World Academy of Science, Engineering and Technology
International Journal of Energy and Power Engineering
Vol:10, No:5, 2016

Concept, Modules and Objectives of the Syllabus Course: Small Power Plants and Renewable Energy Sources

Rade M. Ciric, Nikola L. J. Rajakovic

Abstract—This paper presents a curriculum of the subject small power plants and renewable energy sources, dealing with the concept of distributed generation, renewable energy sources, hydropower, wind farms, geothermal power plants, cogeneration plants, biogas plants of agriculture and animal origin, solar power and fuel cells. The course is taught the manner of connecting small power plants to the grid, the impact of small generators on the distribution system, as well as economic, environmental and legal aspects of operation of distributed generators.

Keywords—Distributed generation, renewable energy sources, techno-economic analysis, energy policy, curriculum.

I. Introduction

THE appearance of distributed renewable and non-renewable generation and its increasing share in supplying the consumers plays an important role in planning the development and operation of power systems at the beginning of the 21st century [1]-[6]. Great attention is paid to the development of new and sustainable ways of producing energy and its exploitation. Impact on the environment is now one of the most important factors when considering the connection of new generation units to the electric grid. Particular attention is paid to the development of technologies to enable better use of solar, wind, hydropower, biomass, geothermal energy, etc. [4], [6]. Such sources are commonly referred to as distributed sources and in the literature are multiple variants of this term including the most common: distributed generation (DG), dispersed generation, decentralized generation, on-site generation, embedded generation etc. Today, in the midst of liberalization and deregulation of the energy sector, power distribution companies are faced with numerous demands of private investors and companies for connecting small generators to distribution system.

Driven by the "feed-in" tariffs, legislation and international protocols and standards, integration of small generators in the distribution system is an important factor of stable and secure operation of the distribution system as a whole, but is also a challenge for the engineers [7].

Rade M. Ciric is with Higher Education Technical School of Professional Studies in Novi Sad (corresponding author, e-mail: rade.ciric@aol.com).

Nikola LJ. Rajakovic is with Faculty of Electrical Engineering, University of Belgrade, Serbia.

This work is part of the Research project *"Integrated Energy Networks"* IEM 42009/2011, supported by the Ministry of Education and Science of The Government of Republic of Serbia.

By increasing the number of DG in the network, challenges for distribution system operators to maintain the system in a stable voltage conditions, to ensure supply to customers in the agreed legal framework in terms of power quality, also increasing [8]-[10].

Modern planning of distribution systems with integrated DG must meet a number of objectives, which often represent a compromise of criteria of economy, which is in the interest of the system operator on the one hand, and the criteria of quality of electricity supply, which is the interest of the customer on the other hand. In doing so goals must be achieved with a transparent and impartial relation of all subjects in the open electricity market. It is obvious that the key link in the effective implementation of renewable energy sources consists of experts, engineers and technicians of different backgrounds who need new skills.

Based on the above mentioned facts, the question is how to align the curriculum in higher education with increasing requirement of industry and markets in the electricity sector.

The subject of *Small power plants and renewable energy sources* is taught in advanced studies at the Higher Technical School of Professional Studies in Novi Sad at the Electrical Department. The aim of the course is to enable students to manage construction projects and operation of renewable energy sources.

The course is designed as a one semester in accordance with the *Bologna Declaration*, carries 8 ESP points, and is provided two hours of lectures and two hours of exercises per week and a total of 70 hours. Pre duties consist of the preparation and defense of seminar work, and laboratory exercises. The examination is written and consists of theoretical questions and arithmetic tasks. The Higher Technical School of Professional Studies in Novi Sad is equipped with the modern Laboratory for Renewable Energy Sources allowing execution of the exercises by practical measuring in groups of three students.

This paper presents a curriculum of the course *Small power plants and renewable energy sources* on the Higher Technical School of Professional Studies in Novi Sad. The course consists of seven modules which cover the concept of distributed generation, renewable energy sources, hydropower, wind farms, geothermal power plants, biogas plants, solar power and fuel cells.

In the course the connecting of DG to the low and medium voltage distribution network, impact of DG on distribution system, as well as economic and ecological aspects of operating small power plants, is being taught. Finally, the legal framework for the implementation of renewable energy and energy policy in the Republic of Serbia is considered.

The material was collected from several textbooks and exercise books, technical recommendations of Electric Power Industry of Serbia, official documents of Ministry of Energy of the Republic of Serbia, as well as lectures and exercises performed at the Higher Technical School of Professional Studies in Novi Sad.

The above mentioned contents establish a correlation with other educational subjects at the study program of Electrical Engineering - Power Engineering as: *Fundamentals of Engineering 1*, *Distributive and Industrial Systems*, *Electrical Measurement, Electrical Installations and Electrical Machinery*.

II. Renewable Energy Sources

Renewable energy sources (RES), sometimes dubbed as permanent sources of energy, are resources that are used to produce electricity or heat, or any useful work, and whose reserves are constantly or cyclically renewed.

On the course *Small power plants and renewable energy sources*, the following renewable resources are studied:

- Wind energy, Fig. 1,
- Solar energy, Fig. 2,
- Biomass, Fig. 3,
- Small hydro (up to 10 MW), Fig. 4,
- Geothermal energy, and
- Fuel cells.

In the general part of the module, students are introduced to physical phenomenon of energy circulation in nature and to the fact that all renewable energy resources only modalities of solar energy. Students become familiar with the trend of increasing the share of renewable energy in total energy consumption as well as the reasons that led to it:

Growing shortage of fossil fuels,

- Global environmental protection of the Earth,
- Local environmental protection,
- Reduction of energy dependency etc.

The course further handles the problems that accompany the implementation of renewable energy sources such as:

- Higher capital costs per power unit compared to conventional sources,
- Slow paying off the investment,
- Lower energy potential compared to conventional sources,
- Unpredictable and intermittent operation,
- Complex exploitation etc.

The classification of DG by power and its role in the system, the price of electricity from various sources, the concept of distributed generation and the concept of micro grids [11] is studied.

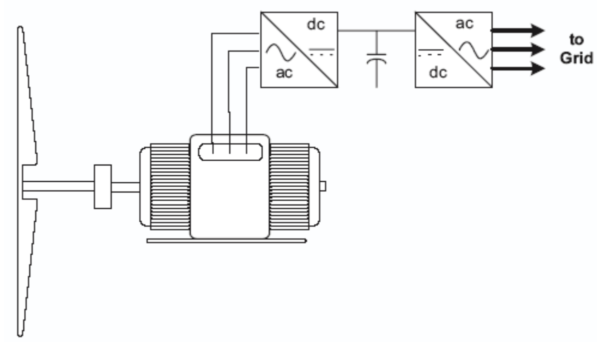

Fig. 1 Connecting wind turbines to the grid

III. Connecting Small Power Plant to the Grid

This module is dedicated to the technical requirements for the connection of small power plants to the distribution network and it has been given special attention. The terms and conditions small power plants must meet to be eligible to connect and smooth operate in parallel to the distribution system, are [12]:

1) The criterion of allowed power of solar plant,
2) The criterion of allowed flickers,
3) The criterion of allowed harmonics currents,
4) The criterion of short-circuit power,
5) The criterion of voltage fluctuations due to the simultaneous connection and disconnection of the plant,
6) The criterion of voltage variation in steady state, and
7) The criterion of permanently allowed current of the connecting line conductor.

Besides, it is necessary to perform synchronization of DG on the grid. The above criteria and schemes for the connection of small power plants to the grid, which are in accordance with the technical recommendations, IEC and Serbian standards, are thoroughly studied.

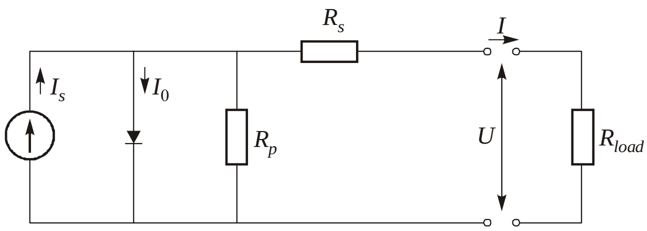

Fig. 2 Equivalent scheme of photovoltaic cell

TABLE I
Maximum Power of DG Connected to the Grid

DG Connecting Point	Maximum DG power
In the 400 V network	50 kVA
On the bus bar 400 V	200 – 250 kVA
In the 10 kV network	2 – 3 MVA
On the bus bar 10 kV	8 MVA
In the 20 kV network	7 MVA
On the bus bar 20 kV	10 MVA
In the 35 kV network	12 – 15 MVA
On the bus bar 35 kV	25 – 30 MVA

In Table I, the recommended values of maximum power of connected DG, depending on the voltage level and the connection point are given [12].

IV. Impact of Distributed Generators on the Distribution System

While generally impact of DG to the distribution system is positive, they can cause some problems such as increased level of short circuit, voltage fluctuations, flicker, disruption of relay protection, etc. Firstly, the module deals with modeling of DG in power systems analysis (PQ, PV, and PQV node). Further, the impact of DG on the stationary conditions of the distribution system is considered, in particular: power quality, short circuit power, voltage profile, voltage regulation, relay protection, reliability of supply etc. [12].

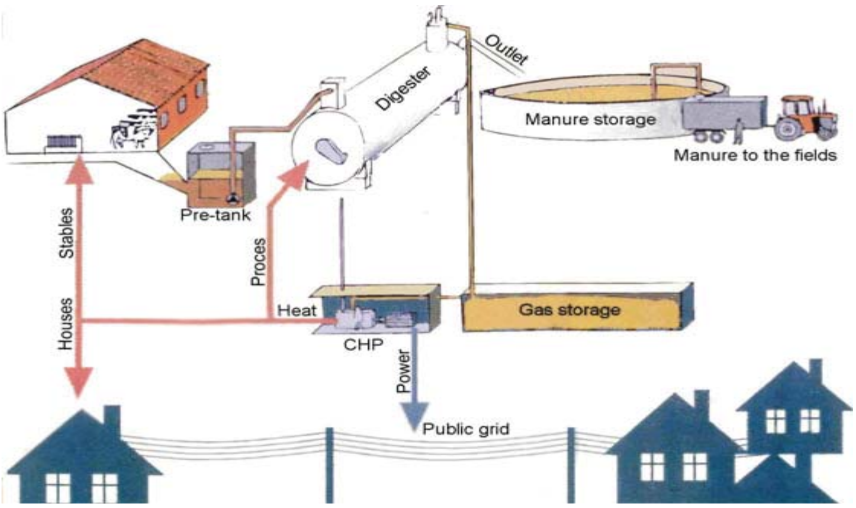

Fig. 3 Cogeneration of electricity and heat using biogas of animal origin

Students learn about the benefits of the application of distributed energy resources [5]:

- multiple choice option,
- reduced overall investment,
- modular approach,
- easy to provide locations,
- fast construction,
- improving voltage profile and power factor,
- Reducing energy loss,
- Increasing reliability of supply etc.

The impact of DG on the stationary and dynamic conditions of the distribution system is analyzed on the real life medium and low voltage networks, using *Matlab*® and *SKM*® *Systems Analysis, Inc* software. An example of distribution network for verification of DG connection criteria is shown in Fig. 5.

V. Techno-Economic and Environment Aspects

This module deals with techno-economic aspects of the construction and operation of distributed energy sources [5] such as:

- electricity price from various sources,
- SWOT analysis of small power plants,
- investment costs and annual costs of DG,
- index of return of investment,
- net present value of investment,
- cash flow analysis of small power plants,
- business plan of small power plants,
- effectiveness of investments, etc.

In addition, the environmental aspect of operation of small power plants, which is of increasing importance in recent years, is studied, including: emissions, noise, vibrations, water and soil pollution, impact on people and animal life, fitting into the landscape etc. Besides, it gives estimates of energy consumed for production of renewable energy facilities.

VI. Regulations

In this module, students get familiar with the applicable legal framework for connecting DG to the grid and operation of small power plants in Serbia. It discusses the procedure of acquiring the status of privileged electricity producer, as well as incentives for the privileged producers, so called feed-in tariff.

The category of privileged power producers in Serbia is defined by the *Energy Law* in 2004 [13]. The power plants are considered to be privileged energy producers if:

1) In the process of producing electricity use renewable energy sources, and
2) They belong to small power plants up to 10 MW.

The *Energy Law* was established that privileged power producers shall have:

- The right of priority in the regulated energy market in comparison to other manufacturers that offer electricity under the same conditions and,
- Eligibility for subsidies, tax, customs and other benefits in accordance to the law.

A key step to begin market development of renewable energy sources in Serbia was to determine the feed-in-tariff in

2011th, respectively guaranteed purchase prices for electricity produced from renewable energy sources for 12 years from the start of production, Table II [14].

The state takes over the balance responsibility for the privileged power producers.

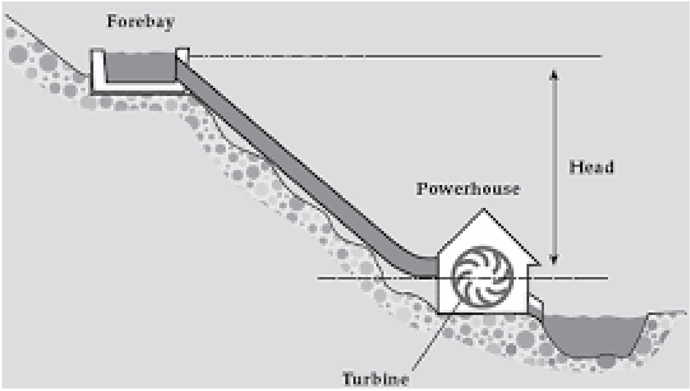

Fig. 4 Concept of small hydroelectric plant

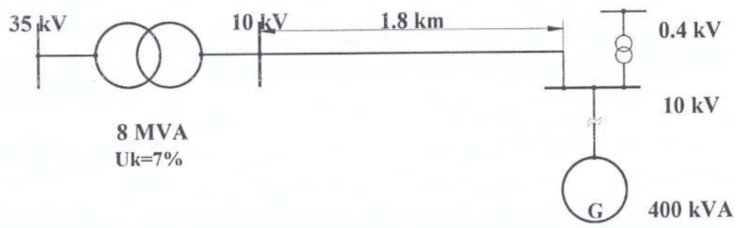

Fig. 5 Distribution network for verification of DG connection criteria

TABLE II
FEED-IN-TARIFF IN SERBIA

Type of Facilities	Guaranteed Purchase Price – Feed-in-Tariff (c€/kWh)
small hydro	7.8 – 9.7
biogas	12 – 16
biomass	11.4 – 13.6
wind turbine	9.5
solar	16 – 23
geothermal	7.5
waste	8.6 – 9.2

VII. POTENTIAL OF RENEWABLE ENERGY SOURCES

In this module, students learn about the potential of renewable energy sources in Serbia. Renewable energy sources are the backbone of energy independence of Serbia in the future. The general assessment is that country has significant renewable energy potential [15]-[17]. Some estimates state the wind energy potential of 1300 MW, while the potential of small hydro power plants is estimated to be at least 500 MW. However, with regard to the usage of renewable energy sources in Serbia, the current situation is not satisfactory. Apart from hydropower and the limited scope of geothermal energy and biomass, other renewable energy sources in Serbia are not used. Large hydro power plants have the installed capacity of 2831 MW with annual production around 10.3 TWh. However, there are 900 potential sites of small hydro power up to 10 MW, with a total production of 1800 GWh/year, while 90% of these would be less than 1 MW, Fig. 6.

The total annual capacity of small hydropower is 16.7 PJ, and total technical potential of renewable energy sources in Serbia is 160 PJ /year, Table III [19]. As for the wind energy, the existing data suggest that the six sites measured wind speeds 6-7 m/s, which corresponds to the level of the annual load of 18-25% [19].

TABLE III
POTENTIAL OF RENEWABLE ENERGY SOURCES IN SERBIA

Energy Source	annual potential (PJ)
biomass	100.4
small hydro (< 10 MW)	16.7
geothermal	8.3
wind	7.9
solar	26.7
total potential	160

PJ = 10^{15} J

In the field of biomass combustion for heat and electricity, Serbia has significant opportunities, including the use of briquettes and pellets. Wider use of briquettes and pellets for heating households instead of electricity, requires solving multiple problems, including lack of standards for their production, absence of biomass exchange and low electricity prices [15],[20].

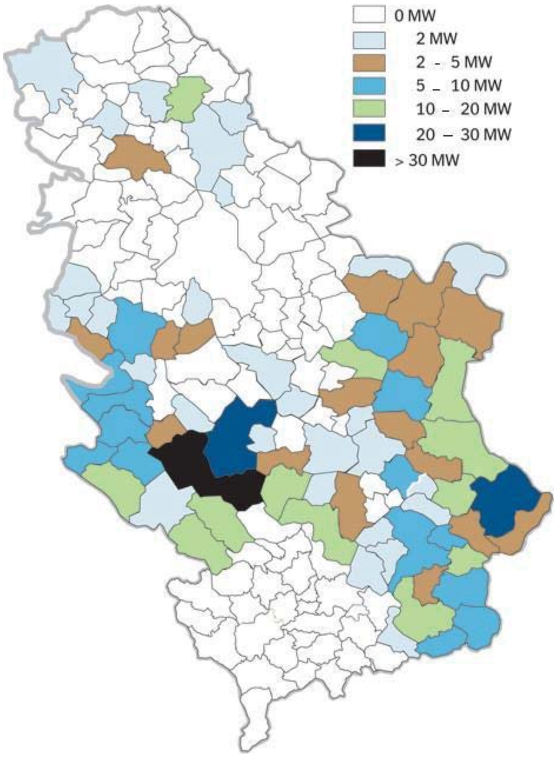

Fig. 6 Small hydro potential in Serbia

VIII. Energy Policy

The aim of this module is to introduce students with the *National Action Plan of the Strategy of the Republic of Serbia* by 2015, as the key of the energy policy [18], [20]. Energy import dependency of Serbia in 2010 was 33.6% and it is of the utmost importance to provide safe, quality and reliable supply of energy and reduce the country's energy dependence in the future. In this respect, main objectives of the energy policy of the Republic of Serbia were defined, as follows:

- Development of energy infrastructure,
- Diversification of energy sources to ensure security of supply,
- Introduction of modern technologies in the energy sector,
- Reducing the growth of final consumption,
- Increasing energy efficiency, and
- Increasing the use of renewable energy.

National Action Plan for Renewable Energy includes [19]:

- The share of energy from renewable sources in the gross final consumption,
- Dynamics for achieving the renewable share by year,
- Measures and the estimated financial resources for the realization of the planned share of energy from renewable resources, and
- Holders of the activities and timelines for achievement of planned activities.

According to agreement with the EU since 2009th, Serbia took over the obligation to increase the share of renewable energy in total energy consumption from the current 21.2% to 27% to the 2020th [19]. Energy Development Strategy of the Republic of Serbia by 2015 envisages that the share of new renewable sources in total primary energy consumption, should reach 1.1% in the 2015th [19].

IX. Conclusion

Objective of the course *Small power plants and renewable energy sources* in the Higher Education Technical School of Professional Studies in Novi Sad, is to train students for project management and implementation of renewable energy sources.

The issue of renewable energy sources is very complex, interdisciplinary and strongly influenced by the use of ICT and new materials, as well as energy policy and the electricity market. Willingness of local communities to pay for renewables is observed to be correlated to socioeconomic characteristics including education, interest in environmental issues and knowledge of renewable energy sources [20]. Need for renewable energy education and training at all levels is globally recognized. During the last three decades a large number of countries across the globe have initiated academic programmes on renewable energy technologies and related aspects [21]. Nevertheless, designing of curricula and programs in the field of renewable energy sources is a challenge for higher school and college teachers. This particularly refers to higher schools, since from the professional engineer is expected a solid theoretical knowledge but also the practical skills applicable in the industry.

Despite the significant potential for the application of renewable energy, as well as the feed-in tariff, due to the unfavorable loans and complicated procedure for obtaining permission to connect DG to the grid, the number of implemented renewable energy sources in Serbia is negligibly small. As a result, Serbia lacks practical knowledge, good practice and experience in the construction and operation of renewable energy sources.

It is clear that investing in human resources in the field of renewable energy sources is of great importance [17]. Therefore, the curriculum of the subject *Small power plants and renewable energy sources* should be developed in accordance with the modern, commercially viable renewable technologies, experience and good practice, the real needs of the Republic of Serbia, as well as the requirements of an open electricity market [22]. Success in the field of greater implementation of renewable energy sources in Serbia will largely depend on the quality of the curriculum.

References

[1] H. L. Willis, *Distributed power generation: Planning and Evaluation*, CRC Press, 2000.
[2] A-M. Borbely, J. F. Kreider, *Distributed generation: The power paradigm for the new millennium,* CRC Press, 2001.
[3] T. Ackermann, G. Andersson, L. Soder, "Distributed generation: A definition, Electric Power Systems Research", 57, (2001), 195-204.
[4] Gilbert M. Masters, *Renewable and Efficient Electric Power Systems*, John Wiley and Sons Inc, 2004.
[5] D.N. Gaonkar, *Distributed generation*, InTech, 2010
[6] V. Mijailovic, *Renewable energy sources*, Academic mind, Belgrade, 2011, in Serbian.

[7] M. Mendonca, *Feed-in tariffs: Accelerating the deployment of renewable energy,* World Future Council, 2009

[8] N. Jenkins, R. Allan, P. Crossley, D. Kirschen, and G. Strbac, *Embedded Generation*, London: IEE Power & Energy Series 31, 2000.

[9] J.A.P. Lopes, N. Hatziargyriou, J. Mutale, P. Djapic, “Integrating distributed generation into electric power systems: A review of drivers, challenges and opportunities”, Electric Power Systems Research 77 (2007), 1189-1203.

[10] M. Bollen, F. Hassan, *Integration of distributed generation in the power system*, Willey-IEEE Press, 2011

[11] N. Rajakovic, D. Tasic, G. Savanovic, *Distribution and industrial networks*, Academic mind, Belgrade, in Serbian, 2003.

[12] Technical recommendation no. 16: Technical requirements for the connecting of small power plants to the grid, Serbian Electric Power Industry, Belgrade 2003.

[13] Energy Law, Official Gazette of the Republic of Serbia, no. 84/2004.

[14] Regulation on conditions for acquiring the status of privileged producer of electricity, Official Gazette of the Republic of Serbia no. 72/2009.

[15] D. Gvozdenac, R. Ciric, M. Tesic, “Prospects of Energy Efficiency Improvement and Development of the Renewable Energy Sources in Province of Vojvodina”, *20th World Energy Congress*, 12-15 November 2007, Rome.

[16] *Study on the evaluation of the total solar resources - solar atlas and production capabilities in Vojvodina*, Provincial Secretariat for Energy and Mineral Resources AP Vovodine, 2011.

[17] *The main directions of technological development of AP Vojvodina*, Provincial Secretariat for Science and Technological Development of AP Vojvodina, Novi Sad, 2007.

[18] *Energy Strategy of the Republic of Serbia by 2015*, The Ministry of Mining and Energy of the Republic of Serbia, Belgrade 2004th

[19] *White Book of the Power Industry of Serbia*, Belgrade, 2009.

[20] Stigka E.K, Paravantis J.A, Mihalakakou G.K, “Social acceptance of renewable energy sources: A review of contigent valuation applications”, Renewable and Sustainable Energy Reviews, Vol. 32, April 2014, pp. 100-106.

[21] Kandpal T.C, Broman L, “Renewable energy education: A global status review”, Renewable and Sustainable Energy Reviews, Vol. 34, June 2014, pp. 300-324.

[22] D. Gvozdenac, R. Ciric, J. Petrovic, “Energy Efficiency and Renewable Energy Sources in Province of Vojvodina – Strategy Implementation Program”, *6th MedPower 2008*, 2-5 November 2008, paper no. 226, Thessalonica.

Rade Ciric gained Dipl.- Ing diploma from the University of Novi Sad in 1987, Master of Science degree from the University of Belgrade in 1992, and Doctor of technical science degree (PhD) from the University of Novi Sad - Serbia in 2000, all in electrical engineering.

From 1987 to 2003 he was with EPS- *Elektrovojvodina Novi Sad*. Dr Ciric was Post-Doctoral Research Fellow at the UNESP Ilha Solteira-SP, Brazil in 2001/2002 and the Visiting Professor in Power Systems and Electronics Research Group, University of the West of England (UWE), Bristol, UK in 2004/2005, through *The Leverhulme Trust* scheme. He was with the Secretariat for Science and Technological Development in the Government of AP Vojvodina, from 2005 to 2012.

Dr Ciric is now Professor at the Higher Education Technical School of Professional Studies in Novi Sad (Skolska 1, 21000 Novi Sad, SERBIA), and the Associated Professor at the Faculty of Electrical Engineering at the University of Belgrade, Serbia.

Nikola Rajakovic received his Dipl.-Ing. degree in Electric Power Engineering in 1974, M.Sc. in 1977 and Ph.D. in 1983, all from Electrical Engineering Faculty, University of Belgrade, Serbia.
Presently he is a full-time professor at the same University. His research interests include steady-state analysis of power systems, power-system optimization and renewable energy sources.

Prof. Rajakovic is a senior member of IEEE, a member of CIGRE and chairman of the Energy Society in Serbia.