IMPLEMENTATION OF PILOT AMR SYSTEM

N. Radovanović, Elektrovojvodina d.o.o. Novi Sad, Serbia
S. Marčeta, Elektrovojvodina d.o.o. Novi Sad, Serbia
B.Holik, Elektrovojvodina d.o.o. Novi Sad, Serbia
T.Papić, Executive Council of The Autonomous Province of Vojvodina – Secretariat for Energy, Serbia

ABSTRACT

These paper describes concept of Automatic Meter Reading system, overview of applied functions and achieved results. Like other distribution utilities comprising Electric Power Industry of Serbia (EPS), Elektrovojvodina is facing a rise in energy theft and non-paid bills, economical losses due to out-of-date electricity meters, meter reading costs as well as problems and costs when disconnecting non paying customers. These are potential ways of significant saving and increase of company's economical efficiency.
New technological solutions of AMR system, such as integration of power, communication and data management functions enable increase in both economical and energy efficiency of a distribution utility. In order to gain some experience with AMR system's functionality in real networks and its complexity, Elektrovojvodina has started in the 2003. with installation and testing of AMR system on test area: around 1300 customers, in two sub-utility areas. The reliability and availability of communication system and technical requirements fullfilment have been tested, as well as achieved effects for both the company and customers assessed.
During the trial period, equipment and available functions have been tested, following the appropriate protocols. Reduction of electrical energy distribution losses, fast fault localisation, decrease of meter reading costs and avoided problems when disconnecting non-paying customers all indicate level of feasibility of AMR system in Elektrovojvodina's network.
Implementation and testing of singular AMR system components (meters, communication system, hardware and software) during trial period has provided us with enough experience to evaluate whole complex problematic with process of AMR introduction and load management in our conditions and to determine level of system's performances. With achieved results we had conducted cost benefit analysis aiming to estimate justification of the AMR system deployment across whole Elektrovojvodina's distribution area.

INTRODUCTION

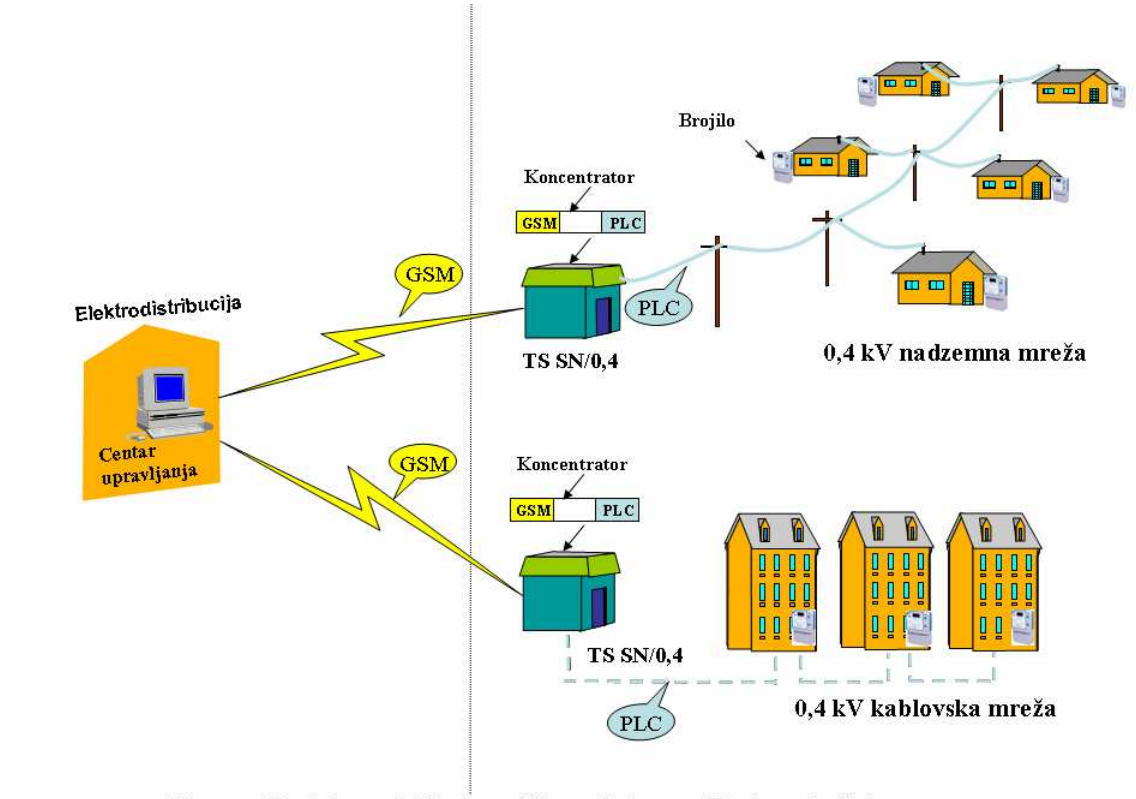
Increase in economical efficiency of power distribution company, as well as in quality and reliability of electrical energy distribution to its customers is possible to obtain when accurate information on grid condition and energy consumption are available (supervision), combined with an efficient means of management (control). Therefore, in Elektrovojvodina a pilot project with two different AMR systems in

Nada Radovanović, Elektrovojvodina, 21000 Novi Sad, e-mail:nada.radovanovic@ev.co.yu

two sub-utility areas has been implemented. In ED"Novi Sad" equipment from "Sitel" manufacturer has been installed and in ED"Ruma" "Mackatica" has been chosen as an equipment vendor. Implementation of these two different technical solutions and result analysis has provided us with significant experience which will help when addressing the problems with AMR system deployment on the larger consumption area.

AMR SYSTEM OVERVIEW

Applied technical solution is comprised of multifunctional electronic meters, a telecommunication subsystem and control centre. Data transfer from meters to the substation (DT) is realised with two-way PLC (Power Line Carrier) communication on low voltage (LV) network. Data are transferred from the substation to the control centre via GSM channels.



Koncepcija sistema daljinskog očitavanja i upravljanja potrošnjom

Multifunctional electronic residential kWh meters measure electrical energy consumption, maximum 15 minute interval demand and monitor events at meter's location. Meters installed in ED"Ruma" measure voltage, current and demand in every phase. All meters have time switch incorporated, communication PLC module and infra-red port for local reading. Meters for load management have also latching relays for remote customer disconnecting/reconnecting. Event monitoring at meter's location relates to opening of the meter's cover (compromising meter's integrity), reversing phases and their outage. Remote adjustment of tariffs and incorporated real time clocks (RTCs) is especially convenient: in control centre tariffs are by the means of appropriate software prepared and then sent to concentrator (piece of equipment in charge of collecting the meters data and for meter control) in DT, which updates tariffs of all corresponding meters. That way are tariffs on all meters synchronized with just one command. With benefits of remote meter communication, utilities can implement most flexible tariff programs since implementation of new ones is very easy and efficient.

Apart from residential meters, industrial meters have been also installed: in DT through transformer connection and through direct connection at customers with special contracts. Therefore, in pilot areas

is now possible to remotely monitor voltage in DT, to calculate energy balance, to assess distribution losses and to record individual phases outages.

Telecommunication subsystem provides two-way data transfer by PLC communication from meters to DT and by GSM network from DT to the system control centre**.** Data collecting, processing and storing is done in concentrators in DT. Since low voltage grid is aggressive medium for communication purposes and significantly fades a signal, repeaters are commonly used in PLC communication system. They can be made as stand-alone devices or even incorporated in meters. Experience with pilot system has shown that repeaters are needed in areas with overhead grid, especially when it is in detonated condition. They are seldom needed in areas with cable grid. Still, too many repeaters can significantly slow down communication, so they need to be rationally installed. In our test areas, number of repeaters on low voltage section with maximal length of 300m is 2. Speeds of data transfer in ED"Ruma" and ED"Novi Sad" are, respectively, 300 bits per second and 100 bits per second.

Control center, where server with GSM modem and appropriate software is located, initialize all realized functions and provides system supervision and management. Software enables automatic acquisition of all measured values, remote meter programming (tariff, date and time, demand limit) and also remote load management. In order to be up to date with events (phase outage, communication errors), daily system reports have been generated.

Realised system functions:

- Remote meter reading
- Remote reading of real time values of voltage and current per phase (implemented only in ED"Ruma"
- Remote tariff programming
- Storage of all measured values
- Event monitoring at meter's location (meter tampering, phases outage)
- Remote meter parameterization (demand limit)
- Billing of spent energy, instead of estimated
- Remote disconnecting / reconnecting of non-paying customers
- Remote synchronisation of meter RTC
- Supervision of load, demand, losses and LV network configuration

ACHIEVED RESULTS

Rate of successful reading

Rate of successful reading is different in overhead and in cable grid. Independently from equipment vendor and applied method of PLC communication, rate of successful reading is significantly higher in cable grid – almost 100%. Rate of successful reading on daily basis is 99.5% and in the next two days whole 100%. According to our experience, signal propagation is greatly influenced by the grid's homogeneity. In distribution areas with overhead grid, lines are made of Al-steel wires, and customers are connected mostly with cables. PLC communication is hampered with such a meshed network, especially when connections are in poor condition. In overhead grid, rate of success is between 95% and 98% during the day. Since low voltage grid has variable impedance on hourly basis, reading is more efficient when it is done on 1 hour schedule.: in 24 hour period communication with meter is possible at least for a couple of hours so data transfer is possible.
Traditional method of meter reading has rate of successful reading of 92% per month (one monthly value) due to the meter inaccessibility. AMR can in 5 days get data from all meters in test areas. Therefore, there is no need for consumption estimates. What is more, as metered values are directly transferred, customer and billing complaints have been avoided.

Revenues increase

Remote disconnecting of non-paying customers has turned out as very efficient mean for strengthening of customer's financial discipline and revenues increase. 20 non-paying customers have been disconnected in 10 minutes. Number of them has tried to reconnect themselves, but without any success. In all these cases, signal that meter's integrity has been compromised, was regularly received in system operating centre. After these actions, a number of non-paying customers has

drastically fallen. Due to the superior efficiency of remote disconnecting system, debt margins can be even further reduced, with increased revenues as a result. Furthermore, problem with debt accumulating (up to the millions) due to the meters inaccessibility is now a thing of the past – customers with rich non-paying history are now paying regularly for the amount of spent energy.

Energy balance analysis

The complete consumption overseeing and simultaneously reading of all meters enable losses and energy flows analyses, as well as precise energy balancing. For billing purposes, meters are being read at 7h in the morning, every first day in a month. At the same time, these data have been used for estimation of distribution losses. Tables 1, 2 and 3 show energy balances in period from October 2004 until October 2005. It is evident that losses in cable grid are in range 2%-3.5% and in overhead grid in 3.5% - 5% range, with up to 11% surge in winter period. Due to the unusually high distribution losses at distribution area "Fejes Klare" in ED" Novi Sad", installation of industrial meters on every low voltage section and subsequent search for a cause and exact location of these losses are planned in the near future.
Comparing losses before and after deployment of AMR system is highly problematic, and often gives a distorted picture, due to the following reasons encountered in praxis:

- Customer's membership to distribution area is often unsynchronized with map of the same distribution area. Therefore, situations in which losses were 30% or even negative, were quite common before AMR system was deployed.
- Reading of all meters installed at the same moment were practically impossible in traditional way, since process of reading was 5 days long – delay in reading customer's meters and industrial meter in DT of just one day results in 3% losses increase.

TABLE 1 – Energy balance in distribution area „Blok B", ED Ruma, cable grid

Year	Month	Customers	IM DT	Diff	Losses	T2/T2+T1
		[KWh]	[KWh]	[KWh]	%	(%)
2004	OKTOBAR	78.792	80.919	2.126	2,63	30
	NOVEMBAR	98.068	99.616	1.548	1,55	38
	DECEMBAR	123.449	125.701	2.252	1,79	40
2005	JANUAR	124.631	126.978	2.347	1,85	42
	FEBRUAR	111.860	113.862	2.002	1,76	42
	MART	101.529	103.164	1.635	1,58	41
	APRIL	72.225	73.796	1.571	2,13	31
	MAJ	61.206	63.156	1.949	3,09	25
	JUN	58.469	59.954	1.485	2,48	24
	JUL	59.898	61.402	1.504	2,45	24
	AVGUST	57.533	59.110	1.577	2,67	24
	SEPTEMBAR	59.838	61.252	1.414	2,31	23
	OKTOBAR	68.913	70.690	1.777	2,51	30

Data analysis, based on data in Tables 1, 2 and 3, shows that losses in distribution areas are quite different. This fact implies that more precise measurements on low voltage sections and its fragments is needed. This way, technical and commercial losses can be determined.

TABLE 2 – Energy balance in distribution area „Fees Klare" ED „Novi Sad", overhead grid

Year	Month	Customers	IM DT	Diff	Losses	T2/T2+T1
		[KWh]	[KWh]	[KWh]	%	
2004	OKTOBAR	146.789	159.424	12.635	7,93	0,23
	NOVEMBAR	175.119	193.312	18.193	9,41	0,25
	DECEMBAR	183.414	205.790	22.376	10,87	0,26
2005	JANUAR	210.566	234.750	24.184	10,30	0,26

	FEBRUAR	179.667	202.296	22.629	11,19	0,26
	MART	180.016	199.100	19.084	9,59	0,25
	APRIL, MAJ	276.774	302.562	25.788	8,52	0,23
	JUN	129.106	136.502	7.396	5,42	0,24
	JUL	129.482	138.364	8.882	6,42	0,24
	AVGUST	129.300	136.034	6.734	4,95	0,24
	SEPTEMBAR	122.782	132.606	9.824	7,41	0,23
	OKTOBAR	150.060	161.668	11.608	7,18	0,23

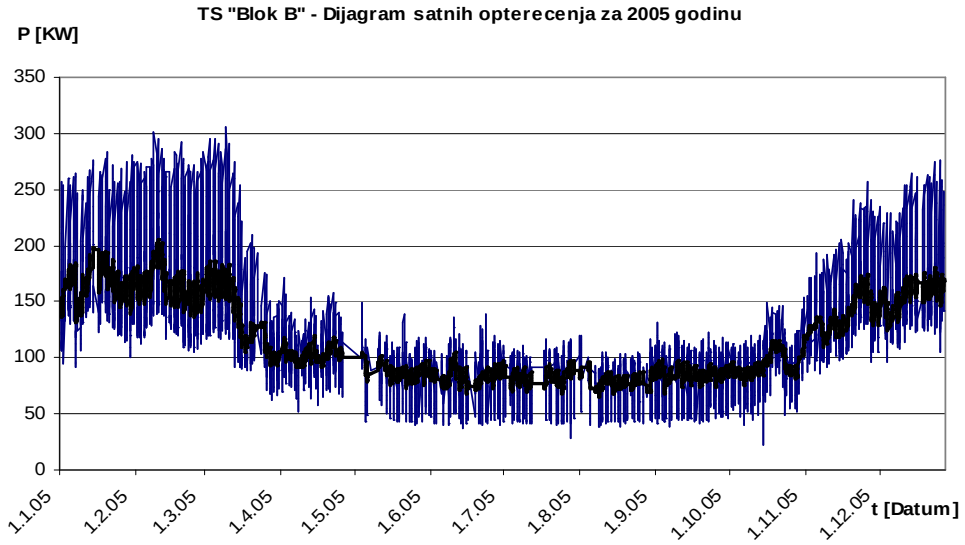
TABLE 3 – Distribution losses in distribution area „Prvomajska“, ED“Ruma“, - overhead grid

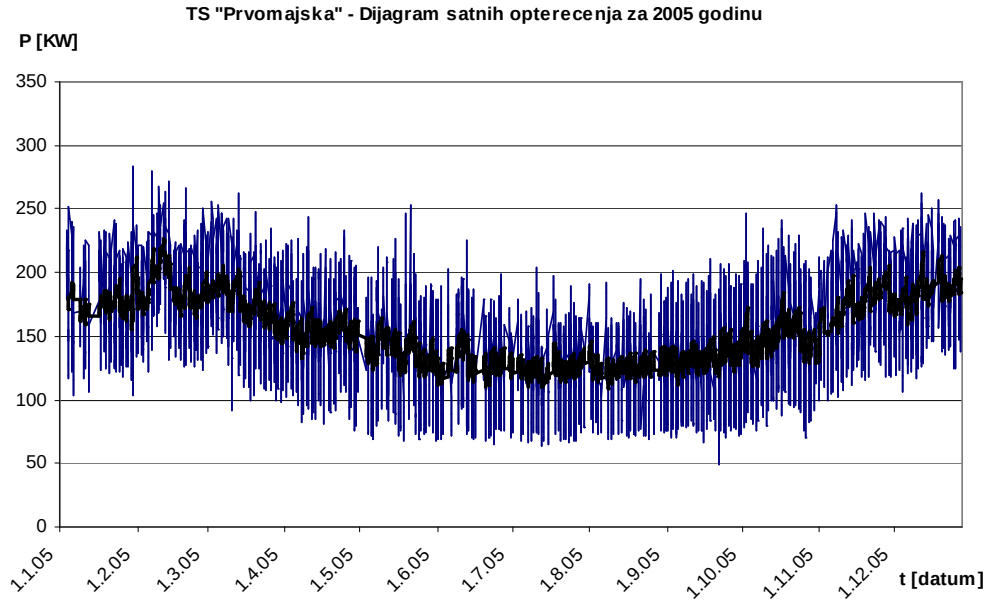
Year	Month	Customers [KWh]	IM DT [KWh]	Diff [KWh]	Losses %
2004	OKTOBAR	102.871	107.716	4.845	4,50
	NOVEMBAR	110.765	116.410	5.645	4,85
	DECEMBAR	127.695	135.266	7.571	5,60
2005	JANUAR	125.288	132.440	7.152	5,40
	FEBRUAR	118.649	125.968	7.319	5,81
	MART	124.583	130.518	5.935	4,55
	APRIL	107.749	111.546	3.797	3,40
	MAJ	94.370	99.962	5.592	5,59
	JUN	88.322	91.660	3.338	3,64
	JUL	89.440	92.786	3.346	3,61
	AVGUST	90.567	93.772	3.205	3,42
	SEPTEMBAR	92.666	96.426	3.760	3,90
	OKTOBAR	107.423	112.604	5.181	4,60

By regular losses overseeing, significant changes are momentarily noticed and necessary actions to find cause are taken, whether it is a new customer, unauthorised consumption, or change in grid configuration.

Load-profile diagrams

By measuring 15-min loads in DT “Blok B” and in DT “Prvomajska” in ED ”Ruma” hourly load-profile diagrams for the year 2005 have been produced. With these diagrams, disproportion between power of installed transformer and load demand of whole distribution area can easily be checked and regulated.





In both distribution areas installed transformers are of 630kVA nominal power each. Combining these diagrams, losses in transformer's iron and copper, the result is that in 40 year period losses in DT „Blok B" would decrease for 45.3 MWh, or 8.7%, if 400kVA transformer were installed, instead of 630kVA-one. On the other hand, difference in DT"Prvomajska" is almost neglible (1.3%). As is it is clearly shown, with data like these, an improvement of energy efficiency and losses reduction losses, where possible, is easily achievable.

Revenue increase

Considering all consumption data in all 6 distribution areas with total of 1130 customers in AMR project, we have found that 25% of total consumption is in second tariff. This ratio was 37% in distribution areas ED"Novi Sad" and ED"Ruma", for the year 2005, and in whole distribution area of

Elektrovojvodina even higher – 41%.This high consumption in second tariff is result of malfunctioned or even tampered mechanical time switches It is a well known fact that, on classical mechanical time switches, periods of off-peak tariff is easily, although without authorization, adjustable, according to the customer's wish. With new generation meters, these actions are virtually impossible, since there is integrated RTC. Furthermore, with remote system supervision of tariff program, control of whole system is even more implemented.
Provided that AMR system is deployed across whole Elektrovojvodina distribution area, according to presently ratio between tariffs on pilot areas, as well price difference (1 kWh in peak tariff = 4 kWh in off-peak tariff), just on the issue of offseted time switches, yearly benefit will be 6,047,490 €.

Real time metered values

Real time voltage, current and power values, though not interesting for billing, can give valuable information about low voltage grid: asymmetrical loads, phases overloads, voltage levels at every customers premises. Not only that, but by measuring voltage levels in real time, borders of distribution areas can been more efficiently distiuingished and that wise make maps more up to date. All these pieces of information can be used in order to optimise low voltage grid.

COST BENEFIT ANALYSIS

Following results obtained in two years of AMR system deployment on test areas, we can say that many positive effects have been achieved: a decrease in energy losses, an increase in successful billing, a reduction of meter reading costs and costs of disconnecting of non-paying customers, a decrease in unauthorised consumption and a decrease in number of billing complaints. Based on this results, a cost benefit analysis of justification of AMR system deployment across whole Elektrovojvodina distribution area has been made. It must be emphasised that in this analysis, the price of this multifunctional meters is approximated, since these meters will be acquired according to regular EPS plans. Therefore, economical estimate comprises only of investments in automatic reading and management: communication modules, latching relays, concentrators, industrial meters in substations, all necessary hardware and software in control centre.
Investment in AMR project in Elektrovojvodina's whole distribution area is 19,879,560 €. Equipping meters with latching relays, this investment rises to 77,999,020 €. On the other hand, automatic meter reading will annually benefits 7,564,203 €. By adding latching relays, profit will rise to 8,373,240 €. To calculate these figures, the costs of traditional meter reading and for manpower reading meters for commercial and industrial consumers, as well costs of disconnecting non-paying customers, the impact of offseted time switches and effect of reducing the number of unauthorised energy consumption cases are all taken into account. For functions of automatic reading and remote disconnecting/reconnecting, costs for GSM communication and system maintenance are also taken into consideration. Based on these data, static marker – payback period can be calculated as ratio between total costs and annual benefits, assuming that whole system is deployed within a year:

1. remote meter reading	19,879,560/7,564,203 = 2,63 years
2. remote meter reading and remote disconnecting/reconnecting	77,999,020/8,373,240 = 9,32 years

These payback periods are valid only when whole system is deployed in one year. Payback period as static marker do not show money flow in system deployment and functioning period and as such, it is not reliable marker for assessment of investment feasibility. Therefore, dynamic markers are used, which are determined by evaluating this time period. In this dynamic assessment of economical effectiveness and project efficiency, these rentability markers have been used: net present value (NPV) internal rate of return (IRR) and payback period. According to the thoroughly made calculations, analysis have shown that automatic meter reading is feasible, regardless of observation period in question. Also, analysis shows that only 20% of whole distribution area need to be equipped for remote disconnecting/reconnecting. This way, both criteria of NPV and IRR are satisfied, and payback period is 5.77 years.
It is very important to emphasise that this analysis has been made based on small statistical sample (0.12% of whole consumption area), which does not represent whole Elektrovojvodina's distribution area. Although a bit simplified, we still consider that analysis gives valid results.

Recommendations based on experience with AMR project

1. Standardisation – interoperability. Since our two pilot projects are realised by two different vendors with two completely independent and different AMR systems, a question of maintenance and efficient system functioning has been raised. As these systems are fully autonomous, for each of these two systems, independent reports need to be generated, as well as records updated, database administered, faults diagnosed. Furthermore, not even meters from one vendor are interchangeable with another vendor's meters. This concept is inconvenient for power distribution company. Therefore, each system, regardless of manufacturer, is required to satisfy same standard for local and remote data exchange. With majority of Europe's meter manufacturers, it is IEC 62 056 which encompasses a series of standards, which provide a high level of data protection and unique data and interface structure.
2. Concentrator in DT needs to be more autonomous and with more advanced functions, so system control centre resources can be more effectively used in system overseeing, which is especially important if system is to be even widely deployed. Automatic collecting of hourly meter values is highly useful, since this way problem with dynamic changes of resistance of LV grid is avoided – with 24 daily readings, metered values at 07 o clock are most certainly obtained. Besides that, these hourly readings can provide us with information about quality of communication structure of LV network on whose basis we can reach conclusions on grid conditions.
3. Real time current, voltage and load per phase values, though not valid for billing, are of essential value for supervision and fault localization in LV grid. Updated regularly, these data can provide reliable information about loads in some LV grid areas, as well about quality of electrical energy delivered to customer.
4. In AMR system, only highly reliable and of the highest quality meters are to be deployed. As meters are multifunctional, one fault in one of the subsystems demands replacement of the whole meter, which influences maintenance costs and, on the other hand, decrease the rate of successful reading.
5. Automatic update of communication structure in LV network is very important feature for losses management. Each new installed meter needs to be automatically signed-in in system control centre and appropriate settings for location in question need to be made. Without this function, there would be no precise information about meter location, to which distribution area it belongs, and therefore, energy balance would be offset and losses would be wrongly assessed.
6. To validate and check the quality of LV network for communication purposes, special diagnostically equipment is needed. This equipment would be used for preparation of LV network for AMR system deployment, as well as for fault detection in case of meter communication failure.

CONCLUSION

Summing up experiences we have obtained, effects we have achieved on our test areas and restrictions due to the small statistical sample, we are of opinion that there is to be continued with AMR deployment, now on much wider area, and covering all types of electrical energy consumption. New area for AMR deployment would ideally be the one where there are significant problems with losses, unpaid bills, high percentage of low rate tariff consumption and high percentage of unread meters. Only with these experiences on wider test area, the whole problem of AMR system deployment on whole distribution area of Elektrovojvodina can be assessed.

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