Paper accepted for presentation at 2009 IEEE Bucharest Power Tech Conference, June 28th - July 2nd, Bucharest, Romania

Cost benefit analysis for implementation of a system for remote control and automatic meter reading

Nikola Rajaković, Dušan Nikolić, Jovan Vujasinović

Abstract **-- This paper presents possibilities of implementing the system for remote control and automatic meter reading in Distribution Utilities in Serbia. Conception and structure of new system is illustrated. Advantages of new meter reading system over conventional system, like reducing the costs due to unpaid electric energy, non-technical losses, improving the quality of delivered electric energy and possibility of load control are pointed out. On an example of Belgrade Distribution utility, cost-benefit analysis for wide-scale implementation of new remote control and automatic meter reading in a distribution grid has been outlined.**

Index Terms **-- Automatic meter reading, non-technical losses, costs due to unpaid electric energy.**

I. Introduction

With the development of new computer technologies possibilities for more efficient management of electric power distribution grids arouse along with the new solutions for some old problems. During the 1990s the wider application of new electronic meters had started. Modern types of electronic meters have microprocessors which enable multifunctional applications. Their basic advantages over conventional meters are increased accuracy, possibility of measuring active and reactive power, recording of average values of 15 – minute load, measuring of voltage per phase, measuring of cosφ, etc. Their advantage is also the possibility for integration in systems for automatic meter reading, which would enable monitoring and remote control of customers (switching on and off) from distribution center.

Remote control system applications in distribution networks covered all voltage levels so far, except the LV lines[1]. In a new and improved remote control system of distribution network all consumers are included, acquisition of relevant data is instantaneous and possibilities for load management emerge. Properly implemented, system for remote control and automatic meter reading would also give the distribution utility an overview on complete status of electric energy consumption, for each consumer and distribution network as a whole[2]. But, most important advantages of the system for remote control and automatic meter reading are reduced operating costs (i.e. meter readout crews are no longer needed), and reduced non-technical losses (including unpaid electric energy).

Prof. dr Nikola Rajaković (rajakovic@etf.rs) is with the Faculty of Electrical Engineering, University of Belgrade.

Dušan Nikolić (dusan.nikolic@etf.rs) is with Innovations Centre of Faculty of Electrical Engineering, Belgrade.

Jovan Vujasinovic (jovan.vujasinovic@meterandcontrol.rs) is with Meter & Control, Belgrade.

II. Description of a System for Remote Control and Automatic Meter Reading

System for remote control and electricity meter reading is technologically improved solution compared to conventional system. It can be implemented like an upgrade to present system by introducing new devices:

at customers' side - New digital meter, PLC modem, Concentrator, GPRS modem,

at utility's side - GPRS modem, AMR communication server.

Overview of such system [3] is shown in Fig. 1.

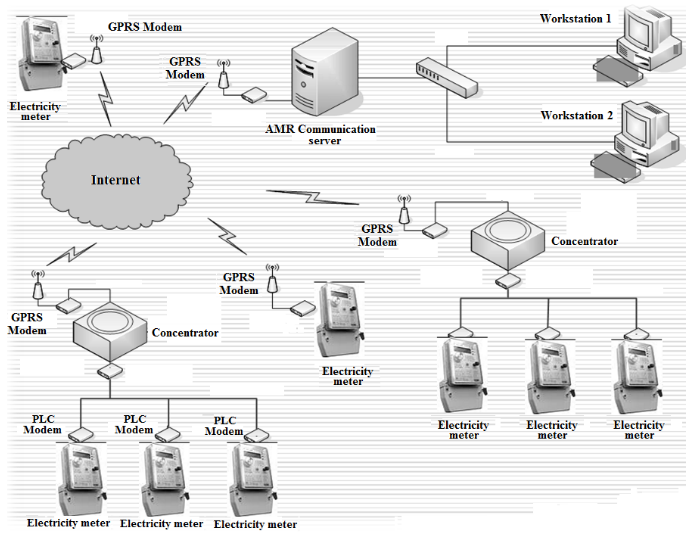

Fig. 1. Example - System for remote control and electricity meter reading.

III. Advantages of System for Remote Control and Electricity Meter Reading

There are several advantages of a system for remote control and automatic meter reading over conventional electricity meter reading systems[3].

A. Reducing of costs due to unpaid electric energy

Regular and proper charging of consumed electric energy presents the basic income for a distribution utility. Major problems are caused by consumers who are connected to the distribution network and have bypassed their meters (or even are connected to distribution grid without meters). This results in electric energy supply without having to pay for it – and all at the cost of distribution utility. Such consumers are more often found living in their own (individual) houses. Cabinets, containing electric energy meters, are often placed inside the house, and not on facade or some easily accessible place. Being placed like that, meters are easily accessible to be manipulated

978-1-4244-2235-7/09/$25.00 ©2009 IEEE

and misused. Distribution utility of Belgrade tries to prevent this problem by conducting new internal standard which places meters outside customer's property. Additionally, by using new digital meters almost all "energy leaks" could be easily detected and tracked. Remote electricity meter communication, as a kind of control, could help in reducing these losses and unauthorized electric energy usage.

By manipulating with power grid, unauthorized consumers endanger others, connected to the same feeder. For example, unskilled manipulation of electric power grid can cause fires. Besides that, feeders with unauthorized consumers suffer higher overloads which lead to their faster deterioration and causes more often faults.

Besides illegal electric energy usage, constant problem are also consumers whose meters are mostly non accessible and can't be read. Every month, Distribution utility of Belgrade suffers losses about 1 – 1.5 %, due to unread customer's meters. This problem could be also reduced by using proposed internal standard. One of solution to almost total elimination of the problem is application of new remotely controlled electricity meters. New system would stimulate consumers' higher financial discipline, because all buyers who don't pay for their electric energy supply could be easily left without.

B. Reducing labor and equipment costs

System for remote control and electricity meter reading enables constant monitoring of consumers. It is not necessary to use labor for readout of electric meters and field crews who connect or disconnect consumers from power grid.

Automatic acquisition and processing of data also saves utility's funds, because it is no longer necessary to hire labor to do that. Besides, it is possible to totally eliminate costs caused by miscalculations and misreading of electricity meters. These costs are called correction costs. When they occur, recalculating and resending of bills is needed and sometimes even a technical revision of electricity meters.

Through the system for remote control and electricity meter reading distribution utility can monitor and control maximum consumption of every user. In a case of communication breakdown, all registered data are being stored in customer's electricity meter or transformer substation concentrator, and is waiting for a new command.

C. Communication with customers' meters

System for remote control and electricity meter reading has two – way communication between customers' meter and concentrator in transformer substation 10/0.4 kV using power lines. Next level of two – way communication is between concentrator and distribution center using GPRS modems.

D. Remote load control

Adequate equipment can provide remote load control by limiting consumer's maximum current values per phase. Also, it is easy to monitor maximum demand, which provides valuable data for further analysis of transformer substation 10/0.4 kV.

If a consumer has separate installations for his basic needs (primary consumption) and additional small-business installation (secondary consumption) like boilers or furnaces, it is possible to separately control those consumptions.

Furthermore, it is also possible to program the reconnection of a consumer if he was disconnected due to exceeding maximum allowed power. All these interventions could be directed from distribution center.

E. Improving the quality of electric energy

System for remote control and electricity meter reading monitors quality of electric energy in all transformer substations 10/0.4 kV. Measured values are voltages, currents, harmonics, power factors, etc. All data are instantly available in distribution centre, where it can be analyzed. Soon after, all places within distribution network with lower quality of electric energy are precisely determined, and repair crews could be instantly sent on site.

F. Reducing non-technical losses

By favor of system for remote control and electricity meter reading it is easy to locate macro and micro non-technical losses. The sum of all customers' power demand and total technical losses should be equal to total power supplied by one transformer substation. If that is not true, micro locating of non-technical looses is necessary. This is usually done by placing additional measuring devices, which can detect non-technical looses. Micro locating of non-technical losses can be a very slow process, while the remote controlled meters can show this information instantly. Also, digital multifunctional meter has higher accuracy class, and reduces non-technical looses caused by lower accuracy of older types of electricity meters. There are a number of customers in every distribution network with inaccurate meters, or old meters which have not tested for years and with the passage of time they have reduced accuracy. Such irregularities are very hard to be located and fixed. In the system of remote control and electricity meter reading such irregularities are practically non-existent, since they could be instantly discovered and eliminated.

G. Flexibility of electric energy tariffs

An additional advantage of system of remote control and electricity meter reading is a possibility of setting up a different tariff for each customer. Having that possibility, distribution utility can offer a large variety of tariffs and electric energy prices which always lead to better load control (avoiding demand peaks which occur during lower tariff periods).

Existent tariff system in Serbia already anticipates special, more favorable tariffs for customers with integrated remote control and electricity meter reading system. Unfortunately, those tariffs are not widely implemented at a present time. Installment of new, remote controlled metering system will provide broader application of more favorable tariffs for customers. New system provides even better results if a customer has separate installations for primary and secondary consumption. In times of high load peaks, secondary consumption could be remotely switched off by distribution utility. This possibility of reducing the peak demands would relieve the distribution grid and delay the investment in new grid capacities. However, the advances of new tariffs cannot be quantified and accordingly, are not included in further analysis.

IV. Cost - Benefit Analysis Results

Cost benefit analysis is based on comparison of investment costs (purchase and installment costs of new system) to annual savings achieved by remote control and electricity meter reading system.

Investment costs consist of equipment and installation costs. Equipment costs are purchasing of new meters, modems, concentrators, etc. Installation costs contain labor costs, distribution utility's vehicles utilization costs and costs caused by undelivered electric energy (during the installation).

New system for remote control and automatic meter reading would annul most of the costs which occurred in the conventional metering system. In other words, every year distribution utility would experience annual savings due to installation of new system.

Those annual savings are actualized by favor of:

- unnecessary electricity meters readout crews (all meter readouts are remote),
- unnecessary field crews in charge of plugging and unplugging the customers from the grid,
- unnecessary utility's vehicles engagement by readout and field crews,
- savings due to collecting, inputting and analyzing the data (the system is automated, and all the data is instantly processed) and finally, and
- savings due to non-technical losses (unpaid electric energy).

This cost-benefit analysis is based on the assumption that new system is being implemented by replacing the conventional equipment with new one on whole distribution grid (this cost-benefit analysis will be referred to as the first cost-benefit analysis). It is interesting to notice that second cost benefit analysis is performed to show what if the new system becomes a standard and would be implemented in new buildings and households instead of conventional metering system. In a second case, cost benefit analysis shows, logically, lower rates of investment return. Both cost-benefit analyses are performed on an example of Belgrade's distribution utility. In a wide-scale replacement of conventional system with new one, calculated rates of return would be as presented in Table I.

TABLE I
CALCULATED RATES OF RETURN FOR FIRST COST BENEFIT ANALYSIS

Method	Years
Simple payback period	2.955
Internal rate of return	3.588

Results for second cost-benefit analysis are:

TABLE II
CALCULATED RATES OF RETURN FOR SECOND COST BENEFIT ANALYSIS

Method	Years
Simple payback period	2.155
Internal rate of return	2.501

As mentioned above, rates of return in second cost-benefit analysis are lower. It means that as soon as the new system is implemented into current standards, lower would be the investments into distribution grid, because there will be no need to install one system and then replace it with another.

Sensitivity analysis of a first cost-benefit analysis was performed with input parameters which influence rate of investment return. Those parameters are: projected price of electric energy during the service life of new system, percentage of unpaid electric energy in total losses and number of customers per transformer substation. Results are shown on Fig. 2 to Fig. 4.

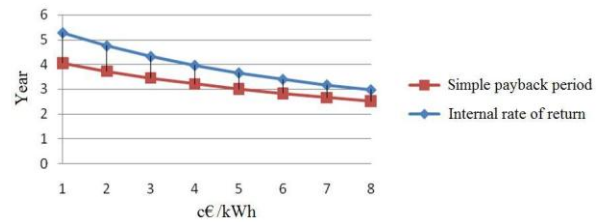

Fig. 2. Rate of investment return compared to projected average electric energy prices in Serbia during next 10 years (Current price of electric energy is around 5 ¢€/kWh).

Fig. 2 shows that future increase of electric energy price in Serbia will contribute to shorter periods of investment return. Conclusion can be drawn to distribution grids in general – higher the electric energy price, shorter the period of investment return for the implementation of system for remote control and automatic meter reading.

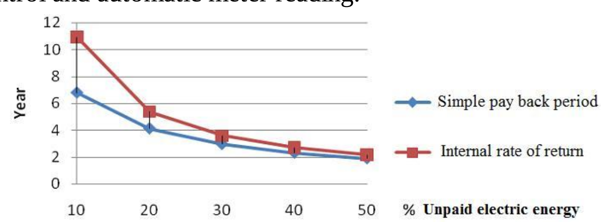

Fig. 3. Rate of investment return versus percent of unpaid electric energy in total losses.

Unpaid electric energy is one of the biggest problems in Belgrade's distribution utility, which is expected to be almost completely solved by implementation of a new system. Fig. 3. varies this percentage of unpaid electric energy in total losses and shows that distribution grids with very weak financial discipline over customers are first to benefit from implementing the system for remote control and automatic meter reading.

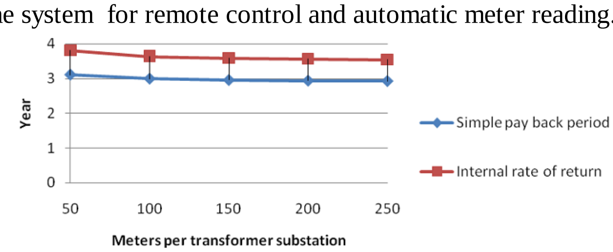

Fig. 4. Rate of investment return compared to number of electric meters per transformer substation.

Fig. 4 shows that distribution grids with higher number of electric energy meters per transformer would have shorter periods of investment return. It is also interesting to notice, that if an implementation of system for remote control and automatic meter reading would commence in a distribution grid, it should be first installed in transformer substations with higher number of electric energy meters.

V. Appendix: Cost- benefit analysis outline

Due to data availability, cost benefit analysis presented in this paper is based on an example of Belgrade's distribution grid. This appendix will present a structure analysis of purchasing and installation of new system and distribution utility potential annual savings. Moreover, procedure of cost benefit analysis of the system for remote control and automatic meter reading will be outlined[3].

A. Purchase and installment investment costs of a new system for remote control and automatic meter reading

1) Purchasing new equipment

New equipment contains of new digital electricity meters concentrators, GPRS and PLC modems and additional electric equipment. There has to be one digital electricity meter and PLC modem for each customer.

Belgrade's distribution grid covers roughly

$$N_{customers} = 750.000 \text{ customers},$$

which also presents total number of needed new digital electricity meters.

Each transformer substation has to be equipped with concentrator, which collects data from all customers supplied by that transformer. Besides concentrator, every transformer substation has its own electricity meter, and a GPRS modem which allows communication with distribution utility.

Number of customers connected to one transformer substation usually varies from 100 to 300. Value used in this analysis will be:

$$n_{cstmr/TS} = 150 \text{ customers}.$$

In this paper equipment costs are chosen as follows:

- Digital electricity meters and accompanying equipment, $c_{meter} = 170$ €.
- Concentrator, electricity meter and GPRS modem, $c_{concentrator} = 450$ €.
- Installation material (cables, etc.), per transformer substation, $c_{elsup} = 250$ €.

Total price of equipment per transformer substation is:

$$C_{equipment/TS} = c_{meter} \cdot n_{cstmr/TS} + c_{concentrator} + c_{elsup}$$

The price of electric equipment per one customer can be determined by:

$$C_{equipment/meter} = \frac{C_{equipment/TS}}{n_{cstmr/TS}} = c_{meter} + \frac{c_{concentrator} + c_{elsup}}{n_{cstmr/TS}}$$

2) Installation costs of automatic meter reading system

Time needed for the installation of one digital meter and additional equipment, including time for preparations and transport of equipment, is about

$$t_{inst\text{-}meter} \approx 1 \text{ h}.$$

Installation time of equipment inside transformer substation amounts roughly:

$$t_{inst\text{-}TS} = 2 \text{ h}.$$

Number of workers needed for equipment installation:

$$n_{install\text{-}worker} = 2.$$

Workers engagement (man-hour price):

$$c_{man\text{-}hr} = 8 \text{ €/h}.$$

Summarily, costs for installation of one new digital meter are being calculated as a sum of costs for installation of all meters and appropriate equipment in one substation, divided by number of customers being supplied from that transformer substation,

$$C_{install/meter} = \left(n_{inst-worker} \cdot c_{man-hr}\right) \cdot t_{inst-meter} + \\ + \frac{1}{n_{cstmr/TS}} \cdot \left(n_{inst-worker} \cdot c_{man-hr}\right) \cdot t_{inst-TS}$$

3) Costs due to undelivered electric energy

During the installation of a new system, distribution utility is not going to be able to sell electric energy to those customers, which implies further costs. One customer will be taken off grid during the time period of

$$t_{unplug} \approx 3 \text{ h}.$$

If a customer is using an average of 30 kWh per day, during the time of installation distribution utility will not sell about

$$30\,\text{kWh} \cdot \frac{t_{unplug}}{24} \approx 3.75 \text{ kWh} \cdot$$

If a price of electric energy is about 8 ¢€/kWh, costs of undelivered electric energy per customer are about:

$$3.75 \text{ kWh} \cdot 8\,¢€/\text{kWh} = 30\,¢€ = 0.3\,€\,.$$

Compared to prices of equipment and installation costs, undelivered electric energy has no significant influence, and can be excluded from further analysis.

At the end, total costs for equipment and installation (per meter) could be presented as follows:

$$C_{investment/meter} = C_{equipment/meter} + C_{install/meter}\,.$$

B. Purchase and installment investment costs of conventional system for meter reading

1) Equipment costs for conventional system

Equipment for conventional system consists of conventional, induction meters and some additional equipment. Every customer has one inductive meter, and no additional equipment is needed in transformer substation.

Average price of conventional equipment is around:

$$C^{(2)}_{equipment/meter} = 80 \text{ €}.$$

2) Installation costs for conventional system

These costs are lower than installation costs of new system, because no equipment is being installed in transformer substations; hence no time is wasted on it. With already defined terms in previous chapter, installation costs for conventional system are:

$$C^{(2)}_{install/meter} = \left(n_{inst-worker} \cdot c_{man-hr} + c_{veh,\,h}\right) \cdot t_{inst-meter} + c_{veh,\,km} \cdot s_{veh}$$

At the end, total costs for equipment and installation (per meter) could be presented:

$$C^{(2)}_{investment/meter} = C^{(2)}_{equipment/meter} + C^{(2)}_{install/meter}$$

C. Difference of exploitation costs in system for automatic meter reading and conventional system

Basic difference in exploitation costs between new and conventional system is the price of periodic maintenance of new digital and conventional induction meters.

1) Conventional system exploitation costs

Maintenance of conventional induction meters is being done once in 12 years, in other words once during its service life. According to price list of Belgrade's distribution utility, maintenance costs for this meter are about

$$C_{maintenance}^{ind.meter} = 20\ €.$$

2) Automatic meter reading system exploitation costs

Maintenance of digital meters is being done once in 12 years, or once during their service life. According to price list of Belgrade's distribution utility, maintenance costs for this type of meter are about

$$C_{maintenance}^{dig.meter} = 50\ €.$$

Expected service life for both conventional and new meters is around 20 years, hence average maintenance costs per annum are:

$$C_{maintenance,\,yr}^{ind.meter} = \frac{C_{maintenance}^{ind.meter}}{20}, \quad C_{maintenance,\,yr}^{dig.meter} = \frac{C_{maintenance}^{dig.meter}}{20}$$

Difference in exploitation costs per annum are:

$$\Delta C_{exp}^{yr} = C_{maintenance,\,yr}^{dig.meter} - C_{maintenance,\,yr}^{ind.meter}$$

D. Structure of annual costs for Belgrade's Distribution Utility

1) Annual costs of readouts of electricity meters

Total number of employed workers for the purpose of electricity meters readout is roughly

$$n_{read\text{-}workers} = 450 \text{ workers.}$$

Average number of working hours per month for each worker is

$$t_{read\text{-}workers} = 84 \text{ h.}$$

Engagement of readout workers costs

$$c_{read\text{-}man\text{-}hr} = 8\ €/\text{h.}$$

Summarily, annual readout costs for Belgrade distribution utility are:

$$C_{readout} = 12 \cdot (n_{read\text{-}workers} \cdot t_{read\text{-}workers} \cdot c_{read\text{-}man\text{-}hr})$$

2) Annual costs of field crews

This category includes those field crews who could be substituted by distribution center remote control. These crews are usually plugging or unplugging customers from distribution grid. Total number of workers is

$$n_{unplug} = 210 \text{ workers.}$$

Average number of working hours per month for every worker is

$$t_{unplug} = 60 \text{ h.}$$

Engagement of field workers costs

$$c_{unplug} = 8\ €/\text{h.}$$

Summarily, annual field crew costs for Belgrade distribution utility are:

$$C_{unplug} = 12 \cdot (\, n_{unplug} \cdot t_{unplug} \cdot c_{unplug})$$

3) Annual costs for distribution utility's vehicles engagement by field and readout crews

Smaller number of readout crews uses vehicles for their transport, and that happens mostly in rural areas. Adopted value for the purpose of this analysis is 5%,

$$k_{veh\text{-}read} = 0.05.$$

Engagement of utility's vehicle costs

$$c_{veh} = 0.5\ €/\text{h,}$$

while the price of km is

$$c_{veh,km} = 0.5\ €/\text{km.}$$

Engagement of vehicles costs per month is

$$C_{veh-read} = k_{veh-read} \cdot n_{read\text{-}workers} \cdot \left(t_{read\text{-}workers} \cdot c_{veh,h} + c_{veh,\,km} \cdot s_{veh}\right)$$

On the other hand, all field crews use utility's vehicles. Engagement of utility's vehicle costs for these purposes costs:

$$C_{veh\text{-}unplg/plg} = n_{unplug} \cdot \left(t_{unplug} \cdot c_{veh,h} + c_{veh,\,km} \cdot s_{veh}\right)$$

Summarily, annual vehicle engagements costs for Belgrade distribution utility are:

$$C_{veh} = 12 \cdot (k_{veh-read} \cdot n_{read\text{-}workers} \cdot \left(t_{read\text{-}workers} \cdot c_{veh,h} + c_{veh,\,km} \cdot s_{veh}\right) + \\ + n_{unplug} \cdot t_{unplug} \cdot c_{veh})$$

4) Annual costs on collecting, input and analyzing the data

Data gathered during the meters readout is being processed, printed, and checked. In distribution utility of Belgrade, for this purpose, there are around

$$n_{data} = 45 \text{ workers.}$$

With their brut salaries c_{data} , annual data processing costs for Belgrade distribution utility are:

$$C_{data} = 12 \cdot n_{data} \cdot c_{data}$$

5) Annual losses due to unpaid electric energy

Losses due to irregular consumption of electric energy present the highest economic losses of Belgrade distribution utility. Average electric energy bought by Belgrade distribution utility from Serbian transmission utility in the last 10 years is about 7000 GWh/year. Adopted value for this analysis is 7500 GWh/year, because of projected increase in consumption over the next 20 years. Estimated losses of distribution grid are about 16%. Adopted value for non-technical losses is only 30% of total losses, or

$$k_{irregular} = 0.3.$$

Summarily, annual losses in Belgrade distribution utility are:

$$C_{irregular} = 0.165 \cdot 7500 \text{ GWh/year} \cdot k_{irregular} \cdot c_{el.en.}$$

where $c_{el.en.}$ is average price of electric energy.

Total annual costs of Belgrade's distribution utility due to readouts of electricity meters, field crews, distribution utility's vehicles engagement by field and readout crews, collecting, inputting and analyzing the data and non-technical losses are:

$$C_{annual\ costs} = C_{readout} + C_{unplug} + C_{veh} + C_{data} + C_{irregular}$$

To conclude, new system for remote control and electricity meter reading would not experience almost any of these annual costs when installed. In a way, presented costs could be then seen as annual savings by distribution utility,

$$C_{savings} = C_{annual\ costs}$$

E. New system implementation

During the installation of system for remote control and automatic meter reading on whole distribution grid large quantities of equipment are needed, so discounts are in order:

$$k_{discount} = 30\%$$

For the Belgrade distribution utility, investment costs during new system implementation are:

$$C_{investment} = k_{discount} \cdot C_{investment/meter} \cdot N_{customer}$$

F. Investment rate of return periods

Simple payback period could be determined easily using next formula:

$$r_{phase} = \frac{C_{investment}}{\left(C_{savings} - C_{maintenance,\ yr}^{dig.mtr.}\right)}$$

where are:

$C_{investment}$ – total investment costs,

$C_{savings}$ – savings due to implementation of new system.

One more indicator for successful investments is internal rate of return. It is similar to simple payback period while it accounts for present money value.

Factor of accounting the present money value is:

$$f_i = \frac{(1+i)^N - 1}{(1+i)^N \cdot i}.$$

with:

i – discount rate (in Serbia this rate is 9%),

N – service life of device (adopted value $N = 20$).

Investment becomes economically viable at the moment when it is equal to savings,

$$C_{investment} = f_i \cdot \left(C_{savings} - C_{maintenance,\ yr}^{dig.met.}\right) = \frac{(1+i)^{IRR} - 1}{(1+i)^{IRR} \cdot i} \cdot \left(C_{savings} - C_{maintenance,\ yr}^{dig.met.}\right)$$

The internal rate of return (IRR) can be then calculated from the above formula as:

$$IRR = \frac{\log_{10}\left[\frac{1}{\left(1 - i \cdot \frac{C_{investment}}{\left(C_{savings} - C_{maintenance,\ yr}^{dig.met.}\right)}\right)}\right]}{\log_{10}(1+i)}.$$

Second cost benefit analysis is based on presumption that the new system for remote control and automatic meter reading will be installed in new buildings and households, instead of conventional one. Then, there will not be any need to eventually replace conventional system with the new one.

Simple payback period is being calculated as difference between investment and installation costs of conventional and new system.

Purchase of equipment:

$$C_{difference-equipment} = C_{equipment} - C_{equipment}^{(2)}$$

Installation of equipment:

$$C_{difference-installation} = C_{installation/meter} - C_{installation/meter}^{(2)}$$

Exploitation costs:

$$\Delta C_{\exp}^{yr}$$

Simple payback period is then:

$$r^{(2)} = \frac{C_{difference-equipment} + C_{difference-installation}}{C_{savings} + \Delta C_{exp}^{yr}}.$$

Internal rate of return in this case is being calculated in the same manner as in the first cost benefit analysis.

VI. Conclusion

Advantages of a new system for remote control and electricity meter reading are beneficial for both distribution utility and customers.

For the distribution utilities, implementation of a new system means technological improvement which doesn't only solve current problems, but also opens great possibilities for better distribution network operation.

Economic benefits come from the fact that distribution utilities will be paid for almost every delivered kWh and as a consequence, they would be able to rise the quality of electric energy, which would imply higher customer satisfaction, and is of a great interest in any deregulated system.

At the end, better insight in functioning of a distribution grid could help in prevention of future failures which would result in more reliable electric energy supply.

VII. References

[1] T. A. Short, *Electric Power Distribution Handbook*, Florida CRC Press LLC, 2004.

[2] William H. Kersting, *The electric power engineering Handbook*, vol. 6 - Distribution systems, CRC Press LLC, 2004.

[3] N.Rajaković, D. Nikolić, V. Šiljkut, S. Milošević, *Cost benefit analysis for implementation of a system for remote control and automatic meter reading*, Case study, Belgrade 2008.

VIII. Biographies

Nikola Rajaković (rajakovic@etf.rs), is professor at the Faculty of Electrical Engineering of University of Belgrade, and senior member of IEEE. The areas of his interest are electric power system analysis and optimization and recently, renewable energy sources and distributed generation. He is the author and co-author of several dozen articles and papers at national and international level.

Dušan Nikolić (Belgrade, Serbia, 1980) earned his graduate diploma at the Faculty of Electrical Engineering of University of Belgrade, where is currently undergoing PhD studies. The areas of his interest are distribution, renewable energy sources and distributed generation.

Jovan Vujasinović (Belgrade, Serbia, 1977) earned his graduate diploma at the Faculty of Electrical Engineering of University of Belgrade, and currently is undergoing PhD studies. The areas of his interest are remote control system, advanced metering infrastructure and smart metering. He is the author and co-author of several dozen articles and papers at national and international level.