This study aims to characterize and quantify the environmental aspects of energy conversion, transport and end-use to be included in multiple criteria decision methods. Characterization also means inclusion of qualitative aspects, such as aesthetics and nature that can be given priorities and weights in a multiple criteria analysis. Life cycle analysis (LCA) is rather well known from other areas, but has not been widely applied and tested within the framework of energy systems. Other important aspects are:

- Emissions (CO_2, NO_x), audible noise and electromagnetic fields
- Use of resources, efficiency
- Aesthetics
- Land use
- Flora and fauna

3.2.4 Multiple criteria decision methods

This study focus on the integration of technical, economical and environmental aspects related to planning and operation of mixed energy distribution systems. This is a wide area, which might include several doctor studies exploring and testing different models and techniques. A main reason to apply multiple criteria instead of 'classical' (cost) optimisation is that it gives the decision-maker a better view of alternatives. On the other hand more responsibility is left to the decision-maker who has to specify priorities and weights, as well as risk attitude to cope with the uncertainties, soft constraints and fuzzy numbers inherent in the problem. Important issues are:

- Testing, evaluation and adaptation of available methods and models
- (Conflicting) Objectives and criteria
- Uncertainties and risks
- Identification and quantification of parameters
- Model development
- Case studies

4 Research approach, methods

4.1 Network building

An important objective and goal for the project is to create a multi-disciplinary scientific network and a meeting place for planning methods, models and tools. This is what we call building a scientific knowledge base. The instruments for obtaining this are:

- Development of a planning framework for mixed energy distribution systems.
- Development of software models and toolboxes for simulation and demonstration of specific technical-economical issues, environmental impact, reliability of supply, risk management etc.

The organization and co-ordination of these activities are demanding tasks, and three important aspects are:

- *Modularity:* Due to the complexity of the subjects covered and also because of the learning aspect (competence building), the activities should be carefully structured in modules. This is particularly true for building the planning framework.
- *Experimental nature*: Both for research and for learning it is of great value to have a simulation environment where mechanisms and ideas can be demonstrated and visualized. Hence, the activity called '*Development of a software toolbox environment for simulation and demonstration'* is proposed.
- *Learning and competence building*: Participation of students on MSc level in project and thesis work is an important instrument for giving them insight in methodologies and application of theories and methods to practical problems. It is a great motivation factor for recruiting students to this important area. Well organized and integrated with current research activities student projects and thesis work can also be a good instrument for testing ideas, enhance knowledge and competence both in the academic society and in industry.

4.2 Application of specific theories and methods

Energy distribution systems planning involves application of theories and methods from a quite broad range of scientific disciplines, such as:

- Process modelling and simulation (electrical, thermal)
- Economic theory (cost-benefit, investment etc.)
- Life cycle analysis
- Risk analysis modelling (uncertainties, decision paradigms etc.)
- Multi-criteria models
- Scenario building and optimisation
- Spatial forecasting, including application of geographical information systems (GIS-systems)
- Evolutionary computing

The main challenge in the proposed project is to bring together specialists from various disciplines and include these theories and methods in a consistent planning framework for energy distribution systems. Hence, network building and creating a toolbox environment for simulation and demonstration are important and integral parts of the project.

4.3 Publication

For PhD studies publication at recognized conferences and journals with referees is an important part to verify scientific quality and substance. Therefore such ambitions and plans will be part of the proposed PhD projects. Also, for the tasks 3.1.1 'Planning framework' and 3.1.2 'Models and tools' publication will be given priority, particularly since international participation is planned.
Arenas for publication will be selected according to the specific core content of the paper. The following are examples of journals and conferences for publication from this project:

Power System Computation Conference (PSCC)
Probability Methods Applied to Power Systems (PMAPS)
IEEE /PES WM, SM and Powertech conferences
IEEE Journals
International Journal of Electrical Power & Energy Systems
Journal of Multi-Criteria Decision Analysis
Fernwärme International
District Energy

5. Project organization and management

From the fact that this project particularly emphasizes network building and has substantial parts of scientific as well as administrative management and co-ordination, a project management group will be established. In this group we will find people with senior research competence as well as experience from management of research programs and projects. Furthermore, the administrative staff of Department of Electrical Power Engineering and SINTEF Energy Research will assist, and SINTEF has the structure and extensive experience of conducting research programs.

The project organization and activities are shown in figure 2. The advisory council consists of representatives from the funding partners and from NTNU and SINTEF Energy Research. Representatives from the funding partners will also participate in specialist groups focused on particular issues (methods and applications). For example, each PhD candidate will have a specialist (reference) group.

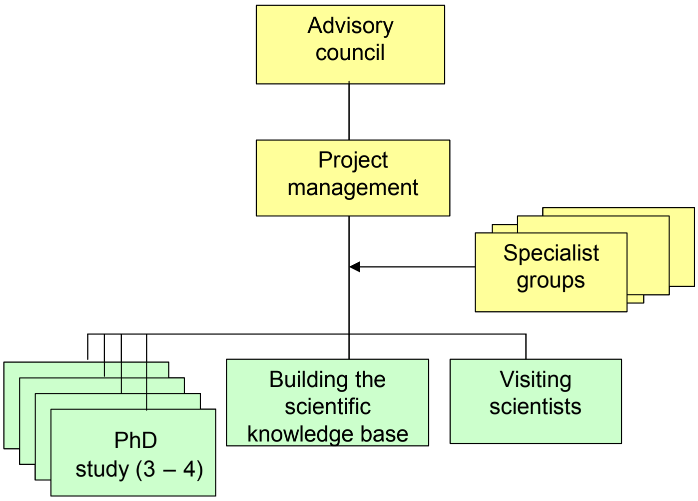

Figure 2: Project organization and activities

The project management includes administrative tasks: Project planning, reporting of scientific progress and cost statements, follow-up of activities according to the project plan, planning/reporting/follow-up of meetings in the advisory council and specialist groups, arrangement of seminars and workshops etc.

Important responsibilities of the scientific co-ordination are to organize seminars and discussions and encourage interdisciplinary co-operation. The project involves participation from several partners and aims to bring many pieces of existing and new knowledge together in a common framework with consistent terminology and concepts. Integration of knowledge from international participants and related research projects at SINTEF Energy Research and IFE, as well as graduate and doctoral students' works, is also part of this. Finally, one important responsibility of the scientific co-ordination is to establish a multi-disciplinary network and competence environment of scientists and teachers at NTNU and SINTEF Energy Research. Therefore, a co-ordination from a scientific point of view becomes a very important part of the project. This scientific co-ordination is the 'glue' that keeps all the pieces together. This is illustrated in figure 3.

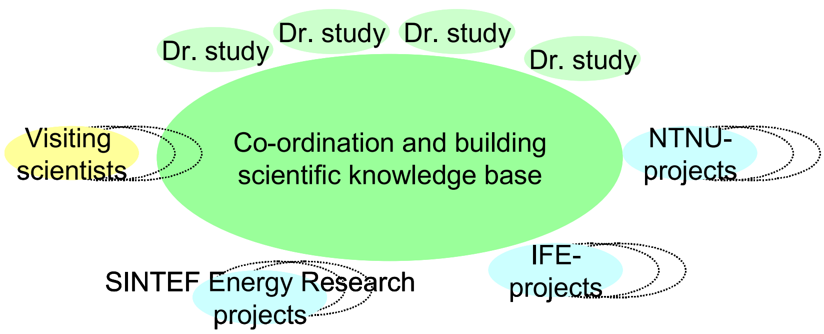

Figure 3: Scientific coordination of planning methods and models

Below is a list of the most relevant projects (per 2002) for co-ordination at NTNU and SINTEF Energy Research:

- 'Technologies for reliable distributed generation of electrical power from renewable energy sources' (NTNU, dept. of electrical power eng)
- 'Analysis of transport systems with multiple energy carriers' (SINTEF Energy Research)
- 'Local generation at the customer site' (SINTEF Energy Research)
- 'Network connection of distributed generation' (SINTEF Energy Research)
- 'DEBORA' (SINTEF Energy Research)
- 'Energy consumption in multiple energy carrier distribution systems' (SINTEF Energy Research)
- 'Sustainable electric services in northern Europe' (Industrial innovation fund at NTNU, Alliance for global sustainability)
- 'User flexibility by effective use of ICT' (SINTEF Energy Research)

6 International co-operation

6.1 Visiting scientists (professors, senior researchers) and post doctors

The proposed project will benefit considerably from internationally recognised scientists that are given opportunities to share knowledge and know-how with the project team at NTNU/SINTEF. Professors and senior researchers from universities and research institutions as well as post doctors visiting Trondheim is also a door opener for Norwegian researchers, and particularly doctor candidates, visiting foreign research institutions. There are particular areas where such specialists can contribute to curricula building, such as:

- Multiple criteria, decision support and risk based methodology
- Life cycle assessment (LCA) techniques
- Load/customer modelling and end-user aspects
- System representation and model design for the new generation of energy distribution systems planning models

The visitors will contribute to building of MSc and/or PhD courses, teaching courses for scientists at NTNU/SINTEF Energy Research, project work related to building the scientific knowledge base for planning methodology and as supervisors for PhD students in the project. Exchange of PhD students may also be of interest.

6.2 Partners

University of Porto/INESC
Department of Electrical Power Engineering has for some years been in contact with University of Porto and the associated research institution INESC based on mutual research interests. These Portuguese institutions have knowledge and experience within planning methodology and distributed energy sources that make them interesting as international partners for developing a new generation of planning tools. Based on a recent meeting and seminar in Trondheim the following areas were particularly identified:

- Risk analysis
- Multi-criteria models
- Decision aid
- Soft computing: fuzzy sets, neural networks etc. applied to power systems

Helsinki University of Technology (HUT)/Technical Research Centre of Finland (VTT)
These institutions have knowledge and experience in several areas that are focused in the project, and based on discussions in a recent meeting the following areas were particularly identified:

- Planning methods and models for electrical distribution systems and for district heating
- Load and customer modelling
- Life cycle assessment (LCA)
- Quality and reliability issues

6.3 Co-operating institutions

Since network building and a meeting place are two important objectives, the project will seek to involve other institutions on the international arena working with issues related to energy distribution systems planning. Different universities and R&D institutes will be invited to co-operate in the project mainly through participation in seminars and workshops and exchange of PhD students. University of Washington, Seattle will be one of the co-operating institutions in the project.

7 Progress plan – milestones

The main activities in the project are described below including deliverables and milestones:

7.1 Project management and co-ordination
7.2 Development of new planning methods and models (PhD studies)
7.3 Building the scientific knowledge base
7.4 Visiting scientists

7.1 Project management and co-ordination

The project management and co-ordination is described in Ch. 5. Main products/deliverables and milestones in this activity are:

- Annual meetings in the advisory council
- Regular meetings (or on demand) in specialist groups
- Annual seminar related to planning methodology
- Workshops, one per year on average, covering selected areas
- Multi-disciplinary network and competence environment of scientists and teachers at NTNU and SINTEF Energy Research (2007)

7.2 Development of new planning methods and models (PhD studies)

The main deliverables from this activity will be:

- PhD candidates and new models and methods related to the areas described in section 3.2. Each study will last for four years: Effectively three years and one year with additional duties as teaching assistants.
- The candidates are supposed to submit at least one publication per year per candidate the two last years of the study.

  Milestones: 2007 (Two PhDs) and 2008 (Two PhDs)

7.3 Building the scientific knowledge base

This activity is divided in three parts as described in section 3.1. Main products/deliverables and milestones related to these are:

7.3.1 Development of a consistent planning framework for mixed energy distribution systems

- Definition of the planning process, elements, aspects and parameters involved (spring 2004)
- Establishment of a common terminology (spring 2004)
- Establishment of a common planning methodology/framework (spring 2005)
- Establishment of the data basis structure and attributes (information model) (spring 2005)
- Handling of risks and uncertainties, quality and reliability of supply, environmental impacts, multiple criteria etc. (2006)

  Milestones: 2004, 2005 and 2006

7.3.2 Development of a software toolbox environment for simulation and demonstration

- Survey of existing planning methods and tools (2003)
- Definition of the contents (type of models, methods and tools) and choice of platform for the toolbox environment (2004)
- Collection of models, methods and tools (2005 - 2007)
- Collection of cases/examples (2005 - 2007)
- Establishment of the data basis: Structures, attributes, functions, interfaces etc. (2005 - 2007)

Milestones: 2003, 2004 and 2007

7.3.3 Student projects and thesis work

There will be 5 – 10 student projects in the 'Energy and environment' program each autumn and 5 – 10 thesis works (MSc) each spring semester related to the project.

7.4 Visiting scientists

The visiting scientists and post doctor(s) will contribute to the competence building through conducting courses and help building courses/curricula within the areas mentioned in Ch 6. Main products/deliverables and milestones in this activity are:

- Post doctor fellowship: Establishment of 1 – 2 courses (2004) related to
  1) Multi-criteria decision support for mixed energy distribution systems planning
  2) Risk based planning methodology
- Courses for scientists at NTNU and SINTEF Energy Research within these two areas (2004)
- Contributions to the scientific knowledge base (2003 – 2006)

Milestones: 2004 and 2006

The progress plan is summarized in the table below:

Activity	Year	2003	2004	2005	2006	2007
7.1 Project management		-----------	-----------	-----------	---------	---------∇
7.2 New planning methods and models (PhD)		------	-----------	-----------	---------	---------∇
7.3 Building the scientific knowledge base		-----------	--∇-------	--∇-------	-------∇	---------∇
7.4 Visiting scientists		-------	---------∇	-----------	-------∇	

∇ - Milestone(s)
In addition there will be a milestone in 2008 when two more PhD will be finished

8 Costs incurred by each research partner

The budget for the main activities is shown in the table below, given in 1000 NOK.

Year	2003	2004	2005	2006	2007	Total
Project management and coordination	500	500	450	450	300	2200
New planning methods and models (4 PhD)	550	1650	2200	1650	550	6600
Building the scientific knowledge base	900	700	650	650	650	3550
Visiting scientists	450	700	250	200		1600
Travels and stays abroad [1)]	100	250	300	250	150	1050
Project total (1000 NOK)	**2500**	**3800**	**3850**	**3200**	**1650**	**15000**

[1)] Direct costs

The budget divided between the main scientific partners NTNU and SINTEF Energy Research is as follows. Costs are given in 1000 NOK.

		Year	2003	2004	2005	2006	2007	Total
NTNU	Labour costs		980	2290	2380	1780	530	7960
	Equipment [1)		100	100	100	100	100	500
	Other costs [2)		200	350	400	350	200	1500
SINTEF Energy	Labour costs		1070	940	850	850	720	4430
Research	Equipment [1)		0	0	0	0	0	0
	Other costs [2)		150	120	120	120	100	610
Total (1000 NOK)			**2500**	**3800**	**3850**	**3200**	**1650**	**15000**

[1)] Equipment costs in this project will be relatively low, covering software and hardware.
[2)] Direct costs

9 Financial contribution by partner

The table below shows the funding partners and their financial contributions. Other contributions are described in part 3: Declaration from the main industrial partners.

	Year	2003	2004	2005	2006	2007	Total
Statkraft alliance [1)]		250	250	250	250	250	1250
Lyse Energi		100	100	100	100	100	500
Statoil		150	150	150	150	150	750
Viken Nett		100	100	100	100	100	500
Total (1000 NOK)		**600**	**600**	**600**	**600**	**600**	**3000**

[1)] Statkraft alliance: Statkraft SF, Trondheim Energiverk and Bergen Kommunale Kraftselskap

These companies will cover 20 % of the total budget, NOK 600 000 per year, a total of NOK 3 000 000 for the five-year period.

In addition to the industrial partners the regulatory body NVE will participate in the advisory council and specialist groups.

PART 2: Exploitation of results

10 Relevance for knowledge-building areas

The proposed project is particularly relevant for the knowledge-building area 'Energy and Petroleum' in the Norwegian Research Council's Industry and Energy program. The typical trends are: Environmental concerns present challenges and set the agenda for developments in the energy sector, for example the tendency towards integration of distributed and renewable energy sources in the electric distribution system. This fact has a distinct influence on system planning issues and methods, which is the main focus of the proposed project. Significant contributions from the project in relation to this knowledge-building area:

- *Knowledge-building in planning methods and models.*
  Quality of research in mixed energy distribution systems depends heavily on the success of developing a common 'culture': terminology, concepts etc. for participants coming from different scientific backgrounds and traditions. This is particularly important for interdisciplinary doctor studies but also for well established researchers coming from different scientific traditions. It is an urgent need for planning and operation of mixed energy systems.
- *A cornerstone for the curriculum "Energy and environment" at NTNU.*
  Planning methods and models for sustainable energy systems is an area of vital importance for this curriculum which will 'produce' candidates that are going to be key personnel in the future energy sector

in Norway and as such responsible for planning and operation of this sector. High scientific standing, a stimulating and high-quality learning environment as well as importance and relevance of courses and projects will attract motivated and gifted students to the curriculum and then to the energy sector.

- *International network building.*
  Making contacts and including internationally recognized scientists and specialists within various aspects of planning methodologies guarantee scientific substance and quality. International network building is encouraged by the Norwegian Research Council and is also much emphasized in research within the European Union (EU).

11 Importance to Norwegian industry

The importance to Norwegian industry and public energy agencies can be described from different point of views:

- *Competence building and new knowledge*
  The project will contribute to new knowledge and models for planning, design and operation of mixed energy distribution systems. More specifically, development of system, load and environment data models, collection of data for testing of planning models, feasibility studies, estimation of market potential and benefits of new technologies, products and services, improvement of infrastructure management etc. The project will contribute to the industries' internal competence building through courses, workshops and seminars.
- *Strengthening the ties between the university and industry*
  The project will contribute to and improve the industrial basis for the curriculum 'Energy and environment' at NTNU. The candidates will obtain more relevant competence as the project provides:
  - Meeting place for students, industry and scientists
  - Exchange of ideas and user needs on workshops and seminars
  - Student projects and thesis work in close co-operation with industrial partners.
- *New activities/products*
  Scientific based methods and models are also necessary prerequisites for improved commercial software tools adequate for planning sustainable energy systems for the future. Several existing – and blooming – consulting companies in the energy sector are based on know-how and knowledge implemented in software products. This project proposal is aiming at providing the knowledge base for the new generation of tools for distribution systems planning.
- *National goals*
  From Norwegian governmental and public energy agency point of view there are national goals regarding development of supplemental energy supply to the traditional hydroelectric power system, such as wind power and district heating. Energy companies will need qualified candidates to plan 'optimally' in order to reach good solutions from technical, economical and environmental point of view, as well as user quality point of view. The project will definitely contribute through more qualified candidates from NTNU.

12 Relevance for IE Innovation programs

The proposed project has particular relevance to the innovation program 'Energy, Environment, Construction' (EMBa) within the Norwegian Research Council's Industry and Energy program. In this program it is stated that we in the future will see more complex energy systems which present totally new requirements to <u>system knowledge and competence</u>. Effective organization and co-operation between the different actors are important issues. The proposed project activities called 'Building the scientific knowledge base' (for planning methods and tools) and 'Project co-ordination' is looking particularly at these important concerns, and should therefore be very timely and relevant to the EMBa program.

Furthermore, it is observed that the network building activity, nationally and internationally emphasized in the proposed project is in line with the idea of building 'Networks of Excellence' within the upcoming EU research program in the energy area.

13 Environmental impact

One of the proposed doctoral projects is particularly aiming at how to deal with environmental impacts in the planning methods. This project is called '*Environmental aspects and consequences'* described in section 3.2.3 above. Another doctoral project is called '*Multiple criteria decision methods'*, section 3.2.4, and one of the main ideas here is to include environmental aspects in the set of criteria that characterize a certain plan and therefore have influence on the decisions. Hence, the proposed project will have a substantial impact on how environmental issues are included in the planning process. The overall effect will be a positive environmental impact.

14 Information and dissemination of results

Exchange of information about the project (activities, events, progress, ideas, terminology, models, etc) and dissemination of results are essential elements in the process of building a scientific knowledge base. The project will be a meeting place where students, industry and scientists exchange information and knowledge, both within the project, and with external colleagues within 'networks of excellence'. Main 'channels' for exchange of information and dissemination of results are:

- A *web-site* with all available information, and links to related projects, persons, institutions, etc.
- Frequently issued *news letters* (e.g. every sixth month) on the web-site and by email with updates regarding results, events, etc.
- *Workshops* and *seminars* on specific subjects in the project where students, industry and scientists come together to create, develop and exchange ideas.
- *Courses* on MSc and PhD levels, conducted by visiting scientists, PhD students, and research scientists at NTNU and SINTEF Energy Research.
- *Publications:* Journals and conferences
- *Tutorials* in planning, design and operation of mixed energy distribution systems that also focuses on environmental requirements.

PART 3: Background information (enclosures)

a. Project partner form

b. Declaration from the main industrial partners

c. Information regarding professional competence

d. Suggested expert reviewers

e. Comments on the project from INESC Porto

a. Project partner form

Prosjekt-/seksjonsnr.: ____________________
Prosjekttittel: **Sustainable energy distribution systems**
Program: **EMBa** **Energi og Petroleum**
Utfylt av /dato: **Arne T Holen** **2002-06-06**

Kontraktspartner:

Org.navn	Org.nr. (9 siffer)	Adresse		Antall* ansatte
		Postnr.	Poststed	
NTNU, institutt for elkraftteknikk				
		N-7491	Trondheim	

Norske samarbeidspartnere (inkl. selvstendige lokale enheter i større bedrifter)**:**
Samarbeidspartnere er enheter som ifølge godkjent prosjektplan bidrar til prosjektet med finansiering (penger/egeninnsats) eller er innleid i prosjektet for å utføre FoU-aktiviteter.

Org.navn	Org.nr. (9 siffer)	Adresse		Antall* ansatte
		Postnr.	Poststed	
SINTEF Energiforskning	NO 939 350 675			180
		N-7465	Trondheim	
Statoil ASA	Legal Reg No 8210380	Arkitekt Ebbells veg 10		16900
		7005	Trondheim	
Statkraft SF (på vegne av alliansen)	NO 962 986 277	Veritasveien 26		800
		1323	Høvik	
Viken Nett AS		Postboks 2468 Solli		
		0202	Oslo	
Lyse Energi AS	NO 980001482	Postboks 8124		500
		4069	Stavanger	

* antall ansatte skal kun oppgis for bedrifter

Utenlandske samarbeidspartnere (bidraget fra disse trenger ikke å inngå i prosjektregnskapet)**:**

Org.navn	Land	Adresse
Univ. of Porto/INESC	Portugal	Praça da República 93, 4050 - 497 Porto
Helsinki univ. of Techn./VTT	Finland	Power systems lab., P.O.Box 3000, FIN – 02015 HUT

b) Declaration from the main industrial partners

Partner: STATOIL ASA , Arkitekt Ebbells veg 10, 7005 Trondheim, Legal Reg No:8210380

Funding (intention): 1000 NOK per year in the period 2003 - 2007

1000 NOK

2003	2004	2005	2006	2007
150	150	150	150	150

Other contributions

Statoil Asa (Research center) will be involved in the project work by the following contributions (marked with X):

Participation in reference groups, steering committee etc.	X
Making data and cases available	
Student projects and examination works	
Testing of methods and models	
Own (internal) activities related to the project	

Date: 21/05-02…………………. Signature:Kåre Kløv…………………………………..

KMB Project: Sustainable energy distribution systems: Planning methods and models

Declaration from industrial partner

Partner: **STATKRAFT SF**
Org. nr. NO 962 986 277
Forretningsadresse: Veritasveien 26. 1323 Høvik

Funding (intention): <1000 NOK per year> in the period 2003 - 2007

1000 NOK

2003	2004	2005	2006	2007
250	250	250	250	250

Other contributions

The alliance Statkraft SF, Trondheim Energiverk (TEV) and Bergen Kommunale Kraftselskap (BKK) will be involved in the project work by the following contributions (marked with X):

Participation in reference groups, steering committee etc.	X
Making data and cases available	X
Student projects and examination works	X
Testing of methods and models	X
Own (internal) activities related to the project	X

Date: 16/5-02 .... Signature: [signature] ....

KMB Project: Sustainable energy distribution systems: Planning methods and models

Declaration from industrial partner

Partner: Viken Nett AS, P.O. Box 2468 Solli, N-0202 Oslo,

Org. No.: NO 980 489 698 MVA

Funding (intention): <1000 NOK per year> in the period 2003 - 2007

1000 NOK

2003	2004	2005	2006	2007
100kNOK	100kNOK	100kNOK	100kNOK	100kNOK

Other contributions

<The company> will be involved in the project work by the following contributions (marked with X):

Participation in reference groups, steering committee etc.	X
Making data and cases available	
Student projects and examination works	
Testing of methods and models	X*
Own (internal) activities related to the project	X*

* To be discussed!

Date:……2002-05-31….   Signature:…Jan Chr. Andreassen ……..

10/6 - 2002.

KMB Project: Sustainable energy distribution systems: Planning methods and models

Declaration from industrial partner

Partner: Lyse Energi AS, Postboks 8124, 4069 Stavanger, org. nr. 980 001 482

Number of employees: 500

Funding (intention): <1000 NOK per year> in the period 2003 - 2007

1000 NOK

2003	2004	2005	2006	2007
100	100	100	100	100

Other contributions

Lyse Energi AS will be involved in the project work by the following contributions (marked with X):

Participation in reference groups, steering committee etc.	X
Making data and cases available	X
Student projects and examination works	X
Testing of methods and models	X
Own (internal) activities related to the project	

Date:15.05.02 Signature:……………………………………

c. Information regarding professional competence

c1. Project management group

Professor, Dr.ing. Arne T. Holen
He is professor in Electrical Power Engineering at Norwegian University of Science & Technology. He is also scientific advisor at SINTEF Energy Research and currently chairing the program committee for the curriculum Energy and environment at NTNU. His particular areas of research are: Steady state and dynamic power system analysis, reliability and security assessment, application of intelligent systems to power systems. He has been the principal advisor for several dr.ing. (PhD) students in the power system area. He has been involved in international co-operation, such as:

- International Conference on Intelligent Systems Application to Power Systems. Chairman of this conference and co-editor of Proceedings at ISAP'94, Montpellier, France, 5-9 Sept. 1994.
- 13th Power Systems Computation Conference (PSCC'99), June 28-July 2, 1999, Trondheim, Norway, Chairman of local organisation.
- International Journal of Engineering Intelligent Systems for Electrical Engineering and Communications, Member of Editorial Advisory Board.
- Member of Cigré Task Force 38.06.01. “Methods to consider interruption costs in power system analysis”. Report completed in 2000.

Senior Research Scientist, Dr.ing. Gerd H. Kjølle
She is senior research scientist at SINTEF Energy Research, Division of Energy Systems. Her main areas of competence and research are: Reliability analysis of power systems, fault and interruption statistics, interruption cost assessment, electric power network planning (technical-economical analyses), design of electrical distribution networks (MV and LV), information modelling as a basis for network information systems. She has been supervisor for several graduate (MSc) students and lecturer in various courses for personnel at Norwegian power companies. She has been involved in project management and international co-operation, such as:

- Project manager (1993 – 1995) for the development of the fault and interruption information system FASIT (Norwegian standard)
- Project manager for various R&D projects since 1996 concerning power system planning and operation, reliability methods and analyses, assessment of power supply interruption costs
- Project manager from 2002 for a Nordic R&D project regarding reliability based optimal power system solutions for protection, control and automation
- Participant in proposed Networks of Excellence (EU) related to 1) crisis management of urban infrastructure and 2) secure electrical energy distribution
- Member of the European Safety and Reliability Associaton

Senior Research Scientist, MSc. Eivind Solvang
He is senior research scientist at SINTEF Energy Research, Division of Energy Systems. He is also adjunct associate professor in Electrical Power Engineering at Norwegian University of Science & Technology. His main areas of competence and research are: Technical and economical analyses and planning of MV and LV distribution network (investments, renewal and maintenance), network design, network information systems (NIS), strategies and decision support systems for renewal, maintenance and condition monitoring. He has been involved in project management and international co-operation, such as:

- Project manager (1984-1990) for the development of the Netbas transmission and distribution network information system (NIS).
- Project manager for Workpackage 4, ‘Innovative maintenance functions needs’, in the EU/ESPRIT Project REMAFEX (REmote MAintenance for Facilities EXploitation), as well as project co-ordinator for all REMAFEX workpackages at SINTEF Energy Research (1996-1999).
- Project manager for several Norwegian and Nordic R&D projects since 1990 regarding MV and LV distribution network planning and design, including renewal and maintenance planning.
- Secretary of UNIPEDE Group of Experts on “Network configuration and design” (50.04.DISNET). Four reports completed in 1995.
- Member of CIRED WG07 ‘New technologies and tools for network design’ (2000-).

c2. Project participants

Professor, Dr.ing. Olav B. Fosso
He is professor in Electrical Power Engineering at Norwegian University of Science & Technology. He is also scientific advisor at SINTEF Energy Research. His particular areas of research are: Power system operation, steady state security assessment, voltage instability, optimising techniques. He has significant international experience from various CIGRE Working Groups and Task Forces, also as convenor. He has been the Norwegian representative in the CIGRE Study Committee 38 Power System Analysis and Techniques (1994-2000). He is currently member of Technical Programme Committee of Power Systems Computation Conference.

Associate Professor, Rolf Ulseth
He is associate professor at Department of Refrigeration and Air Conditioning, Norwegian University of Science & Technology. He is also scientific advisor at SINTEF Energy Research. His particular areas of research are: heat load and energy demand in buildings, energy supply systems for buildings, energy and heat planning, energy flexible heating systems, heating system simulation. He is active in research executive committees and boards:

- Norwegian Member of the Executive Committee, IEA- Implementing Agreement on District Heating and Cooling Project (Appointed by The Research Council of Norway).
- Norwegian Member of the Executive Board for 'Energy-flexible Heating Systems', Nordic Energy Research Programme. (Appointed by the Ministry of Petroleum and Energy (OED)).
- Norwegian Member of the Executive Board for District Heating Research, Nordic Energy Research Programme. (Appointed by the Ministry of Petroleum and Energy (OED)).

Professor, Per Finden
He is adjunct professor in Energy Systems Planning at Norwegian University of Science & Technology. His main position is Head of Department of Energy Systems at Institute for Energy Technology at Kjeller, Norway. His department is active in local and regional energy planning and has knowledge and experience in development and application of models for scenario studies of energy systems planning. His department is also conducting research on renewable sources: wind, hydrogen and solar systems. As head of department professor Per Finden has an extensive international network within energy systems.

c3. Selected international publications

Warland L., Holen A.T.: Estimation of distance to voltage collapse: Testing an algorithm based on local measurements. Proceedings of 14th Power Systems Computation Conference (PSCC'02), Sevilla, Spain. June 24-28, 2002.

Korpås M., Hildrum R., Holen A.T.: Operation and sizing of energy storage for wind power plants in a market system. Proceedings of 14th Power Systems Computation Conference (PSCC'02), Sevilla, Spain. June 24-28, 2002.

Kjølle G., Holen A.T., Samdal K., Solum G.: Adequate interruption cost assessment in a quality based regulation regime. Proceedings of IEEE Porto Power Tech, Porto, Portugal. September 10-13, 2001.

Warland G., Holen A.T.: Transmission operating limits: A decision problem in the environment of uncertainty. Proceedings of Probability Methods Applied to Power Systems (PMAPS' 2000), Funchal, Madeira. September 25-28, 2000.

Warland G., Holen A.T.: Fuzzy models in power system security assessment and power system operation. Proceedings of Intelligent Systems Applied to Power Systems (ISAP'99), Rio de Janeiro, Brazil. April 4-8, 1999.

Heggset J., Kjølle, G.: Experiences with the FASIT reliability data collection system.
IEEE/PES Winter Meeting, January 2000, Singapore.

Kjølle, G; Uthus, B; Heggset, J.: Assessment of power supply interruption cost. Proceedings of European Conference on Safety and Reliability, ESREL 98, Trondheim, June 16-19, 1998.

Kjølle, G; Holen, A. T.: Reliability and interruption cost prediction using time dependent failure rates and interruption costs, Quality and Reliability Engineering International, vol.14 1998, s. 159-165

Heggset, J., Kjølle, G., Trengereid, F. Ween, H.O.: Quality of supply in the deregulated Norwegian power system, Proceedings of IEEE Porto Power Tech, Porto, Portugal, September 10-13, 2001.

Ulseth, R. Stang, J., Hoel, T. I., Noeres, P., Klose, P., Hölder, D., Althaus,W., Ahonen, M., Koo, Ki-Dong: District Heating and Cooling in Future Buildings, Report from IEA-project, Novem NL, 1998: T5, ISBN 90-5748-006-9.

Ulseth, R., Volla, R., Stang, J., Frederiksen, S., Johnson, A., Besant, R.: Efficient Substations and Installations (CHESS-ESI), Report from IEA-project, Novem NL, 1996: N5, ISBN 90-72130-88-X.

Belsnes M, Fosso O B, Warland G: 'Combining production and transmission system using relaxed constraints', Proceedings of 14th Power System Computation Conference, Sevilla, Spain, June 24 – 28, 2002.

Fosso O B, Gjelsvik A, Haugstad A, Mo B, Wangensteen I: 'Generation scheduling in a deregulated system. The Norwegian case', IEEE Transactions on Power Systems, Vol.14, no 1, Feb. 1999.

c4. International participants

University of Porto and INESC

Professor, Ph.D. Vladimiro Miranda
He is currently Director of INESC Porto and Associate Professor at the Faculty of Engineering of the University of Porto. His particular areas of research are: Power system planning and analysis, soft computing (fuzzy sets, evolutionary computing, neural networks) applications to power systems. Multiple criteria decision aid. Professor Miranda is very well known and recognised internationally, often used as keynote speaker at international conferences within his areas of research.

Professor, Ph.D. Manuel Matos
He is currently Professor at the Faculty of Engineering of the University of Porto and is also co-ordinator of the Power Systems Unit of INESC. His particular areas of research are: Tools for decision-aid and analysis, including fuzzy sets and multiple criteria decision aid. Professor Matos is recognised as an international expert in decision-making techniques giving tutorials at international seminars and courses.

Selected publications:

Van Acker, McCalley, Matos: Multiple Criteria Decision Making using Risk in Power System Operation, Proceedings of PMAPS'2000, paper PSO2-127.

V. Miranda, L.M. Proença, Why Risk Analysis outperforms Probabilistic Choice as the effective decision support paradigm for power system planning, IEEE Transactions on PWRS, vol 13, n.2, May 1998

V. Miranda, Fuzzy reliability analysis of Power Systems, Proceedings of PSCC 96 - 12th Power System Computation Conference, Dresden, Germany, Aug.19-23 1996

Research projects

- JAC - Advanced Control of Power Systems with Renewable Sources through Neural Networks - a **JOULE** project
- SOLARGIS - GIS/based information system for the assessment of the economic interest of renewable energy sources in industrialized and developing countries - a **JOULE** project
- DMS2000 - Distribution Management System Advanced Concepts for EDP - Electricidade de Portugal, SA. - an **ESPRIT** project

- ESCADINA - Cooperation in Energy Systems with the Universities of Lodz, Poland, and Athens, Greece - a **TEMPUS** project
- JOR3-CT96-0119 - Advanced control advice for power systems with large-scale integration of renewable energy sources - CARE.

Helsinki University of Technology and VTT

Professor, Ph.D. Matti Ilmari Lehtonen
He is currently Professor of Information Technology Application in Power Systems at Helsinki University of Technology and is also a research scientist at the Technical Research Centre of Finland (VTT). His particular areas of research are: Applications of information technology in power systems and distribution automation. Professor Lehtonen is a well-known expert within his areas of research and he has been a member and convenor of CIRED working groups related to fault location, distribution automation and distribution utility telecommunications.

Professor, Ph.D. Seppo Tapio Kärkkäinen
He is currently a research professor at the Technical Research Centre of Finland (VTT). His particular areas of research are: Energy economy, demand-side management and integrated resource planning, competitive electricity market. Professor Kärkkäinen is a well-known expert within his areas of research and he is a member of various professional societies and has been a chairman or vice-chairman in different conferences within organizations such as IEEE, IFAC, IEA and DA/DSM.

Selected publications:

Kärkkäinen, Seppo, Lakervi, Erkki, Heine, Pirjo: DSM and customer services in competitive electricity market in Finland. Cired'99 Conference. 1 -4 June 1999. Nice. 5 p.

Sipilä, Kari, Kärkkäinen, Seppo: Demand Side Management in District Heating Systems. Euroheat & Power - Fernwärme international 3/2000, pp. 36 - 45

Kärkkäinen, Seppo: Energy Efficiency Based Products and Services in Competitive Electricity Market - The Utility Perspective. IEA International Conference ‘Energy Efficiency in Distribution and Usage of Electricity’, Ankara, April 3 - 4, 2000. 31 p.

Lehtonen, M., Matsinen, A., Antila, E. Kuru, J.: An advanced model for automatic fault management in distribution networks. . IEEE PES Winter Meeting 2000, January 23-27, 2000, Singapore.

Hänninen, S., Lehtonen, M.: Earth fault distance computation with artificial neural network trained by neutral voltage transients. IEEE PES Summer Meeting, 15^{th}-19^{th} July 2001, Vancouver, Canada.

Research projects

- TESLA – Information technology and electric power systems
- EDISON – Network automation, control centre computer systems, demand side management, computer tools in deregulated power market and the telecommunication technologies
- EU-SAVE - Improved strategies for better environmental quality and energy efficiency in a changing electricity market

c5. Co-operating institutions

University of Washington, Seattle

The research activity at this university, which is particularly relevant for the proposed project is an investigation of the technical and economic impact of distributed generation on the power grid, including advanced control techniques. University of Washington will be a co-operating institution in the proposed project and mainly through exchange of Ph.D. students and short term visiting scientists.

Professor, Ph.D. Chen-Ching Liu
He is currently Professor at Department of Electrical Engineering and Associate Dean of Engineering at University of Washington, Seattle, USA. He is also Director of Advanced Power Technologies (APT) Centre at the Department of Electrical Engineering. His areas of research particularly relevant for the proposed project are: Intelligent systems applications to power systems, decision making and risk assessment applied to competitive electricity markets, distributed generation in an open access environment. Professor Liu is very well known internationally within his areas of expertise. He has been Principal Investigator in several research grants/contracts sponsored by Department of Defense, National Science Foundation, Electric Power Research Institute, Puget Sound Energy, Bonneville Power Administration, PECO Energy, Pacific Gas & Electric, ALSTOM ESCA, Mistsubishi Electric, LG Industrial Systems, and CESI. He has achieved several honours and recognitions.

Selected publications:

C. C. Liu, J. Jung, G. T. Heydt, V. Vittal and A. G. Phadke: Conceptual Design of the Strategic Power Infrastructure Defense (SPID) System, IEEE Control System Magazine, Aug. 2000, pp. 40-52.

G. T. Heydt, C. C. Liu, A. Phadke and V. Vittal: Solutions for the Crisis in Electric Power Supply, IEEE Computer Applications in Power, July 2001, pp. 22-30.

d. Suggested expert reviewers

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e. Comments on the project proposal from INESC Porto

Comments on the project SEDS (Sustainable energy distribution systems: Planning methods and models)

Vladimiro Miranda, Manuel Matos

March 2002

Abstract

This document summarizes the comments of INESC Porto about the project SEDS (Sustainable energy distribution systems: Planning methods and models), including the identification of the technical and scientific aspects where INESC Porto may have a contribution and the cooperation procedures that could be implemented.

1. The project concept

Although the purpose of the present comments is not to make a judgment about the merits of the project SEDS, it is important to point out that this initiative of the Department of Electric Power Engineering of the Norwegian University of Science and Technology is very timely and well founded, also presenting a very good scientific and didactic potential. Therefore, it was with pleasure that INESC Porto (together with the Faculty of Engineering of the University of Porto) accepted the invitation to collaborate in the project, as international partners.

As a general comment, it seems that three main aspects must be emphasized:

- Modularity. Due to the complexity of the subjects covered by the project, and also because of its educational purpose, it is advisable to structure its activities in separate modules (as much as possible). This requires an initial phase dedicated to the specification of module contents and interconnections (namely regarding a common database). This strategy allows the assignment of smaller modules to graduation students' projects, while more complex modules could be assigned to MSc and PhD work. Of course, coordination and integration tasks must also be defined, in order to maintain the integrality of the project objectives.
- Experimental nature. There is always an added value, both for didactic and research purposes, when the possibility of experimenting is included. We strongly recommend that this feature will be central in the project, namely through the development of simulation functionalities. This idea implies the implementation of a *simulation platform* where the different modules are progressively incorporated, allowing the user to try and see the result of a decision or of a set of decisions. It should be pointed out that this feature can be understood at different levels, from simple decisions (e.g. "building three new feeders in 2005") to decision paradigms (e.g. "minimizing regret"). In any case, since decisions are made from the point of view of a specific agent, the platform must include some way to represent (or sample) the behavior of other agents (see 2.2 for a small discussion on this subject). Note also that *policy simulation* should also be possible, through constraint changes, penalty variation (e.g. decreasing emission limits or widening the incentives for good quality of service) or by setting new rules, allowing a true evaluation of social impacts.
- Didactic nature. Besides the participation of students in the development of the modules, the experimental characteristic mentioned before is directly usable as a tool to give students insight regarding the problems and methodologies associated with planning. This is a clear benefit from the project, which opens the possibility of exploiting the final results by the international academic community.

In summary, it seems advisable to use this idea of a simulation platform as the kernel of the project, working as an infrastructure where the scientific, technical and didactic developments are incorporated in a structured way. This will give everyone an objective framework of reference to his work, but it is not an obstacle to complementary developments, not directly related to the platform implementation.

2. Technical and scientific participation of INESC Porto

2.1 Geographical Information Systems

The modern understanding of sustainable energy distribution must be allied to two factors: competition (market) and geographical representation.

The geographical representation is achieved with the use of GIS – Geographical Information Systems. However, GIS should not be understood as just a repository of data. Modern GIS are equipped with efficient tools able to deal with massive quantities of data in complex parallel-like operations. Therefore, the challenge is to develop modules that make direct use of such tools in building computationally efficient simulation environments.

While it is true that GIS may be associated with heavy computation efforts, it must be recognized that it is the most efficient way to build a comprehensive model of phenomena that have clear geographical dependencies. In fact, GIS allow the apprehension of factors that influence the development of the phenomena - but GIS also provide a unique interface, extremely flexible and allowing a holistic perception of results and their consequences.

The development of competitive energy distribution systems will be strongly dependent of local conditions, in each case, which will determine neighborhood characteristics, preferences, costs, feasibility of supply, competitive advantages and many other factors. All these factors should be captured directly from maps by automatic and intelligent tools. This approach will contribute to building a general model and a simulation platform not dependent of the specific characteristics of a given problem.

2.1.1 Spatial forecasting

One of the strong efforts in the project should be the development of true spatial demand forecasting models, that may display geographical realism and represent accurately the interactions among competitors and potential clients, and also give explicit inclusion to geographical influence factors, which may be depending on orography, on urban development plans and on neighborhood effects. Furthermore, only a spatial prediction of demand will correctly interact with plans of development for infrastructures such as networks and localized conversion processes (gas to electricity, electricity to heat, etc.).

Spatial forecasting for electric power is not entirely new; however, at INESC one has recently developed fuzzy inference systems (FIS) on GIS that take in account influencing factors to produce a prediction of demand growth for a region, spread out through the territory.

This kind of spatial forecasting, with FIS-on-GIS, is so powerful that its concept may be surely applied to a diversity of energy types. The fact that the FIS-on-GIS is based on rules and not only on a mathematical model makes it a powerful tool to build models of behavior for the diversity of agents playing in the local energy market.

Furthermore, one cannot envisage a working simulation platform for energy distribution expansion without having, at its foundation, the most powerful demand prediction model.

2.1.2 Simulation platform

The concept of simulation platform puts together several contributions and concepts.

Modularity. One should aim, not at a finished and polished model, but at an open-ended platform, where new modules could be plugged in at any time, testing for new models, new strategies, new market rules, etc.

Interactivity. One should aim at the highest degree of interaction between human and models, to assure not only the didactic nature of the platform but also the full understanding of the results obtained, it its full complexity.

Agent-based approach. The platform should allow the representation of any kind of agents in the market with total independence (distributors, consumers, regulators, etc.), and in the form of “black boxes” reacting on the input of variable values, sensed from other agents outputs. Special agents such as “observers” could be defined in order to extract values for human information, or “blackboards” to register data of systemic or global nature. The degree of complexity of each agent cannot be foreseen beforehand, but one may state that any internal model could be possible.

Asynchronous operation. The simulations to be performed will develop along time and will include the representation of a number of agents with complex behavior. The interaction among agents should be as asynchronous as possible, to allow the independence of models representing each one and to allow for each one a degree of freedom in the time scale adopted to define each one's behavior. This asynchronous operation will allow each agent to act and react under its own motivations and whenever enough information is available to trigger decisions.

Non-imperative definition. The simulation environment should be as little normative as possible, avoiding the external definition of patterns of behavior of agents. Instead, these patterns should emerge from the natural interaction among agents. However, constraints or global objectives imposed externally would be able to condition such interaction, although not in a direct but rather in an indirect manner.

Evolving agents. The models representing distributors, utilities, consumers or other should be provided with mechanisms allowing evolution, so that new strategies could emerge. In fact, one of the most creative and promising possibilities offered by a simulation platform would be the observation of the development of strategies and counter strategies running along time. At the same time, the competitive environment would also be a challenge to researchers and students to develop new intelligent and evolutionary models for market agents, constituting a further element of incentive to research.

Scenario generator. The definition of agents should allow for a sort of "capacity of prediction" for each type, and this should be coupled with concepts like risk and decision. This is only possible if decisions are taken based on scenario evaluation and this requires that the simulation platform be provided with enough flexibility for such purpose.

INESC Porto has experience in most of the topics mentioned before, namely:

- Spatial demand forecasting;
- Geographical Information Systems and competitive energy evaluations;
- Fuzzy Inference Systems applied over GIS (FIS-on-GIS)

2.2 Risk analysis models

Dealing with uncertainty is one of the major issues in the planning activity. Uncertainty comes essentially from the behavior of consumers, decisions by other agents and macroeconomic parameters, leading in each case, to probabilistic or possibilistic (fuzzy) models or to the definition of scenarios. In order to deal with uncertainty, the following steps are needed:

- Identification and characterization of the sources of uncertainty. This means defining the variables (e.g. heat consumption) and using historical data or expert statements to build adequate models that describe the uncertainty in their future evolution. This may include, besides forecasting, models of demand variation with price and similar approaches.
- Construction of impact models that propagate the uncertainties, leading to (uncertain) measures of feasibility and criteria satisfaction, in the sequence of a possible decision. Combination of models may be necessary, in order to take advantage of existing approaches (e.g. heat market + network models for gas, electricity and district heating). Generally, these compound models are not suitable for analytic optimization (even if we forget the multiple-criteria aspects), so alternative approaches are needed (see 2.4), unless we want to allow many simplifications. Of course, the impact models will be directly used in the simulation exercise, in conjunction to a random generator.
- Definition of possible *decision paradigms* for each agent – robustness enhancement (including different types of regret minimization) is one of the hypotheses, but other choices are possible (e.g. utility models) and can be maintained as simulation alternatives. Also, different agents may have different paradigms, due to their attitude towards risk. As an alternative, deterministic equivalents related to risk may be constructed and incorporated as additional criteria (robustness index, repressed demand index, cost percentiles, probability of loss, etc.).

It is worth mentioning that failure events represent a special type of uncertainty, usually addressed in the framework of *reliability studies*, that generate deterministic equivalents like the expected energy not supplied (ENS) or other reliability indices such as SAIFI (system average interruption frequency index), SAIDI (duration), CAIFI or CAIDI (customer). Therefore, they usually constitute planning criteria (see 2.3) and the related uncertainty is not generally included in risk related models, expect for the fact that the indices vary with load uncertainty.

Agents modeling utilities, for instance, will need to take in account reliability by "sensing" the target or threshold values sent to them by agents representing regulators, to develop a behavior that may avoid penalties; but also they can include reliability as a strategic target required to avoid client insatisfaction and conquest by competitors. In either case, reliability is present, but it will be evaluated by distinct models inside the agent representing a utility.

INESC Porto has experience in most of the topics mentioned before, namely:

- Uncertainty modeling, through fuzzy approaches and scenario definition;
- Impact models for electricity and gas and simple energy markets (see **Error! Reference source not found.**);
- Reliability models and techniques;
- Monte-Carlo methodologies;
- Definition of consistent decision paradigms;
- Development of utility models;
- Construction of deterministic equivalents.

2.3 Multicriteria models

Minimizing the investment cost is always an essential criterion in every planning exercise, from the point of view of a distribution company, that nevertheless is also sensitive to operation cost (which includes losses in electric networks) and may be required to follow technical (e.g. voltage level), environmental and reliability constraints. If energy traders are to be considered, their criteria are of course different, since they must minimize fixed and variable costs and maximize their gross profits. If the model reaches generation companies, minimization of generation costs and minimization of emissions are the relevant criteria, for a specific energy price. Consumers want to minimize the total price they pay for a specific amount of energy, and they have also goals regarding reliability indices. Finally, regulatory authorities (working as just another class of agents) may define hard or soft constraints regarding the quality of supply, or they may establish penalties or incentives related to reliability, associated to targets or thresholds that they define and communicate to other agents. All of this may vary very much from country to country.

On the other hand, as stated in the previous section, deterministic equivalents of uncertain outcomes may be introduced as additional criteria. Soft constraints may also be modeled this way, with a *degree of constraint satisfaction* that must be maximized.

Therefore, we have, for each agent, a decision problem with multiple criteria, where the concept of optimal decision (or solution) makes no sense, since the criteria are generally conflicting. The *preferred solution* will be thus one of the efficient (or non-dominated) alternatives, according to the preferences of the specific agent and the available information at each (asynchronous) moment of decision. Modeling these preferences may be done in many different ways, from prescriptive approaches (like value functions) to decision-aid methodologies, passing through interactive procedures. It is also to point out that, since there are different agents, each one with particular points of view, it is also not possible to find a *global preferred solution* (and even less a global optimum), in the sense this concept had in centralized planning.

INESC Porto has experience in building multicriteria models for many problems related to electricity and gas systems planning (including network planning), and also regarding different types of methodologies appropriate to address this issue, including true formal procedures for constructing value functions.

2.4 Use of Meta-heuristics

An important aspect is the generation of feasible alternatives and the search for optimality (even if a global optimum doesn't exist). In the proposed simulation platform, each agent will own its particular optimization process, based on the rules at its core and the available information at any moment. Therefore, each agent may need to search for an adequate strategy to expand its business or simply to survive. In such a complex environment, meta-heuristics are an attractive alternative to classical optimization models, because they allow exploring multiple scenarios and multiple solutions. Evolutionary computing, among the meta-heuristics available nowadays, seem to be the most promising.

Furthermore, evolutionary computing models have in themselves already the basic ideas of evolution and improvement and therefore are likely to be extremely compatible with the simulation platform concept proposed.

INESC Porto has extensive experience with meta-heuristics such as simulated annealing, genetic algorithms, evolutionary programming, evolution strategies and even particle swarm models.

3. Cooperation procedures

INESC Porto is available to cooperate in the development of project SEDS, in the forms that may be agreed upon. These include the following:

Cooperation in the general project concept development.

The project should be organized in the form of tasks clearly assigned to each partner, so that the responsibility is clearly identified, the manpower and other resources clearly allocated, a schedule organized, and so that a specification may be written and targets may be defined, allowing a judgment on its completion and success.

Task specification and development.

For each task assigned, INESC Porto will allocate the necessary resources to deliver the expected results.

Consulting.

INESC Porto will make its specialists available to cooperate with the project in a consulting role, for all tasks that have not been directly assigned to it. This cooperation will include the availability to travel to Trondheim for regular meetings.

Reception of visitors.

INECS Porto will gladly receive visitors in the frame of SEDS, for short periods of stay. These visitors may be senior scientists of students wishing to establish contact with the working environment of INESC Porto.

PhD Programmes.

INESC Porto will open the possibility to exchange students at the level of post-graduation, and to include students from Throndheim in its own Ph.D. programmes.

Ownership agreement.

INESC Porto is open to discuss, within the frame of the project and of the assigned tasks to each partner, forms of translating partner involvement into ownership and exploitation of results.

Financing.

INESC Porto is open to discuss with the partners and with the project leader the financing requirements needed to complete the assigned tasks, and is ready to cooperate in demanding and obtaining financing from any convenient sources, namely in the European Union.