# Research and courses on optimization methods in the Department "Information Processes & Decision Support Systems" in IICT - BAS

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**Kick-off Meeting,**
**CEEPUS Network: CIII-BG-1103-01-1617**
05-09 October 2016, Technical University-Sofia, Bulgaria

# RESEARCH

- Ph.D. Thesis

Gouljashki V. G.,

“Algorithms for Solving Convex Nonlinear Integer Programming Problems”,

Institute of Information Technologies – BAS, Sofia, November, 1994.

1. Tabu search algorithm for single obj. NIPP
2. Exact algorithm for single objective NIPP
3. Interactive algorithm for multiple obj. NIPP

# RESEARCH

| Optimization problem | Method / algorithm |
|---|---|
| Single objective Convex Nonlinear Integer Programming Problem | - Tabu Search algorithm (1992-1993)<br>- Exact (enumeration) algorithm (1993) |
| Multiple objective Convex Nonlinear Integer Programming Problem | - Interactive algorithm (1994)<br>- Interactive Reference direction algorithm (1997, 2001)<br>- Genetic algorithm (1998)<br>- Parallel genetic algorithm (2002) |
| Two-Groups Classification Problem (Linear Discriminant Analysis) | - Polynomial heuristic algorithm (1999, 2006) |
| Determining spatial parameters of flaws in materials | - Heuristic algorithm (1999)<br>- Distributed system for parallel data processing of eddy current test (ECT) signals for electromagnetic flaw detection in materials (2000) |

# RESEARCH

| Optimization problem | Method / algorithm |
|---|---|
| Optimization of test signals for analog circuits | - Genetic algorithm (2002, 2003, 2007) |
| Design centering in a reduced search space for electronic circuit optimization | - Exact algorithm (2004, 2005) |
| Secure Multicarrier Modem in FPGA (optimization of the area of elements location) | - Heuristic algorithm (2006, 2007) |
| Multiple objective programming | - Accelerating technique for population based algorithms (2008) |
| Inverse Electrical Impedance Tomography (EIT) Problem | - Hybrid Direct Search – Quasi-Newton method (2008)<br>- Accelerated genetic algorithm (2009, 2010) |
| MCDM Convex Integer Problem | - SPEA-based method (2009)<br>- Interactive evolutionary method FIEM (2011) |

# RESEARCH

| Optimization problem | Method / algorithm |
|---|---|
| MCDM Convex continuous problem | - Generalized scalarizing metod GENS-IM (2012)<br>- Web-based decision support system WebOptim (2011, 2012, 2013) |
| Multiple objective voltage regulator optimization | - A Promethee-based approach (2014) |
| Flexible job shop scheduling problem | - Genetic algorithm (2014) |
| Multiple objective Flexible job shop scheduling problem | - Promethee algorithm (2015) |
| Optimization of battery schedule for residential microgrid applications | - MATLAB (Optimization Toolbox – fmincon, patternsearch) (2016)<br>(Global Optimization Toolbox – ga) |

# RESEARCH

DAAD-specialization 07.-08.2002. in Hannover, Germany

Project:

Generation of Optimum Test Stimuli for Nonlinear Analog Circuits Using Nonlinear Programming and Time-Domain Sensitivities", Institute of Electromagnetic Theory and Microwave Technique, Hannover University, Germany, leader: Prof. Dr. Wolfgang Mathis (with participation of Dipl. Eng. Bernhard Burdiek), (see http://www.tet.uni-hannover.de/research/test/analog_test.htm), 2003.

# RESEARCH

- Guliashki V., Burdiek B., Mathis W., (2003) "Optimization of Test Signals for Analog Circuits", Proceedings of Papers, Volume 1, of 6-th International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services TELSIKS 2003, 1-3. October, 2003, Nis, Serbia and Montenegro, Editor: Prof. Dr. Bratislav Milovanovic, pp. 133-136.
- "Optimization of Test Signals for Analog Circuits", *Electronics*, **ISSN 1450-5843**, Vol. 8, № 1, May 2004, pp. 10-13.

# RESEARCH

- Galia Marinova, Vassil Guliashki, Didier Le Ruyet, Maurice Bellanger, (2007) **“Secure Multicarrier Modem on FPGA”**, *Lecture Notes in Engineering and Computer Science*, World Congress on Engineering 2007, July 2-4, 2007, London, United Kingdom, ISBN: 978-988-98671-5-7, Volume I, Editors: S. I. Ao, Leonid Gelman, David W.L. Hukins, Andrew Hunter, A. M. Korsunsky, IAENG, International Association of Engineers, CPCI № 56547, pp. 563-567.

Sponsored by the NATO-project:

**CLG.981551 / 2005**, “System Approach in Secure Modem Design”, Bulgarian coordinator: Assist. Prof. Dr. Galia Marinova, TU – Sofia, 2005-2007.

# RESEARCH AWARD

**The World Congress on Engineering (WCE 2007)**

**2 – 4 July 2007, London, U.K.**

Presents this

*Certificate of Merit for*

*The 2007 International Conference of*

*Information Security and Internet Engineering*

to

*Galia Marinova, Vassil Guliashki, Didier LeRuyet, and Maurice Bellanger*

for the paper entitled

*Secure Multicarrier Modem on FPGA*

INTERNATIONAL ASSOCIATION OF ENGINEERS IAENG

IAENG

20 August 2007

Anna Lee, Assistant Secretary, on behalf of the International Association of Engineers

# RESEARCH

Genova K., L. Kirilov, V. Guliashki, B. Staykov, D. Vatov, (2011) **"A Prototype of a Web-based Decision Support System for Building Models and Solving Optimization and Decision Making Problems",** In: *Proceedings of Papers* of *XII International Conference on Computer Systems and Technologies CompSysTech'11*, **ISBN: 978-954-9641-52-3**, Wien, Austria, 16-17 June, 2011, pp. 167-172.

Supported by the Bulgarian National Science Fund, Grant No DTK02/71 "Web-Based Interactive System, Supporting the Building Models and Solving Optimization and Decision Making Problems".

# RESEARCH

- Genova K., L. Kirilov, V. Guliashki, B. Staykov, D. Vatov, (2011) **"A Prototype of a Web-based Decision Support System for Building Models and Solving Optimization and Decision Making Problems",** In: *Proceedings of Papers* of *XII International Conference on Computer Systems and Technologies CompSysTech'11*, **ISBN: 978-954-9641-52-3**, Wien, Austria, 16-17 June, 2011, pp. 167-172.
- Staykov B., F. Andonov, D. Vatov, K. Genova, L. Kirilov and V. Guliashki, (2011) **"Architecture of a flexible web-based framework for building models and solving decision optimization problem",** In: *Proceedings of Papers of XLVI International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST2011*, Nis, Serbia, 29 June – 01 July, 2011, Vol. 3, 857-860.

# RESEARCH

- Guliashki V., L. Kirilov, K. Genova, B. Staykov, (2012) **"Scalarizing methods in DSS WebOptim"**, In: *Conference Programme of 25-th European Conference on Operational Research,* 8-11 July, 2012, Vilnius, Lithuania, page 210.
- Kirilov L., Genova K., Guliashki V., Zhivkov P., (2013) **"Interactive Environment for Solving Multiple Objective Programming Problems GENS-IM",** In: *Proceedings of Papers of the XLVIII International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST2013*, (Editor Prof. Dr. Mitrovski, C.), June 26 – 29, 2013, Ohrid, Macedonia, vol. I, pp. 179-182.

# RESEARCH

- The WEB-based decision support system WebOptim: http://weboptim.iinf.bas.bg/

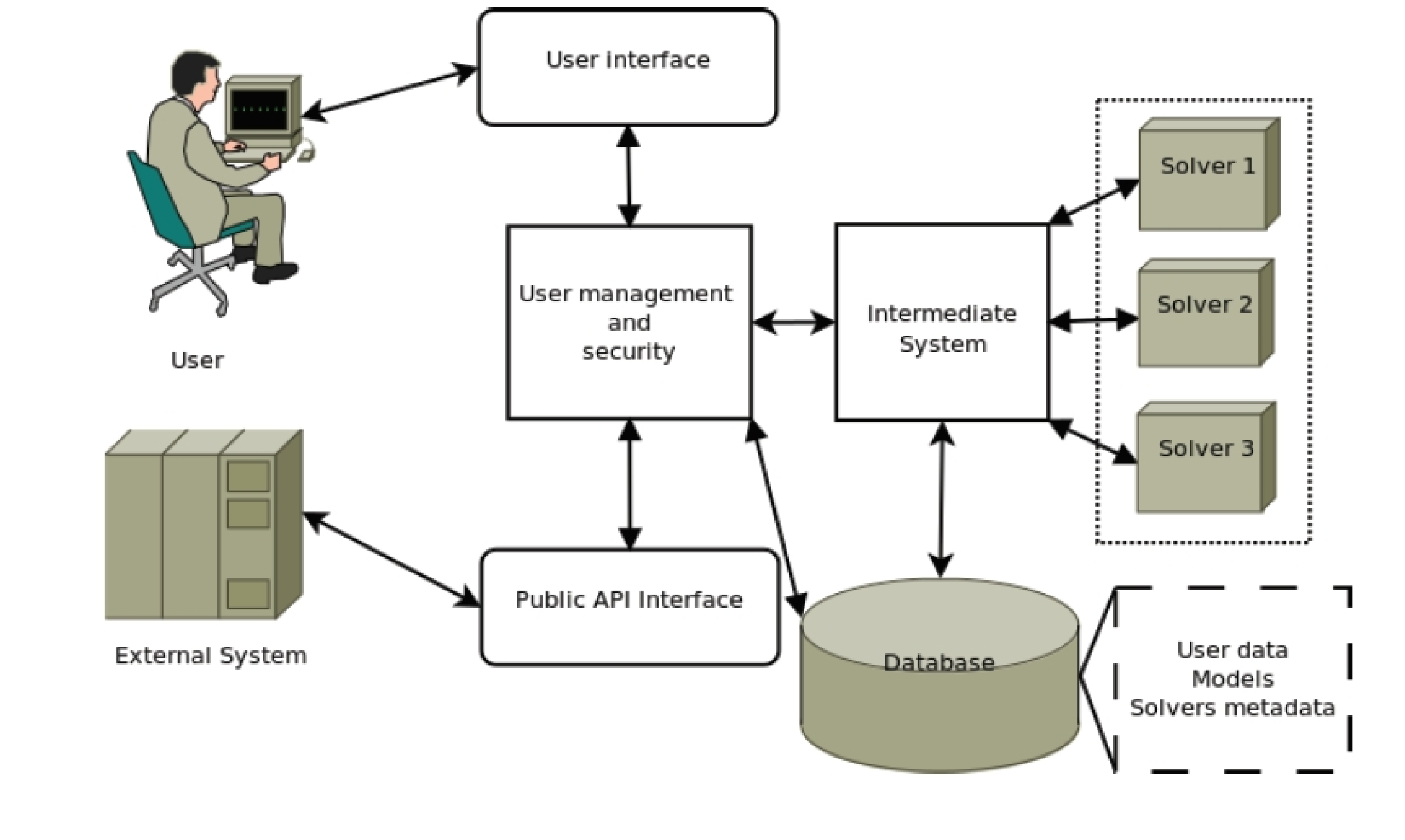


Fig. 1. Architecture of WebOptim

# RESEARCH

- WebOptim Solvers:

| Solver name | Description |
| --- | --- |
| GENS-IM | Open source lib LP Solve. Currently supported syntaxes: LP syntax, MPS syntax |
| FIEM | Evolutionary solver |

# RESEARCH

- Purpose of DSS WebOptim:

DSS WebOptim is designed to solve multiobjective optimization problems.
The multiobjective optimization problem (MOP) can be defined as:

Maximize $\{f_k(x), k \in K\}$ **(1.1)**

subject to: $x \in X$ **(1.2)**

where $f(x) = (f_1(x), f_2(x), \ldots\ldots f_k(x))$ is a vector of $k$ concave objective functions, which must be simultaneously maximized.

A solution $x = (x_1, x_2, \ldots\ldots, x_n)$ is a vector of $n$ decision variables, belonging to non-empty feasible convex set $X \subset R^n$. The objective functions (1.1) constitute a $k$-dimensional subspace, called objective space $F \subset R^k$, $F = \{f(x) \mid x \in X\}$.

# RESEARCH

- The generalized scalarizing method for solving MOPs is based on a generalized scalarizing model GENS. This model is introduced firstly in Vassilev (2002)

The generalized scalarizing problem GENS is defined as:

Minimize:

$$T(x) = \max\left\{ \max_{k \in K^{\geq}} \left[F_k^1 - f_k(x)\right] G_k^1 \; r_1 \; \max_{k \in K^{\leq}} \left[F_k^2 - f_k(x)\right] G_k^2 \; r_2 \; \max_{k \in K^{<}} \left[F_k^3 - f_k(x)\right] G_k^3 \; r_3 \; \max_{k \in K^{>}} \left[F_k^4 - f_k(x)\right] G_k^4 \right\} +$$

$$+ \sum_{k \in K^{0}} \left[F_k^5 - f_k(x)\right] G_k^5 + \rho \left\{ \sum_{k \in K^{\geq}} \left[F_k^1 - f_k(x)\right] G_k^1 + \sum_{k \in K^{\leq}} \left[F_k^2 - f_k(x)\right] G_k^2 + \sum_{k \in K^{<}} \left[F_k^3 - f_k(x)\right] G_k^3 + \right.$$

$$\left. + \sum_{k \in K^{>}} \left[F_k^4 - f_k(x)\right] G_k^4 - \sum_{k \in K^{=} \cup K^{><}} f_k(x) G_k^5 \right\} \qquad \textbf{(2.1)}$$

# RESEARCH

subject to

$$f_k(x) \geq f_k, \quad k \in K^{>} \cup K^{=}, \qquad \textbf{(2.2)}$$

$$f_k(x) \geq f_k - D_k, \quad k \in K^{\leq}, \qquad \textbf{(2.3)}$$

$$f_k(x) \geq f_k - t_k^-, k \in K^{><}, \qquad \textbf{(2.4)}$$

$$f_k(x) \leq f_k + t_k^+, k \in K^{><}, \qquad \textbf{(2.5)}$$

$$x \in X, \qquad \textbf{(2.6)}$$

where

– ρ is a small positive number;
– $K$ is the set of all objectives' indices;
– $f_k$ - the current objective value of $f_k(x), \quad k \in K$ ;
– $G_k^1, G_k^2, G_k^3, G_k^4, G_k^5$ are scalarizing coefficients for 5 classes of objectives' indices;
– $F_k^1, F_k^2, F_k^3, F_k^4, F_k^5$ are parameters, concerning aspiration, current or other levels of objectives' values;
– $r_1, r_2, r_3 \in \{"+", " , "\}$
– $D_\kappa$ is the amount by which the DM agrees to deteriorate the objective value $f_k$ $(0 < D_\kappa < \infty)$;

# RESEARCH

– $K^{\geq}$ is the set of objectives' indices for which the DM wants to improve the corresponding objective values till to the given aspiration levels $F_k^1$;

– $K^{>}$ is the set of objective' indices for which the DM wants to improve the corresponding objective values;

– $K^{\leq}$ is the set of objective' indices for which the DM agrees to deteriorate the corresponding objective values till to the given aspiration levels $F_k^2$,

i.e. $F_k^2 \geq f_k - D_k$;

– $K^{<}$ is the set of objective' indices for which the DM agrees to deteriorate the corresponding objective values;

– $K^{=}$ is the set of objective' indices for which the DM wants their current values not to be deteriorated;

– $K^{><}$ is the set of objective' indices for which the DM wants to change the corresponding objective values in some intervals;

– $t_k^-$ and $t_k^+$ are the lower and upper bounds for the objective values of the objective $f_k(x)$ with index $k \in K^{><}$;

– $K^0$ is the set of objective' indices for which the DM does not set explicitly aspirations to change the corresponding objective values.

# RESEARCH

- This scalarizing problem is correctly defined under the natural requirements $K^{\geq} \neq \emptyset$ and/or $K^{>} \neq \emptyset$ and $K^{0} \neq K$. In other words, the problem is correct if the DM wants to improve at least one objective or he/she sets his/her preferences in an implicit way.
- The solutions of this problem are weak Pareto optimal or Pareto optimal in case the additive part is included - see formula (2.1).

# RESEARCH

The generalized interactive method GENS - IM is developed on the basis of the scalarizing model GENS and has the following characteristics:

- the DM may set his/her preferences with the help of the criteria weights, $\varepsilon$ - constraints, desired and acceptable levels of change of the criteria values, directions and intervals of alteration in the criteria values;
- during the multicriteria problems solving process, the DM may change the way of presenting his/her preferences;
- starting from one and the same current solution and applying different scalarizing problems (with respective alteration of GENS parameters), the DM may obtain different new (weak) Pareto optimal solutions at a given iteration. This opportunity is especially useful in education and in comparison of different scalarizing methods.

# RESEARCH

- Kirilov L., Guliashki V., Genova K., Vassileva M., Staykov B., (2013) **"Generalized scalarizing model GENS in DSS WebOptim"**, *International Journal of Decision Support System Technology*, vol. 5, issue 3, pp. 1-11, Special Issue from the Decision Support Systems Stream on the EUROXXV Conference in Vilnius, (Sessions WA-27; WB-27; WC-27; WD-27). Guest Editors: Fatima Dargam, Shaofeng Liu, Isabelle Linden, DOI: 10.4018/IJDSST, ISSN: 1941-6296, EISSN: 1941-630X

  http://www.igi-global.com/journal/international-journal-decision-support-system/1120

  http://www.igi-global.com/article/generalized-scalarizing-model-gens-in-dss-weboptim/95091

# RESEARCH AWARD

http://www.igi-global.com/newsroom/archive/igi-global-announces-winners-sixth/1903/

Honoring the Best Articles From the 2013 Volume Year

IGI Global Announces The Winners Of
The Sixth Annual Excellence In Research Journal Awards

By IGI Global on Aug. 12, 2014

Award Winning Articles

EXCELLENCE IN RESEARCH JOURNAL AWARDS

Generalized Scalarizing Model GENS in DSS WebOptim

# RESEARCH AWARD

The outstanding published journal articles were selected based on the following criteria:

- Contribution to the field
- Originality of the research
- Practicality of research/results
- Quality of writing
- Rigor of the research
- Substantive research and methodology

# RESEARCH

Kirilov, L., V. Guliashki, K. Genova, P. Zhivkov, B. Staykov, D. Vatov (2015) **Interactive Environment WebOptim for Solving Multiple-Objective Problems Using Scalarising and Evolutionary Approaches**, *International Journal for Reasoning-based Intelligent Systems*, Vol. 7, No. 1/2, ISSN online: 1755-0564, ISSN print: 1755-0556, DOI: 10.1504/IJRIS.2015.070907, pp. 4-15.

http://www.inderscience.com/jhome.php?jcode=ijris#issue

http://www.inderscience.com/info/inarticletoc.php?jcode=ijris&year=2015&vol=7&issue=1/2

http://www.inderscienceonline.com/doi/abs/10.1504/IJRIS.2015.070907

# RESEARCH

Project № BG161PO003-1.1.06-0083 to the EU operative program „Development of Bulgarian economy competitiveness” entitled: “Scientific research for the purposes of development of software tool for generating efficient schedules by an innovative method for multiple objective optimization in discrete manufacturing within the scope of small and medium enterprises”

# RESEARCH

- Kirilov, L. and V. Guliashki (2014), **"An Extension of Flexible Job Shop Problem (FJSP) and Method for Solving"**, In: *Proceedings of the 15th International Conference on Computer Systems and Technologies CompSysTech'14*, **ISBN: 978-1-4503-2753-4**, Ruse, Bulgaria, 27 June, 2014, ACM International Conference Proceeding Series, pp. 210-217.
- Guliashki V., Kirilov L., (2015) **"A Promethee-based Approach to Multi-Criteria Flexible Job Shop Scheduling Problem"**, In: *Proceedings of Papers of the L International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST'2015*, (Editor: Assoc. Prof. Kalin Dimitrov, PhD), June 24 – 26, 2015, Sofia, Bulgaria, **ISBN: 978-619-167-182-3**, pp. 113-116.

# RESEARCH

- Kirilov L., V. Guliashki, K. Genova, V. Angelova, (2016) **"An Overview of Multiple Objective Job Shop Scheduling Techniques",** *JÖKULL Journal*, **Impact factor: 1.604**, ISSN: 0449-0576, Vol. 66, No 2; Feb. 2016, pp. 172-206
- MONOGRAPHY:

Kirilov L., V. Guliashki, K. Genova, (2016) ***Multicriteria Decision Making in Manufacturing Scheduling***, Editor: Prof. Dr. Ivan Mustakerov, 281 pages, ISBN 978-954-552-074-7, "Education" Ltd., 2016.

# RESEARCH

- Marinova G. and V. Guliashki, (2016), **“Economic Energy Scheduling of an Islanded Microgrid”**, In: *Proceedings of Papers of the LI International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST2016*, (Editor Prof. Dr. Mitrovski, C.), June 28 – 30, 2016, Ohrid, Macedonia, vol. I, (in press).
- Marinova, G. and V. Guliashki (2016), “**Optimization of the Battery Schedule for Residential Microgrid Applications”,** IFAC International Conference on International Stability, Technology and Culture TECIS 2016, October 26-28, 2016, Dürres, Albania (in press)
- Marinova, G. and V. Guliashki (2016), **“Energy Scheduling for Island Microgrid Applications“,** *Journal of Communication and Computer*, **ISSN: 1548-7709**, USA (accepted, in press)

# RESEARCH

A **microgrid** is a low-voltage distribution system, integrating distributed energy resources (DERs) or renewable energy sources (RES) and controllable loads, which can be used/controlled in either islanded or grid-connected mode.

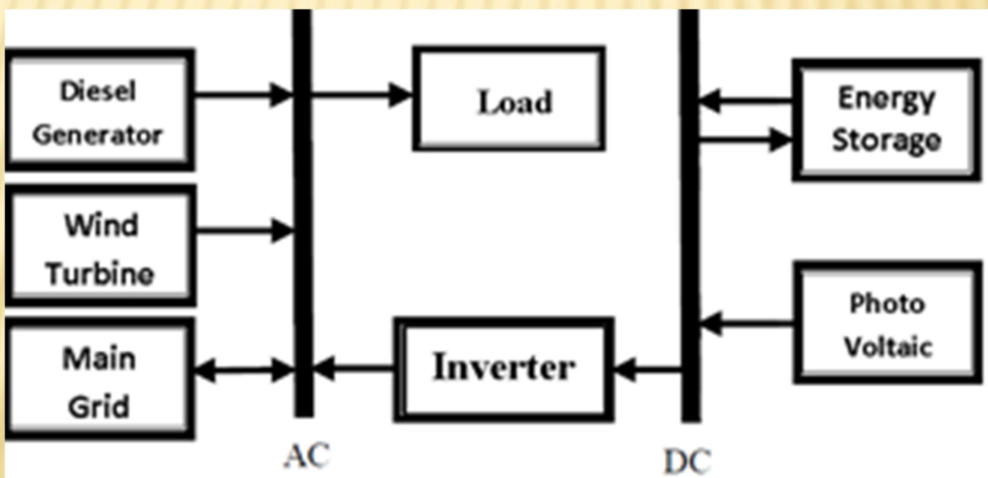


Fig. 2 Microgrid system configuration

# RESEARCH

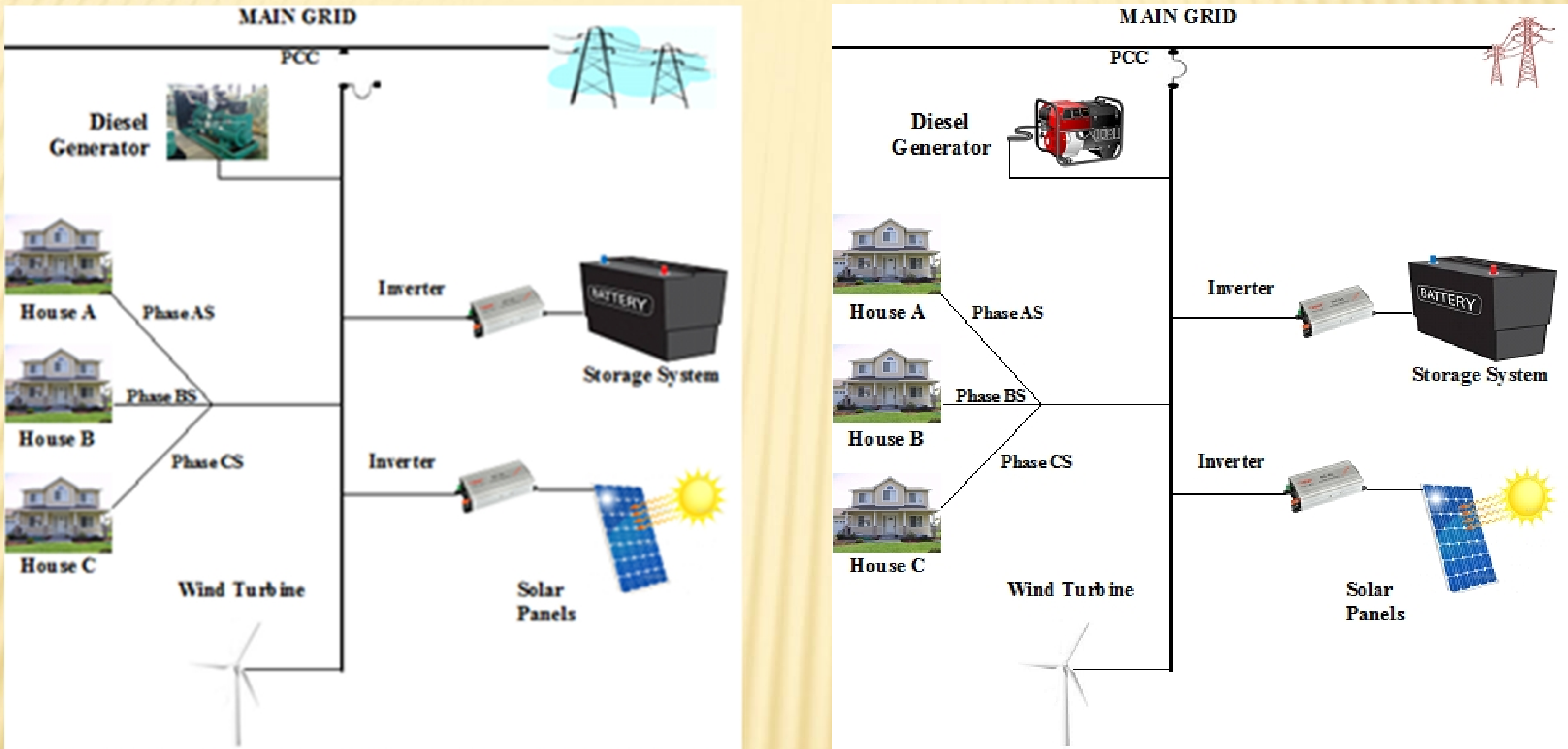


Fig 3. The experimental microgrid

Used tools: MATLAB, GridLab-D, GridMat

# RESEARCH

Tasks:

1. Costs minimization

$$F = \sum_{t=1}^{24} (C_t . P_{Bt}) = \sum_{t=1}^{24} CC_{DG}(t) + OM_{DG}(t) + FC_{DG}(t) +$$
$$+ EC_{DG}(t) + \sum_{t=1}^{24} OM_{Bat}(t) + RC_{Bat}(t) + CC_{Inv}(t)$$

2. Energy optimization of battery schedule

$$\min F1 = \sqrt{\sum_{i=1}^{24} [(H(i) - PV(i) - WT(i) - x(i)).\Delta t_i]^2}$$

3. Economic optimization of battery schedule

$$\min F2 = \sum_{i=1}^{24} [(H(i) - PV(i) - WT(i) - x(i)).\Delta t_i].P(i)$$

# RESEARCH

The results show that by means of optimal battery schedules the energy consumption from the main grid can be minimized, as well as that a reduction of energy costs for the end user can be achieved. For having a correct application of optimization problem in Task 2 formulation, good forecasted data for the RES production and houses consumption should be used. For exact calculation of optimal costs value in Tasks 1 an 3 the initial investments in devices like wind turbines and photovoltaic panels should be taken into account.

# TEACHING COURSES

PROJECT № **BG051PO001-3.3.06-0046 to the EU operative program** „Development of the human resources" entitled: „Support of development of Ph.D. students, post doc. and young scientists in the area of virtual engineering and industrial technologies", with coordinator Prof. Ph.D. Georgi Todorov (MTF) at the Technical Unniversity – Sofia, Bulgaria in 2013.

Courses: 1) **Optimization methods, 2) Numerical methods;** The curricula are available on the addresses:

http://youngfit.tu-sofia.bg/index.php?page=ProgramModule2_bg
http://youngfit.tu-sofia.bg/uploads/Documents/MO.pdf
http://youngfit.tu-sofia.bg/uploads/Documents/Lectures_2.1.pdf

- http://youngfit.tu-sofia.bg/uploads/Documents/4M.pdf
- http://youngfit.tu-sofia.bg/uploads/Documents/Lectures_1.3.pdf

# COURSE "OPTIMIZATION METHODS"

1. Single objective optimization
   - Optimality conditions
   - Methods for unconstrained optimization problems
   - Methods for constrained optimization
   - Metaheuristic methods for global optimization (Simulated Annealing, Tabu Search, Genetic Algorithms, Evolutionary Algorithms)
   - Mathematical modeling (problems reformulation, variables scaling, constraints setup)

# COURSE "OPTIMIZATION METHODS"

- Exercises: MATLAB (Optimization Toolbox):
  - Linear Programming and Mixed-Integer Linear Programming
  - Nonlinear optimization (Unconstrained optimization, constrained optimization)
  - Quadratic Programming
  - Least squares
  - Systems of nonlinear equations

MATLAB (Global Optimization Toolbox):

- Global or Multiple Starting Point Search
- Direct Search (Pattern Search)
- Genetic Algorithm
- Simulated Annealing

# COURSE “OPTIMIZATION METHODS”

Exercises:

MATLAB (Symbolic Math Toolbox) → MuPAD notebook

- Symbolic computations in MATLAB
- Mathematics
- Graphics
- MuPAD
- MATLAB and MuPAD integration

# COURSE “OPTIMIZATION METHODS”

2. Multiple objective optimization

- Basic notions and definitions, optimality conditions
- No-preference methods
- A priori methods
- A posteriori methods
- Interactive methods.
- Multi-criteria analysis methods Electre and Promethee

# COURSE "OPTIMIZATION METHODS"

- Exercises: MATLAB (Optimization Toolbox):
  - Nonlinear optimization (Multiobjective optimization)

MATLAB (Global Optimization Toolbox):

- Multiobjective optimization (Genetic Algorithm)

Annotation

The aim of the teaching course "Optimization methods" is to provide knowledge about the methods, techniques and approaches for single and multiple objective optimization. This knowledge could be useful for everybody, who intends to solve optimization problems. The course is useful for engineers, economists, persons making decisions (decision makers) in the management of enterprises and production processes, for experts in distributing districts, resources, distribution of peoples in vote sections, as well as for all kinds of experts, who solve real optimization problems in their activities.

THANK YOU

FOR YOUR KIND ATTENTION!