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Energy efficiency of electrical drives: between energy engineering, energy policy and energy education[1]

Miroslav Bjekić[2] and Dragana Bjekić[2]
[2]Faculty of Technical Sciences in Čačak – University of Kragujevac, Čačak, Serbia
e-mail mbjekic@gmail.com, dragana.bjekic@ftn.kg.ac.rs

Abstract: *For implementation of the concept of energy efficiency of electrical drives (EEED) it is necessary to accomplish some prerequists: to train engineers for of (energy efficient) electrical drives construction, to design and realize ED, to define principles and create procedures of energy efficient implementation of ED, to choose energy efficient use of ED, to accept energy efficient behaviour in this field and to train to use it. According to the multidisciplinarity of the concept of energy efficiency, three basic dimensions of energy efficiency are considered: (electrical) engineering, policy and education in this field. Necessity of the connection of three dimensions to meet energy efficient criteria, is presented with the practical examples – activities and results of scientific research focused on the energy efficiency of ED.*

Keywords: *energy engineering, energy policy, energy education, energy efficiency of electric drives, multidisciplinary.*

1. INTRODUCTION

General concept of energy efficiency refers the quality of energy consumption.

Realization of energy efficiency in different domains of human dealing demands positive attitudes to the energy efficiency as a style of individual life, and life of the community (policy of energy efficiency), construction of the energy efficient equipment and technology (engineering), development capacities for energy efficient behaviour (education). Looking from the industrial companies position, it is necessary to develop integrated approach to energy efficiency and to overcoming the gap between theory and theoretical research, and industrial practice [1].

The main concepts on the topic of this paper – energy engineering, energy education and energy policy – are considered in the field of energy efficiency, and they are three dimensions of the project „Research, development and implementation of the programmes and measures of energy efficiency of electrical drives“. Complexity of the field of energy

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efficiency of eletrical drives (EEED), team multidisciplinarity [2], multidisciplinary and interdisciplinary competence of team members individaully and as a team, are illustrated by the activities of the project team. Based on description of activities and results of the project, the relationship between engineering, education and policy is considered. Their interdependance for realization of expected results and energy efficient behaviour, and availability of the energy efficient technology system are considered, too.

2. ENGINEERING, POLICY AND EDUCATION IN THE FIELD OF ENERGY EFFICIENCY

Today, engineering-technological aspects of energy efficiency or *energy (efficiency) engineering* means an approach of development of technological equipment, machines, industrial systems etc., because, the concept of energy efficiency is generally accepted concept and request of modern society. Therefore, all of engineers' constructions, products and all of developed processes, are necessary to fulfil minimum of the energy efficiency standards.

Engineering-technological aspect of EEED or energy engineering of ED is focused on energy efficient electrical motors and energy efficient electrical drives. It means the next [2], [3]:

- correct selection of motor type and elements of electric drive system,
- correct selection (choice) of nominal values of electrical drives system, electric motors in these systems, because overdimensioning is very often case in the practice (overdimensioning is a problem because it increases the coast of equipment, removes the work point of it without nominal designing value for these etc.)

Policy of the energy efficiency or *energy policy* includes activities and measures in the field of legislative regulations, law documents and the other regulations and standards based on the political decisions, agreement of different institutions in the system, and of a wider community which is important to accept and implement these regulations, and to develop positive attitudes and readiness for energy efficient dealing in a specific field. Adoption of the international criteria is crucial aspect of creation of the policy of energy efficiency [3], and definition of indicators of energy efficiency is one of the operationalized activities of the policy [4].

Energy policy of ED or policy of EEED [5] should to obtain commitment for EEED implementation, defined by standards (IEC60034-1, IEC60034-2-1, IEC60034-30, on Serbian: SRPS60034-2-1 and SRPS60034-30), and legislative framework for measures and regulatives implementation. Specific topic of EEED policy are: laws, regulatives, standards, directives, nominal values of the electrical motor with high performance, financial iniciatives for supporting to implement more efficient electrical drives, energy control [3].

Policy of EEED is more realistic as an element of the general policy of energy efficiency. By using adequate technology it is possible to realize significance energy conservation and energy saving, but, most conversation and most quality using of electrical energy are possible by changing of human behavior. Than, energy efficient behaviour becomes a part of the national and international strategy of energy efficiency and scenarious of sustainable energy policy.

Creation of the culture of energy efficiency is educational process. Education for energy efficient dealing or energy education has goals which are depended from the purpose of

educational activities and strategies. Different goals are defined – from the goal to develop energy awareness on indivudual level, to develop awareness of social groups, and to the goal to master of the knowledge and skills (general and professional). All of these are the base to acquire energy efficient behaviourand responsibility of users, decision makes, or engineers(from the constructor to the system maintainer).

Energy education or education for energy efficient behavior in domain of using electrical drives should to provide development of theenergy awareness and energy efficient behavioru of all actors – designer of ED, mainainer, user, creator of social context of energy efficiency. The focus of the energy education is not on designers–constructors of electrical motor and drive because they are the small professional specialized groups which acquire professional knowledge and skills in the stage of formal education. The focus of the enregy education is on the educaiton of the users of ED (managers of energy efficiency, operators on ED, users of ED in industrial context, users of small ED in nonindustrial context, etc.). The expansion of energy efficient behaviour of ED users is based on development of the positive energy awareness by education, by techological innovations, by timely information for the actors, by actors inclusion in the communication network of EEED policy.

The first step of education for energy efficient using of energy is development of the energy awareness and energy efficient using of everydays equipment in early education, in the family, and in the school. Training students of electrical engineering for construction, design, using and maintain electrical motors and drives on energy efficient manner is the crucial for EEED. But, this education is realized at the Serbian universities partially, not as integral concept.

3. REVIEW OF THE PROJECT ACTIVITIES AND RESULTS

These three dimensions of energy efficiency are the basis of development and realization of the project „Research, development and implementation of programmes and measures of energy efficiency of electrical drives“. The project started in 2011 as a project in the field of technological development (the research field according to Serbian Ministry of education and science), and it realizes in 2016, too.

3.1. Project phases and activities

The subject of the research in the project is: regulation and promotion of the energy efficiency of electrical drives (EEED), most often present in modern industry [3]. The successivelly realization of the project goals is presented in the next review of the research phases (realized from 2011 to 2016):

Phase 1. Research of programmes and procedures of EEED:

- analysis of the program of EEED in EU and the world (measures, organization, control, sanctions);
- legislative regulations of EEED – review of the standards, regulations, measurements, and recommendation in the world, EU and Serbia;
- analysis of realized effects and possible savings by implementation of the energy efficient electrical drives in EU and world;

- defining of the conditions of EEED policy implementation: analysis of needs of target groups, readiness and posibilites to implement regulations, possibilities to inform target public.

Phase 2.1. Development of the programmes and measures of EEED:

- Harmonization of the standards in the field of energy efficiency of electrical machines and electrical drives: IEC60034-1, IEC60034-2-1, IEC60034-30 i rečnika 60050-411;
- Defining of recommendations for selection of the energy efficient electrical motor.

Phase 2.2: Analysis of energy efficiency of realized practical sollutions in the field of electrical drives:

- Analysis of possible technical solutions for reconstruction of the electrical drives of dredge from the aspects of energy efficiency;
- Reset of the higher harmonics in regulated multi–motor drives.

Phase 3.1: Implementation of the programmes and measures of EEED – methodology development:

- development of the standard method of measurement of magnetic properties of ferromagnetic plates, and development of the optimal method and dimension of measured samples;
- development of the new method of regulation of induction motor drives.

Phase 3.2: Implementation of the programmes and procedures/measures of EEED – development of technical solutions and training:

- teasting magnet losses of the materials which are used in the construction of the motors, from the aspect of the energy efficiency;
- design of the laboratory (space and equipment) for EEED control;
- construction and analysis of measurement equipment for testing classes of EEED, according to the proscribed standards;
- realization of the software for determination of the class of EEED;
- solutions of EEED realized in the practice;
- team for implementation of the policy of EEED – structure, competence and development of the team;
- organization of the symposium of EEED.

Phase 3.3. Implementation of the programmes and measures/procedures of EEED – realization of the solutions and education programmes:

- development of the new magnetization model of the materials which are used in the construction of electrical motors;
- realization of the complet measurement set – testing station for electrical motors testing;
- modification and improvement of the algorithm of the induction motor machines regulations;
- preparation of the manual for design and construction of EEED;

- analysis of energy efficiency of the practical realized solution ED;
- development of the team to the policy implementation and measures of EEED;
- preparation of the handbook for the managers of EEED.

Phase 3.4. Implementation of the programmes and measures/procedures of EEED – realization of the solutions and evaluation of the activities:

- realization of the laboratory set for testing of three phases induction motor;
- preparation of the Laboratory for electrical machines, drives and regulation at FTN Čačak for realization of remote laboratory testing;
- continuiation of the activities in the Commission of the Institute for standardization – Commission N02: Rotating electrical machines;
- evaluation of the programme of engineers education for implementation of the policy and measures of EEED;
- defining of energy efficiency of the multimotor drive in work regime;
- experimental testing of the results obtained with the new magnetisation model of ferromagnetic plates;

Phase 3.5.Implementation of the programmes and measures/procedures of EEED – evaluation of the activities:

- Practical implementation of the mathematical models of hysteresis of ferromagnetic plates (engineering practice example);
- improvement of DTC algorithm of regulation of induction motors, with the goal to minimizing torque ripple and losses on motors;
- experimental evaluation of the standard of belt conveyor under the conditions of implementation of the current regulated electrical drives;
- research/evaluation of effects of specialized initial training of electrical engineering students – future engineers in the field of EEED and development of the methodology of training evaluation.

3.2. Structure of the project results in domains of energy engineering, policy and education

The research had wide goals and gave contributions in all three energy efficiency domains (dimensions). But, the basic contributions are in the field of testing, improvement and construction of EEED and development of the measurement methodology of EEED. Research results are published in 62 units (14 papers in the international journals – M20 scientific categories in Serbia, 27 papers in the internatnional conference - M33 scientific categories in Serbia), including scientific monography [3] and two technical solutions [6, 7]. Focus on the research in all three domains of energy efficiency is illustrated with the problems and selected works/papers which present solutions of the problems, and research results representative for three dimensions (table 1).

Table 1. Contributions/Results of the project TR33016 in 3 dimensions of EEED

	Energy engineering	Energy policy	Energy education
Phase 1. Research of programmes and measures / procedures of EEED	Overcoming barriers of introducing EEEM/EEED [8]	Legislative regulations of EEED –standards, propisi, mere and recommendations in the world, EU and Serbia [9]	Energy efficiency behaviour in industry [10]
Phase 2.1. Development of programmes and procedures of EEED	Potential electricity sving by using EEED [11]	Public relations as method of EEED policy promotion [12]	
Phase 2.2. Analysis of practical solutions	Energy efficiency of Pumps electrical drives [13]	Standards in the field of EEED [14]	
Phase 3.1. Implementation of EEED programmes and measures / procedures – development of methodology	Reduction of torque ripple in DTC induction motor drive [15] Software for testing the level of exploitation and class of EE motors [6] Application of Standard and Modified Eh-Star Test Method for Ind. Motor Stray Load Losses [16]	Introducing of energy management system in Serbia [17]	
Phase 3.2. Implementation of EEED programmes and procedures – dev. of technical solutions and training	Efficiency classes of three-phase, cage-induction motors software ([18] Design, construction, calibration and use of electromagnetic brake [19]		Team competence of the specialized team for EEED [2] E-course: Designing of EEED [20]
Phase 3.3. Impl. of EEED programmes and procedures – realization of solutions and ed. programmes	Development of the platform for testing algorithm of regulation AC motors [21]	Vocabulary SRPS IEC 60050-411: Obrtne mašine [22] Vocabulary on the IEC web page [23]	E-course: EEED: implementation of policies and procedures/ measures [24]
Phase 3.4. Implementation of EEED programmes and procedures – realization of solutions and evaluation of activities	Electrical motor testing station with electromagnetic load emulator [25] EE of belt conveyor at constant speed operation [26] Electromagnetic brake with one rotating disk for laboratory testing of EM [7]		Communication competence of engineers in EEED teams – education and evaluation [27]
Phase 3.5. Impl. of EEED programmes and procedures – evaluation	Remote control of electromagnetic load emulator for electric motors [28]		Professional develop-ment of EEED el. engineers [29]

4. CONCLUSION

Researchers' step toward energy efficiency gives social framework and social significance for their researshes. According to the social importance of EEED (electrical drives are the holders/basis of industrial systems), it is necessary to consider not only technological dimensions of researches, but also policy dimensions of energy efficiency and energy education. It provides a multidisciplinary context, researchers collaboration, multidisciplinarity of the results/contributions, and leads to integrated approaches to energy efficiency of electrical drives.

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