



**2009 EDITION**

PLANNING OF  
**OPTIMAL POWER SYSTEMS**

ASKO VUORINEN

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**2009 Edition**

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The book is available for internet orders  
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## **Preface**

It has been a privilege for me to be in the team of engineers planning and building the Finnish power system from the hydro to the nuclear age. In the beginning of my engineering years in 1970, Finland had 3500 MW power capacity or less than one kW/capita. The average construction pace was about 600 MW power capacity annually between 1970 and 2000. The total capacity today is 16 000 MW or 3 kW/capita. Finland is now the world leader in combined heat and power capacity per capita (1 kW/capita) and number three in nuclear capacity per capita (0.5 kW/capita) after Sweden and France.

It was a small step for me in 1992 to change from my utility engineering job to an export engineering service in the Wärtsilä Corporation; the leader in selling diesel engines to developing countries and remote places. The Finnish engineering industry is building about 2000 - 3000 MW of power capacity annually for the export markets in Europe, the United States of America and in the developing world.

The liberalisation of the power markets started in the UK with the Electricity Act of 1989. It made the generation, transmission and distribution of electricity unbundled and separate sectors of electricity markets. The Nordic countries have been among the first countries to have liberalised the electricity markets after the UK. The opening of the ancillary service markets started in 1996 in the USA. The FERC determined about ten ancillary services that should be offered as competitive products in the new electricity markets. Among them were the automatic generation control (AGC), the spinning, and the non-spinning reserves.

The largest challenge is to build a future power system that would be economically optimal and at the same time environmentally sound. In this book the main idea is to give the planner basic tools to find the optimal system for the future. We will start from the basics of power plant concepts and their cost estimates. The main goal is to plan an optimal system that gives the lowest costs and satisfies the criteria of greenhouse gas emissions.

Finally, an optimal power system for the world in the year 2050 and a strategy, how to get there has been outlined. For the decision makers a good plan is like a map; it will give us the correct way to a better energy future.

This is a 2009 edition of the book on power system optimisation originally written in 2007. I have now updated all prices to be relevant for power plants that will be starting commercial operation in 2012. The new chapter three describes the fundamentals of emissions control and global warming issues. The new chapter five describes the optimisation of decentralised power systems and wind power.

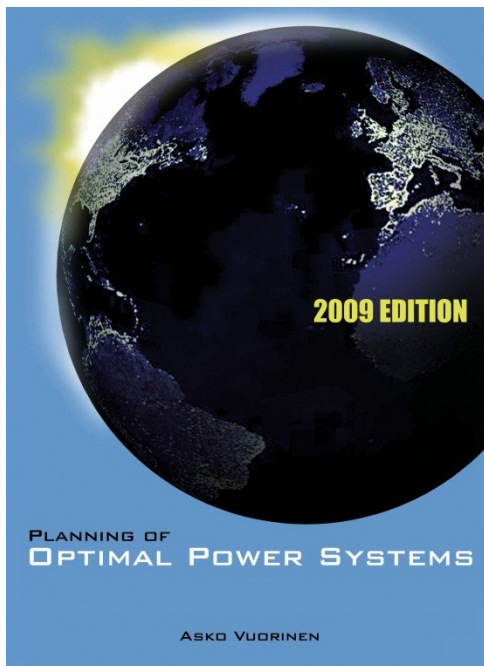
This book is made to encourage the electricity planners to make their own plans. The case examples have been created by using Excel-programs. The programs used in this book are available on the internet, at [www.optimalpowersystems.com](http://www.optimalpowersystems.com).

November 2008 in Espoo

Asko Vuorinen

## PLANNING OF OPTIMAL POWER SYSTEMS

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The power industry is changing very rapidly because the electricity markets are becoming competitive. The new competitive markets have ancillary services, which will change the competitive positions of power plants completely. In the new markets the flexibility is one way to achieve competitiveness.

Much of the contents of the book have been given to explain, how the power plant owner can get more net revenues from the regulation, spinning and non-spinning services. The author shows, how the profitability analysis of the new power plants can be made in the competitive markets, which will trade also the ancillary services.

The main emphasis in the book is to plan optimal capacity mix in national and municipal power systems. The methods how to plan the optimal capacity mix of combined heat and power plants in the municipal system has also been demonstrated.

The optimal system of the world in 2050 has been planned and the strategy of the future investments has been outlined. The electricity demand will be more than double and the emissions of greenhouse gases should be reduced by 30 % from the present level. The readers are encouraged to plan the optimal systems of their home countries using the same programs, which are available at internet site ([www.optimalpowersystems.com](http://www.optimalpowersystems.com)).

**Author: Asko Vuorinen**



The author, Asko Vuorinen is from Finland which has had good and bad experiences from the competition since 1996. Finland has the highest electricity consumption per capita in the EU area and it has the highest CHP capacity per capita in the world.

It has four nuclear reactors in operation, one reactor in Olkiluoto in construction and two reactors in planning stage. The nuclear generation per capita in 2015 will be the highest in the world (7500 kWh/capita) after 2015 the Olkiluoto 3 plant will be in operation.

## **CV**

### **Education**

- **High School:** Keski-Suomen Yhteiskoulu, Student examination 1965
- **Technical University of Helsinki**, Electrical Department, Control Systems and Automation, Master of Science 1971
- **Technical University of Helsinki**, Mechanical Engineering Department, Power Plants and energy Economics, Licentiate 1994

### **Work experience**

- **Imatran Voima Oy**, Nuclear Power Project, Design Engineer of the process computer system of Loviisa Nuclear Plant 1971-80
- **Imatran Voima Oy**, Power Plant Dep., Chief Design Engineer of investment and feasibility studies for new power plants, 1981-91
- **Wärtsilä Oy, Modigen Oy**, Managing Director, Development of gas and oil fired power plants, trading of electricity and planning of power systems in several countries including Finland, USA, India, Russia, Estonia and Latvia 1992-2010
- **Ekoenergo Oy**, Energy consulting and energy systems planning, teaching energy systems and publishing books and internet pages 2010-

## **Part time jobs:**

- **Ekoenergo Oy, Family Company**, Managing director, energy saving and consultation services 1979-2010

- **Espoon Jalkapalloilun Tuki Oy**, Managing director, construction of football hall and maintaining building and property services, 1989-2005

- **Espoo Stars Oy, Football Club**, Managing director, financing of football club and establishing youth soccer services 2001-2005

- **Teovision Oy, Family company**, Managing director, construction and maintaining building and property services, 2006-

- **Lappeenranta University of Technology**, teacher in doctoral course of Power Systems, 2012-

## **Publication of following books:**

1. **Planning of Optimal Power Systems**, the first edition 2007, 349 p. second edition 2008
2. **Energiankäyttäjän käsikirja** (Energy User's Handbook). 204 p., 2009
3. **Planning of Nuclear Power Systems to Save the Planet**, 304 p., 2011
4. **Energiankäyttäjän käsikirja 2013**, 241 pages, 2013

## **Fortum Oy (e.g. Imatran Voima Oy)**

Originally a state owned utility company which is building power plants and transmission networks. Today the company is generating 53 TWh of electricity and 17 TWh of heat in Nordic Countries, 17 TWh of electricity and 25 TWh of heat in Russia and about 2 TWh of electricity and 7 TWh in other countries including Poland and Great Britain. The company has power capacity of about 10.000 MW and turnover of 6000 million euros annually.

## **Wärtsilä Oy**

Wärtsilä is one of the oldest engineering companies in Finland, which was established in 1834. It is constructing, selling and maintaining diesel, gas and dual fuel engines for power plants. Today the sales of engines for power plants and marine applications are about 6000-8000 MW annually. The power plants sales in about 3000-4000 MW, which includes 2000 MW of gas and dual-fuel power plants and 1000 MW of oil fired plants. The turnover of Wärtsilä is about 5000 million euros annually.

## **Ekoenergo Oy**

Ekoenergo Oy was established as a consulting company for energy services in 1979. It is one of the first companies which are thinking ecologically to save the world. It is publishing books and maintaining internet pages for education purposes. The books have been used as a text books in many universities and internal courses in large companies.