Microgrids – A Possible Future Energy Configuration?

Nikos Hatziargyriou
Nh@power.ece.ntua.gr
NTUA, Greece

Goran Strbac
Goran.Strbac@umist.ac.uk
UMIST, UK

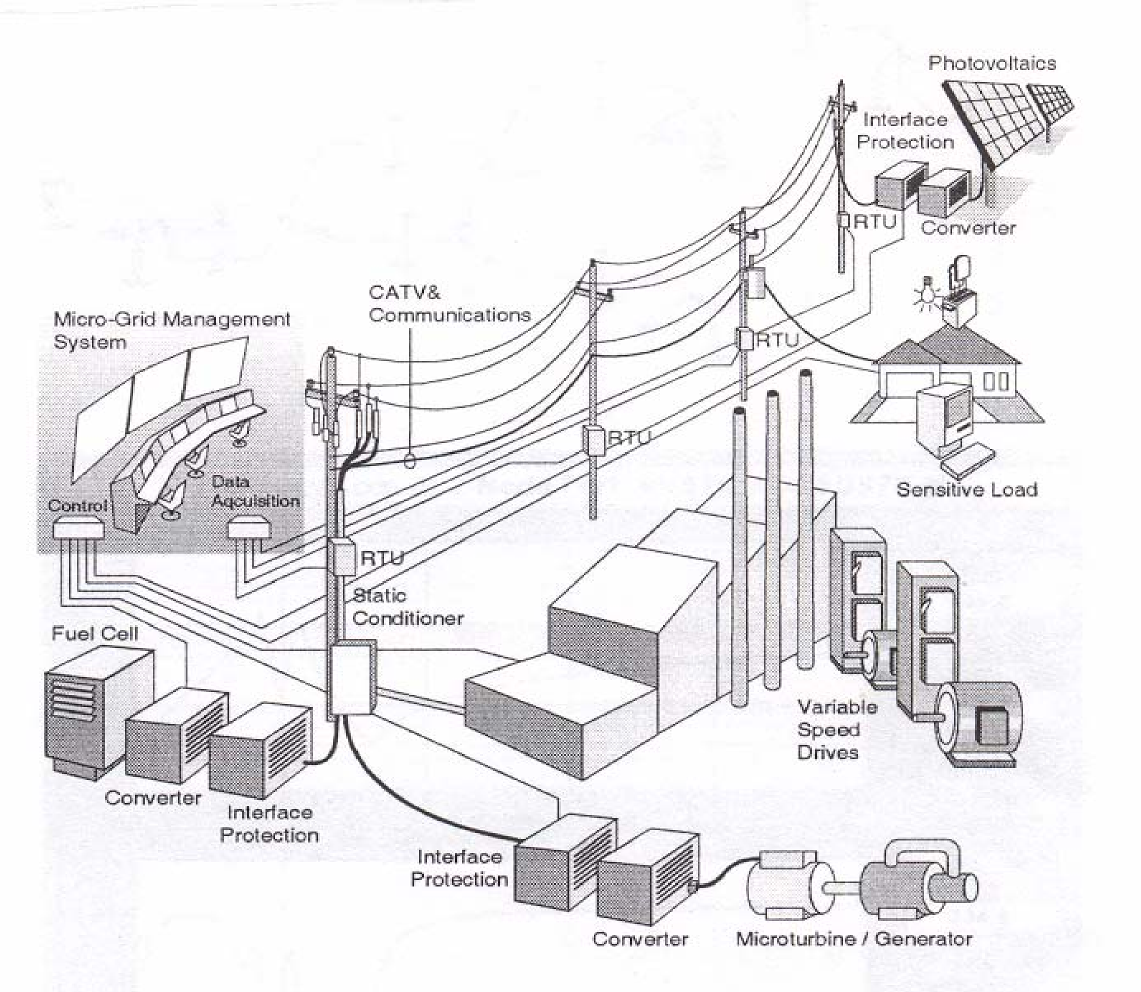
IEA Seminar "*DISTRIBUTED GENERATION: KEY ISSUES, CHALLENGES, ROLES*", Paris, 1st March 2004

Topics

- Definition
- Technical, Economic and Environmental Benefits of MicroGrids
- Conceptual design of MicroGrids
- Integration requirements and device-network interfaces
- Market and regulatory frameworks for MicroGrids
- Modelling and simulation of MicroGrids
- The MicroGrids Project
- Conclusions

What are MICROGRIDS?

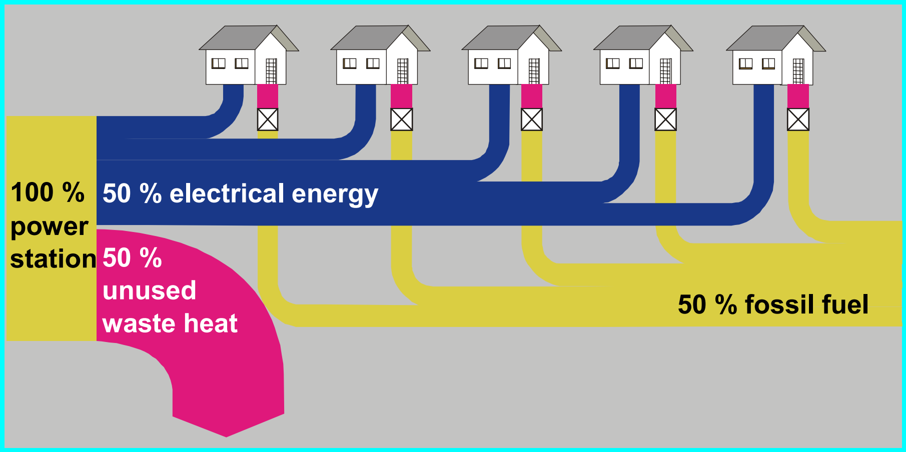
Interconnection of small, modular generation to low voltage distribution systems forms a new type of power system, **the MicroGrid**.
MicroGrids can be connected to the main power network or be operated autonomously, similar to power systems of physical islands.

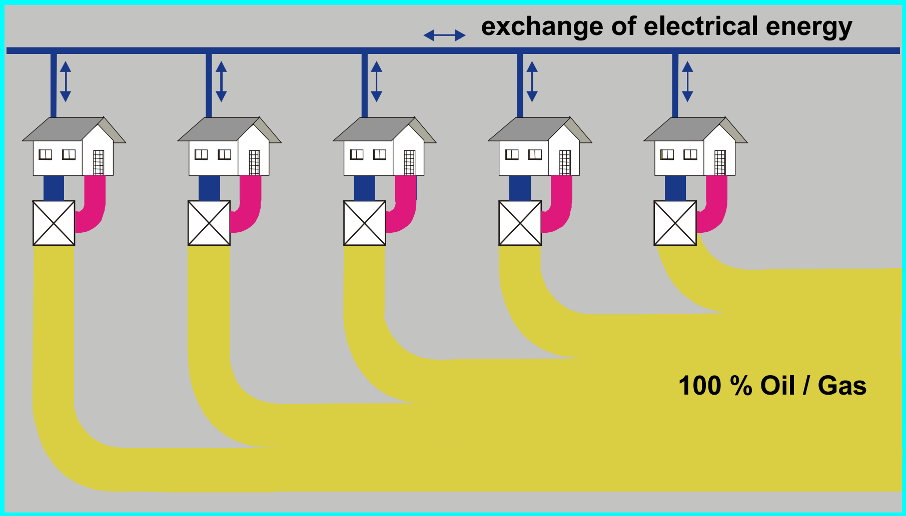


Technical, economic and environmental benefits

- Energy efficiency
- Minimisation of the overall energy consumption
- Improved environmental impact
- Improvement of energy system reliability and resilience
- Network benefits
- Cost efficient electricity infrastructure replacement strategies
- *Cost benefit assessment*

Energy Efficiency - Combined Heat and Power





Prof. Dr. J. Schmid

Up to now:

- Central power stations
- Decentral heat production

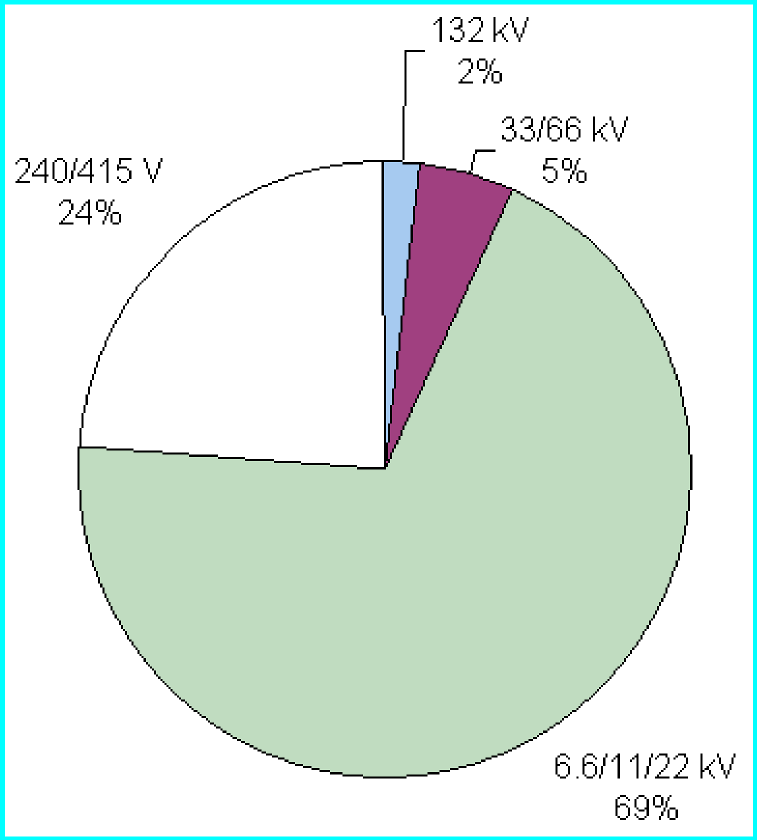
In Future:

- Decentral combined heat and power

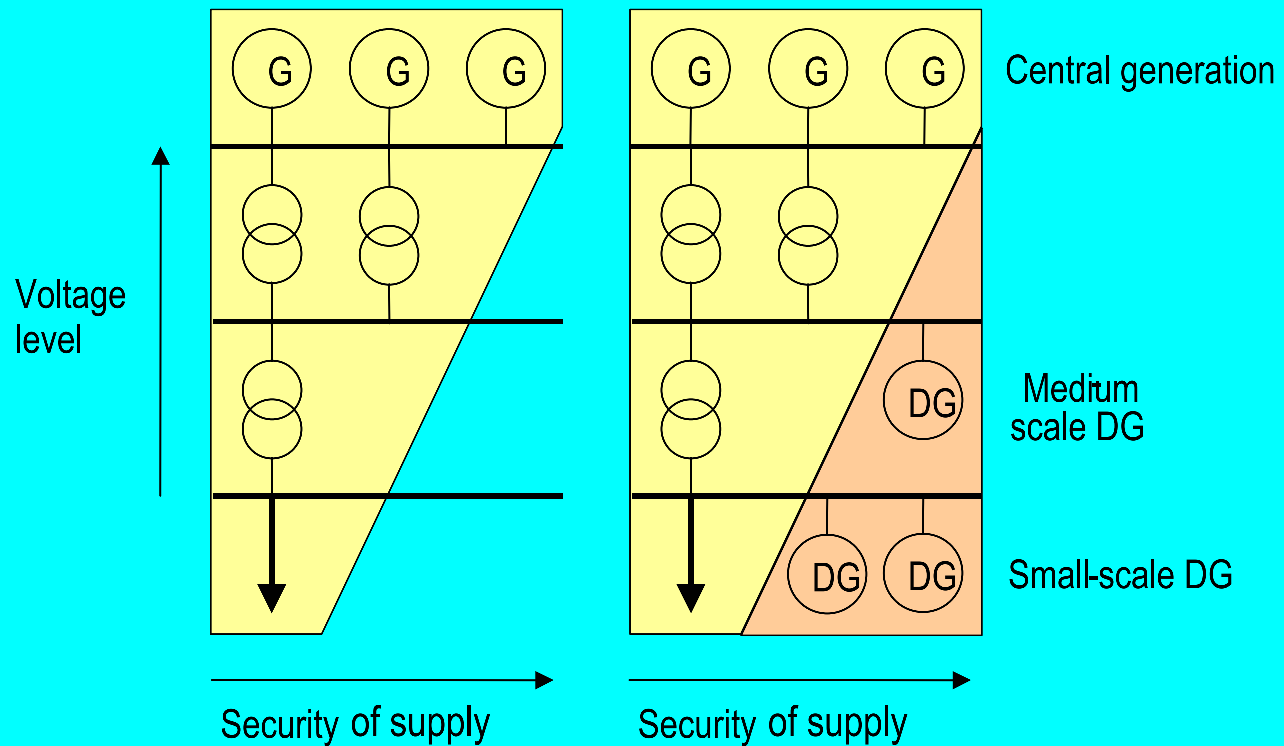
⇒ 1/3 less consumption of fossil sources of energy

Improvement of Reliability

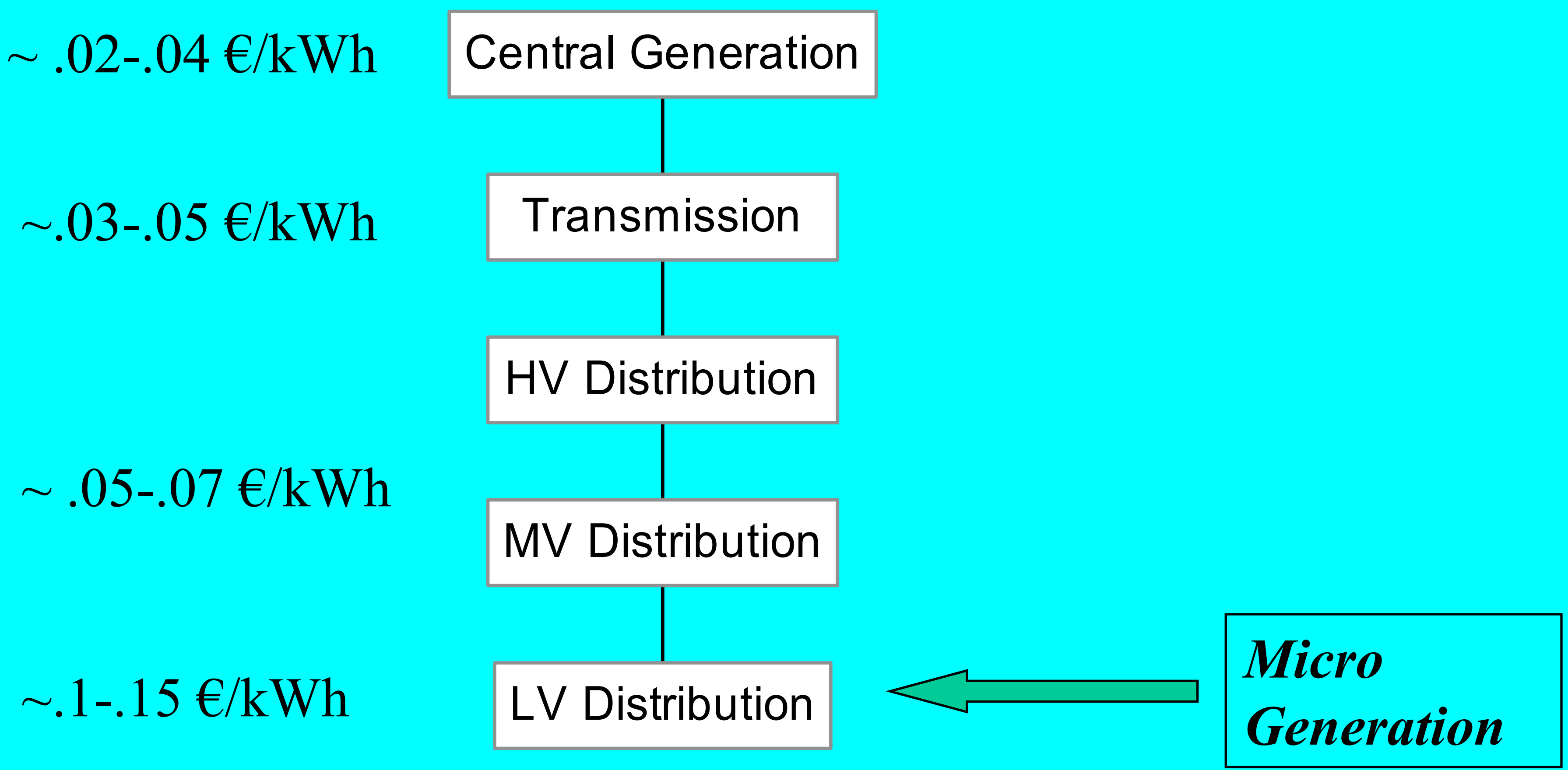
Distribution of CMLs



Potential for DG to improve service quality

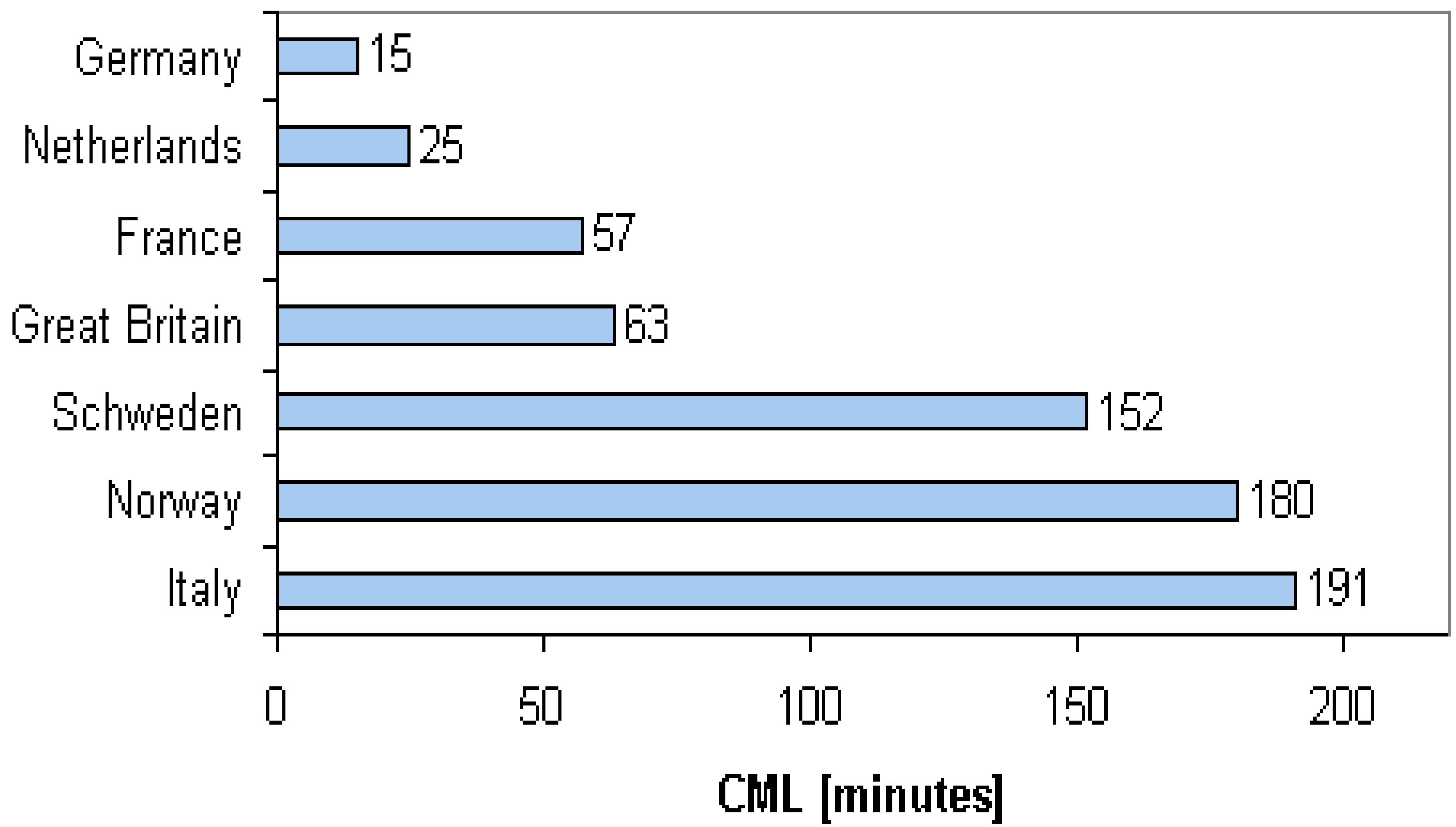


Network Benefits –
Value of Micro Generation



Cost benefit assessment

CMLs of European countries (in 1999) - Is it worth?



Cost of Power Outages for Selected Commercial Customers

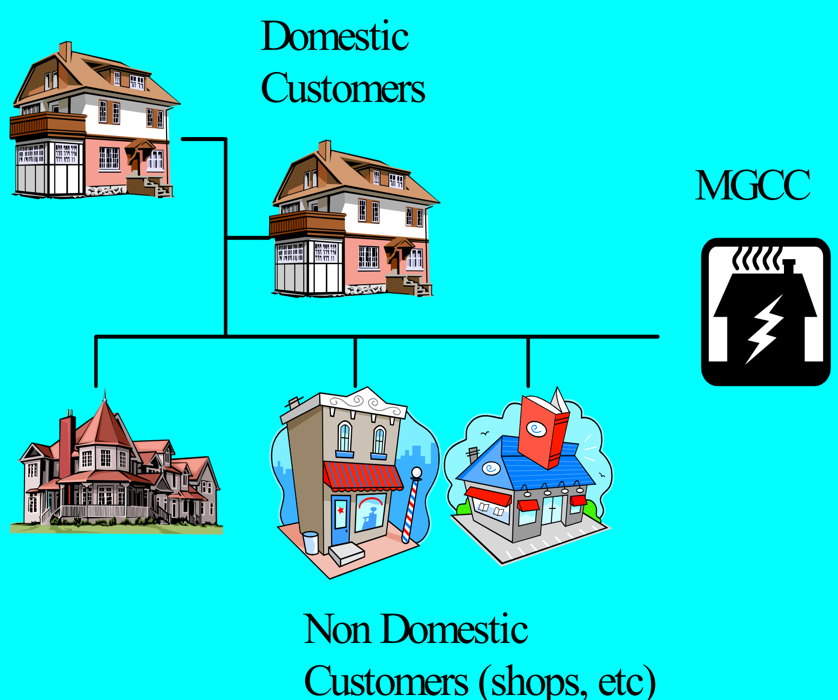
- Brokerage Operations $6,480,000 per hour
- Credit Card Operations $2,580,000 per hour
- Airline Reservations $90,000 per hour
- Telephone Ticket Sales $72,000 per hour
- Cellular Communications $41,000 per hour

Source: "Reliability and Distributed Generation", a White Paper by Arthur D. Little

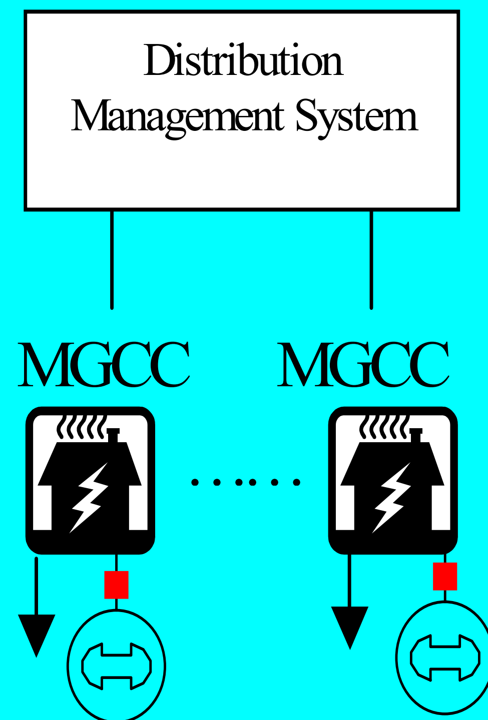
Conceptual Design of MicroGrids

- energy management within and outside of the distributed power system
- control philosophies (hierarchical or distributed)
- islanding and interconnected operation philosophy
- type of networks (ac or dc, fixed or variable frequency)
- management of power flow constraints, voltage and frequency
- device and interface response and intelligence requirements
- protection options for networks of variable configurations
- next-generation communications infrastructure (slow, fast)
- standardisation of technical and commercial protocols and hardware

Internal and External Markets



(A) Markets within a microgrid cell
(internal interaction)

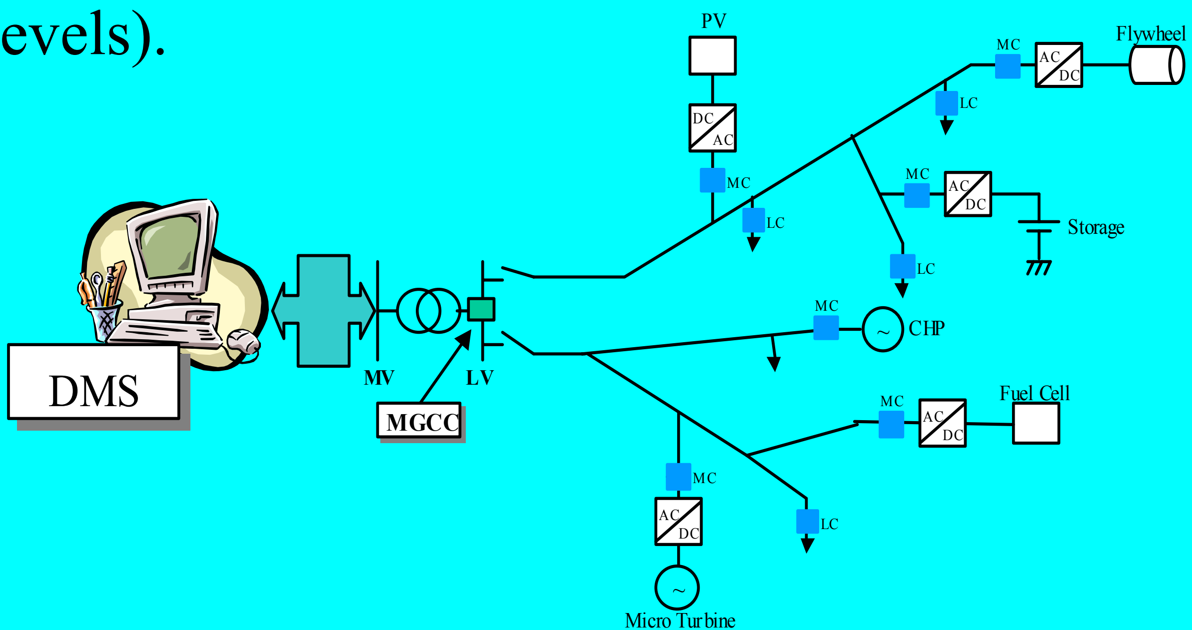


(B) Markets outside a microgrid cell
(external interaction)

MicroGrids – Hierarchical Control

MicroGrid Central Controller (MGCC) promotes technical and economical operation, provides set points to LC and MC; Interface with loads and micro sources and **DMS;**

MC and LC Controllers: interfaces to control interruptible loads and micro sources (active and reactive generation levels).



Interconnected Operation

- MicroGrids can operate:
  - Normal Interconnected Mode :
    - Connection with the main MV grid;
    - Supply, at least partially, the loads or injecting in the MV grid;
    - In this case, the MGCC:
      - Interfaces with MC, LC and DMS;
      - Perform studies (forecasting, economic scheduling, DSM functions,…);

Islanding Operation

Improved reliability and resilience

- MicroGrids can operate:
  - Island Mode :
    - In case of failure of the MV grid;
    - Possible operation in an isolated mode as in physical islands;
    - In this case, the MGCC:
      - Changes the output control of generators from a dispatch power mode to a frequency mode;
      - Primary control – MC and LC;
      - Secondary control – MGCC (storage devices, load shedding,…);
      - Eventually, triggers a black start function.

Integration requirements and device-network interfaces

- operation as the "good" and "model citizen"
- seamless transition between connection/islanding
- resilience under changing conditions
- operation fault level management and protection
- recovery from disturbances and contribution to network restoration
- interfacing ac and dc networks
- Safety, modularity, robustness, low losses, calibration and self-tuning

Modelling and simulation of MicroGrids

- modelling of generator technologies (micro generators, biomass fuelled generation, fuel cells, PV, wind turbines), storage, and interfaces
- load modelling and demand side management
- unbalanced deterministic and probabilistic load flow and fault calculators
- unbalanced transient stability models
- stability and electrical protection
- simulation of steady state and dynamic operation
- simulation of interactions between Microgrids

Market and Regulatory frameworks for MicroGrids

- coordinated but decentralised energy trading and management
- market mechanisms to ensure efficient, fair and secure supply and demand balancing
- development of open and closed loop price-based energy and ancillary services arrangements for congestion management
- secure and open access to the network and efficient allocation of network costs
- alternative ownership structures, energy service providers
- new roles and responsibilities of supply company, distribution company, and consumer/customer

MICROGRIDS Project

"Large Scale Integration of Micro-Generation to Low Voltage Grids

Contract : ENK5-CT-2002-00610

GREAT BRITAIN
- **UMIST**
- **URENCO**

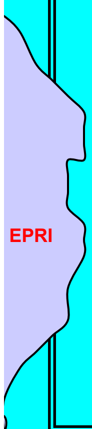
PORTUGAL
- **EDP**
- **INESC**

SPAIN
- **LABEIN**

NETHERLANDS
- **EMforce**

USA
- **EPRI**

14 PARTNERS,
7 COUNTRIES



GREECE
- **GERMANOS**
- **ICCS/NTUA**
- **PPC /NAMD&RESD**

GERMANY
- **SMA**
- **ISET**

FRANCE
- **EDF**
- **Ecole des Mines de Paris/ARMINES**
- **CENERG**

http://microgrids.power.ece.ntua.gr

IEA Seminar "*DISTRIBUTED GENERATION: KEY ISSUES, CHALLENGES, ROLES*", Paris, 1st March 2004

The MicroGrids Project

R&D Objectives:

- Contribute to increase the share of renewables and to reduce GHG emissions;
- Study the operation of MicroGrids in normal and islanding conditions;
- Optimize the operation of local generation sources;
- Develop and demonstrate control strategies to ensure efficient, reliable and economic operation;
- Simulate and demonstrate a MicroGrid in lab conditions;
- Define protection and grounding schemes;
- Define communication infrastructure and protocols;
- Identify legal, administrative and regulatory barriers and propose measures to eliminate them;

MICROGRIDS - 9 Workpackages

WP A: Development of Steady State and Dynamic Simulation Tools

WPB Development of Local Micro Source Controllers

WPC Development of Micro Grid Central Controller

WPD Development of Emergency Functions

WPE Investigation of Safety and Protection

WPF Investigation of Telecommunication Infrastructures and Communication Protocols

WPG Investigation of Regulatory, Commercial, Economic and Environmental Issues

WPH Development of Laboratory MicroGrids

WPI Evaluation of the system performance on study case networks

Challenges

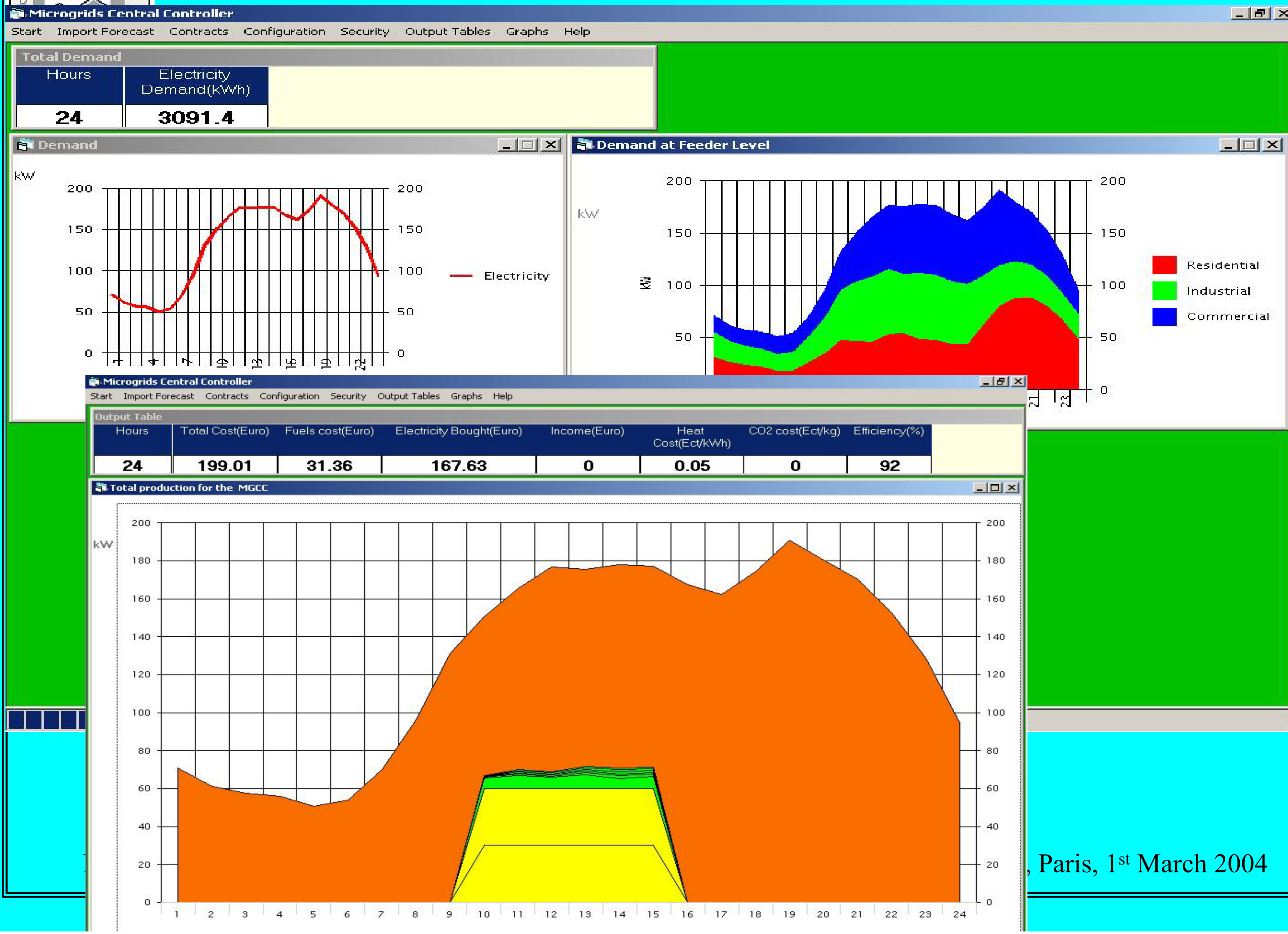
Specific technical challenges:

- Relatively large imbalances between load and generation to be managed (significant load participation required, need for new technologies, review of the boundaries of microgrids)
- Specific network characteristics (strong interaction between active and reactive power, control and market implications)
- Small size (challenging management)
- Use of different generation technologies (prime movers)
- Presence of power electronic interfaces
- Protection
- Unbalanced operation

Highlight - Permissible expenditure to enable islanding

Customer Sector:		Residential	Commercial
Annual benefit	=	1.4 £/kW_{pk}	15 £/kW_{pk}
Net present value	=	15 £/kW_{pk}	160 £/kW_{pk}
Peak demand	=	2 kW	1000 kW
Perm. expenditure	=	£30	£160,000
MicroGrid (2,000kW)		£30,000	£320,000

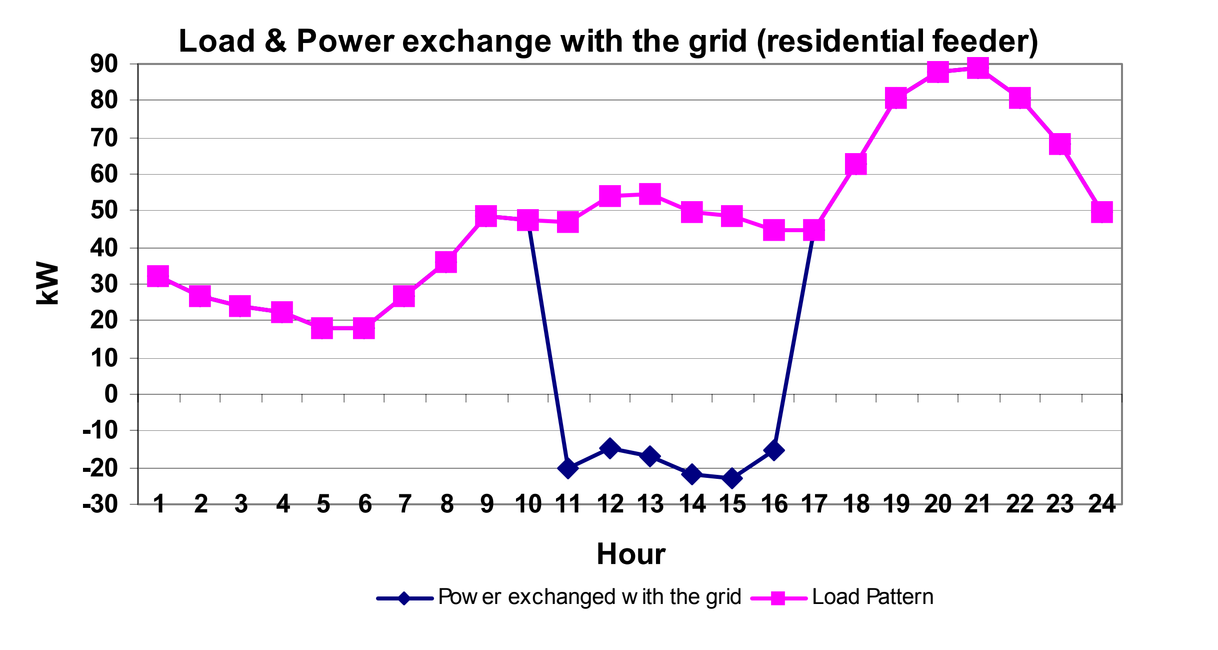
Highlight: MGCC Simulation Tool



Residential Feeder with DGs

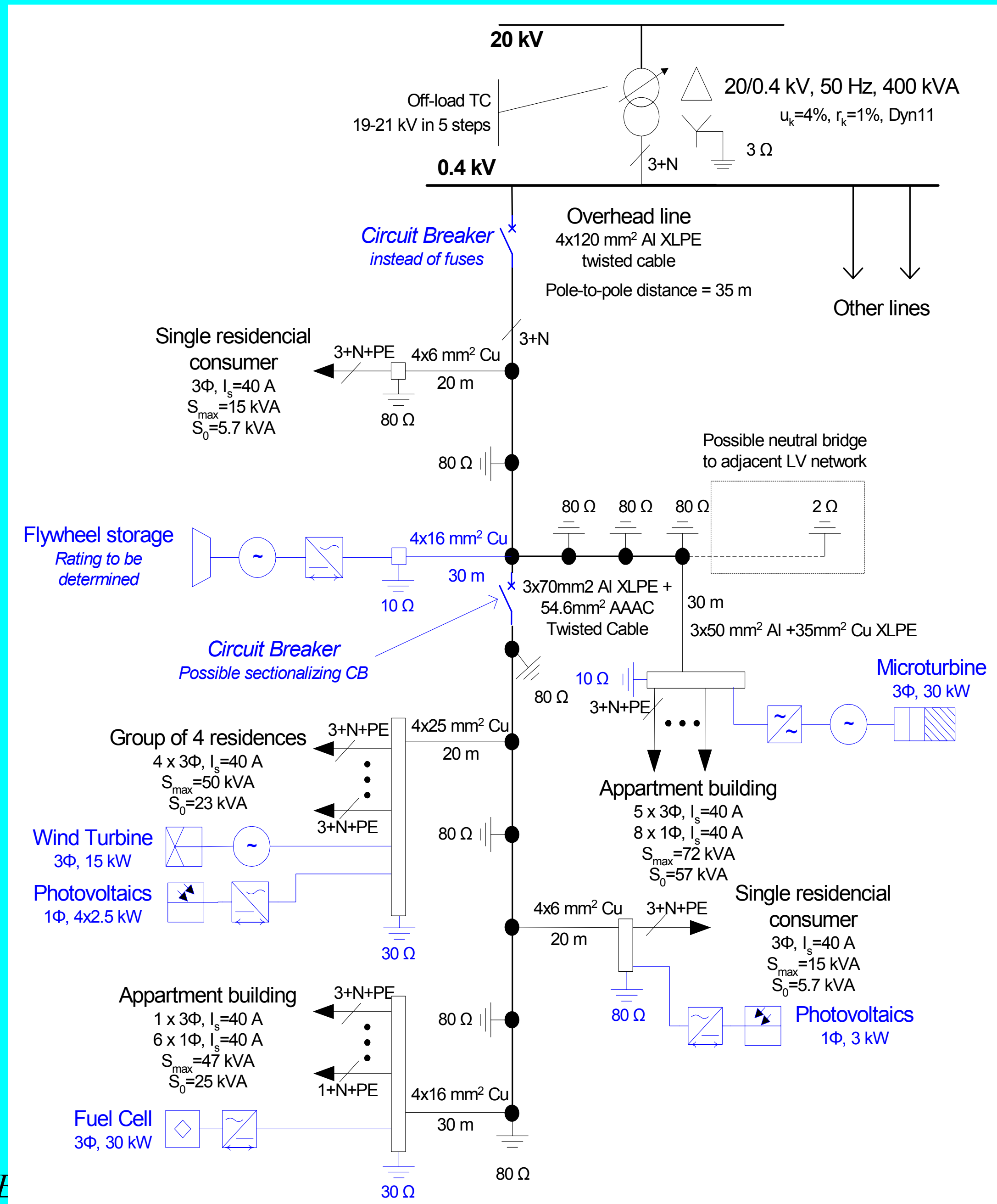
Good Citizen Cost Reduction : 12.29 %

Model Citizen Cost reduction : 18.66%



Steady state security increases cost by 27% and 29% respectively.

Study Case
LV Feeder
with DG
sources



LV network with multiple feeders