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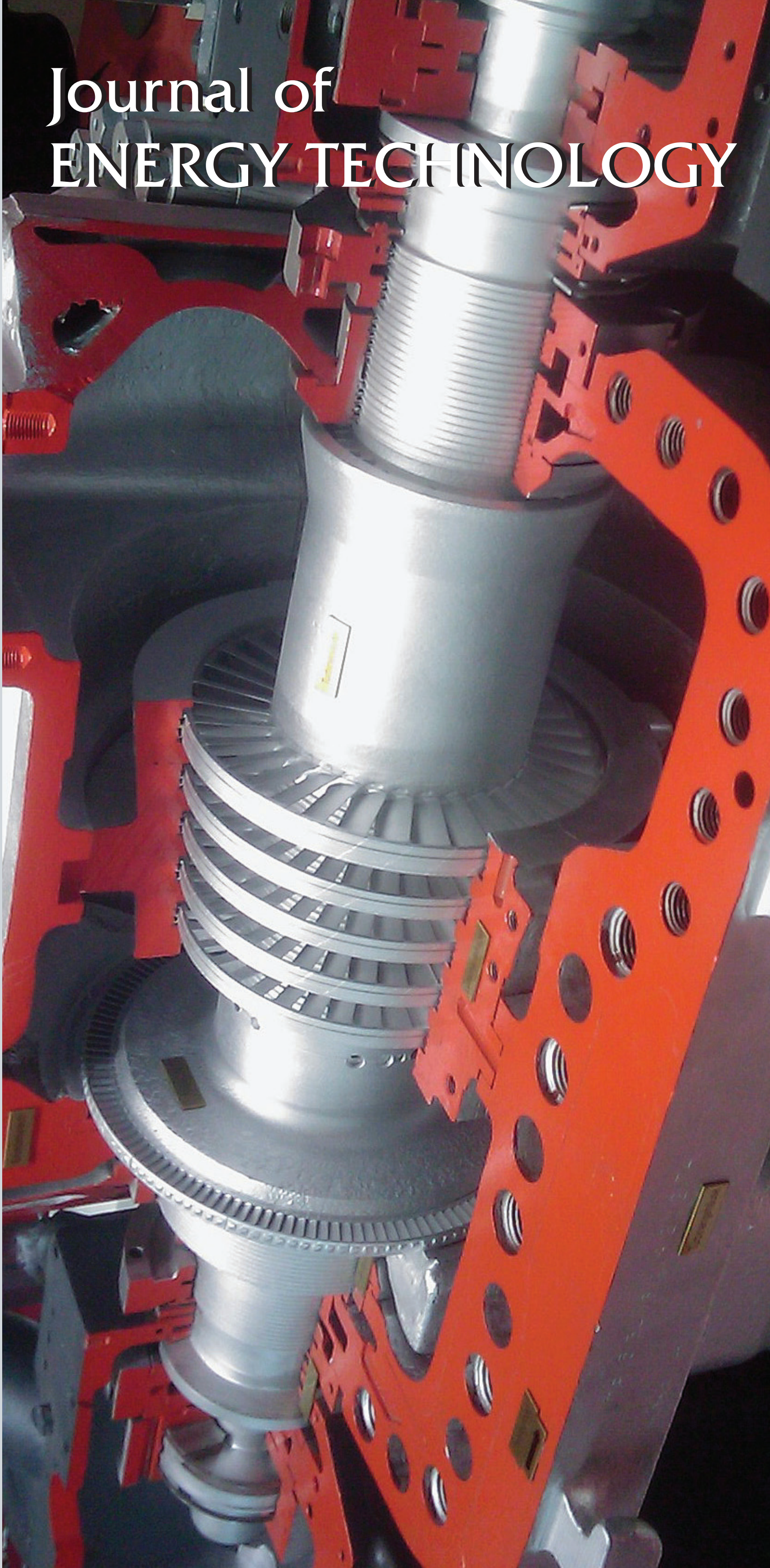

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Dogajanja v svetu in njih vpliv na energetiko v Evropi in pri nas

Razmere v Ukrajini kažejo, kakšno ranljivost Evrope prinaša raba fosilnih goriv na energetskem področju. Velik del Evropske energetike zavisi od pipice ruskega plina. Zato, za nekatere ambiciozni načrti rabe OVE virov v Evropi do leta 2030, postajajo še kako aktualni, saj se Evropa lahko izkoplje iz energetske odvisnosti le s povečanjem deleža OVE virov pri svoji energetski porabi.

Razviti deli, ki so še posebej energetsko odvisni od ruskega plina, hitijo in povečujejo delež OVE virov. Predvsem je na tem področju aktivna Nemčija. To pomeni, da bo gospodarstvo na področju OVE virov v Nemčiji še dodatno spodbujeno k čim večji in čim hitrejši rasti.

Kako pri nas? Zgleda, da se še vedno ne zavedamo priložnosti, ki jo ima Slovenija tudi na področju OVE virov. Doma imamo dovolj strokovne pameti, tehnološko proizvodnih zmožnosti in kot konec koncev tudi dobre volje, da se raba in proizvodnja na področju obnovljivih virov energije poveča.

Verjamem, da prihaja čas, ko bomo dejansko primorani razmišljati čim bolj v smeri energetske samostojnosti in oživitve gospodarstva, ki jo v Sloveniji lahko omogoči koriščenje OVE virov.

Andrej PREDIN

Developments in the world and their impact on energy in Europe and for us

The situation in Ukraine is indicative of the vulnerability of Europe brought about by its use of fossil fuels. A large part of Europe's energy depends on Russian pipe lines. Therefore, some ambitious plans for the use of renewable resources in Europe by the year 2030 are becoming of particular interest. Europe can gain energy independence only by increasing the share of renewable sources in its energy consumption.

The European nations that are particularly dependent on Russian gas are rushing to increase the share of renewable sources. All of these are advanced in Europe, especially in Germany, which has a leading position in the production and construction of wind and hydropower plants, which will further help that country to increase its industrial growth.

How is this situation in Slovenia? It seems that we are still not aware of the opportunities that Slovenia also has in the field of renewable resources. Slovenia has sufficient professional expertise, the required technological and production capabilities as well as the will for it to be done.

I believe that the time is coming when we will truly be forced to think as much as possible in the direction of energy independence and economic recovery, which requires Slovenia to make use of renewable resources.

Andrej PREDIN

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Journal of Energy Technology

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ANALYSIS OF VOLTAGE SAG PROPAGATION THROUGH THE DISTRIBUTION NETWORK

ANALIZA ŠIRJENJA UPADOV NAPETOSTI V DISTRIBUCIJSKEM OMREŽJU

Zvonimir Klaić, Krešimir Fekete[R], Goran Knežević

Keywords: power quality, voltage sag, transformer winding, computer simulation

Abstract

Power quality is a hugely important aspect of power delivery. This paper deals with voltage sags, which are reflected in the aspect of power quality. During a voltage sag, the voltage at the customer terminal is reduced and can cause undesirable equipment trips. The main causes of voltage sags are short-circuit faults. Most short-circuits in a power system are either single line-to-ground or two phase short circuits. The causes of voltage sags in the power system are not the subject of this paper. This paper analyses the propagation of single-phase voltage sags caused by a line-to-ground short circuit in a transmission network, from the high voltage level to the distribution level through various types of transformers. The influence of the transformer winding connection on the propagation of voltage sag is investigated from the theoretical aspect, the practical aspect and the computer simulation aspect. One example of voltage sag propagation from the transmission network to the distribution network that is captured with the power quality measurements is analysed. Theoretical calculations of voltage sag propagation through the various types of transformer windings connections are presented and compared to the measurement result. Furthermore, a computer model of the observed distribution network is modelled in DigSILENT Power Factory software. This model is used for the simulation of voltage sag propagation. The results of the computer simulation are presented and compared to the measurements. Conclusions and comments on the results are presented at the end of the paper.

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Povzetek

Kakovost električne energije je zelo pomemben vidik pri razdeljevanju električne energije. Ta članek se ukvarja z upadi napetosti, ki predstavljajo en vidik kakovosti električne energije. Med upadom napetosti je napetost na uporabniškem priključku znižana in lahko povzroča neželene napake opreme. Glavni vzrok upadov napetosti so kratkostične okvare. Večina kratkih stikov v omrežju je enofaznih zemeljskih ali dvofaznih. Vzroki upadov napetosti v elektroenergetskem sistemu niso predmet tega članka. Članek predstavlja analize širjenja enofaznih upadov napetosti zaradi enofaznih zemeljskih kratkih stikov v prenosnem omrežju, od nivoja visoke napetosti do nivoja napetosti distribucije preko različnih tipov transformatorjev. Vpliv vezave transformatorskega navitja na širjenje upada napetosti je raziskan iz teoretičnega vidika, praktičnega vidika in vidika računalniške simulacije. Analiziran je en primer širjenja upada napetosti iz prenosnega omrežja na distribucijsko omrežje, ki je zajeto z merjenjem kakovosti električne energije. Teoretični izračuni širjenja upada napetosti preko različnih tipov vezav navitij transformatorja so predstavljene in primerjane z rezultati meritev. Prav tako je računalniški model opazovanega distribucijskega omrežja modeliran v DigSILENT Power Factory programski opremi. Računalniški model je uporabljen za simulacijo širjenja upada napetosti. Rezultati računalniške simulacije so predstavljeni in primerjani z meritvami. Zaključki in komentarji rezultatov so predstavljeni na koncu članka.

1 INTRODUCTION

Voltage sags are short duration reductions in the rms (root-mean-square) value, [1], and are the most frequent cause of power quality problems, [2]. They can cause interruptions of industrial processes, which could result in a malfunction of equipment and considerable economic losses. The interest in voltage sags is mainly due to the problems they cause on several types of equipment: adjustable-speed drivers, process-control equipment, computers, etc., [1]. Voltage sags are caused by short circuits, overloads or by starting of large motors, [3]. A large number of customer buses in the distribution network may experience voltage sags when faults occur in the transmission systems. Even though some of these buses are distant from the original fault locations, they still encounter voltage sags, [4]. The faults in the distribution systems normally cause voltage sags only at the local customer buses, [5]. Most short circuits in power systems are unsymmetrical (line-to-ground, line-to-line, double-line-to-ground). In that case, calculations must be done in all three phases, or the symmetrical component theory must be used.

The numbers and characteristics of voltage sags (known as 'the performance of voltage sags') at the customer buses may differ from each other and from that at the original fault locations, [1]. The difference in voltage sag performance, i.e. magnitude and phase angle relationships in particular, is a result of the propagation of voltage sags from the original fault locations to different customer buses. The propagation of voltage sags through different types of transformer connections results in a different performance of voltage sags on the secondary side of the transformers, [4]. Voltage sag propagation normally occurs from a higher voltage to a lower voltage level. Due to impedance of the transformer, the reverse direction of the voltage sag propagation is less significant, [4].

This paper analyses the propagation of single-phase voltage sag caused by a line-to-ground short circuit in a transmission network, from the high voltage level to the distribution level through various types of transformers (regarding winding connections). One example of voltage sag propagation from the transmission to the distribution level that is recorded with the power quality measurements is presented. In the literature, [6], a detailed analysis of voltage sag as well as similar cases of voltage sag propagation that is measured at another time is performed. The innovation of this paper, in comparison to, [6], is the construction of computer model of the observed distribution system and the simulation of voltage sag propagation. The results of the calculation and simulation are presented and compared to measurements.

The structure of this paper is as follows: first, a brief theoretical explanation of voltage sags is made in Section 2. In Section 3, the influence of transformer winding connections on the voltage sag propagation is presented. Section 4 deals with the example of measured voltage sag propagation from the transmission to the distribution level. A computer simulation of voltage sag propagation is presented in Section 5. The conclusion and suggestions for further work are discussed in the last section.

2 VOLTAGE SAGS

2.1 Description and Definition

Voltage sags are two-dimensional electromagnetic disturbances determined according to voltage magnitude and duration time, [1]. Voltage sags are defined as a decrease in the rms value of an AC voltage between 0.1 p.u. and 0.9 p.u. at the power frequency for durations from 0.5 cycles to 1 min, [7], [8]. According to [9], the duration of the voltage sag is defined as the time between the rms of voltage dropping below the threshold and when the rms of voltage returns to the threshold. An example of voltage sag is shown in Figure 1, [10]. It can be seen that the rms voltage drops to a value of about 70% of the pre-event voltage for about 140 mos. Afterwards, the voltage recovers to about the pre-sag value. The threshold is 90% of rated voltage. The magnitude and duration are the main characteristics of voltage sags. The voltage during sag can also contain a rather large number of higher frequency components.

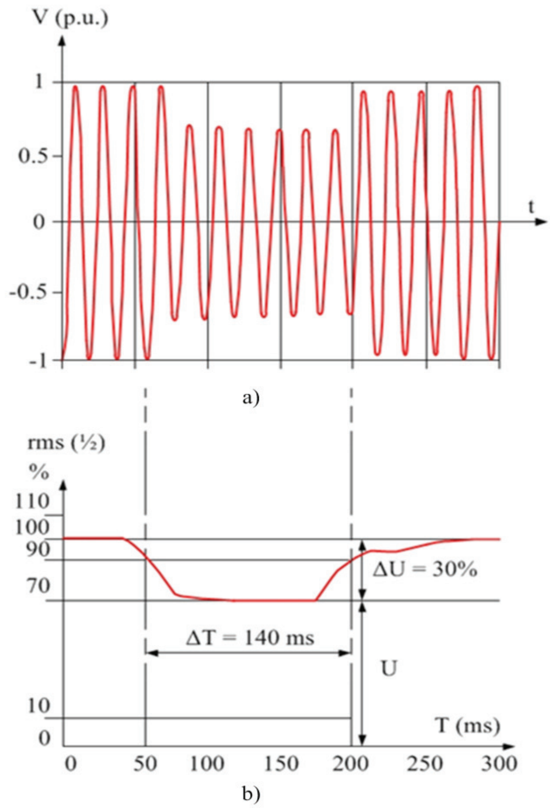

Figure 1: *Example of a voltage sag: a) time domain and b) rms value [10]*

Magnitude and duration are the main characteristics of voltage sags, and they have been used for the development of compatibility charts and indices for equipment. In addition to these, the other characteristics, such as unbalanced voltage sags, phase angle shifts, the point on the wave of initiation and recovery, and waveform distortion, have been found to significantly influence the equipment's sensitivity to the voltage sags, [1].

2.2 Model for Theoretical Calculations

To quantify voltage sag magnitude in radial systems, the voltage divider model, [1], shown in Figure 2, can be used. This is a simplified model, especially for transmission systems (which are meshed), but it can be a useful model to predict some of the properties of sags, [1].

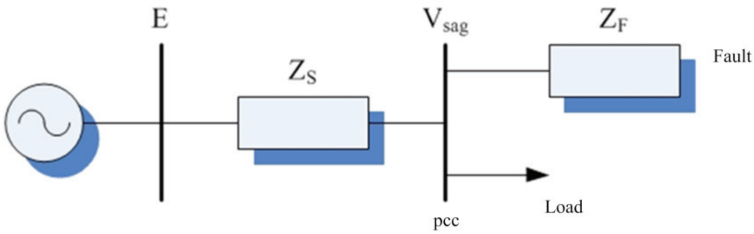

Figure 2: *Voltage divider model [2]*

Z_S is the source impedance seen from the point-of-common coupling (PCC) and Z_F is the impedance between the PCC and the fault location. The PCC coupling is the point from which both the fault and the load are fed, [1]. E is the source voltage. The voltage at the pcc (V_{sag}) can be found using Equation (2.1), [1]:

$$V_{sag} = \frac{Z_F}{Z_S + Z_F} \cdot E \tag{2.1}$$

If it is assumed that the pre-event voltage E is 1 p.u., then Equation (2.1) results in Equation (2.2):

$$V_{sag} = \frac{Z_F}{Z_S + Z_F} \tag{2.2}$$

It can be seen from Equation 2.2 that the sag becomes deeper for faults electrically closer to the customer (Z_F becomes smaller), and for systems with a smaller fault level (Z_S becomes larger), [1].

2.3 Single Line-to-Ground Fault

This type of fault is non-symmetrical, and the symmetrical component theory will be used for calculation. The voltage divider model presented in the previous subsection has to be split into its three components: a positive-sequence network, a negative-sequence network and a zero-sequence network. The three component networks have to be connected into one equivalent circuit at the fault position depending on the fault type. For a single line-to-ground fault, the three networks should be connected in a series at the fault position, as shown in Figure 3, [1]. Index 1 denotes positive-sequence quantities; Index 2 denotes negative-sequence quantities; and Index 0 denotes zero-sequence quantities.

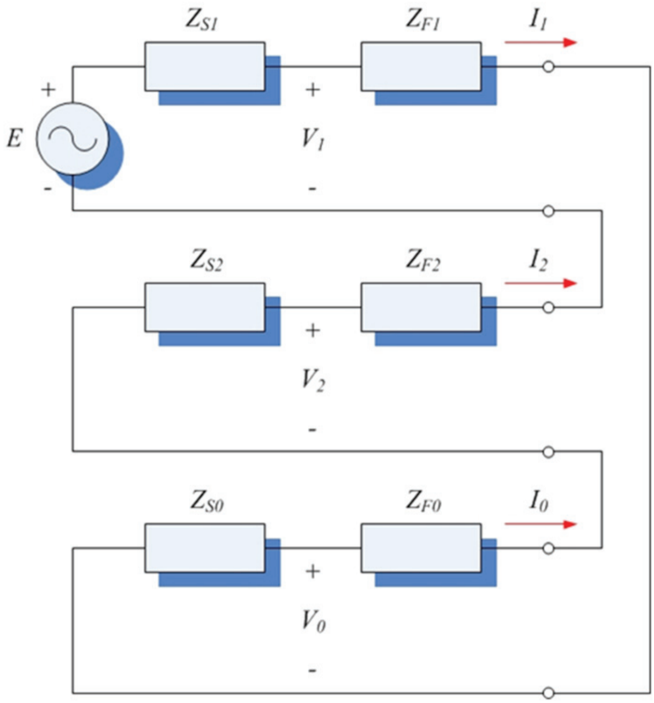

Figure 3: *Equivalent circuit for a single line-to-ground fault, [1]*

The following expressions are obtained for the component voltages at the PCC, [1]:

$$V_1 = \frac{Z_{F1} + Z_{S2} + Z_{F2} + Z_{S0} + Z_{F0}}{(Z_{F1} + Z_{F2} + Z_{F0}) + (Z_{S1} + Z_{S2} + Z_{S0})} \tag{2.3}$$

$$V_2 = \frac{Z_{S2}}{(Z_{F1} + Z_{F2} + Z_{F0}) + (Z_{S1} + Z_{S2} + Z_{S0})} \tag{2.4}$$

$$V_0 = \frac{Z_{S0}}{(Z_{F1} + Z_{F2} + Z_{F0}) + (Z_{S1} + Z_{S2} + Z_{S0})} \tag{2.5}$$

The voltages in the three phases at the PCC during the fault are, [1],:

$$V_a = V_1 + V_2 + V_0 \tag{2.6}$$

$$V_b = a^2 V_1 + a V_2 + V_0 \tag{2.7}$$

$$V_c = a V_1 + a^2 V_2 + V_0 \tag{2.8}$$

Indices *a*, *b* and *c* denotes original phases and operator *a* is equal to, [1],:

$$a = 1^{\angle 120^\circ} \tag{2.9}$$

Substituting $Z_F = Z_{F1}+Z_{F2}+Z_{F0}$ and $Z_S = Z_{S1}+Z_{S2}+Z_{S0}$, the voltages in the three phases are, [1],:

$$V_a = 1 - \frac{Z_{S1}+Z_{S2}+Z_{S0}}{\left(Z_{F1}+Z_{F2}+Z_{F0}\right)+\left(Z_{S1}+Z_{S2}+Z_{S0}\right)} \tag{2.10}$$

$$V_b = a^2 - \frac{a^2 Z_{S1}+aZ_{S2}+Z_{S0}}{\left(Z_{F1}+Z_{F2}+Z_{F0}\right)+\left(Z_{S1}+Z_{S2}+Z_{S0}\right)} \tag{2.11}$$

$$V_c = a - \frac{aZ_{S1}+a^2 Z_{S2}+Z_{S0}}{\left(Z_{F1}+Z_{F2}+Z_{F0}\right)+\left(Z_{S1}+Z_{S2}+Z_{S0}\right)} \tag{2.12}$$

In a solidly-grounded system, the source impedances in the three sequence components are often about equal, [1]. The voltages during the single line-to-ground fault in solidly-grounded systems regarding the mentioned assumption are:

$$V_a = -\frac{Z_{S1}}{\frac{1}{3}\left(Z_{F1}+Z_{F2}+Z_{F0}\right)+Z_{S1}} \tag{2.13}$$

$$V_b = a^2 \tag{2.14}$$

$$V_c = a \tag{2.15}$$

In a resistance or high-impedance grounded system, the zero-sequence source impedance differs from the positive and negative sequence. The assumption that the positive- and negative-sequence impedances are equal can be used. The voltages during single line-to-ground fault in impedance-grounded systems at PCC are, [1],:

$$V_a = 1 - \frac{3Z_{S1}}{\left(2Z_{F1}+Z_{F0}\right)+\left(2Z_{S1}+Z_{S0}\right)} \tag{2.16}$$

$$V_b = a^2 \tag{2.17}$$

$$V_c = a \tag{2.18}$$

3 INFLUENCE OF THE TRANSFORMER WINDING CONNECTIONS ON THE VOLTAGE SAG PROPAGATION

Transformers can be divided into three groups regarding their influence on the propagation of voltage sag, [1], [4],:

- transformers that do not affect voltage sag performance: the only type of the transformer into this group is the star-star connection with both star points grounded.
- transformers that remove the zero-sequence voltage: examples are the star-star connected transformer with one or both sides not grounded, and the delta-delta connected transformer.
- transformers that swap line and phase voltages: for these transformers, each secondary-side voltage equals the difference between two primary-side voltages. Examples are the delta-star (Dy) and the star-delta (Yd) transformer as well as the star-zigzag (Yz) transformer.

The transformers from the first (Ynyn) and from the second group (Yd) will be analysed in this paper. A detailed theoretical analysis of influence of different types of transformer winding connections on voltage sag propagation can be found in the available literature on power quality, [1], [4], [11] and [12]. In the aforementioned literature, the influence of the clock number is further explained.

If voltage sag caused by a single line-to-ground fault comes to the Yd transformer, the voltage at the secondary side can be calculated, [1]:

$$V_a = 1 \tag{3.1}$$

$$V_b = -\frac{1}{2} - \left(\frac{1}{6} + \frac{1}{3}V\right) j\sqrt{3} \tag{3.2}$$

$$V_c = -\frac{1}{2} + \left(\frac{1}{6} + \frac{1}{3}V\right) j\sqrt{3} \tag{3.3}$$

The voltage sag that is present only in one phase on the primary side of the transformer is present in two phases on the secondary side, as shown in Figure 4, [4].

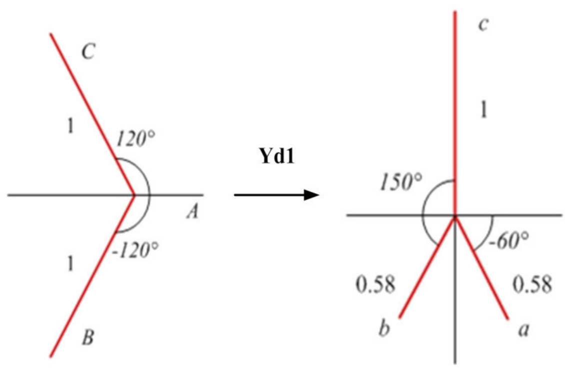

Figure 4: *The propagation of single phase voltage sag through Yd1 transformer*

4 ANALYSIS OF THE MEASURED VOLTAGE SAG PROPAGATION

During a power quality measurement campaign in the transmission and distribution transformer stations in Croatia that was performed by the authors of the paper, the propagation of single phase voltage sags was recorded on 30th June 2007. The values obtained from measurements are presented and compared with those obtained using Equations (3.1)-(3.3). Figure 5 presents the single-line diagram of the analysed system. 'MT' indicates the points where power quality analysers were connected.

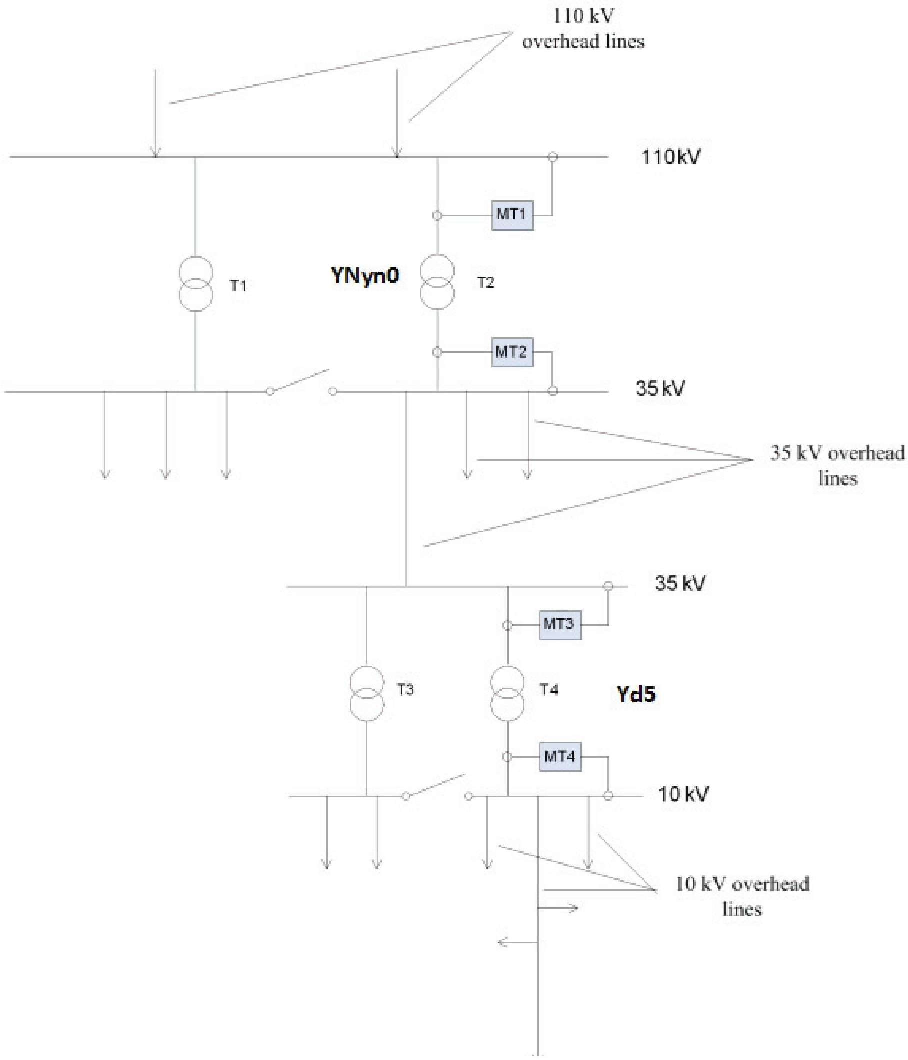

Figure 5: *The single-line diagram of the analysed system*

The voltage sag that was recorded on 30th June was a single-line voltage sag that was caused by the single line-to-ground short circuit in the transmission network. The measured data of the voltage sag propagation through the 110/35 kV and 35/10 kV transformers are shown in Table 1, in which only the voltages of affected phases are presented.

Table 1: *Data for the measured example of voltage sag propagation*

Transformer 110/35 kV (YNyn0)			
	Primary winding	Secondary winding	
Date	30/06/2007	30/06/2007	
Phase	V_a	V_a	
Duration [ms]	80.004	80	
Phase Voltage [V]	44100	14563.18	
Relative voltage [%]	69.439	72.07	
Transformer 35/10 kV (Yd5)			
Date	30/06/2007	30/06/2007	
Phase	V_a	V_a	V_c
Duration [s]	80	80.022	70.0019
Phase voltage [V]	14630.64	4776	4937
Relative voltage [%]	72.4	82.72	85.51

The single line voltage sag does not change after the first transformer (110/35 kV, connection YNyn). After the second transformer, the voltage sag is present in two phases. This case is similar to those presented in Figure 4, and the difference is only in clock number. The voltage sag that is presented in phase *a* at the primary side of Yd5 transformer, at the secondary side is presented in phases *a* and *c*. The magnitude of the voltages after the Yd5 transformer can be calculated using Equations (3.1)-(3.3).

$$V_a = -\frac{1}{2} - \left(\frac{1}{6} + \frac{1}{3}V\right) j\sqrt{3} = 0.8657 \ pu \tag{4.1}$$

$$V_b = 1 \tag{4.2}$$

$$V_c = -\frac{1}{2} + \left(\frac{1}{6} + \frac{1}{3}V\right) j\sqrt{3} = 0.8657 \ pu \tag{4.3}$$

V is the pu value of the phase voltage magnitude on the primary side of the affected phase, i.e. *V* = 0.724pu. Equations (3.1) to (3.3) are adopted for Yd5 transformer according to literature [4] i.e. voltage sag at the secondary side of the transformer is present in phase *a* and *c* and voltage in phase b remains unchanged. It can be concluded that measurement results and results that are obtained using Equations (3.1)-(3.3) are close to each other. The differences between measured and calculated values are 3.84% for phase *a* and 1.06% for phase *c* respectively.

5 SIMULATION OF THE VOLTAGE SAG PROPAGATION

In order to make a simulation of the measured example of the voltage sag propagation that is discussed in Section 4, a computer model of the observed distribution network is created in DIGSilent Power Factory software [13]. Figure 6 shows the single line diagram of distribution network that is modelled in DIGSilent and that corresponds to the single line diagram presented in Figure 5.

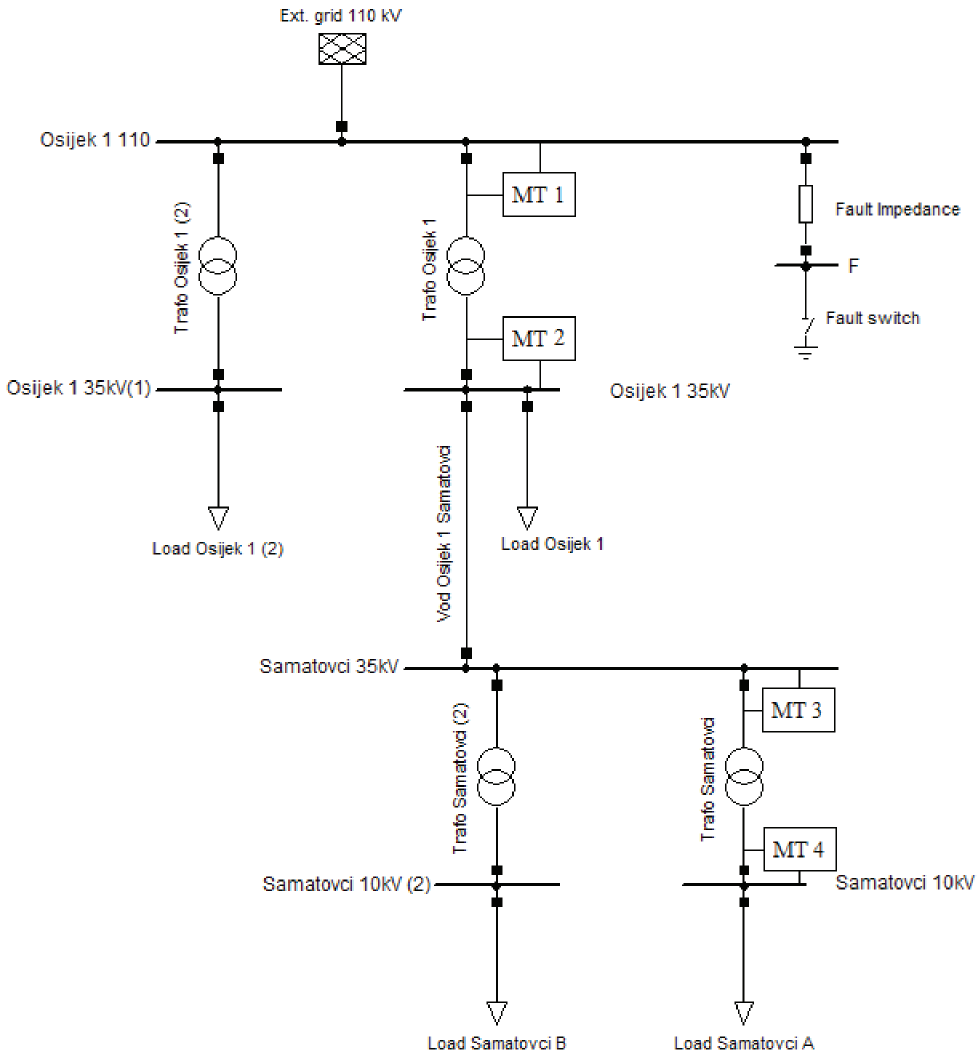

Figure 6: *DIGSilent single line diagram of the modelled distribution network*

Figure 7 presents the simulated voltage sag in phase *a* at the primary side of the YNyn0 transformer (MT1). In order to obtain such a voltage sag, the single line-to-ground short circuit is simulated at the Osijek 1 110 bus. The fault impedance is necessary in order to simulate the same value of voltage sag as is measured. The duration of voltage sag is 80 ms according to Table 1.

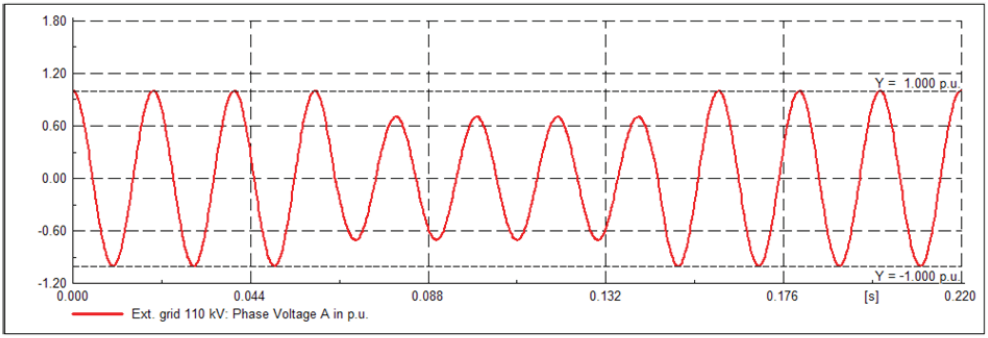

Figure 7: *Simulated voltage sag at the location MT1*

The RMS value of simulated voltage sag can be found in Table 2, where it is compared to the measured and calculated values that are presented in Table 1 and Equations (4.1)-(4.3). Simulated voltage sag propagation through the 110/35 kV transformer is presented in Figure 8. The type of the transformer is YNyn0 and it belongs to the first group of transformers, as explained in Section 3. As can be seen from Figure 8, voltage sag is present in phase *A* at the primary side of the transformer (MT 1) and also in the phase *a* at the secondary side (MT 2), i.e. voltage sag is almost unchanged.

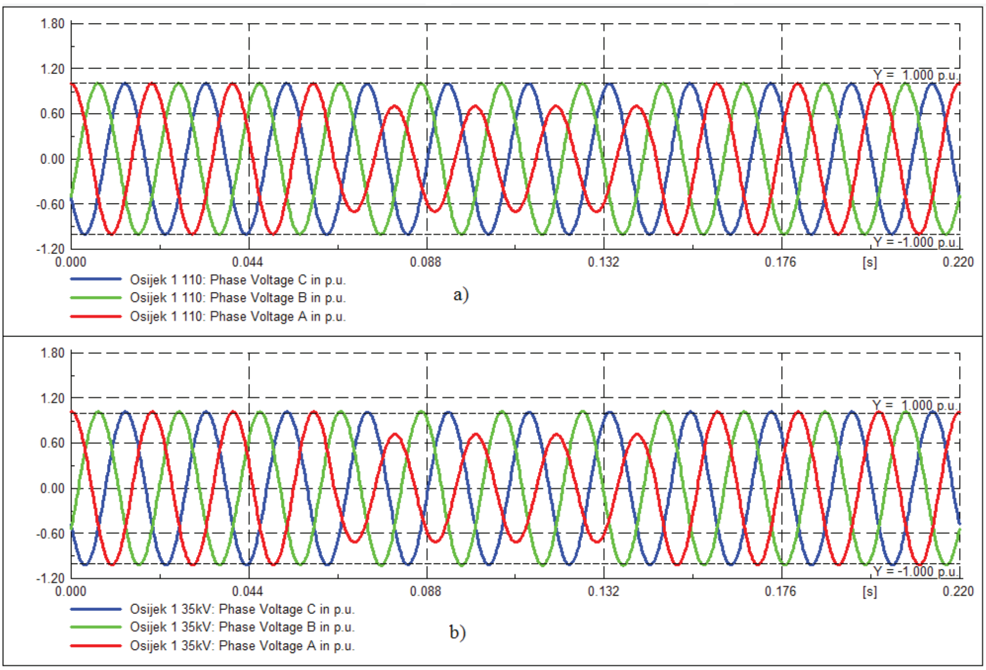

Figure 8: *Simulated voltage sag a) at the location MT 1 and b) at the location MT 2*

Transformer Dy5 (35/10 kV) is more appealing for analysis because it belongs to the second group of transformers, according to classification in Section 3. Transformers from that group remove the zero-sequence voltage and change the performance of voltage sag. The impact of the transformer is reflected in the fact that the voltage sag at the primary side is present only in one phase, while on the secondary side it is present in two phases. Figure 9 shows simulated voltage sag propagation through the 35/10 kV Dy5 transformer, i.e. at the locations MT 3 and MT 4.

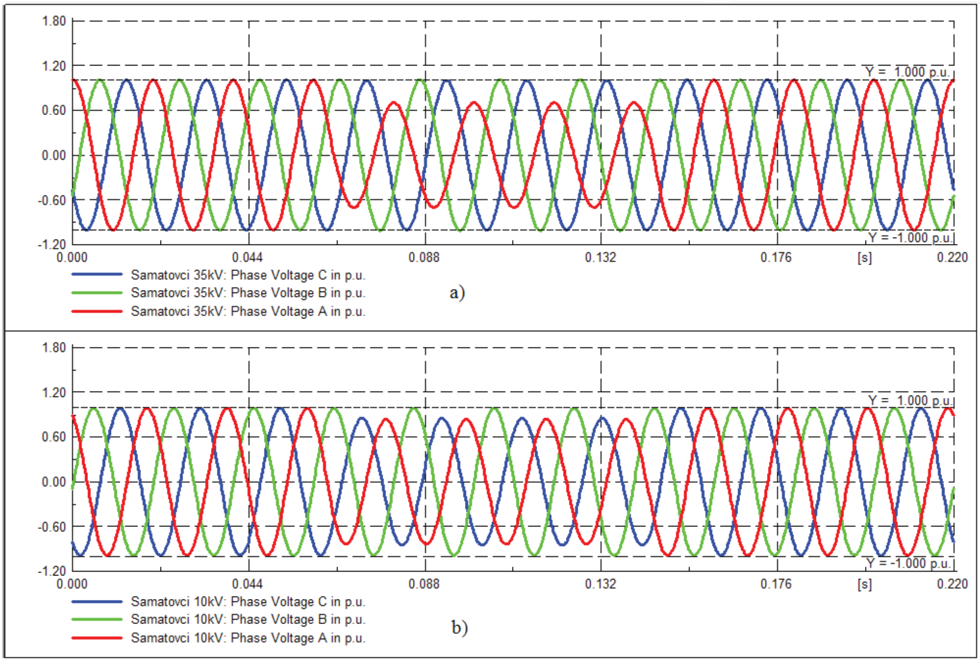

Figure 9: *Simulated voltage sag a) at the location MT 3 and b) at the location MT 4*

The comparison of simulated results with measurement data is presented in Table 2. Good agreement between simulated and measured values is obvious, verifying the computer model

Table 2: *Results of the simulation compared to the measurement data*

Transformer 110/35 kV (YNyn0)			
	Primary winding	Secondary winding	
Date	30/06/2007	30/06/2007	
Phase	V_a	V_a	
Duration [ms]	80.004	80	
Phase Voltage [V]	44100	14563.18	
Relative voltage [%]	69.439	72.07	
Simulation obtained voltage [%]	**70.09**	**72.1**	
Transformer 35/10 kV (Yd5)			
Date	30/06/2007	30/06/2007	
Phase	V_a	V_a	V_c
Duration [s]	80	80.022	70.0019
Phase voltage [V]	14630.64	4776	4937
Relative voltage [%]	72.4	82.72	85.51
Simulation obtained relative voltage [%]	**71.7**	**83.6**	**85.2**

6 CONCLUSION

This paper analyses the propagation of a single-phase voltage sag caused by line-to-ground short circuits in the transmission network, from the high voltage level to the distribution level through various types of transformers. It provides an example how a transformer winding connection influences voltage sag propagation in a real power system. One example of voltage sag propagation from the transmission to the distribution level captured with the power quality measurements is presented. Calculations of voltage sag performance based on the theory explained in Section 3 are made, and the results are compared to measurements. A computer model of the observed distribution network is created and used for simulation of voltage sag propagation. Simulation results match those obtained by measurements. The created computer model can be used for detail analysis of voltage sag propagation and its influence on the distribution network. Further work on this topic will include more types of voltage sags (not only single line) and more combinations of transformer winding connections.

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POTENTIAL OF THE RESEARCH ENERGY CENTRE TO ENHANCE ENERGY SPECIALISATIONS IN THE SAVINJA-ŠALEK REGION

POTENCIAL RAZVOJNEGA CENTRA ENERGIJA PRI SPODBUDITVI ENERGETSKE SPECIALIZACIJE V SAVINJSKO-ŠALEŠKI REGIJI

Marta Svetina Veder[ℜ]

Keywords: potential, development, energetics, RCE, the Savinja-Šalek region

Abstract

This article tackles the significance and potential of the company RCE (Research Energy Centre) to implement a regional development programme and national development goals. RCE was founded in 2011 by the largest energy companies (and companies in other fields) in the Savinja-Šalek sub-region in order to establish a unified development centre for energy activities. This was done to accelerate regional economic growth, emphasising the unifying role of RCE to unite the research& development projects of its founders. The priority of RCE is research & development activity based on the exploitation of a wide range of traditional local knowledge, experience and specialisation in the energy sector. Therefore, it enables the creation of quality workplaces and, in the future, it off employment possibilities for promising young experts to be involved in new innovative projects. This is also the way RCE will enhance and enable a prudent regional specialisation, which is one of priority goals of the national development strategies for the year 2020.

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Povzetek

Prispevek obravnava pomen in potencial družbe RCE – Razvojni center energija pri izvedbi regionalnega razvojnega programa in nacionalnih razvojnih usmeritev. Družbo RCE so v letu 2011 ustanovila največja energetska in druga podjetja v Savinjsko-šaleški subregiji z namenom vzpostavitve združevalnega razvojnega centra na področju energetske dejavnosti. Namen ustanovitve RCE je pospešitev rasti regionalnega gospodarstva na način, da RCE poveže razvojno-raziskovalne projekte svojih ustanoviteljev. Prednostna dejavnost RCE je raziskovalno-razvojna aktivnost, ki je zasnovana na izkoriščanju bogatega tradicionalnega lokalnega znanja, izkušenj in specializacije na področju energetike. S tem omogoča ustvarjanje bolj kakovostnih delovnih mest in tudi v bodoče možnost zaposlovanja obetavnih mladih strokovnjakov na novih inovativnih projektih. Na ta način bo RCE spodbujal in omogočal pametno regionalno specializacijo, ki je ena od prioritetnih ciljev nacionalne razvojne strategije do leta 2020.

1 INTRODUCTION

The world is currently facing a global financial and economic crisis, which has also affected the Slovenian economy in recent years. Slovenian companies are now suffering a lack of competitiveness globally and locally, since they are not able to compete with more the favourable offers of competitive companies arising from developing countries (e.g. China). Those countries are enjoying the substantial financial support of the developed world and, with their cheap workforce, they have developed cutting-edge technology that allows them to enhance their global competitive advantage.

The crowding out of domestic producers in the market consequently leads to deterioration of economic and social position of local people and thus reduces demand. Slovenia has responded to the economic crisis by developing satisfactory national programmes and other similar documents, including the development strategy and industrial policy. The basic guideline of these documents, which will create a further drivefor the Slovenian economy and companies, is to recognise development potentials and investments in the fields that drive economic growth. In this sense, the government will prioritise measures to support some projects related to regional specialisation and economic growth of companies. One such project is certainly the operation and establishment of the Research Centre of Energy (RCE).

RCE was founded in 2011 by the largest energy companies (and companies in other fields) in the Savinja-Šalek sub-region in order to establish a unified development centre for energy activities and supporting activities. The establishment of RCE should accelerate the growth of the regional economy by uniting the R&D projects of all RCE's founders. The primary activity of RCE is research & development based on the exploitation of rich traditional local knowledge, experience and specialisations in the field of energy. It enables the creation of quality workplaces and, in the future, it offers employment possibilities for promising young experts to be involved in new innovative projects. This is also the way RCE will enhance and enable a prudent regional specialisation, which is one of priority goals of the national development strategies for the year 2020.

2 STARTING POINTS

2.1 National guidelines

This chapter is summarised from the draft document 'Strategy of Slovenia from 2014 to 2020' and the document 'Slovenian Industrial Policy by 2020' developed by the Ministry of Economic Development and Technology of the Republic of Slovenia in 2012.

An overview of the development in Slovenia in recent years indicates a deviation from the realisation of the strategic goals in the economic and social fields during the current economic crisis, which is related to insufficient implementation of the guidelines of Slovenia's Development Strategy from 2005 (Development Strategy of Slovenia, 2012).

Within European Community (hereinafter EU), with numerous documents and processes of economic governance, above all with the 'EU 2020' strategy, Slovenia has committed itself to pursuing the goal of growth. Unfortunately, in recent years, Slovenia has encountered difficulties with negative growth. Thus, the Development Strategy of Slovenia 2014–2020 defines only one key guideline: achieving a greater competitiveness and a momentum of growth. The development of Slovenia has to be based on the productivity increase, green growth and a higher rate of employment (Development Strategy of Slovenia, 2012).

A transition to the so-called low-carbon society enables various development opportunities for companies. Such opportunities have not thus far been exploited enough in Slovenia. It is essential to achieve green growth via economic restructuring in terms of modernising outdated technologies and services. Slovenia will provide the opportunity for a rapid and high quality development of companies that are active in the field of environmentally less harmful technologies and services. It will also accelerate its successful market placement and penetration. Reducing green-house gas emissions, particularly reducing energy use and increasing material productivity should become significant activities in all economic sectors. A significant part of attention will be put on adapting to climate change; consequently, employment possibilities will increase in the fields of energy efficiency, use of non-renewable energy sources, and use of wood and wood construction (Development Strategy of Slovenia, 2012).

The purpose of the 'Slovenian Industrial Policy 2020' (SIP) is to establish the priorities of industrial and economic growth for the period of the next financial perspective, i.e. 2014–2020. In the times of financial and economic crisis, which has affected Slovenia more strongly than most of the other EU member states, it is important to enhance a strong healthy core of Slovenian industry if the competitiveness of the Slovenian economy to be maintained and increased. Such an industrial core can create innovations, growth and employment possibilities. However, such restructuring measures will not be sufficient to revive the economy and achieve development goals. Therefore, it will be necessary to look for new sources for growth and development of national economy, particularly those based on a sound specialisation that takes the existing investments and competences into account. New sources of growth particularly include responses to social changes arising from the concepts of green growth, the green economy and a material-efficient low-carbon society, all of which are based on improving efficiency.

Based on challenges, opportunities and the achieved competences, SIP determines priority areas within which technological development and its use in industry will be encouraged. One of the priority sectors is energy activity (SIP, 2012).

2.2 Regional guidelines

Within Slovenia, the Savinja region is in the fifth place by GDP per capita. This region was economically relatively stable in the 2000–2009 period, in comparison to the rest of Slovenia. Despite this, the economic growth is not very good; in 2009 and 2010, its difference to the European average of economic growth was increasing. In 2008–2012, the level of unemployment increased from 8.0 to 12.7 % unemployed residents. The rate of unemployment of residents with higher education rise from 8.7 to 13.0 % in the same period (UMAR – Office for Macroeconomic Analyses and Development, 2012, 2013).

In 2013, this region was developing its 'Regional Development Programme 2020' (hereinafter 'RDP') for the 2014–2020 programming period. The RDP for the Savinja development region will constitute an agreement between thirty-one municipalities of the Savinja development region and the government of the Republic of Slovenia on the Savinja development region. The RDP will be a substantive document designed on the basis of an assessment of the situation in the region and an identified development potential. It shall identify investment areas for the following programming period with the purpose of achieving goals that are set at a national level. This will assure that regional development programmes will be one of the pillars for achieving national goals. Beside the goals that will be set at the national level, the region must set some special goals that shall arise from the region's specific development potential. It is important for the region to specialise its development in the 2014–2020 period.

Upon developing the RDP in the 2014–2020,the Savinja-Šalek sub-region highlighted four main development priorities: knowledge, entrepreneurship, quality of life and green-sustainable development. There were two development specialisations highlighted in the programme: manufacturing and energy industry.

2.3 Research energy centre

The RCE was founded in 2011 with its core business of research & development. It was established as a consequence of acquiring grants to encourage R&D activity in the field of energy technology. The establishment of the RCE is a result of the cooperation of seventeen regional partners who shared and contributed their project ideas to its operations (Kemperle et al., 2011).

The RCE's mission is to intensively encourage and promote the long-term technological development of regional companies in the energy sector, by integrating and creating a critical mass of knowledge to allow the region to achieve technological breakthrough in the field of energy research and consequently to enhance economic growth of the region.

The strategic development goals of the company are as follows:

- to establish an internationally recognised research centre in the field of energy technology that will, with its research & development activities, enhance regional energy companies and raise their competitiveness in the Slovenian and global markets;
- to assure personnel, technological and spatial capacities in order to successfully exploit and develop the already existing well-developed and concentrated local energy expertise into a unique research centre. This centre shall provide concentration and attract the most knowledgeable experts in the field of energy technology and, consequently, increase the number of professional jobs with high added value;

- to establish conditions for intensive networking and cooperation of various economic entities with the research sphere. Cooperation will be intensively encouraged and facilitated by implementing concrete innovative technological projects in the production, distribution, transfer and use of energy, and environmental technologies; and
- to facilitate the commercialisation of results arising from research & development activities by means of establishing new economic entities and jobs, which will increase competitiveness of the energy sector and allow stronger economic development of the region.

2.4 SHOK reference project

The Finnish national vision and strategy regarding scientific-technological development and social progress is reflected in the establishment of strategic centres for science, technology and innovativeness (hereinafter SHOK),[3]. For further competitiveness of the country, Finland has discovered that it is necessary to establish centres that allocate the limited financial resources designed for research and development for the most competitive sectors in industry and science,[4].

The SHOK strategic centre is a new form of public-private partnership that combines various Finnish partners in the field of R&D, with the goal of more accurately target research activity. The main purpose of SHOK is to accelerate Finnish innovative process. This will be achieved by creating sufficient critical knowledge inside priority sectors, which have developed solely on the basis of the demand from the market. Such demand is also the basis for the need for new strategic national decisions in terms of developing or creating national scientific-technological policy. The first SHOK was established in 2007. Today there are six similar centres in Finland,[6].

3 ANALYSIS OF THE RCE'S POTENTIAL

3.1 Analysis of business opportunities of the RCE

Some key opportunities are recognised in the following areas of RCE operations:

- improved utilisation of the existing technologies in the field of thermal energy and electro-energy technology;
- renewable and non-renewable energy sources: solar power, biomass, biogas, geothermal power, wind power, hydro power, fuel cells, hydrogen technology, increased share of renewable and alternative energy sources in final energy consumption;
- efficient energy use: heating techniques and systems, energy-efficient insulation and building protection, district heating, electrical and mechanical installations for low-energy and passive houses;
- efficient reduction of GHG emissions and other pollutants: improvement of electricity generation and transfer of electrical energy and heat;

- design of modern energy systems, solving technological problems in the field of energetics, information-communication technology and automation in the energy sector;
- solving environmental issues related to energetics; innovative solutions in energetics;

The RCE implementation projects are demanding, complex and their results are expected in 2014. Their interim results will not provide commercialisation of products; that is forecast only after 2014. Target markets and market segments are planned in detail within individual projects; generally, the aim of the RCE is domestic and global markets.

Before establishing businesses for the production and marketing of the results (products, services and technologies), adequate market research will be done to improve awareness and to define target market segments and markets and to obtain a more accurate estimate of our market potential. On this basis, some concrete market and production strategies of the RCE will be developed.

Key target markets are:

- domestic markets
- the South-East European market
- the EU market, and
- other global markets.

Table 1: *The RCE's business vision, source: RCE archive*

MISSION	CONCEPTS	ABILITY TO PROVIDE SOURCES
With R&D activities in the field of energy technology, we will significantly contribute to sustainably reliable, qualitative, economic and ecologically acceptable care for energy use, and we will take principles of low-carbon society in consideration.	Non-profit nature of the organisation (profit shall be fully invested in development). Integrating entrepreneurial and technological-research institutions in the energy sector. Project work in the form of project centres. Commercialisation of the results arising from R&D. Integration of experts in a wider area (Slovenia, neighbouring countries and Balkan countries). Providing results for the benefit of the national economy and the society as a whole. An integral approach to encouraging competitiveness of companies in the energy sector.	Many bigger economic entities and some other companies in the local area are interested. Extensive knowledge in the field of energetics – tradition in that area. Acquisition of non-refundable funds.

VISION

To become a leading R&D institution in the field of energy in South-East Europe, to be globally recognised and an important coordinator of professional potential for development and implementation of more advanced energy solutions.

BUSINESS AREA	MARKET SEGMENTS	VALUES	BENCHMARKS
Research, studies, development, prototypes, new products and technologies: • more efficient energy use, renewable energy sources; • development of modern energy systems, technologies to reduce environmental pollution; • processing and use of waste; • better use of the existing technologies; • automation and control over processes of advanced energy technologies.	Production, distribution and energy transfer. Producers of equipment and systems to produce, transfer and use energy. Polluters. Large energy consumers. Government bodies. Non-governmental organisations. Other domestic customers. International markets.	Knowledge and innovativeness. Applicability of the results in practice. Professional independence. Sustainable development. Integration and cooperation. Development of enterprises. Competitiveness of enterprises.	Value of implemented research and studies. The scope of commercialisation of the results. Participation in professional events. Extent of acquired non-refundable funds. Patents and innovations. New workplaces. Products or new technological processes. Added value.

3.2 RCE potentials

The fact that the RCE was established during an economic crisis reflects a need of the regional industry to accelerate development. The RCE represents an opportunity for many regional and local enterprises to realise development projects that they otherwise would not be able to carry out without EU support. Upon establishing their clear and rigid criteria to support operations of development centres, the EU and Slovenia have anticipated their contribution to improve the economic condition in the regions. For this reason, the RCE acquired a strong development potential upon its establishment.

In the next chapter, the following RCE potentials are discussed: employment, development and innovative, entrepreneurial and connective potentials. All these potentials will positively influence the economic activity of the Savinja-Šalek sub-region.

3.2.1 Employment potential

The priority activity of the RCE is research and development, which is based on the exploitation of rich traditional local knowledge, experience and specialisation in the field of energy technology and its supportive activities. Through its operations, the RCE is creating high-quality workplaces and enables the participation of young professionals in specific research-technological projects in the field of energy technology and the environment.

In the future,the RCE will provide possibilities for the recruitment of young promising professionals to work on new innovative projects, in particular in the fields of the efficient use of energy, the use of renewable energy sources and green technologies. The region provides a rangeof sufficiently qualified, skilled and educated workers. This representsan opportunity for employment growth in the society in the near future. This centre will increase the mobility and integration of experienced professionals from the regional energy sector and thus contribute to a greater concentration of knowledge in one place.

The centre is designed as a high-quality multi-discipline research team coming from the industry and research spheres, which will enable a greater critical mass and concentration of applicable knowledge in the field of energy technology. For an efficient implementation of new innovative projects in the future, the RCE is aiming at international integration and cooperation; it will thus provide new knowledge from abroad. Which will facilitate that creation of the critical mass of knowledge in the energy field. The accumulation of highly specialised staff in the field of energy technology and the integration with development cores of enterprises from various industries shall enable the RCE to develop a smart regional specialisation, which is one of the priority goals of the national development strategy for2020.

3.2.2 Development and innovation potential

The transition to a low-carbon society offers numerous development opportunities that have not yet been fully exploited in Slovenia. By means of implementing its R&D projects in the field of energy technology and innovative solutions in the field of renewable energy sources, the RCE shall create and develop new technological solutions, products, prototypes and pilot appliances, and intellectual property. In this way, it will satisfy the priority strategy in Slovenia to use such knowledge for development, and through its contents it will implement a national 'green technology'policy.

The national policy to adapt the economy to climate change is of key importance for the development projects and results of the RCE in the future. The reduction of green-house gas emissions, in particular with the reduced use of energy and with an increase of material productivity, must become an important guide when creating new development projects. The development opportunities of the RCE are seen in developing innovations and methods that will support development of new energy technologies through making their costs of acquiring and care for energy competitive at the European level, and in using technologies to generate power with minimal quantities of GHG emissions.

3.2.3 Entrepreneurial potential

Through its implementation of new R&D projects, the RCE will establish new enterprises and will provide them with counselling and adequate infrastructure. In this way, it will satisfy the priority strategy of Slovenia to encourage entrepreneurship.

Through its content, the RCE will implement development projects that can be described as sustainable in the meaning of following the requirements of the national policy related to low-carbon society and sustainable development. The most important goal of RCE's further operations is the implementation of innovative ideas enriched with accumulated knowledge and experiences, the development of new products and services, and energy technologies thatwill facilitate a breakthrough of enterprises on the domestic market and, above all, on global markets.

Slovenia is planning to encourage the development of new enterprises that will be active in the field of eco-friendly technologies and services, and to accelerate their breakthrough to the market. This represents quite a challenge for the RCE to act as a supportive environment for entrepreneurship. References from economically successful countries reflect the need for sectoral specialisation when establishing new companies. For this reason, the RCE is planning to develop an energy business incubator and a technology centre.

3.2.4 Connective potential

With its integration with business entities and R&D institutions operating in the Savinja-Šalek subregion, Slovenia or abroad, the RCE has encouraged professional potential to develop and implement concrete projects in the field of energy technology. The RCE will provide powerful links between academic knowledge and entrepreneurial ideas and experiences and for participation in European R&D nets in the industrial sector. The RCE shall cover the areas of the production and efficient use of energy and energy sources. With its networking, it will complement the existing research institutions and business entities in Slovenia.

The centre will operate by means of integrating production, educational and research institutions with the purpose of providing comprehensive, proven and compelling results in the field of energy technology, with which no institution in Slovenia is dealing at the moment (the existing institutions are specialised in several specific areas). The centre will be expanded through the partner networks of its founders outside Slovenia, and will cooperate with foreign institutions and other professional and educational institutions.

4 FINAL CONCLUSIONS

The establishment of RCE coincides with a growing economic crisis, and reflects the interest and the need of founders to promote development. The main purpose of the establishment and operations of RCE is the implementation of technological projects in energy-related activities. At the same time, numerous other economic potentials for partners, investors, local and regional economy have been revealed. The R&D activity of RCE is a key factor that provides employment, developmental-innovative, entrepreneurial and connective potential of the centre.

The employment potential is reflected in the intensity of the recruitment of technical experts to support energy projects. Employment involves also the first jobs of young staff coming from the local educational system. A further goal of RCE is to acquire new innovative projects with international participation, which will additionally enhance staff potential and the competitiveness of the results. Slovenia will also support the recruitment process in the areas of energy efficiency, the use of renewable energy sources, and green technologies.

The development potential arises from the main activities of the centre and the interest of its founders and investors to sustainably develop the centre. Considering the orientation of the European and national policy of economic and industrial development in terms of the low-carbon society and sustainable development, projects in the field of energy activities will enjoy further support in the future.

The entrepreneurial potential of the centre is represented by emergence of the new businesses that will be established by the centre in order to commercialise project results. Moreover, with the acquired infrastructure. The RCE provides development opportunities for further business activities. Orientations and policy of national incentives will additionally encourage new enterprises to operate in the field of new technologies and sustainable development.

The role of linking and the potential of the centre are reflected in the fact that 17 regional companies and institutions joined in the field of energy technology and related activities upon the establishment of the RCE. Although it was established by several organisations in the field of energy technology, the centre now is working and connecting with various other organisations. The role of the RCE is to join experts professionally and to participate in professional circles and networks at the regional, national and international levels.

All potentials are directed in activities of the energy sector and its supportive activities; consequently, the RCE's operations clearly reflect the intensive encouragement of local and regional specialisation, which is one of important goals for the development of industrial policy of Slovenia by 2020.

Although national and industrial documents of the Republic of Slovenia for the 2014–2020 period clearly support the activity, project orientation and RCE potentials, this fact alone is not sufficient for the further successful operation of the organisation. The results will depend on the interest of the RCE's partners, investors and their effect on the RCE's management. The RCE provides for an efficient way to adjust to changes brought by globalisation and competitiveness of rapidly growing countries. Slovenia is here a mere promoter of structural changes in the industry;the main actors or drivers are enterprises. Knowledge must be expressed in new market products, processes and technologies.

The SHOK Finnish centres are a classic example of good practice of the technological forecasting and staff concentration in priority development areas. Their operation is directed to thegreater competitiveness of Finnish industry and is an excellent example for the future operations of the RCE.

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DEVELOPMENT OF THE COMPUTER PROGRAMS CORD AND DMR IN ZEL-EN PE GEN ENERGIJA – A STATUS REVIEW

RAZVOJ RAČUNALNIŠKIH PROGRAMOV CORD IN DMR V ZEL-EN PE GEN ENERGIJA – PREGLED STATUSA

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Keywords: nuclear reactor core design, digital reactivity meter, lattice code, nuclear data library, reactivity

Abstract

The planned activities and results achieved in the ZEL-EN's CORD and DMR reactor physics projects are reviewed. In the CORD project, new software tools for the numerical modelling of nuclear reactor cores in pressurized water reactors are being developed. The WIMS-D library update with nuclear data from the ENDF/B-VII.1 library was the first task in that project. The performed procedures and results of the WIMS-D benchmark test calculations with the WIMS-D libraries updated with the data from the ENDF/B-VII.0 and ENDF/B-VII.1 libraries are briefly presented. In the DMR project, a new digital reactivity meter for measuring the time-dependence of the reactivity in the reactor core is being developed. The new DMR software will run on current MS Windows systems and will be compatible with current electronic measuring equipment. Tests of the beta version of the new DMR software, presented in this paper, showed good agreement of the results for the measured reactivity with those obtained with the old DMR software, which is a validated MS-DOS application program and is considered as a reference tool.

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Povzetek

Predstavljen je pregled načrtovanih dejavnosti in doseženih rezultatov v ZEL-EN-ovih projektih na področju reaktorske fizike CORD in DMR. V projektu CORD bo razvita nova računalniška programska oprema za numerično modeliranje reaktorske sredice v tlačnovodnih jedrskih reaktorjih. Prva naloga v tem projektu je bila posodobitev knjižnice jedrskih podatkov programa WIMS-D z jedrskimi podatki iz knjižnice ENDF/B-VII.1. Na kratko so predstavljeni izvedeni postopki in rezultati referenčnih testnih izračunov s programom WIMS-D, ki so uporabljali knjižnice jedrskih podatkov posodobljene s podatki iz knjižnic ENDF/B-VII.0 in ENDF/B-VII.1. V projektu DMR bo razvit novi digitalni merilnik reaktivnosti za merjenje časovne odvisnosti reaktivnosti v reaktorski sredici. Programska oprema novega DMR bo delovala na sodobnih računalniških sistemih z operacijskim sistemom MS Windows in bo kompatibilna s sodobno elektronsko merilno opremo. Testi beta verzije programske opreme novega DMR, predstavljeni v tem prispevku, so pokazali dobro ujemanje rezultatov za izmerjeno reaktivnost z rezultati pridobljenimi s programsko opremo starega DMR, ki deluje na MS-DOS-u in velja za referenčno orodje.

1 INTRODUCTION

In this paper, the planned activities and results achieved in a development of updated versions of the CORD and DMR computer programs are reviewed. The development of the program CORD is being performed by ZEL-EN team members Dušan Čalić and Mladen Stanojević, and of the program DMR by ZEL-EN team member Slavko Slavič. These activities are being performed in collaboration with the Reactor Physics Division of the Jožef Stefan Institute.

The development of CORD is a part of ZEL-EN's reactor physics project, in which state-of-the-art software tools for numerical modelling of pressurized water reactors (PWRs) will be developed. These tools will enable more accurate prediction of nuclear reactor behaviour and, consequently, economically more efficient usage of the reactor fuel and safer operation. This represents a new business opportunity on the global nuclear energy market for the existing and new western-type PWRs that are planned or already being built. The expected final product will be a set of computer programs for the numerical modelling of western-type PWRs. In addition, new knowledge necessary for performing related services on the nuclear power plants with these computer programs will be obtained.

The development will be based on existing computer programs, which offer only some partial solutions. They will be upgraded with more detailed and accurate theoretical and computational models, and their results will be cross-checked and verified with other available computer programs and measurement results. The final product will have the following new capabilities:

- more precise modelling of the isotopic composition of the burned-up fuel due to explicitly taking into account the fuel cooling time between particular burning cycles;
- determination of the increase of the necessary time for project calculations (i.e. the core design calculations) due to more accurate burn-up modelling, and other improvements and optimizations of the models;
- improved lattice model calculations with the WIMS-D code, incorporated into the new CORD package, in particular, significant improvements in modelling MOX fuel (i.e. mixed oxide nuclear fuel that contains more than one oxide of fissile material, usually consisting of plutonium

blended with natural uranium, reprocessed uranium or depleted uranium) and burnable absorbers (especially gadolinium) included within the mixed fuel;

- reliable project calculations for various western-type PWRs.

The new CORD will be based on an existing software package, CORD-2, [1], which is already used for modelling and designing the reactor core in the Krško Nuclear Power Plant (KNPP). The CORD-2 includes reactor physics programs, WIMS-D, [2], and GNOMER, [3], and numerous libraries with various data and utility programs for manipulating these libraries and data (see Figure 1). An important part of this project, which is presented in this paper, is an update of the WIMS-D nuclear data libraries with the new data included in the ENDF/B-VII.1 nuclear data library. After the testing and validation of these libraries with standard benchmark tests for the WIMS-D, they will be used for modelling selected previous reactor fuel cycles of KNPP with CORD-2. Their validity will be verified by comparisons with relevant measured data for these fuel cycles.

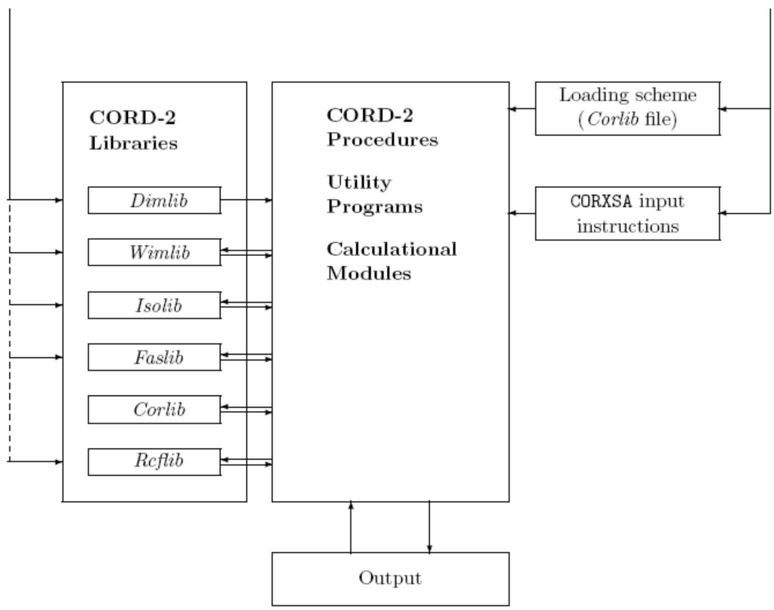

Figure 1: *Block diagram representing the CORD-2 system, [1]*

The development of the Digital Reactivity Meter (DMR) software [15] is a part of ZEL-EN's project in which a new generation of this measuring device will be developed. Digital reactivity meters are indispensable parts of the measuring equipment in nuclear energetics. However, the so-called rod-insertion method (or 'rod-in method') is mostly not allowed in the existing products available on the market, and additional functions for measuring and displaying measured data are not available. The new DMR will be applicable for physics tests in nuclear power plants, research reactors and for educational purposes, so it can be appealing for the nuclear energy market. It will be based on verified physical models, and numerical and experimental methods already applied into the existing DMR-043, [4] (see Figure 2), which is used in the start-up tests in Krško NPP and research on the TRIGA reactor at the Jožef Stefan Institute. The DMR-043 software and hardware use technologies developed in the 1980s, i.e. a computer program running on MS-DOS and analogue electronic measuring equipment. From the measured neutron flux (proportional to the measured current (I) in Figure 2) and temperature (proportional to the voltage (V) in Figure 2, measured by the thermocouple) and with the point-kinetics equations, the time-dependence of the reactivity in various operating conditions of the reactor core, determined by a position of the control rods, the concentration of boric acid (i.e. neutron absorber) and temperature of the primary coolant is calculated. The purpose of these tests in the commercial reactors is to verify the control rod worth and reliability of the operation. The new DMR software will run on modern MS Windows systems (such as XP, Vista, 7, 8) and will have a graphical user interface (GUI), in addition to the old command line interface (CLI). It will be compatible with both previous analogue and modern digital electronic measuring equipment.

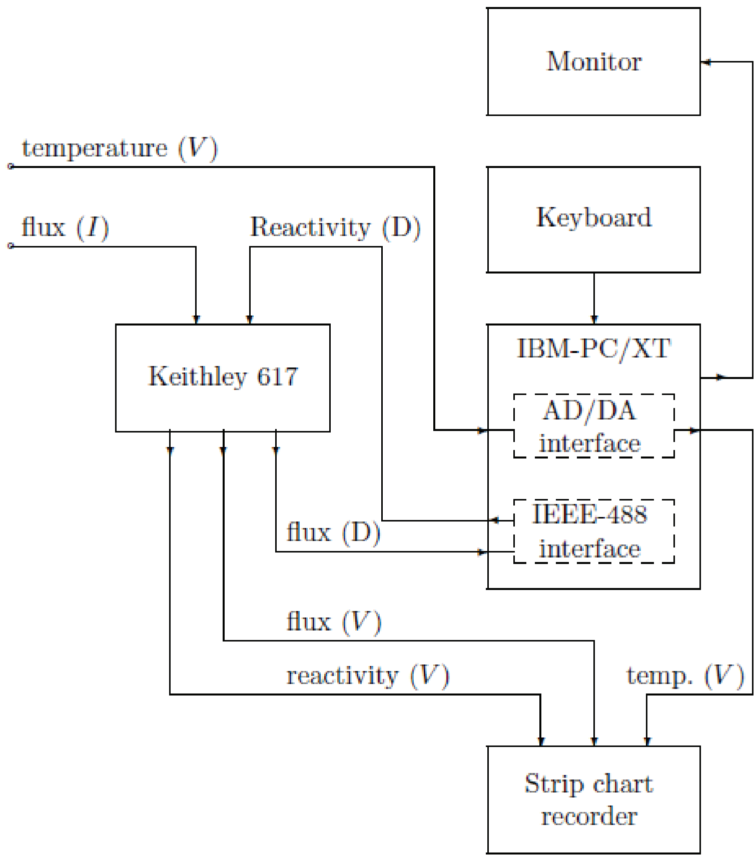

Figure 2: *Block diagram representing the digital reactivity meter DMR-043 hardware connections. (D) represents a digital signal, (V) represents an analogue voltage signal, and (I) represents an analogue current signal, [4]*

The present status of the new DMR and results of its first tests on the experimental TRIGA reactor at the Jožef Stefan Institute are presented in this paper.

2 METHODS

2.1 The WIMS-D library update with nuclear data from the ENDF/B-VII.1 library

The WIMS-D code is a reactor lattice code, [2], for solving the Boltzmann equation for neutron transport in simple geometries, such as a homogeneous medium, one-dimensional cylindrical, spherical and Cartesian geometry, and two-dimensional cylindrical geometry. It is used to calculate neutron flux distribution and neutron multiplication factor in an infinite medium, k_{inf}. Finite dimensions of the system and, consequently, a possibility that neutrons can escape from the system can be taken into account by specifying experimental or geometrical buckling as input parameter. In such cases, the effective multiplication factor for the finite system, k_{eff}, can be calculated. The WIMS-D takes as input the multi-group library of isotopic nuclear data and a description of the reactor lattice, and solves the neutron transport equation over a specified region of the reactor lattice. This region may be a unit cell or a macro-cell. Therefore, it includes methods for solving an appropriate set of equations for neutron flux and k_{inf} in a discrete energy and spatial mesh (i.e. energy groups and discrete spatial points). The calculated neutron flux may be used to calculate sets of neutron flux-averaged or flux-weighted macroscopic cross sections homogenized over chosen sub-regions and in a chosen broad energy group structure, [5]. These sets of macroscopic cross sections can be used as material data in the input for various codes solving the neutron transport equation or diffusion equation over the whole reactor or its fragment. In the CORD-2 package, this is done with the GNOMER code, which solves the neutron diffusion equation in three-dimensional Cartesian geometry with Green's function nodal method, [6]. The calculated neutron flux can also be used for reaction rate calculations or in fuel depletion calculations. A simplified flowchart of the WIMS-D calculations is presented in Figure 3.

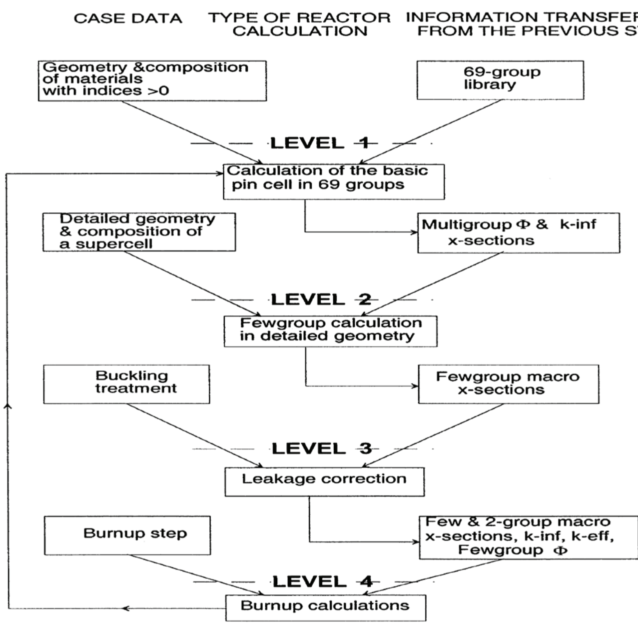

Figure 3: *Simplified flowchart of the WIMS-D calculations, [2]*

Updating the 69- and 172-group WIMS-D libraries with nuclear data from the ENDF/B-VII.1 library was the first task in the development of a new CORD package; this was accomplished by the author of this paper. Improvements of the fuel burn-up models are also being investigated, but this pending activity will not be presented in this paper. The WIMS-D code library update with nuclear data from the ENDF/B-VII.1 library could be considered as a continuation or supplement of the WIMS-D Library Update Project (WLUP), [7], which was supported by the International Atomic Energy Agency (IAEA). In that project, 69- and 172-energy group WIMS-D libraries based on nuclear data from the ENDF/B-VII.0 and other available nuclear data libraries were created and validated with the standard WIMS-D benchmark tests. Since a detailed presentation of this project and all relevant software is available on the WLUP web-page, [8], only changes of the input files and scripts that were used for processing input data based on the ENDF/B-VII.1 library are briefly described in this paper. The results of the benchmark calculations performed with the WIMSD-5B code and comparisons of the effective multiplication factors k_{eff} calculated with the WIMS-D libraries based on nuclear data from the ENDF/B-VII.0 and ENDF/B-VII.1 libraries are also briefly described.

The NJOY 99.364 code was used for processing ENDF files instead of the NJOY 99.65 code that was originally used in the WLUP. The NJOY 2012 is a new version of the NJOY Nuclear Data Processing System using Fortran-90/95 style, [9]. It includes all the capabilities of the NJOY 99 plus an ability to process evaluations, using the newer Reich-Moore Limited (RML) resonance format now allowed in ENDF files. This new version was not available for the calculations presented in this paper. The other codes, such as AVRFPY code for processing fission product yield and decay data, WILLIE code for managing the WIMS-D libraries, etc. were the same as those used in the WLUP (see page 63 in [7]).

The first step was to reproduce the WLUP results obtained with the ENDF/B-VII.0 library, as available on the WLUP web-page, and in that way to verify the reliability of the software package used in these calculations. In the next step, it was necessary to modify some input files and scripts, originally used in the WLUP, in order to process the ENDF/B-VII.1 library data. Then, after executing the benchmark calculations, the results of the benchmark tests were compared and validated.

The WIMS-D library updating under MS-DOS on PC is described in detail on the WLUP web-page. The input files for the NJOY and WILLIE codes are also available therein. Calculations of the 69- and 172-group WIMS-D libraries were performed by executing the batch script that runs all the calculations, including the benchmark tests. However, during the processing of the original nuclear data from the ENDF/B-VII.0 library with the NJOY 99.364, several errors were reported by the latter. Therefore, the following changes of the original input files had to be made in order to avoid these errors:

- minor changes of the co-variances of resonance parameters for thorium isotope Th-232 (ENDF material 9040);
- missing data in the ENDF/B-VII.0 library for energy distributions of delayed neutrons for U-232 (ENDF material 9219), Am-242m (ENDF material 9547), Cm-243 (ENDF material 9634) and Cm-244 (ENDF material 9637) had to be replaced with the corresponding data for U-234 (ENDF material 9225), Am-243 (ENDF material 9549), Cm-242 (ENDF material 9631) and Cm-245 (ENDF material 9640).

For the latter task, several ENDF pre-processing codes, which assure correct replacement of the data and correct format of the created ENDF data files, were used in a rather tedious procedure. After these changes had been implemented, the calculations of the WIMS-D libraries and benchmark test calculations were successfully completed with the set of WLUP programs and scripts.

To calculate the WIMS-D libraries with the data from the ENDF/B-VII.1 library, appropriate input data files that include all WIMS-D materials should be prepared. In addition, the following changes of the NJOY and WILLIE input files and the batch script that runs all the calculations had to be made.

The NJOY and WILLIE input files with names 'endfb7...' were renamed to 'endfb71...'. In the renamed NJOY input files 'endfb71.nji' (for calculating the 69-group library) and 'endfb71gx.nji' (for calculating the 172-group library), the input data for natural vanadium were replaced by the input data for vanadium isotopes V-50 (ENDF material 2325) and V-51 (ENDF material 2328). In the renamed WILLIE input files 'endfb71.wli' and 'endfb71gx.wli', the natural vanadium had to be specified as a mixture of these two isotopes. Because of these changes, the batch script that runs all the calculations was also changed in the part relevant to processing of vanadium isotopes.

Examination of the original ENDF/B-VII.1 input data showed that the data for energy distributions of delayed neutrons were missing for the isotopes listed above (Am-242m, Cm-243 and Cm-244), so they were replaced with the corresponding data for Am-243, Cm-242 and Cm-245, using the same procedure as described above. However, the most serious problem was found while processing Cl-35 (ENDF material 1725) with the NJOY 99.364, because this material was written in the new ENDF format that can be processed by the NJOY 2012. Therefore, Cl-35 was first pre-processed with LINEAR and RECENT codes, which are available at the ENDF web-page, [10], and then with the 2013-versions of ENDF pre-processing codes STANEF, CHECKR, FIZCON and PSYCHE codes. Since the NJOY 99.364 could not process the resonance parameters for the Reich-Moore theory, they were replaced by a simple model without resonance parameters except for the scattering radius, as used in the ENDF/B-VII.0 library. The co-variances of resonance parameters were also deleted. After all these changes had been implemented, the calculations of the WIMS-D libraries and benchmark test calculations were successfully completed.

Each set of the calculations for the 69- and 172-group libraries, including almost 300 benchmark test cases, took about three days on Intel Core i7-3630QM CPU 2.40 GHz system with 8 GB RAM. The necessary changes of the input files due to the processing errors mentioned above were mostly not known in advance, so several test runs had to be executed before discovering all these errors and finding appropriate solutions.

2.2 Development of the new DMR ('DMReS')

The theoretical basis for the design of the DMR is the point kinetics equation, [4], [11]:

$$\rho = \frac{\Lambda}{T(t)}\frac{dT}{dt} + \sum_{i=1}^{I}\frac{\beta_i}{T(t)}e^{-\lambda_i t}\int_0^t \frac{dT}{dt'}e^{\lambda_i t'}dt' - \Lambda\frac{Q(t)}{T(t)} \tag{2.1}$$

where ρ = (k-1)/k is the reactivity (*k* is the neutron multiplication factor), Q is the neutron source strength, β_i is the effective delayed neutron fraction of group *i* of the delayed neutrons (i.e. the ratio of the number of delayed neutrons from precursor group *i* to the total number of fission neutrons ν, usually 6 groups are used), λ_i is the decay constant of group *i* of the delayed neutrons, Λ is the prompt neutron lifetime and T is the strongly time-dependent neutron flux amplitude function, defined with equation:

$$\Phi(\vec{r},t)=T(t)S(\vec{r},t); \qquad \int_V S(\vec{r},t)dV=1 \tag{2.2}$$

that splits the total neutron flux $\Phi(\vec{r},t)$ at position $\vec{r}$ and in time *t* into the strongly time-dependent neutron flux amplitude function $T(t)$ and the shape function $S(\vec{r},t)$, which varies slowly with time and is normalized such that the integral over the core is constant. It is assumed that Q, β_i, λ_i and Λ are averaged over the core and constant. The source strength Q is the only non-homogeneous term in the point-kinetics equation (2.1). If the neutron source strength Q contribution to the signal is assumed constant, it can be measured quite easily while approaching criticality, [12]. Note that on the right side of equation (2.1) the average neutron flux and its derivative appear as a ratio, except in the neutron source contribution. For this reason, we do not need to know the neutron flux in absolute terms, so the measured signal that is proportional to the neutron flux can be used, except for the neutron source contribution term, where the ratio of the neutron source signal and the fission neutron flux signal are required.

A recurrent numerical algorithm was derived to solve equation (2.1) and was implemented in DMR-043. The point kinetics equation (2.1) is valid exactly if either the reactor core is homogeneous, so that the delayed neutron data are the same for the whole core, or if the neutron flux distribution shape function $S(\vec{r},t)$ does not change significantly during the transient. However, experience and numerous measurements have shown that these restrictions alone do not limit the use of this equation for practical applications, [11].

The principle of the rod-insertion method is to start from a critical reactor operating at low power and to measure the time-dependent reactivity change while a control rod is inserted into the core. Unlike in the rod-drop method, the measured control rod is inserted with the drive mechanism at normal speed. By analysing the flux trace using the point-kinetics, not only the total rod worth but also the differential and the integral control rod worth curves are obtained. During the rod-insertion measurement, the flux may drop by several orders of magnitude. Therefore, a high-quality electrometer is required for monitoring the neutron flux. The analysis is performed by transferring the data to a computer with the DMR software.

The new DMR software is being developed by S. Slavič [15] as a stand-alone 32-bit MS Windows application program running on MS Windows XP or newer operating systems (e.g., Vista, 7, 8, etc.). It was developed in the Xbase++ programming language, with the Alaska Xbase++ toolkit. It has a GUI (see *Figure 4*), with additional pre- and post-processing features that are not included in the DMR-043, such as saving all configuration files and results as text data files (by default), saving all projects or measurement scenarios in a way that they can easily be reproduced or re-run, exporting plots as JPG- or GIF-files, simple (auto) or advanced input options, etc. In addition, the programs INHOUR and BORDIL, [13], are included in the software package and can be run with the GUI. These two MS-DOS application programs (i.e., the '.exe'-binaries) have previously been developed, tested and verified. They have not been ported to MS Windows, so they are not included in the new DMR software source code. The INHOUR and BORDIL utilities are used to approximately relate the measured power doubling time (or reactor period) to the reactivity and to relate the boron concentration in the primary circuit to the added volumes of water or concentrated boron solution, respectively. The Inhour equation can be derived from the point kinetics equations, [14], if the neutron source term Q is neglected, the reactivity ρ is constant and asymptotic exponential solution for the neutron flux is assumed (i.e. $\Phi(t) \propto e^{\omega t}$). Assuming that there are six delayed-neutron precursor groups, the Inhour equation can be written as:

$$\rho = \omega\Lambda + \sum_{i=1}^{6} \frac{\omega\beta_i}{\omega + \lambda_i}, \tag{2.3}$$

where $\omega = \ln 2/t_d$ is the inverse reactor period and t_d is the reactor doubling time and other quantities in equation (2.3) are the same as defined above.

The beta version of the new DMR software, called 'DMReS', was initially tested with simulated measured signals for the neutron flux and temperature, which were generated by an electronic circuit made for that purpose, and then with the measured signals from the TRIGA experimental reactor at the Jožef Stefan Institute. The results of these tests are presented in the next section. It was also verified that DMReS is operational with both a Keithley 617 analogue electrometer (1980s technology) and a Keithley 6517 digital electrometer (late 1990s–early 2000s technology). The development of DMReS is still in progress, because some GUI errors must be corrected, and the usability of some of its functions must be improved.

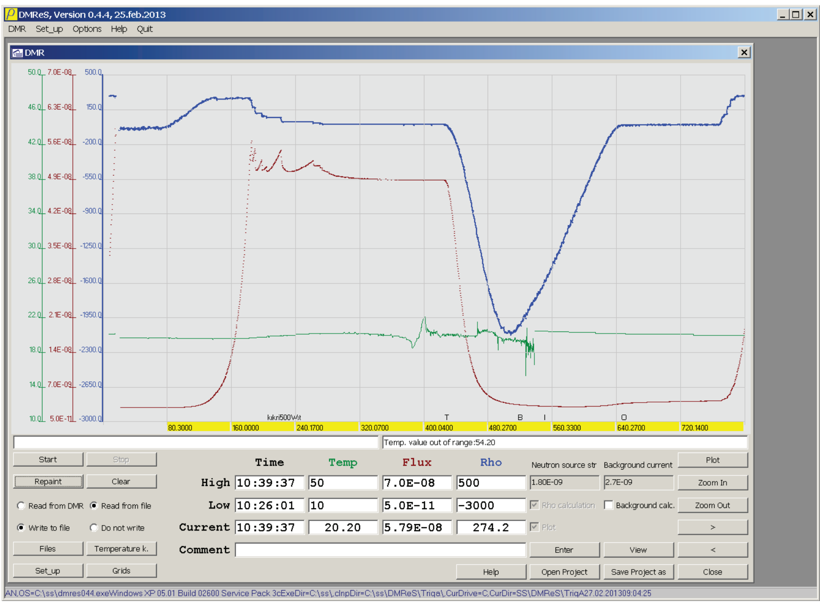

Figure 4: *Screen-shot of the DMReS GUI*

3 RESULTS

3.1 The WIMS-D benchmark test calculations

Detailed analyses of the results of the benchmark calculations with the updated WIMS-D libraries were performed in order to confirm the validity of these libraries for the planned calculations with the CORD-2 package. The benchmark calculations should reproduce the reference values of the effective multiplication factor k_{eff} for various experimental test cases that include different geometry parameters and combinations of nuclear fuel, cladding, moderator, neutron absorber and structural materials, which are relevant to commercial nuclear fuel systems. Considering the possible differences between the input data and versions of the NJOY code used in the calculations with the ENDF/B-VII.0 library data presented in this paper and those available on the WLUP web-page, they provided almost the same results for the k_{eff}s. The differences between the k_{eff}s were mostly of the order of 10^{-5} (1 pcm) and only in a small number of test cases were they of the order of 10^{-4} (10 pcm). Thus, the reliability of the software package for updating the WIMS-D libraries was verified with these calculations.

Comparisons of the k_{eff}s calculated with the data from the ENDF/B-VII.0 and ENDF/B-VII.1 libraries showed the following trends and characteristics:

in the benchmark tests with uranium fuel, which do not include some structural materials, in particular natural chromium (Cr-nat), manganese (Mn-nat) and nickel (Ni-nat), and natural zirconium (Zr-nat) as the fuel cladding material, where the differences between the nuclear data in the ENDF/B-VII.0 and ENDF/B-VII.1 libraries are significant, the k_{eff}s calculated with the ENDF/B-VII.1 data are mostly smaller than the k_{eff}s obtained in the analogous calculations with the ENDF/B-VII.0 data; the differences between these k_{eff}s are from the order of 10^{-5} (1 pcm) to the order of 10^{-4} (10 pcm);

in the benchmark tests with uranium fuel, which include the aforementioned structural materials and natural zirconium, the k_{eff}s calculated with the ENDF/B-VII.1 data can be smaller or bigger than the k_{eff}s obtained in the analogous calculations with the ENDF/B-VII.0 data, depending on the content of the structural materials and zirconium, the differences between the k_{eff}s are from the order of 10^{-4} (10 pcm) to the order of 10^{-3} (100 pcm);

in the benchmark tests with a fuel containing a mixture of uranium and plutonium isotopes (MOX), the k_{eff}s calculated with the ENDF/B-VII.1 data are mostly smaller than the k_{eff}s obtained in the analogous calculations with the ENDF/B-VII.0 data; the differences between the k_{eff}s are from the order of 10^{-4} (10 pcm) to the order of 10^{-3} (100 pcm), and because they are also strongly dependent on the content of the structural materials and zirconium, qualitatively different results for the k_{eff}s are obtained in some cases, e.g. in Rowlands Pu Pin-cell benchmarks; [7]

in the benchmark tests with thorium fuel, the k_{eff}s calculated with the ENDF/B-VII.1 data are smaller than the k_{eff}s obtained in the analogous calculations with the ENDF/B-VII.0 data; the differences between the k_{eff}s are from the order of 10^{-4} (10 pcm) to the order of 10^{-3} (100 pcm) and they are also dependent on the content of the structural materials, zirconium (Zr-nat) and cadmium (Cd-nat);

changes of the dimensions and buckling of the system can significantly reduce the influence of the differences between the ENDF/B-VII.0 and ENDF/B-VII.1 data on the results for the k_{eff}s while keeping the same content of the materials used in the benchmark tests.

Therefore, it can be summarized that in about 90% of the test cases the k_{eff}s calculated with the ENDF/B-VII.1 data are smaller than the k_{eff}s obtained in the analogous calculations with the ENDF/B-VII.0 data. However, the important exceptions from this ‘rule’ are found in some MOX-fuel benchmark calculations (for example, in Rowland’s Pu Pin-cell benchmarks), which are relevant to the reactor fuel burn-up calculations.

3.2 Tests of DMReS with simulated and measured signals from the TRIGA reactor

Comparisons of the time-variations of the neutron flux and reactivity obtained with DMReS and DMR-043 using simulated measured signals are presented in Figures 5 and 6, respectively. The 'DMR-043+'-label indicates the measurement with the DMR-043 using higher sampling rate.

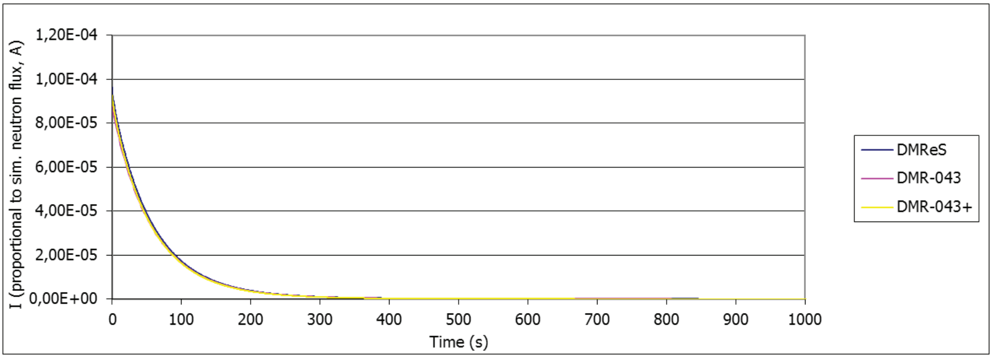

Figure 5: *Time-variation of the measured simulated neutron flux*

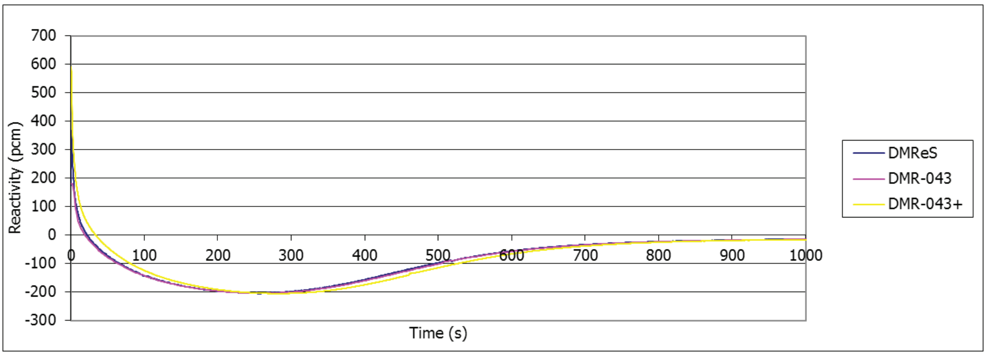

Figure 6: *Time-variation of the reactivity calculated with the measured simulated neutron flux*

It can be concluded from these results that the relative differences between the reactivities calculated with DMReS and DMR-043 are extremely small, i.e. up to a few percentage points or within the experimental error. However, the sampling rate or the density of the measured data can be extremely important, especially when the time-derivative of the neutron flux is large. In such cases, the relative differences between the reactivities calculated with either DMReS or DMR-043 using significantly different number of measured data can be from about 10 to 50%. Arbitrary changes of the sampling rate in the measurements in the real reactors are not possible, so the dependence of the numerical algorithm implemented in DMReS on the sampling rate must be minimized as much as possible, at least for processing realistic measured signals. This 'fine-tuning' of the free parameters of the numerical algorithm remains a pending task in the further development of DMReS.

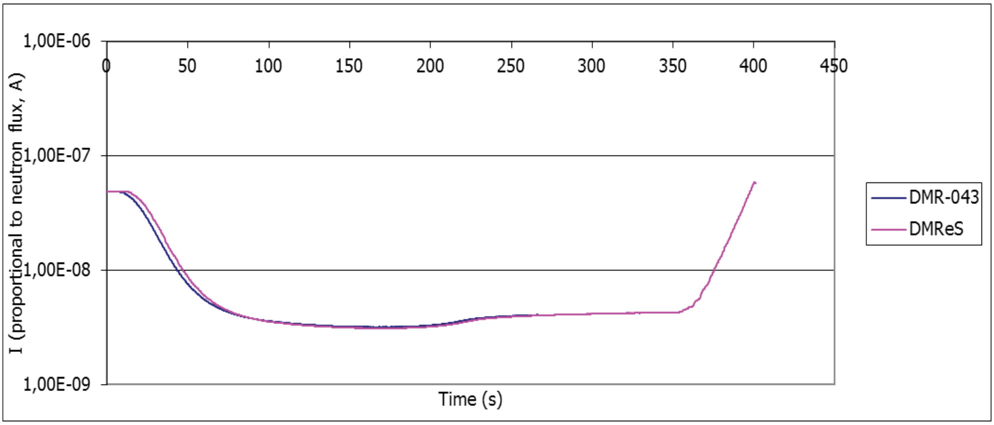

Figure 7: *Time-variation of the neutron flux measured in the TRIGA reactor*

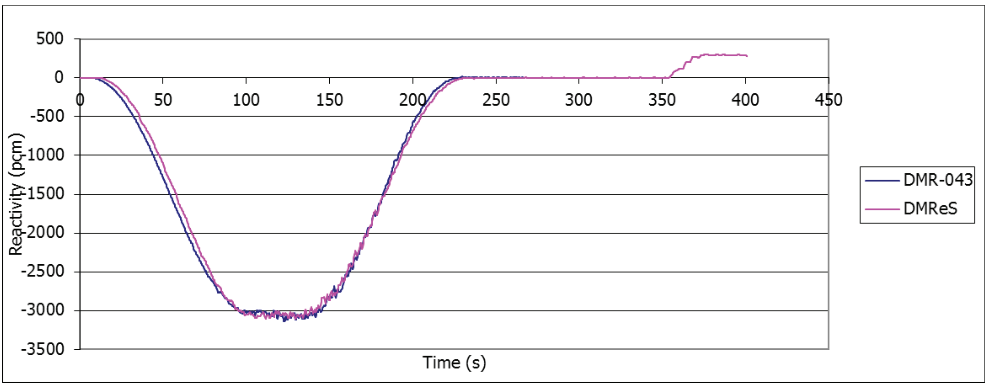

Figure 8: *Time-variation of the reactivity calculated with the neutron flux measured in the TRIGA reactor*

The rod-in method was used in the reactivity measurements on the TRIGA reactor with DMReS and DMR-043. Comparisons of the time-variations of the neutron flux and reactivity obtained with DMReS and DMR-043 are presented in Figures 7 and 8, respectively.

It is obvious from Figures 7 and 8 that the small differences between the measured neutron fluxes at the beginning of the experiment (i.e. in the first 100 s) have a strong influence on the results for the reactivity, because it is a time-interval in which the time-derivative of the neutron flux is large. These initial differences between the measured neutron fluxes occurred because simultaneous measurements of the neutron fluxes under identical initial conditions were not possible due to technical reasons (measured current from the ionization detector could not be simultaneously transferred to both DMR systems) and limitations of the experimental set-up. Later, the variations of the neutron flux were much slower, the differences between the measured neutron fluxes were extremely small; consequently, the relative differences between the calculated reactivities were a few percentage points within the experimental error.

4 DISCUSSION

The 69-group WIMS-D library based on the nuclear data from the ENDF/B-VII.1 library will be used in the KNPP core design calculations with the CORD-2 package, from the first to the 25th fuel cycle. The results of these calculations will be compared with the corresponding results of the calculations using the ‘1986’ WIMS Nuclear Data Library, which is included in the WIMS-D5 code package and available experimental results. If better agreement with the experimental results is obtained with the new WIMS-D library, it will be used in the future KNPP core design calculations. This will also give additional motive to repeat the calculations of the new WIMS-D libraries with the NJOY 2012 code. Following the results of the WIMS-D benchmark calculations presented in this paper and considering the significant differences between the old and new nuclear data for zirconium and some structural materials, it may be expected that certain differences between the results obtained with the ‘1986’ and new WIMS-D library will appear. However, because of the importance of the buckling parameter, it is not possible to predict how large they will be, as has been shown in some test cases in which changes of the dimensions and buckling of the system significantly reduced the differences between the calculated k_{eff}s. When the improved fuel burn-up model is developed and implemented in the CORD-2 package, the influence of the differences between the data in various WIMS-D libraries on the results of the burn-up calculations will also be investigated.

The first tests of DMReS, presented in this paper, showed good agreement of the results for the reactivity with those obtained with the DMR-043, which is considered to be a reference tool. However, additional development and tests of the updated software releases are necessary, in order to improve its precision, usability and quality of the GUI. These activities are already in progress. A patent application for the new DMR system has also been planned.

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Nomenclature

$\boldsymbol{k}$	neutron multiplication factor
$\boldsymbol{k_{inf}}$	neutron multiplication factor in an infinite medium
$\boldsymbol{k_{eff}}$	effective neutron multiplication factor for a finite system
$\rho = (k-1)/k$	reactivity
$\boldsymbol{t}$	time
$\vec{r}$	spatial position vector
Q	neutron source strength
β_i	effective delayed neutron fraction of group *i* of the delayed neutrons (i.e. the ratio of the number of delayed neutrons from precursor group *i* to the total number of fission neutrons, usually 6 groups are used)
λ_i	decay constant of group *i* of the delayed neutrons
Λ	prompt neutron lifetime
$\Phi(\vec{r},t)$	total neutron flux at position $\vec{r}$ and in time $\boldsymbol{t}$
$T(t)$	strongly time-dependent neutron flux amplitude function
$S(\vec{r},t)$	neutron flux shape function, which varies slowly with time and is normalized such that the integral over the core is constant
t_d	reactor doubling time
$\omega = \ln 2/t_d$	inverse reactor period

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OVERVIEW OF RESEARCH STUDIES ON UNDERGROUND COAL GASIFICATION IN SLOVENIA

PREGLED RAZISKAV V ZVEZI S PODZEMNIM UPLINJANJEM PREMOGA V SLOVENIJI

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Keywords: coal gasification, lignite, research overview, UCG, underground

Abstract

The first concepts regarding the commercial processing of lignite date back to 1948, and in 1961 the EKK power plant was formally established. It was liquidated in 1968, due to low oil and gas prices on the world market. In 1962, the first Slovenian research project analysing underground coal gasification (UCG) technologies was published. In 1980, the activities that should be taken to perform the first Slovenian UCG test in 1984 were specified. From 1983 to 1987, the first laboratory experiments were conducted. The purpose of the experiments was to study the impact of operating parameters on coal combustion and gas quality. Since 2000, interest in UCG technology has been rising again. Research has been funded by the CMV and implemented by ERICo, IREET, FNT, NIC and CMV. The main purpose of these studies was to obtain information on the state of the art in the world regarding UCG technologies and the geological characterization of coal seams appropriate for UCG. From 2010 to 2012, the CMV produced a study on the efficiency of a power plant using gas produced by lignite UCG. In 2011, the RCE started a project under which the first Slovenian gasification test is planned to be carried out in-situ in 2014.

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Povzetek

Prve ideje o komercialni predelavi lignita datirajo v leto 1948. Energetsko kemijski kombinat EKK je bil formalno ustanovljen leta 1961 in leta 1968 likvidiran, zato ker tehnologija pridelave plina ni bila konkurenčna ceni nafte in plina na svetovnem trgu. Leta 1962 je bila opravljena prva raziskava, ki posega na področje PUP. V letu 1980 so izdelali projekt aktivnosti za izvedbo prvega testa uplinjanja premoga v Sloveniji, ki naj bi ga izvedli leta 1984. V letih 1983-1987 so se izvajali prvi laboratorijski poskusi. Namen teh poskusov je bil določiti vpliv obratovalnih parametrov na potek nastajanja izgorevalne votline, sestavo nastalega premogovega plina in njegovo kalorično vrednost. Po letu 2000 se je zanimanje za tehnologijo PUP zopet povečalo, raziskave je financiral PV izvajali pa so jih ERICo, KI, IREET, FNT in PV. Namen teh študij je bil predvsem informiranje s stanjem tehnike v svetu in geološka opredelitev potencialnih ležišč primernih za PUP. V letih 2010 do 2012 je PV izdelal študijo o energetski učinkovitosti obrata, ki bi baziral na plinu, pridobljenem pri podzemnem uplinjanju lignita. Leta 2011 je RCE pričel s projektom v okviru katerega naj bi prišlo tudi do prvega testnega uplinjanja premoga v naravi v letu 2014.

1 INTRODUCTION

At the end of 19th century, underground coal gasification (UCG) was known as a technology suitable for the exploitation of coal layers. Initially, the main purpose of UCG was to reduce heavy smoke emissions from coal-fuelled industrial plants, to relieve the miners of difficult work underground and to explore the coal layers that remained unexplored after the abolition of mining operations. Recently, UCG has been emerging as an alternative technology for the production of energy and fuels, and as an alternative technology of oil production. With the development of drilling methods, the coal seams that were unreachable by traditional mining methods, due to their specific location, depth or lack of coal thickness, have become available. The development of drilling techniques has led to improvements in UCG technology that ensure constant quality and constant amounts of gas produced in a single reactor over a long period. The principles of traditional and current state-of-the-art UCG technology are schematically presented in Figure 1. The main differences are in the gasification site preparation, the size of the resulting underground reactor and the direction of the combustion front propagation.

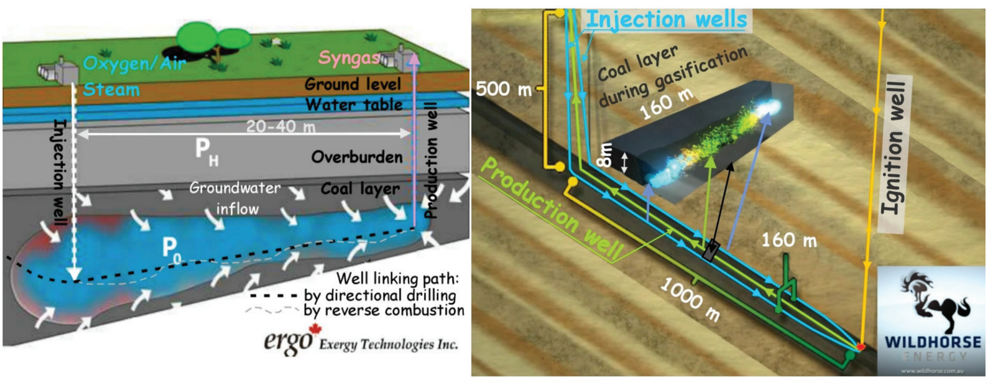

Figure 1: *Comparison between different UCG technologies. Linked vertical wells (LVW) technology (left) and parallel controlled retracting injection point (CRIP) technology (right).*

The traditional linked vertical wells (LVW) method is based on two vertical wells drilled from the surface toward the coal layer at a distance of 20–40 m. In the coal layer, a linking between wells is obtained mostly with the reverse combustion method or with directional drilling. For the parallel CRIP method, the gasification site is prepared by directional drilling only. Since the drilling costs increase with the depth, the parallel CRIP method is preferable after exceeding a certain depth. During gasification with the LVW method, the combustion front spread three-dimensionally. To ensure a constant quality of produced gas, operating at a variable feed rate or performing UCG in multiple locations at the same time is required, but at different stages of cavity formation, which assures constant quality of produced gas and, therefore, a suitable supply for an integrated energy and processing plant. Parallel CRIP technology provides that, during the exploitation of coal beds, the non-stationary conditions are only at the initial stage of combustion; afterwards, the combustion front retains its shape during the gasification of the entire layer (theoretically up to a period of two years), which allows a direct connection to a power plant or an integrated chemical processing plant.

The scope of studies and investments in new technologies for coal processing is linked to the price of other energy sources. From the data presented in Figure 2, it is clear that a rise in oil prices increases the interest in investing in research of coal gasification, which is reflected in the increased occurrence of phrases ‘coal gasification’ and ‘underground coal gasification’ in the titles of articles, abstracts of articles and related keywords. Slovenia has also followed this trend.

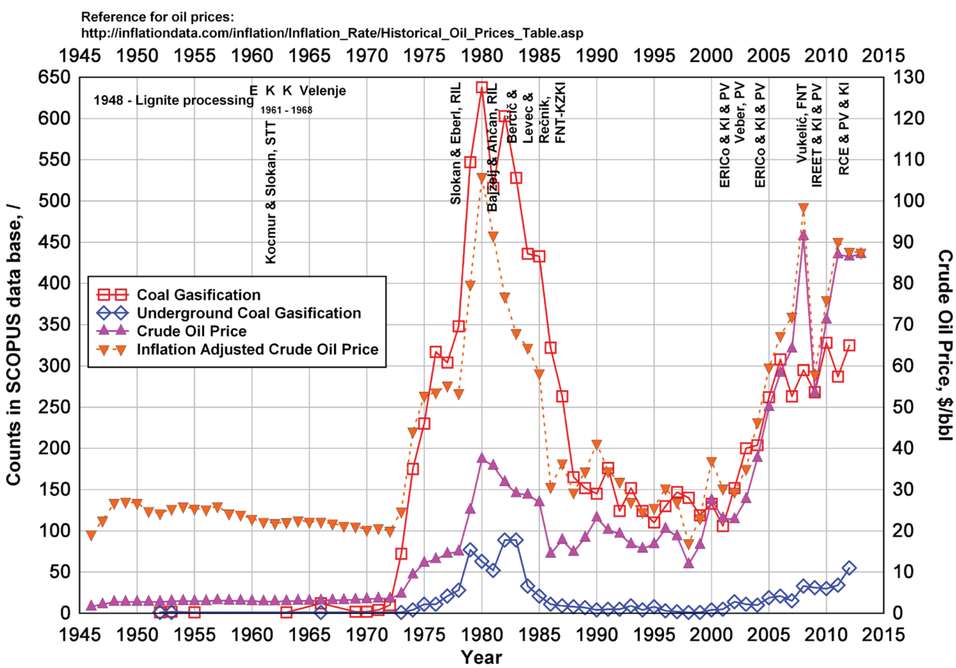

Figure 2: *Influence of oil prices on research of coal gasification technologies.*

In Figure 2, the relevant Slovenian research works concerning UCG technology are labelled chronologically under the upper x-axis. The first initiative to commercially process lignite from the Velenje

Coal Mine dates back to 1948. In 1961, the EKK (Energo-Chemical Plant) was formally established, but it was liquidated in 1968, because the technology for gas production from the lignite was not competitive with the prices of oil and gas on the world market. In 1962, the first survey on implementation of UCG technologies was carried out by the Institute for Separations within the Trbovlje Machine Factory. In 1980, the Ljubljana Institute of Mines started a project which should lead to the first UCG test in Slovenia in 1984. Unfortunately, the project was not implemented in accordance with the planned schedule and scope of works. During the 1983–1987 period, laboratory experiments were conducted at the Department for Chemical Engineering (KZKI) within the Faculty for Natural Sciences and Technology (FNT). The purpose of these experiments was to determine the effect of operating parameters on the formation process of the combustion cavity, on the composition of the resulting gas from coal and its calorific value. After the year 2000, interest in UCG technology increased again. The research was funded by the Velenje Coal Mine and conducted by the ERICo (Environmental Research & Industrial Cooperation, Velenje), the IREET (Energy, Ecology and Technology Research Institute, Ljubljana), the FNT, the KI (National Institute of Chemistry, Ljubljana) and the PV (Coal Mine Velenje). The purpose of these studies was to obtain information on the state of the art of UCG in the world, a theoretical analysis of the implementation of the UCG process in the layer of lignite and the geological definition of the Slovenian coal seams suitable for UCG. From 2010 to 2012, the Velenje Coal Mine produced a study on the efficiency of a power plant that would use gas obtained by the underground gasification of lignite. In 2011, the RCE (Research Center Energy) started the project under which the first coal gasification test should be performed in situ.

2 REVIEW OF THE FIRST REPORTS ON IMPLEMENTATION OF UCG TECHNOLOGY IN SLOVENIA

As early as the 1950s, the lignite from the Velenje coal basin was considered to be the main raw material and energy source in Slovenia, [1]. Due to a large content of non-combustible materials (ash and water), ideas about the lignite gasification emerged immediately after the Second World War. Gasification would significantly reduce the energy transport costs and reduce pollution in the vicinity of industrial facilities. The preliminary gasification tests with the lignite were carried out at the Most power plant in Czechoslovakia in 1948. The proposal for building a large gasification plant in Velenje was continuously supported and defended by the Velenje Coal Mine and the Šoštanj Termal Power Plant. At the request from the Velenje Coal Mine, the Boris Kidrič Chemical Institute Ljubljana and the Industrial Office Ljubljana prepared an investment study for the construction of a large gasification plant in Velenje in 1960, [2]. In 1961, the trade association for the construction of a large gasification plant in Velenje was registered, and the procedures for construction, selection of a proper technology and procurement of equipment started. However, the financial construction of the project was always problematic. In the 1960s, on the global market of energy sources, oil and natural gas started to replace coal and, therefore, the financial construction of a large gasification plant EKK became economically questionable. In 1968, the Slovenian government decided liquidate the business association for the construction of EKK; this also ended the efforts to implement technologies based on coal gasification in Slovenia. In 1962, the Trbovlje Institute for Separations of Machine Factory (STT) issued a first report on the underground coal gasification technology. The authors, engineer Janez Kocmur and Prof. Karel Slokan, [3], reported in detail the principles of underground coal gasification, the course of gasification and the methods used in the world. They also presented the methods of construction and the connection of holes needed for UCG and the background chemistry of the gasification process. They showed results of the experimental study of the influence of flow of gasification gasses on the composition of formed gas and the variation of produced gas composition when passing coal seams on the way out. In their report, the authors also gave a detailed summary of the research and results obtained during UCG tests carried out in the Soviet Union, Italy, Belgium, France, England, the United States and Czechoslovakia. In their conclusions, they pointed out that the problem of underground coal gasification cannot be solved within a single institute and that the integrated efforts of several mining research institutions are needed for a success. Together, they should first carefully examine the work and results of the gasification processes in other countries and, on the basis on this and their own experiences, set the suitable locations for underground coal gasification and choose one of them for carrying out the initial experiments.

At the end of 1975, the Research Community of Slovenia approved the research project ‘Options for Underground Coal Gasification in the SRS (Socialistic Republic of Slovenia)’. The study should examine the international professional literature and present the latest information in the field of underground gasification, find suitable coal seams and categorize parts which are suitable for underground gasification. The task was carried out in the 1976–77 period by the Ljubljana Mining Institute under the project entitled ‘Underground coal gasification and its possible applications in the Slovenian coal mines’ [4]. The holder of the assignment was Prof. Slokan. The final report was made on the basis of the report which Prof. Slokan had already made for the STT. The information about coal gasification trials in West Germany and a review of the Slovenian resources suitable for underground coal gasification were added. The report gave also detailed analysis of stocks, options and methods for underground gasification in the Coal Mine Velenje, coal mines in Zasavje (Dol-Hrastnik, Ojstro-Trbovlje and Zagorje), and coal seams around Lendava. In their guidelines for further research, the authors stressed that relevant Slovenian research and scientific institutions and Slovenian companies producing energy should join in the research and implementation of underground coal gasification technology.

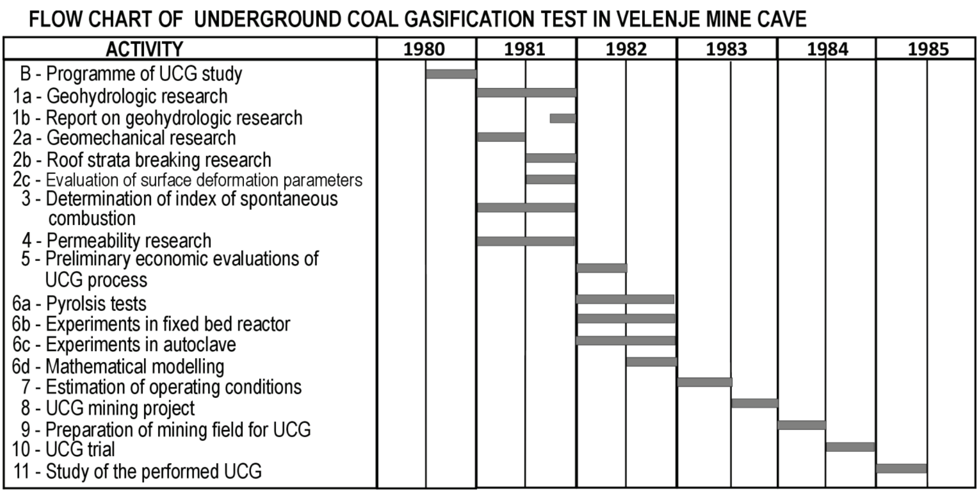

***Figure 3**: Flow chart of research activities planned under the project entitled Underground Gasification of Lignite in Velenje Mine Cave [5].*

In 1980, the SOZD of the Joint Electric and Economy Companies of Slovenia and the Ljubljana Mining Institute concluded a contract assigning the Ljubljana Mining Institute to provide a study ‘Underground Gasification of Lignite in Velenje Mine Cave ’, [5]. According to the plan, the study was to last five years and result in a test gasification of coal at a selected location in 1984. The time course of the study is in the form of a bar graph shown in Figure 3.

It turned out that the timetable of the project was too ambitious and unrealistic regarding the capacities of research institutions involved. Activities under numbers 1-5 were carried out and presented in the report by the Mining Institute in 1981, [6]. Implementation of chemical engineering research (Items 6a to 6c) ended in 1987 with the diploma thesis by Aleksander Rečnik, [7]. However, chemical engineering research could not be carried out using the existing experimental equipment, since it was necessary to construct every single piece of equipment, which resulted in a prolonged experimentation period. Moreover, there were no researchers with the experimental experience from similar fields, which certainly would have sped up development of the experimental apparatuses. The results of chemical engineering research are given independently in the form of reports of the Department of Chemical Engineering and as an integral part of the subsequent reports of the Mining Institute.

3 OVERVIEW OF THE MAIN EXPERIMENTAL WORK REGARDING THE FUNDAMENTALS OF UCG

The experimental work took place primarily in the industrial laboratory of the Department of Chemical Engineering within the Faculty for Natural Sciences and Technology in the 1983–1987 period. In accordance with the work programme, we carried out pyrolysis tests, experiments in a fixed bed reactor, and experiments in an autoclave. In the scope of pyrolysis tests, the thermogravimetric analysis of different coals were made. The temperature range of physicochemical changes and weight losses during the controlled heating treatment of selected types of coal were defined. We also carried out tests in a small fixed bed reactor in order to determine the amount, composition and heating value of the gases released during the pyrolysis of different coals, [8]. In a fixed bed reactor, the continuous layer of crushed lignite was gasified at different operating pressures and at different flow rates of steam and oxygen. We determined that the quality of gas produced by gasification of lignite was comparable to published results. In the most favourable case (pressure = 5 bar, H_2O: O_2 = 4.9), the calorific value of gas was 5.6 MJ/Nm3, [9]. The most relevant results were obtained by the coal gasification tests carried out in autoclave (Figure 4), as these data should give insight into what happens in a layer of coal during gasification.

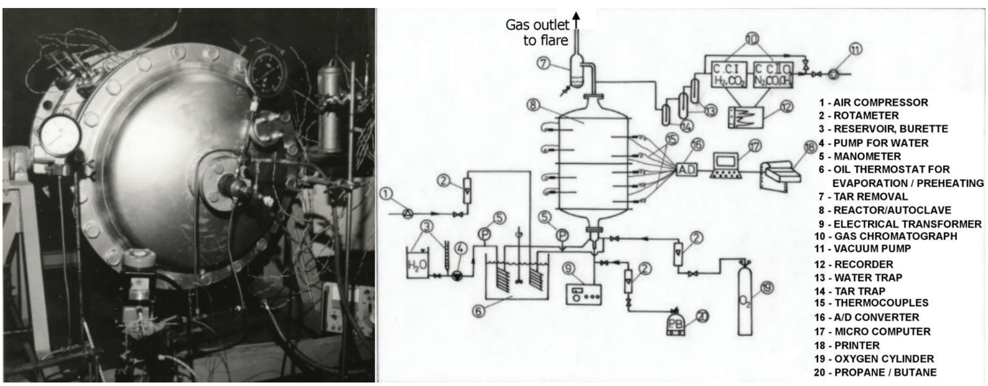

Figure 4: *Picture and scheme of experimental apparatus for coal gasification in an autoclave, [10].*

In the preparation of a representative layer of coal for experiments in autoclave, we concluded that we should prepare a synthetic piece of coal, because the Velenje Coal Mine could not deliver a sufficiently large single piece of coal to fill the entire volume of the reactor. When putting together a larger piece of coal from several smaller pieces [10], we determined that the combustion cavity spread unrealistically on the contact surfaces between two pieces; therefore, new synthetic pieces of coal were prepared in the Coal Mine Velenje by pressing crushed coal of various fractions into a cylinder with a diameter of 50 cm and a length of 100 cm. With compressed pieces of coal, Rečnik completed ten experiments, including seven under his thesis, [7]. Table 1 contains data on the composition of gas obtained during the conditions of pseudo-steady state. In most cases, the gasification experiments were carried out with a mixture of oxygen and water vapour. Calorific values of produced gas were between 7.2 and 7.9 MJ/m³, through gasification with pure oxygen even 8.79 MJ/m³.

Table 1: *Results of gasification tests of compressed lignite blocks*

Experiment	VLN-1	VLN-2	VLN-3	VLN-4	VLN-5	VLN-6	VLN-7	VLN-8	VLN-9	VLN-10
H_2O:O_2	1.0	2.0	1.0	1.0	1.5	1.5	1.0	Air	Air : O_2 1:1	O_2
H_2	40.1	19.4	28.7	28.1	35.1	22.5	31.5	9.2	23.9	33.2
CO	14.9	9.6	15.1	20.1	16.4	12.8	12.3	4.2	15.1	28.7
CH_4	2.1	2.1	2.8	2.8	2.7	3.4	3.7	0.8	2.2	2.2
CO_2	42.9	68.9	53.4	49.0	45.8	61.3	52.7	19.0	28.8	32.0
Calorific value	7.84	4.53	6.69	7.24	7.63	5.84	7.02	2.0	5.85	8.79

Concentrations of gases are in mol%; calorific values of produced gas in MJ/m³.

In Figure 5, the reconstructed sizes of six combustion chambers on the basis of a sequence of photographic images taken during excavation of coal from the block in autoclave are shown. In the case of VLN-7, the coal block was prepared from lignite particles having a diameter up to 30 mm, while in all other cases particles of a diameter up to 10 mm were used. From the presented forms of the resulting combustion cavities, it can be concluded that the composition of the gasification agent (ratio oxygen/steam) affects the shape of the cavity created. In some cases, an atypical prolongation of cavity in the vertical direction was observed, which presumably resulted from mechanical failure, and it was not a result of gasification. On the basis of the carried out tests, we cannot make quantitative conclusions since the individual pieces of synthetic coal block were not made from the same coal. For the same reason, we cannot verify the repeatability of experiments, which would allow us to distinct between the influence of operating conditions and defects in the structure on the shape of the resulting cavity.

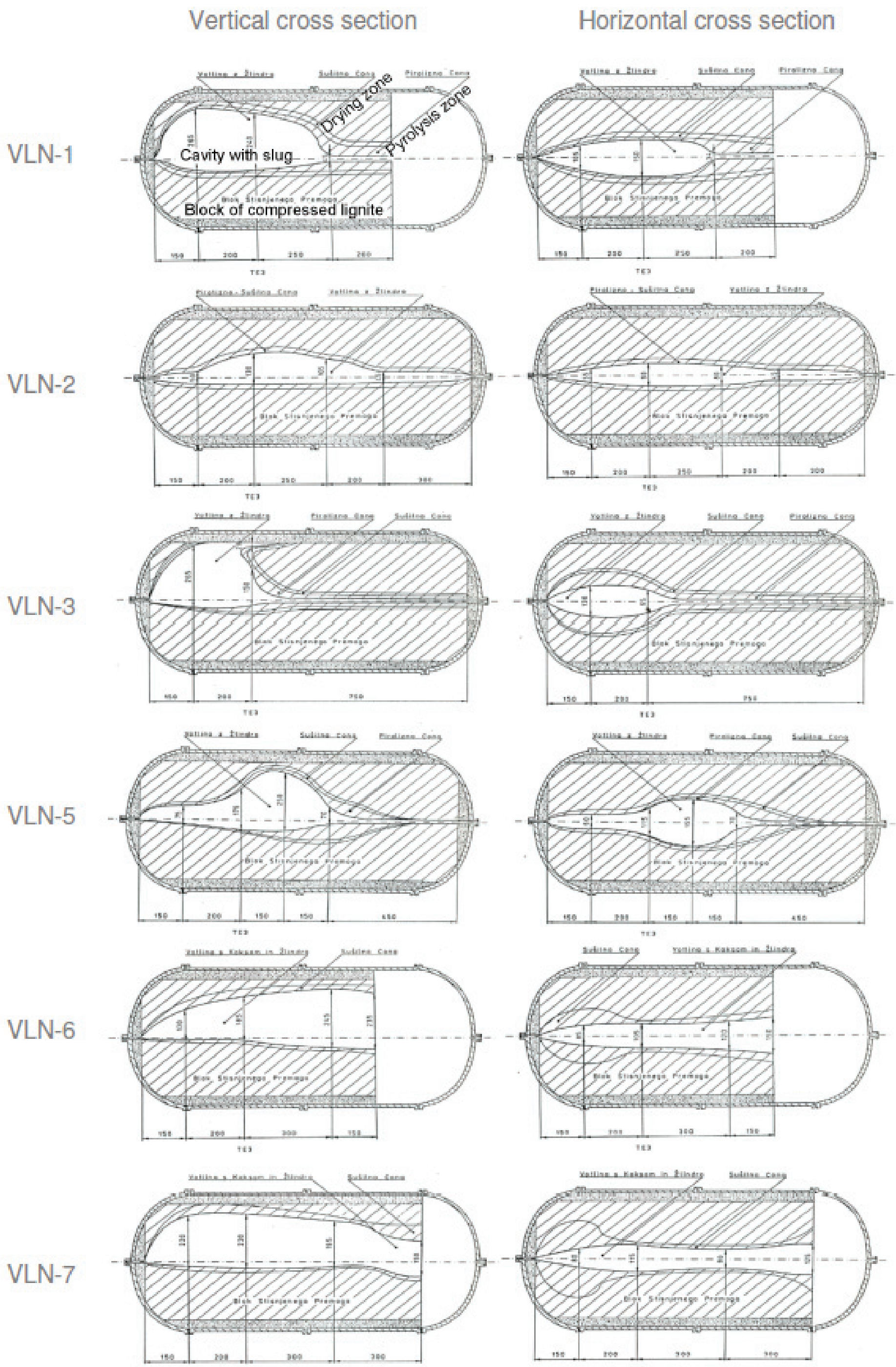

Figure 5: *Comparison of formed cavities during gasification of compressed lignite blocks at different operating conditions [7].*

4 RESEARCH ACTIVITY AFTER 2000

Since the year 2000, the Velenje Coal Mine, in the frame of development of clean coal technologies, had been the main Slovenian financier of research activities on underground coal gasification. In 2001, ERICo, [11], produced a scoping study on UCG, in which an overview of developments in the UCG technology was given. The technology of UCG was presented together with the site preparation techniques and guidelines for UCG. The review of mathematical models describing UCG was also presented. The previously performed Slovenian research activities on UCG were briefly summarized. The problems of environmental protection were outlined and an overview of the factors that may affect the economics of the process was also given. In a 2003 study (ERICo, [12]), the physical, chemical and mineral characterizations of lignite from the two most suitable locations for UCG, i.e. Tičnica and Leženj, [13], were made. The technological requirements for the process were given, and the reasons for the selection of CRIP gasification methods were discussed. The results of thermodynamic prediction of equilibrium composition for the system lignite-oxygen-steam were presented for different operating conditions. The strategy of UCG process control based on the calculation of hypothetical equilibrium temperature in underground coal gasifier using inlet conditions, the measured composition of produced gas, and the estimated water influxes were presented. In a 2007 study, Vukelić, [14], gave an estimate of the suitability of coal resources in Goričko and in NE Slovenia for UCG based on the results and analysis of samples collected by drilling wells during searching for the Slovenian oil and natural gas resources. A region between Strukovci and Kuzma was preferred, where a 10–12 m thick layer of brown coal with calorific value of 17.5MJ/kg was found at a depth of 150 m. A similar coal layer was found also in the vicinity of the borehole Slatine HR-1 at a depth of 600–700 m. As a suitable location for UCG, the following locations were mentioned: Gačani, Beltinci, Rakičan, Križevci, Moščanci and Bukovnica where the coal layer thickness is about 2 m. Nevertheless, additional research drillings will be necessary to identify further proceedings regarding the conduct of UCG on the proposed locations. In 2009, IREET, [15], produced the latest scoping study on UCG, which describes all the parameters that are crucial for the characterization of potential coal seam, provides an estimate of all products generated during UCG and analyses environmental acceptability of the process. The possibility to capture and store generated CO_2 (or CO_2 from other sources) in a formed reactor cavity is also analysed, and the results and locations of recent pilot tests of UCG are mentioned. In the chapter on the energetic efficiency of UCG, the method for the calculation of a mass flow of reactants and products generated on the basis of thermodynamic equilibrium, steady-state assumption and processing scheme proposed by the company Carbon Energy, [17], is introduced. The aforementioned method was also used in the producing of the report *Sizing and economics of power plant based on reserves, products and energy utilization of UCG process*, [16], which was prepared by PV as an enclosure to a study of IREET, [15]. In it, costs are specified for the installation, maintenance and operation of virtual energetic plant that would operate on lignite and use process scheme proposed by the Carbon Energy. A default size of the gasification field was assumed to be 600 m × 180 m × 8 m and the rate of progression of the combustion front was set to 3 cm/hour. Figure 6 presents a flow chart for determining the flow rates of reactants and products that meet the assumed rate of progression of the combustion front during the gasification of lignite through gasification mixtures that have different steam to oxygen ratios. It should be noted that the calculation is based on the assumption of thermodynamic equilibrium and, therefore, at lower temperatures, a higher flow of gasification gases is needed since the part of the lignite that decomposes due to temperature is smaller. In order to assure constant progression velocity of the combustion front, the gas flow rates should be increased at lower temperatures. The horizontal lines denote 60% and 80% transfer efficiency of chemical energy from lignite to the produced gas. By drawing a vertical line through the intersection between the curve presenting power carried by the produced gas and the line showing the energy efficiency of gasification gas, the thermodynamic quasi-equilibrium temperature can be determined. In fact, the velocity of combustion front propagation can be calculated from the carbon mass balance and energetic efficiency from the flow rate and composition of produced syngas. In a real case, the iteration procedure should be included since the water balance must be compensated with the underground water inflow. The estimated quasi-equilibrium temperature aids in adjusting operating conditions, i.e. mainly the ratio between oxygen and water in order to assure desired gasification conditions.

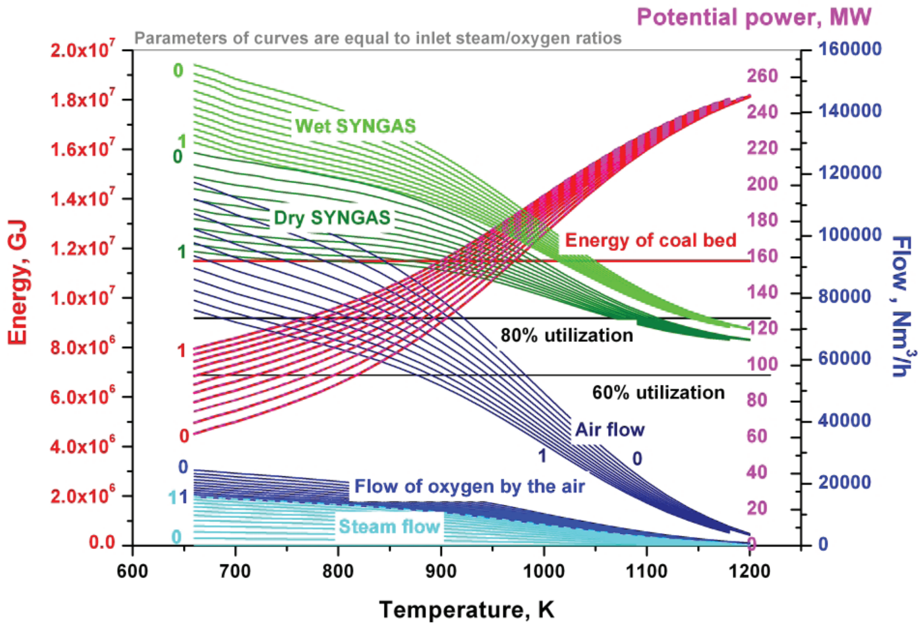

***Figure 6**: Diagram for graphic determination of flow rates of reactants and products for assumed combustion velocity of 3 cm/h at different thermodynamic equilibrium temperatures, [16].*

5 CONCLUSION

The main purpose of this article was to provide a short overview of all research activities regarding UCG in Slovenia. The emphasis is given to relevant experimental results and to theoretical approaches that could be applied during gasification experiments. From the abovementioned research activities, it is evident that a part of the Slovenian expert public has always been aware of UCG technology potentials and its possibility to explore untapped coal resources. The mentioned research projects show that we occasionally 'refresh' our theoretical knowledge about UCG technology and developments on the field of UCG; however, despite the immense potential that UCG certainly has, we have not managed to carry out a field experiment in one of the selected locations. Nevertheless, the opportunity to carry out the first field gasification test has now been opened since the RCE recently started to execute the research and development project entitled *Under-*

ground Coal Gasification. The project is funded by the Slovenian Ministry for Economy and the EU Structural Funds. One of the main goals of this project is also a field experiment, which will be performed in 2014 at a location of Tičnica.

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PROJECT ACHIEVE – REDUCING ENERGY CONSUMPTION IN FUEL-POOR HOUSEHOLDS

PROJEKT ACHIEVE – ZMANJŠEVANJE RABE ENERGIJE V ENERGETSKO REVNIH GOSPODINJSTVIH

Lidija Živčič[ℜ], Marie Moisan, Tomislav Tkalec

Keywords: Energy efficiency, Fuel poverty, Measures for saving energy

Abstract

ACHIEVE is a European project for reducing energy and water consumption in fuel-poor households. The project is carried out in Bulgaria, France, Germany, Great Britain and Slovenia; it addresses the problem of fuel poverty and achieves savings for end customers through practical measures and solutions on a structural level. A group of energy advisers implements free energy audits in households that are experiencing difficulties in meeting their basic energy needs. While implementing free visits to households, energy advisers first, with the help of household members, analyse the situation and check the consumption of electricity, heat and water. On that basis, they calculate potential savings, which is followed by the preparation of a set of advice for reducing the use of energy and water. During the second visit, these recommendations are presented to the household; the advisers also install free devices for energy and water savings. Based on statistics for the first 60 implemented visits in Slovenia, an average reduction in electricity consumption is 12.3%, in water consumption 11.4% and in heating energy consumption 6.2%. CO_2 reductions are 248 kg per year per household, and it is estimated that households could have an average saving of more than €90 per year.

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Povzetek

ACHIEVE je evropski projekt za zmanjševanje rabe energije in vode v energetsko revnih gospodinjstvih. Izvaja se v Bolgariji, Franciji, Nemčiji, Veliki Britaniji in Sloveniji. Projekt naslavlja problem energetske revščine in dosega prihranke za končne porabnike s pomočjo praktičnih ukrepov ter rešitev na strukturni ravni. Skupina energetskih svetovalcev izvaja brezplačne energetske preglede in svetovanje v gospodinjstvih, ki se soočajo s težavami pri zagotavljanju svojih osnovnih energetskih potreb. V sklopu izvedbe brezplačnega obiska v gospodinjstvu, energetski svetovalci najprej, s pomočjo članov gospodinjstva, analizirajo porabo električne energije, toplotne energije in vode. Na podlagi the podatkov izračunajo potencialne prihranke, čemur sledi priprava sklopa priporočil za zmanjšanje rabe energije in vode. V sklopu drugega obiska so ti nasveti predstavljeni gospodinjstvu, svetovalci tudi namestijo naprave za varčevanje z energijo in vodo, ki jih gospodinjstvo prejme brezplačno. Na podlagi statistike za prvih 60 izvedenih obiskov v Sloveniji, je povprečno zmanjšanje porabe električne energije 12,3 %, porabe vode 11,4 % in porabe toplotne energije 6,2 %. Znižanje izpustov CO2 znaša 248 kg na gospodinjstvo na leto, povprečni finančni prihranek gospodinjstva pa znaša 90 EUR na leto.

1 INTRODUCTION

With rising energy prices, increasing numbers of households across Europe are facing fuel poverty. Although the problem is a complex one, some solutions are simple and cost-effective. This paper presents the ACHIEVE project, a pan-European action with practical and structural solutions that help Europeans to address fuel poverty. The paper is based on papers submitted to the EEDAL and EnRe conferences.

ACHIEVE works towards uniting the definition of fuel poverty across Europe and sharing approaches to better identify fuel-poor households. In this action, long-term unemployed people are mobilized and trained to carry out home visits to fuel-poor households, in which energy use is monitored, and tailor-made measures are suggested. The households are encouraged to reduce their energy and water use through free saving devices, accompanied with suggestions for modest behavioural adjustments. The projects primary social innovation is that it contributes to social reintegration, both by empowering households and by engaging long-term unemployed people to fight fuel poverty. The visits also provide an opportunity to identify complementary long-term measures for improving the buildings' energy performance. This paper begins with a definition of the term fuel poverty and problems related to it. In the next section, the ACHIEVE project is presented in greater detail along with the specific circumstances of the pilot areas involved in the project. The following section deals with the transfer of know-how and the implementation of the visits by energy advisers. It is followed by a presentation of the results achieved thus far, illustrated with figures for each country. The paper is concluded with a discussion of key findings.

1.1 Definition of fuel poverty

Defining fuel poverty remains a subject of numerous debates, [1, 2, 3, 4], but as this is not the main focus of this paper, the issue is addressed only briefly here. Boardman, [5], explains the challenge in the following manner: 'Now that the fuel poverty is politically accepted as a real problem, there are some difficult definitional issues to consider. All of these are compounded by the circular argument: who is fuel poor depends on the definition, but the definition depends on who you want to focus on, and this involves political judgement.' Similarly, Moore, [6], asserts that definition of fuel poverty is essential for policy formulation and measures, which tackle this problem.

At the EU level, there is no common definition of what constitutes a fuel-poor household ,[7]. However, one way of defining it (that is in use) is that a household that has twice the median fuel expenditure as a proportion of income is facing fuel poverty, [8]. Another commonly used definition is that any household that would need to spend more than 10% of its annual income on having adequate energy services is in fuel poverty, [9].

For the purpose of the ACHIEVE project, the following definition of a fuel-poor household emerged: a fuel-poor household is one that has a difficulty, or sometimes inability, to be able to afford its basic energy needs, [10]. Households in fuel poverty have energy costs that are excessive compared to overall household income.

1.2 Causes for fuel poverty

Fuel poverty is mainly caused by the convergence of the following interrelated factors, [1, 11]:

- low income, which is often linked to general poverty;
- high energy prices, including the use of relatively expensive fuel sources;
- poor energy efficiency of a home, e.g. through low levels of insulation and old or inefficient heating systems.

Heating is the first item that strains the global energy bill for a household (around 70% of the annual energy consumption), [12]. However, the running of appliances and the energy used for domestic hot water are also noteworthy: appliances account for a growing proportion of households' energy budgets (low income households tend to use older and more inefficient appliances). In addition, water consumption is showing a general tendency to increase (amongst all categories of households), [8].

1.3 Scale of the fuel poverty problem

Even though the European Union is one of the richest areas in the world, many EU citizens have such limited resources that they cannot afford basic needs. Between 50 million and 125 million people in Europe are estimated to be fuel poor, [11]. The span of fuel poverty estimations is so large mostly because (as explained above) in many countries there is no definition that constitutes fuel poverty, and as there is no definition, there is no statistics, [5]. However, most of the evidence shows that the problem is inevitably deemed to increase in the future, in line with rising energy prices, [5]. The problem is particularly visible in the eastern European member states, where the energy liberalization strategies, which had to be put in place in order to become member states, lead many households from a situation with subsidized energy prices into a situation with market-based energy prices, which meant (and still means) a substantial rise in costs for them, [5].

1.4 Health impacts of fuel poverty

Furthermore, fuel poverty has considerable physical and mental impacts, [3]. Living in a cold home exacerbates circulatory and respiratory conditions and accounts for around 40% of excess winter deaths. Around one third of excess winter deaths are due to respiratory illness, [13]. Older people are more likely to be vulnerable to cold weather, partly because they are more likely to have existing medical conditions, [1]. However, young children and people with long-term illness are also vulnerable, [3, 14]. Home energy improvements have proved to decrease school sickness absences by 80% in children with asthma or recurrent respiratory infections, [15]. People living in homes with bedroom temperatures at 21 °C are 50% less likely to suffer depression and anxiety than those with temperatures of 15 °C, [15].

2 PROJECT ACHIEVE IN A NUTSHELL

Project ACHIEVE (*ACtions in low income Households to Improve energy efficiency through Visits and Energy diagnosis)* is a pan-European action, supported by Intelligent Energy Europe, which offers practical and structural solutions that help Europeans to reduce unnecessary energy and water use, [10]. The action reaches the households that are most vulnerable to fuel poverty and works with them to reduce their energy and water consumption. It links dispersed local actors into an EU-wide concerted effort to reduce fuel poverty, and develops common tools and methodologies for addressing fuel poverty at the European level.

2.1 Aim and objectives of the action

The aim of ACHIEVE is to contribute to practical and structural solutions for the reduction of fuel poverty in Europe. The strategic objectives of this action are the following, [16]:

- Improve health and well-being for households facing fuel poverty,
- Link dispersed local actors into an EU-wide concerted effort to eliminate fuel poverty, through common understanding, communication and networking,
- Reduce social exclusion and marginalisation of the households that find themselves in fuel poverty,
- Develop a methodological and economical concept for addressing fuel poverty at the European level.

2.2 Activities of the project

Basing its approach on the best practices throughout Europe, ACHIEVE identifies those households that are most vulnerable to fuel poverty and works with them to implement suitable steps to reduce unnecessary energy use and, of course, costs, [10].

Indeed, households do often not use or know about the solutions to decrease their energy consumptions and bills. The information available often does not suit their specific situation. Moreover, many households lacks the financial resources to make energy efficiency investments in their homes. A proper understanding of their situation, through a socio-technical diagnosis during a home visit, is the first step in helping them further and orientating them towards existing solutions and support.

In ACHIEVE, long-term unemployed people, volunteers or students are mobilized and trained to implement a large-scale campaign of home visits to households that have hitherto not had access to help and support, and that are facing difficulties with their energy bills, [10].

The service is based on home visits, the main purposes of which are to identify on a case-by-case basis the everyday actions that can have a real impact on the energy consumption of households. Visits focus on the following points:

- to understand vulnerable consumers' energy consumption, bills and habits, and to check their appliances with a set of reporting/analysing tools;
- to distribute and install a set of free energy-efficient and water-saving devices (such as light bulbs, power strips, tap aerators, etc.), and give advice to the households on how to implement further practical measures for saving energy;
- to analyse which longer term solutions can be brought to improve the households' situation, including linking local actors into a concerted local action plan, [17].

Fuel poverty and long-term unemployment are often linked with social marginalization. ACHIEVE's foremost social innovation is that it contributes to social reintegration, both by empowering households to fight fuel poverty by improving understanding of their energy use, and by engaging people who have been long-term unemployed to raise the awareness of fuel poverty.

A crucial step of the action is to trigger building improvement when thermal improvement works are needed, by better connecting tenants and landlords, informing, motivating and guiding them with easy-to-understand and customised documents and methods, [16]. To do so, project partners cooperate closely with tenants, home owners, landlords, social services, consumer protection agencies and other relevant actors.

2.3 Expected results and impacts of the project

It is expected that ACHIEVE will result in:

- changing energy using behaviour,
- introducing energy efficiency measures at the household level,
- reducing overall energy consumption and thus
- reducing the risk of fuel poverty in target households,
- saving energy,
- reducing CO_2 emissions in each visited household,
- developing competences and job opportunities for those energy advisers carrying out the visits, and hence in
- reintegrating them into the labour market, [10].

ACHIEVE is also expected to:

- improve the health and wellbeing of households facing fuel poverty,
- link dispersed local actors into a EU-wide concerted effort,
- reduce fuel poverty, through common understanding, communication and networking,
- reduce social exclusion and marginalization of households that live in fuel poverty, and
- develop a concept for addressing fuel poverty at the European level, [10].

A total of 2600 visits are planned to be implemented within the framework of the ACHIEVE (300 to 500 visits in each of the six target areas of the project). Each ACHIEVE visit targets the following reductions, depending on the countries and the saving devices offered:

- 400 to 500 kWh decrease/household/year,
- 150 to 300 kg/CO_2/household/year,
- 20 to 30 m^3 of water/household/year.

These figures are based only on the calculation of the direct savings generated by the installation of energy- and water-saving devices at the households. They do not take into account the potential savings generated by the possible behaviour change of the household, based on the advice given during the visits.

The ACHIEVE concept is based on the simple idea of promoting climate-friendly behaviour, together with consideration of financial savings, and specifically for low-income households. Further developing and replicating the ACHIEVE methodology in Europe would undoubtedly contribute to meeting the 2020 EU target of 20% reduction in EU greenhouse gas emissions, [18].

2.4 Target groups of the action

The key target group is households that have difficulties in affording basic energy needs. Through diagnostic visits and free energy-saving devices, they can save energy and money by better managing their energy consumption, [10].

This implies working with any other local actor that might be able to identify the targeted households and be relevant to propose longer-term and durable aid or solutions to the households, after the visit.

Other target groups are:

- local authorities with access to information on how to reduce fuel poverty: they can support housing schemes and housing renovations that ensure sustainable energy consumption and improve well-being of occupants; they can support the households with technical or legal services;
- owners of the buildings in which fuel poverty conditions are concentrated: by learning how to improve the energy performance of the building they can improve the living conditions in their buildings and improve the value of their property;
- a variety of local actors (such as local housing associations, tenants' associations, health, energy or social actors, for whom addressing poverty challenges are at the core of their mission) can both benefit and take part in implementing the project through networking and shared competences;

- people who have the right basic skills to be trained to give energy advice to low income households, such as volunteers, people who are long-term unemployed or students who wish to gain professional experience, [10].

2.5 Partners of the action

ACHIEVE project partners are:
- **CLER** - Réseau pour la transition énergétique (Coordinator)**,**
- **CARITAS** - Energiesparservice Caritasverband Frankfurt e.V.**,**
- **EAP** - Energy Agency of Plovdiv**,**
- **FOCUS -** društvo za sonaraven razvoj**,**
- **GERES** - Groupe Energies Renouvelables, Environnement et Solidarités**,**
- **IDEMU** - Institut de l'Ecologie en Milieu Urbain**,**
- **Severn Wye** - Severn Wye Energy Agency.

2.6 Local circumstances in countries, covered by the action

The chapter sketches the situation in each of the countries in which ACHIEVE is attempting to make an impact in order to describe the backdrop against which the activities of the project are set, [8, 19, 20].

2.6.1 France

In France, it is assumed that between 4 and 5 million households are facing fuel poverty. It is either because they spend more than 10% of their income on total energy costs, or because they impose self-limitations on their energy consumption and live in a cold home. Despite a national plan and funding scheme starting in 2010 (aiming to help 300,000 low-income owner-occupants to improve the energy performances of their home by 2017), visits remain the initial step for any following action, whether it is related to occupant behaviour or to the building itself. It is important to note, that if actions are not properly organised, it is difficult to implement them. It is up to local actors and authorities to find ways to identify the relevant households in their territory, and to organise and finance the visits. Several local initiatives echoing ACHIEVE activities are being implemented in France to fight fuel poverty. Within the frame of ACHIEVE, the French partners have set up a national taskforce to build a range of structures for carrying out these types of projects that involve visits. These partners include local authorities, professional integration enterprises, and non-profit organizations. This taskforce aims to exchange and share experiences, and to push forward the need and opportunities for public authorities to participate in such type of actions. The final aim of the taskforce meets the ACHIEVE goal: to develop an economical and organisational model for large scale energy visits that is urgently needed.

2.6.2 Bulgaria

The term 'fuel poverty' has no concrete definition in Bulgarian legislation. For the purposes of the project, a fuel-poor household was defined as such that cannot afford its energy needs, evidenced by the fact that the household is applying for social aid for heating during the winter. The Social Ministry in Bulgaria gives out aid for heating during winter to selected households. The target group of ACHIEVE is households applying for this kind of aid. A key target group is households that use coal for heating. As part of the project, EAP will co-operate with the Ministry of Environment and Water and the Ministry of Labour and Social Policy to propose and implement changes in the current legislation so that the use of inefficient and polluting coal in heating is discontinued and the use of modern sources of biomass is promoted.

2.6.3 Slovenia

Due to growing prices of energy, the issue of fuel poverty is becoming a worrying issue in Slovenia. Roughly speaking, about one third of the households in Slovenia are fuel poor (as specified by the UK definition). However, energy prices are not the only contributing factor. The poor condition of buildings is also relevant with 44.5% of low income families and 28% of families with an higher income level live in humid and poorly maintained buildings (leaking roofs, humid foundations, floor or walls, broken windows). Thus, in Slovenia, fuel poverty could also be widespread in households that are not strictly poor. In the municipality of Ljubljana, where the Slovene ACHIEVE activities are conducted, more than half of the buildings date between 1945 and 1990, which characterizes apartments as being generally energy inefficient. However, many unresolved questions remain as to how to identify the households in need of support.

2.6.4 Germany

In Germany, there is neither an official definition for fuel poverty nor are there statistical data about people who live in fuel poverty. The consumer protection association estimates that more than 800,000 households (2%) are cut off from their power supply per year because they are not able to pay their bills. Energy prices in Germany have gone up continuously in recent years. After liberalisation of the electricity market in 1998, the average price for electricity has risen from 15 cents to 24 cents per kWh in 2011. At the same time, there is a lack of control on the side of the households, because they only get a bill once a year, based on their yearly consumption. This leads to significant problems for low-income households if they have to manage additional payments at the end of the year. For low income people, i.e. those receiving social welfare or long-term unemployment benefits, the costs for heating, water and water heating are paid by the municipality. Thus, the main problem is how to pay for the electricity consumption for cooking, washing, cooling. Furthermore, only 5% of the German households use electricity for heating.

2.6.5 United Kingdom

Project ACHIEVE comes at a time when an unfavourable economic climate and rising energy prices have impacted those groups who both traditionally and recently are considered to be at risk of fuel poverty. In 2009, the number of fuel-poor households in the UK was estimated at around 5.5 million. In the UK project, ACHIEVE will be based in the county of Wiltshire, in the west of the county which statistically has a higher propensity towards fuel poverty. Wiltshire has been working towards creating training and employment opportunities for its residents (a policy designed to mitigate the impact of the economic recession). ACHIEVE will work to address the training needs of residents in line with the 'Green Deal', a flagship energy efficiency policy for the domestic sector based on a 'pay as you save' model. The government expects around 250,000 new jobs to be created as a result of this policy. Project ACHIEVE hopes to help advisors on the road to employment within this sector and to develop a local, skilled workforce.

3 METHODS

3.1 Transferring experience and know-how

ACHIEVE covers some countries where advising households on how to abate fuel poverty is already ongoing (Germany, UK and France) and some countries where fuel poverty is hardly tackled at all (Slovenia and Bulgaria). Consequently, the starting step of the action was to present how energy efficiency measures and equipment are being introduced in German households.

Caritas Frankfurt has been running a program for empowering households to act on fuel poverty since 2005. The program, called 'Energiesparservice', was developed as cooperation between the Energy Department, the Department of Social Services, JobCenter Frankfurt am Main and the Caritas Association Frankfurt. The program started with 12 people who were long-term unemployed and has now developed into a national initiative called 'Stromspar-Check' in over 100 cities and communities in Germany, [8].

The program empowers households through two visits of energy-saving advisors. During the first visit, the advisors check the equipment in the household, as well as the energy bills of the household. Based on that information, calculations are made on where energy could be saved most efficiently. A set of recommendations is made, and during the second visit, the experts install easy to use energy-saving devices, such as efficient bulbs, tap aerators or power strips. They also provide advice on changes in behaviour to further save energy and water. Annual savings of households can run up to €140 and over €1100in the long run, [8].

As this program has been successfully running since 2005, it was selected as the starting point of ACHIEVE. The project partners visited Caritas in Frankfurt in May 2011 to see how the visits are implemented in practice. Apart from the visit, the partners also translated Caritas' Guidelines Introducing Advisory Services on How to Save Energy For Low-income Households, [21], which describe the concept of the Cariteam Energy-Saving Service and the procedure of introducing and implementing the project step by step. To provide material for the training of energy advisors, Caritas also developed a Curriculum for Specialised Training Saving Energy and Water, [19]. The curriculum covers topics such as a general introduction to energy, detecting fuel poverty, the concept of thermal comfort and heat loss, procedure and data documentation, evaluation and installation of devices or communication training. For each chapter, a corresponding module has been developed including tips about the method of presentation (exercises, group work, role playing, homework, etc.) and time frame. This curriculum was taken as a general basis for the definition, design and development of training modules and exercises for all ACHIEVE partners.

Equipped with the materials, the partners implemented trainings for energy advisors. Each partner decided to use a different approach to identifying and training energy advisors (see Table 1).

Table 1: *Approaches to identifying and training energy advisors in project Achieve, [22]*

Partner	Used approaches
IDEMU	4 people in an integration program have been recruited for 6 months and trained by IDEMU. The recruitment was done by IDEMU, in cooperation with key recruitment offices. An information event was organized in January 2012 to present the project and the mission to the applicants, followed by individual interviews.
GERES	GERES works with people in an integration program. GERES decided to work with EVOLIO, an NGO implementing integration programs. The recruitment was organized by EVOLIO in close cooperation with unemployed centre and youth organization.
SWEA	Advisors are people who have been long term unemployed. Advisors were recruited through Job Centre Plus. Their training will form part of a national initiative to remove barriers to work (the Sector-Based Work Academy)
CARITAS	Caritas works with long-term unemployed people, people in an integration program and volunteers. People for the integration program come from the job centre. Volunteers are recruited by PR activities.
FOCUS	Focus works mainly with unemployed people (some long-term unemployed) and some recently graduated young people seeking professional experience. The recruitment was done through promotion (leaflet, mailing lists, news and social networks) and presentation at the Office for Employment; 12 advisors were selected and trained.
EAP	EAP works with students from professional schools. Agreements with two professional schools (for household technology and for electric technology) have been signed. The training served as an addition to the students' curriculum. The visits that they implement give a chance to put their knowledge and skills into practice.

3.2 Identification of fuel-poor households

'Fuel poverty' is not a term that households will spontaneously apply to themselves. Rather, fuel-poor households can be identified through a number of relevant indicators including, [8]:

- the inability to pay energy bills,
- cold damp living conditions,
- disconnection from energy supply,
- self-disconnection (in some countries),
- debts owed to the energy supplier,
- health impacts associated with poor living conditions,
- homes with low energy performance

Thus, the first challenge for ACHIEVE when setting up local action plans to tackle fuel poverty was to identify those households that are facing problems in affording their basic energy needs. This challenge was tackled by exchanging experience between partners/countries where there were cases of identification of fuel-poor households, implementing site-tailored discussions and interviews with key actors and households that face fuel poverty and elaborating reports on the findings, [22]. Based on the analysis and consultations, the partners decided on their target group: households that were identified to be the most prone to fuel poverty, as described in Table 2.

***Table 2:** Parameters for identifying fuel-poor households, [23]*

Location	Parameters used for identifying fuel-poor households
Frankfurt, Germany	Results of the evaluation of the program Energiesparservice, which offers visits to fuel-poor households, show that 32% of the households have a migration background, 66% are unemployed and 20% obtain social welfare because of other problems; 35% are single households, 18% are single parent families and in 26% of the households of four and more members. The main problem for these households was covering their electricity costs. In Germany, there is neither an official definition for fuel poverty nor statistical data. There are only some indicators for fuel poverty: very low income or social benefit, problems to pay the bill, cutting off from the power supply. More than 8 million people (thus about 10%) in Germany use social support. The consumer protection association estimates that each year more than 800,000 households (i.e. 2%) are cut off from their power supply because they are not able to pay their bills.
Plaine Commune, France	Given the problems of private housing and the socio-economic characteristics of the population, Plaine Commune appears to be particularly vulnerable to fuel poverty. The area is very exposed to poverty, with 30% of people living under the poverty threshold, compared to 13.6 % at a national level. In 2009, 21,546 people were in receipt of income benefits, and 4649 of households received financial aid to pay energy bills. This aid is proposed in the case of severe fuel debt and with the intervention of social services. There is no specific data or statistics to estimate the number of people living in fuel poverty. The tenants in private housing seem to be particularly vulnerable to fuel poverty: 78% of them live in a building built before 1975 (71.5% for owners, 69% for tenants of social housing); 53% of which use electricity for heating, which is the most expensive energy (23% for owners, 18% for tenants of social housing).
Marseille, France	Households of this area are extremely poor: between 50 and 70% of the population lives under the poverty line; 20% of the population is unemployed and 30% have a part time job. Most households benefit from social welfare (70% receive financial support for housing, 30% support for health security). Around 60% of the households benefiting from social welfare are families with children, including around 16% of families with more than 2 children and 25% of single parent families. In general, the thermal performance of the building stock is very low due to the age of the buildings stock. Consequently, a significant part of the population is at high risk of fuel poverty.

Ljubljana, Slovenia	The unemployment rate is currently slightly under national average: 9.9% compared to the national 11.5%. More than half of the buildings date between 1945 and 1990; this characterizes the flat stock as an energy inefficient one. The structure of social welfare does not enable bills to be paid by the welfare organization; they are paid by the individual regardless of circumstances. A total of 11% of 813,531 households nationally are low income households, which means they live under the poverty threshold. However, when considering fuel poverty, the percentage rises to 30% of persons in Slovenia (British definition of fuel poverty). The target group is households on social benefit or receiving less than €300/month/person (as those often fall just short of the social benefit system).
Plovdiv, Bulgaria	In 2010, 9056 households applied for the Winter Supplement Program and 7138 of them received funding. this program provides partial funding for heating bills of households. To receive funding from the program, a household has to meet certain criteria, e.g. income level, dwelling size, health or other conditions, etc. In the city of Plovdiv, approximately 36% use wood or coal for heating, 23% use electric energy, 21% use district heating, and 20% of the homes are unheated. About 60% of the buildings are 30 years old or older, many of them constructed from prefabricated panels and are highly energy inefficient. The analysis showed that the target group is people who apply for funding through the Winter Supplement Program and especially people who are using inefficient ways of heating (e.g., low-quality coal and electricity).
County of Wiltshire, UK	In 2010, 8.8% of Wiltshire (39,100 people) was classified as having a low income. Other benefits include paying rent, council tax relief, child care vouchers and winter fuel payments. In Wiltshire, 26,650 were claiming benefits in May 2011, 9.3% of the working age group (15–64). In 2011, 22% of Wiltshire's population (99,510) were of retirement age and over. This group is set to be the fastest growing group. The Building Research Establishment estimates that around 12% (19,777) of households in Wiltshire are in fuel poverty. The target group should, besides active recipients of benefits, also include households earning £15,000 per year or less. The elderly is also a growing target group.

3.3 Reaching out to households

An important element of ACHIEVE approach was developing a methodology for accessing the target households. The decision on methodology was based on lessons learned from various projects, which showed that:there is a need to be proactive in approaching households,

- community engagement (neighbourhood events for example) brings success,
- opportunities for co-promotion with partner organisations working with the target group should be sought after,
- promotion of the service through local media is useful, and advisors could explore the possibility of promoting the scheme in ways that the community respond to, e.g. by activity such as door-to-door canvassing as a method of reaching hard to reach households, [24].

Bearing this in mind, the partners developed a variety of communication campaign approaches and tools to reach target households. The information about the project was disseminated to target households by a variety of local actors, such as welfare associations/non-profit associations, municipalities and local authorities, utility providers, presentations in newspapers, unions of low-income, disadvantaged people, employment offices, social housing providers, social landlords, community foundations, [22]. Communicating with agencies who work with families is necessary to get access to the households. In addition, in Germany and UK projects have found that in order to empower households to make real lasting changes to the way that they use energy other agencies who interact with clients need also to be informed about the project, its aims, and possibly key messages that can help to keep households motivated, [24].

There are many projects that have aspired to provide energy advice to households with the overarching aim of reducing households' expenditures on energy. A reoccurring theme of much of the partners' research demonstrated that web-based support tools can be remarkably effective in communicating energy advice messages to both households and stakeholders, [24]. Another successful approach is joining households together into a small 'neighbourhood' to help one another save energy as their community competes against other such communities, [24]. Furthermore, children may be a key agent of change as they are well versed in current discourses around environmental issues, [24]. This experience could be incorporated into tailored energy advice reports to help motivate behaviour change in the whole household. Other examples put forward by partners suggest that a competition element with the prospect of prizes could also stimulate households. Again, this may be an area where partners could explore the possibility of directing clients to such initiatives on a case by case basis, [24].

The key messages communicated to the target households were shaped based on the inputs of focus groups and interviews, which showed that the emphasis should be on the reduction of costs (not environmental matters), on the fact that it is a free offer (no long term engagement), with free devices, and the neutrality of the advisers and the structures managing them, [22].

3.4 Implementation of the visits in households

3.4.1 Devices to be given to households

Good management of energy and water consumptions requires appropriate knowledge to be aware of such consumption, and the minimum devices at disposal to actually be able to control it. Due to wider financial circumstances, households facing fuel poverty are often those who have less opportunity to purchase energy- and water-saving devices, [8], or even simply to have information about their existence and interests. List of devices include efficient light bulbs, thermometers and thermostats, weather stripping for windows and doors, transparent insulation foil for single-glazed windows, tap aerators, dual-flow flush mechanism, and even shower timers. One way to alleviate fuel poverty is to make these devices more accessible for households at risk, either by providing them, or by installing them. The impact of these devices can be easily measured in kWh or litres of water, which are easily turned into euros, [8].

The first step in deciding on which devices to offer to households free of charge was to gather a list of possible energy- and water-saving devices and estimate their savings potentials, costs and easiness of installation. The scope of devices was developed jointly by the partners, a process assisted by CARITAS' experience. This resulted in a list of 26 devices to be potentially used, [25], which showed that the devices that appear to offer the highest savings are those related to space and water heating. However, some appliances (often those with the highest savings) require more skill and time to install. The partners compiled their device packages and decisions based on the following aspects, [22]:

- time and skill needed to install the devices (e.g. draft proofing is extraordinarily efficient, but it can take a lot of time and skill),
- devices must fit to the household's situation: some devices may be systematically distributed (thermometers, CFLs, etc.), but some devices will be installed only when relevant (e.g. transparent thermo-cover insulation foil for windows only where single glazing is currently available),
- availability and costs of each of the devices on the respective national markets (linked to the willingness of transferability and reproducibility of the project activities),
- targets on energy savings and CO_2 reductions,
- quality of the devices: people need to accept the material (user-friendly) and to be able to rely on its efficiency for a long time (quality).

3.4.2 Advising the households

The implementation of the visits on the ground was prepared on the basis of the information and documents that CARITAS provided to the consortium through its experience in Energiesparservice. The first step was organizing a calculation tool to gather and analyse data, and define the devices/tips to be given a priority. The next step was to organize the corresponding data collection sheets to report information about energy and water consumption/habits of the households during the visits. Each partner adapted the final tools to its country context (language, energy prices and emission factors, heating systems, currency, devices used, etc.), [22].

Another step was to define the format of the visits. Generally, the following approach is used, [22]:

- procedure before visits: getting in touch with the household (appointment and first contact);
- first visit: analysis of water and energy consumption and habits;
- second visit: installation of the most relevant devices according to previous observations and calculations from the first visit, likely to generate the best savings for the households; delivery of report and tips for behaviour change;
- third contact (minimum 6 months later): this contact is made over the phone to help evaluate the effects of the visits (currently, a questionnaire is being finalized).

Experience showed that a minimum of eight hours is necessary for each household visit: travel, presence in the households (1-2 hours × 2 visits), analysis of data collected at the household, and evaluation of impacts, [22]. The number of energy advisors to visit a household varies in the countries, depending on the feedback received from focus groups and interviews at the beginning of the project, as presented in Table 3.

Table 3: *Number of energy advisors for visiting households in project ACHIEVE, [22]*

Partner	Number of advisors
IDEMU	The 1st visit will be made in pairs, and the 2nd one by a single advisor.
GERES	The visits are implemented by two advisors at the start of the experimentation. Then, if the energy advisers feel more self-confident, they may perform the visits alone.
SWEA	2 advisors per visit for at least the first 5 visits. After this, advisors will be expected to operate alone.
CARITAS	Two advisors, one with more experience, one with less, are to visit the households
FOCUS	First 1–2 visits of each advisor are done in a pair with a supervisor; the next visits are done by one advisor.
EAP	2 advisers per visit, sometimes advisers are also accompanied by an employee of unions of disabled people (if the visits is in a household of people with disabilities).

3.5 Developing structural solutions

As much as the household visits are designed to make a lasting impact, they cannot have as much influence on the structural components of the fuel poverty problem: they cannot improve energy efficiency of the whole building; they cannot guarantee the financial support needed for large investments in fuel-poor households; they cannot reduce the general level of energy prices, nor increase income level of the households. Hence, one of the objectives of ACHIEVE is to coordinate key actors into a concerted effort for formulating long-term solutions and developing a network for implementing the long-term solutions. The project seeks to develop a concept for addressing fuel poverty at the European level, through a set of tested and assessed structural solutions and a widely transferable set of tools in order to launch similar experiences elsewhere, [26].

One key field to examine is social housing, in which the majority of the fuel poverty cases are concentrated. Social housing is decidedly differently organized in the targeted countries. Table 4 shows the most critical barriers to energy renovations in this owner category. In most countries, either high initial costs or (more frequently) long payback times present a critical barrier. The landlord-tenant dilemma is another fairly widespread barrier, [27].

Table 4: *The most critical barriers to improving energy efficiency of the social/professionally owned rental housing in several EU countries, [27]*

		AT	BG	CZ	DE	FI	FR	IT	RO	ES
Genuine uncertaint	Conflicting information, mistrust of information		■	■				■		
	Heterogeneous outcomes								■	
	Uncertainty in measurement & verification		■	■				■		
Financial barriers	High initial costs		■				■	■	■	■
	Long payback time		■	■	■	■	■	■		■
	Access to/cost of capital		■				■	■	■	■
	Unwillingness to incur debt		■					■	■	■
	Occupant take-back		■		■			■		■
	Low/uncertain resale value of property				■			■		
Organi-zational problems	Landlord-tenant dilemma		■	■	■		■	■	■	■
	Collective decision problems		■	■				■		
	Short timeframe of decisions		■	■						
Lack of information & skills	Lack of customer attention and interest		■					■	■	
	Lack of customer knowledge		■	■				■		
	Lack of reliable advice								■	
Transaction costs	Lack of skilled service providers	■						■	■	
	High information search costs							■		
	Switching costs, concerns over disruption	■				■				
	Risks of failures in renovation	■	■				■			

One key element of developing structural solutions for addressing fuel poverty is that of large scale efficiency retrofits, [24]. Financial aspects are the key barrier in triggering energy retrofits (long pay-back time, access to funds), [2, 14]. Currently, there is a lack of understanding of the process among building owners, including costs and results of undertaking such works, and in this aspect ACHIEVE will help to inform them by providing them a reference database to encourage owners to undertake such works, [22]. For landlords and owner-occupiers, ACHIEVE will provide information tools regarding retrofitting measures (costs, benefits) and local/national existing financial mechanisms. These tools will provide clear guidance on whom to contact to obtain further information and advice.

Another element of the structural solution is to provide pedagogical tools for the visited households, to link the dispersed and often already existing information (about energy or water consumption, prices, contracts, payments, social, economic and health issues) and give them insight into their bills, selection of suppliers, availability of financial assistance, etc.

4 RESULTS

ACHIEVE's energy advisors have been visiting households in five European countries for over a year now. The first results are therefore already visible (see Table 5). Please bear in mind that the presented figures should not be compared directly between countries as each of the covered countries applies a different approach to working with households (e.g. the devices given to households vary between countries; hence, the savings are also different). The presented figures are meant to show the first effects of the project. Thus far, ACHIEVE partners have, [22]:

- Designed and developed training content and modules for people recruited to perform the visits;
- Designed and developed tools to be used by the advisers for the implementation of the visits (e.g. a reference manual on how to prepare and implement a visit, data collection sheets to

collect data during a visit, software to automatically calculate the savings generated by the energy- and water-saving devices distributed and installed);

- Summarised the procedure and materials needed for organisations willing to develop such a service;
- Designed materials to communicate the service locally, visited approximately 1000 households, and trained 94 people to become advisers (among them, 57 students, and 37 volunteers/unemployed people).

Table 5: *Estimated average savings from household visits of ACHIEVE*

Country	No. of visited hh	Avg. investment (€/hh)	Electricity savings (kWh/ hh/a)	Heating savings (kWh/ hh/a)	Water savings (m3/ hh/a)	Energy savings (%/ hh/a)	Water savings (%/hh/a)	CO_2 savings (per site kg /a)	EUR savings/ hh/a
Bulgaria	203	30	793	389	5.4	9	8	126	91
France	138	44	260	815	31	8	26	243	142
Germany	270	60-70	296	693	14	n/a	n/a	433	173
Slovenia	59	31	283	412	13	7	11	248	92
UK	33	31	164	254	1.6	11	2.7	154	42

N/A The figure is not available at the moment.

* Figure is given for electricity only.

Source: Data collected in visits to the households

5 DISCUSSION – KEY FINDINGS AND LESSONS LEARNED

As the project is still ongoing at the time of preparing this contribution, it is difficult to draw final conclusions and lessons learned from the experience. However, some insights into what worked well and what mistakes could be avoided in the future are already available and are presented in this chapter. The chapter is based on feedback provided by project partners during a project meeting, [28], and for the interim report, [29].

The first lessons from the project are oriented to the training modules. It was discovered that during training it is necessary to emphasize knowledge about social issues so that the advisers are able to identify social problems (involve social workers in the training sessions so that advisers know how to identify social issues too, not only technical ones). It is also beneficial to have training regarding communication etiquette. The final significant aspect is to clearly define the limits of the mission during the training to limit frustrations for advisors and households (in practice, it often happens that the household expects more than advisor is able to give, as well as that advisors attempt to provide support which they are not qualified for). In relation to this, it is necessary to better inform the advisers about possible solutions they can propose to households at the end of the visit (orientate them towards the proper structures).

In regard to selecting and training energy advisors, several notable findings came to light. The most important is that when recruiting energy advisers to be trained, particular focus should be put on their social and communication skills; even if a large part of the work around the visits is technical (assessment and calculation of the main possible energy and water savings, advice given to households to reduce their consumption etc.), the visits are also largely about 'human' contact. Technical capacities can be strengthened, but this is not necessary the case with the ability to speak and listen to people. This should be considered when recruiting future advisers. It is also suggested that visits be performed by two advisors, one of whom has an emphasis on technical skills, and the other has an emphasis on social skills.

Another relevant finding is that people who wish to become energy advisers might have different expectations and that the job does not necessarily suit them. To avoid disappointments when starting energy advising in practice, it is suggested that the potential advisors do one visit before they become fully involved in the project, or have a video to present the content of the mission in order to clarify expectations before training. It is also advisable to work closely with the job agencies and employment centres in order to define the competences needed for energy advising.

When working with long-term unemployed people or volunteers, it is highly likely that those who are trained to perform the visits will leave the program when another job opportunity becomes available. This means regular new training sessions to train newcomers to the program that replace the leaving advisers must be planned. The time dedicated to training activities should not be underestimated, nor should the time dedicated to supervise/follow the advisers before they can be fully operational on their own (especially if the turnover of advisers is high). Training activities and general supervision of the visits are thus highly time consuming for project managers willing to implement a home visit service. It is a full time job for project managers. As a great deal of support is needed to help advisers in the management of their own time, to plan the visits for them, and to check the quality of the work and results that they are producing, it is advisable to receive some support from a professional organization when possible.

When dealing with households, it is of utmost importance to pay attention to their circumstances. Fuel poverty closely coincides with general poverty, which means that some of the households are extremely sensitive about their situation and are reserved in asking for support. It is advisable to have teams of one man and one woman, as it seems more acceptable for households (in some cases, the households will only accept to be visited by female advisers).

Visits are an excellent occasion to get in touch with households than sometimes have not received any visits from 'external' parties for a long time. As a consequence, the time needed for one visit can be much higher than expected, as people might have a lot to say to advisers (not necessarily strictly linked to the core purpose of the visit; this calls for social skills, as mentioned above). Furthermore, many critical situations linked to unsanitary/inadequate housing or extreme poverty situations call for the need to organize, from the very beginning of the project, appropriate responses and procedures when such situations are encountered. This means systematically linking with tenant/landlords mediation structures, sanitary services of the municipality, etc.

With regards to mobilizing the local networks, the lessons learned are that creating and maintaining these networks (with social/health services mainly) is time consuming, and must be done regularly. One-time contacts do not deliver long-term results. There can be barriers when working with social/health services. A possible solution is to send a report on the results of visits to them to show and clearly explain the benefit of the visits.

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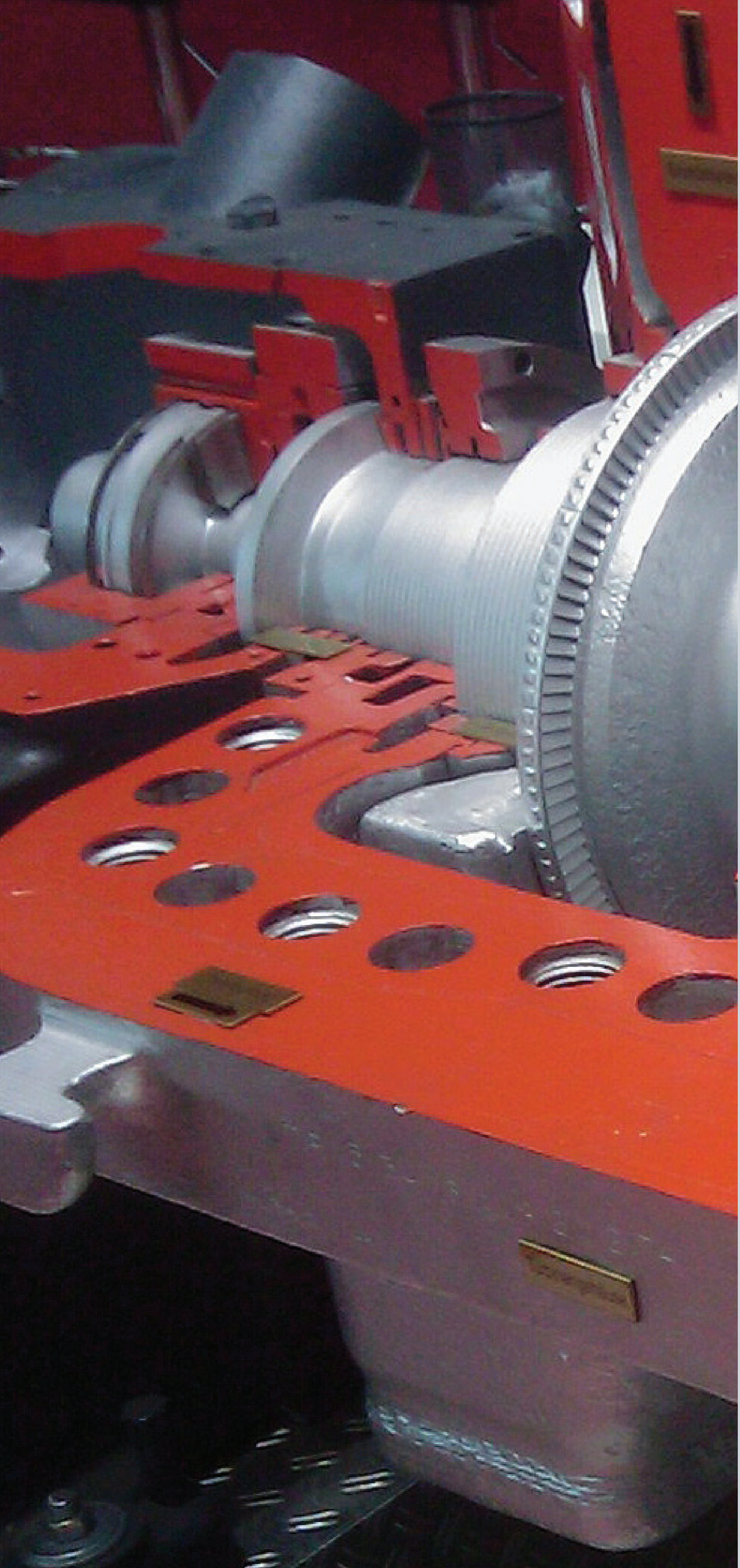

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