ELECTRONIC METERS
-TECHNICAL POSSIBILITIES AND SELECTION OF THE FUNCTIONS
IN ELECTRICITY DISTRIBUTION ACTIVITY

Nikola GASIC, JP ELEKTROPRIVREDA SRBIJE, Direkcija za distribuciju elektricne energije

I INTRODUCTION

Modern third generation electronic/static meters produced on the bases of microprocessor-based technology enables, in addition to the metering, a great number of other functions such as: metering of voltage, current and power instantaneous values, metering and registering of maximum power average values, metering of power factor, registering of load diagram, metering of electrical energy quality parameters, meter operational condition diagnostic and metering integrity, load management with possibility of remote opening/closing of the entire installation, or of a part of it, of the consumer, possibility of automated meter reading, meter operation parameterization and configuration, etc.
As far as design is concerned, meters are generally produced as multifunctional – with built in internal clock, ripple control receiver - module for control of tariff registers, module for communication, memory blocks, with wider current and voltage ranges, as well as with other parameters adaptable to the provisions of tariff systems and other requirements.
From the technical point of view, functioning of deregulated electricity market is inconceivable without application of microprocessor-based electronic meters.
In such circumstances, when deciding on the choice and type classification of metering devices i.e. measuring values and metrological functions, rational access is required, i.e. it is necessary to analyze the real need for and importance of a series of additional functions and certain data for electricity distribution and the influence of the same on operational reliability, price and optimal costs of the entire system in investment and maintenance.

II GENERAL TECHNICAL AND DESIGN-RELATED CHARACTERISTICS OF MODERN ELECTRICAL ENERGY METERS

Development of electronics and its implementation in energy field, especially in the area of metering and relay protection, caused practical use of electronic/static electrical energy meters in electric power industry activities, starting from eighties of the last century.
Induction meters that have been produced and used for more than 100 years, (Galileo Ferraris 1888), with perfectly realized construction, with exceptionally high knowledge of and long experience in maintenance and high level of reliability, (number of outages is reduced to 0.1 up to 0.3 %, while in case of electronic meters, the figure is even up to 3 %–the ratio is more then 1/10)

with high metering accuracy and life time of over 30 years. – yet may not restrain application of electronic meters – primarily due to the modern requirements in the area of electrical energy use.
The fact is also that the application of induction meters and other electro-mechanical metering devices shall be conserved, practically till the expiration of their life time – due to the above mentioned technical properties and due to the economic circumstances, as well.
It is also indisputable that all new consumers shall be mainly connected to the power network with metering carried out by the electronic meters.
Electronic/static meters, in relatively short time period of application of around 20 years, with constant increase of built-in quantities in the power network, have experienced also a series of technological improvements and thus third generation modern electronic meters produced on the bases of microprocessor-based technology are in use.
The first generation of electronic, analogue-hybrid, meters is already being put out of use, because of defects and objectively decreased life time of the components, caused by difficult operational conditions in power network in so called 100% operation, and because of new requirements, as well.
The period from eighties up to present has been used for intensive development and application of new technological solutions – so that devices with satisfactory characteristics for electrical energy metering for billing purpose and other functions expected from these devices are in use.
Parallel with development of new metering devices and new design solutions, a determination of types of metering parameters and metrological functions of electrical energy meters used in electric power industry is accomplished.
Standardization of regulations is determined to a significant extent both on the national level and in the region of EU, and especially through the IEC standards and norms.
In electricity distribution practice, experiences are recognized or their systematization is in course, as well as definition of basic technical conditions and requirements that should be met by the meters, with determination of all functional tasks.
Selection of characteristics of the meters for households and other low voltage consumers is especially important, since they make even up to 90 % of total quantity of meters.
We list below, for distribution activity, mainly standard and classified according to the type, basic technical characteristics of the meters with necessary comment:

Voltage – 3 x 230/400 V – three-phase and 230 V single-phase, for directly connected meters and 3 x 57.7/100 V through voltage transformers. The solution is in compliance with the standard for nominal/indicated voltages in distribution networks.

Current – Measuring range is 5-60 A for directly connected meters i.e. 5 (6) A for connection through current transformers. Selection of this current range, comparing to the previous one of 10-40 A, permits that the meter measures consumption as law as from 17 W of power, comparing to around 34 W in case of 10 A and three-phase connection, which is obviously significant system effect. Increase of the measuring range to 60 A, possibly even up to 100 A, enables avoidance of installation of current instrument transformers, increase in accuracy of the metering and decrease in costs of connection when one part of the consumers is concerned.

Frequency – Standard is 50 Hz.

Accuracy class – Meters are produced/configured with accuracy class of 2.1 and 0.5 for active energy, 3 or 2 for reactive energy and 1 or 0.5 for average maximum active power. Taking into account that the requirements are defined by appropriate tariff systems, they are the same as for induction meters, while the characteristics of electronic meters and constructive solutions usually significantly exceed them.

Number of tariffs – Up to 4 tariffs for active and reactive energy i.e. average maximum active power.

Time of mean maximum power – 15 minutes with possibility of programming from 5 up to 60 minutes.

Metering system – Meters are produced on the basis of microprocessor-based technology with three-phase four-wire and single-phase two-wire connection i.e. connection through instrument transformers in case of indirect or semiindirect metering. Usual configuration is the one with three metering systems.

Display of measured values – They are usually represented on a display for multipurpose displaying, using LCD, and by schedule according to VDEW specification. Sufficient visibility and legibility of the values are requested taking into account the requirement relating to the possibility of direct meter reading. Display of some measured values is cyclic with compulsory installation of a special button for manual selection of display type. In addition to measured data, the display also shows presence of voltages to neutral, regular order of phases, direction of energy flow i.e. quadrant in which the energy is registered, events that are registered, some meter statuses, alarms, etc. Displayed data are identified through OBIS code according to appropriate IEC standard.

Meter case, terminal, dimensions – DIN 43857 is applied by standard with fixed horizontal hanging points (150 mm for three phase and 105 mm for single-phase meters). Meter case and meter cover material should be UV stabilized with good thermal and mechanical properties. Terminal block should enable connection of 25 mm^2 Cu conductor. Operational temperature ranges from -25 to +55 ˚C, and storage temperature ranges from –40 to +70 ˚C. Electrical protection is of the II class and protection against dust, humidity and vermin is IP 51.

Pulse/TEST/outputs – For the purpose of testing, meters are equipped with optical (through LED diode) i.e. electrical output for active and reactive energy with defined constants. In the test mode of operation, display with higher resolution is also possible which shortens the time needed for accuracy test in case of small loads. Pulse characteristics are defined by appropriate IEC standards.

Electromagnetic compatibility and other conditions – Meters are produced and checked in compliance with appropriate IEC standards relating to electromagnetic compatibility and other referential conditions for reliable operation in power network.

Microcomputer – enables functions of the meter at the request of the user, memorizes measured data for determined billing periods according to tariff system and account method, memorizes data and parameters in permanent memory, carries out necessary calculations, enables picture of load curve, tariff registers' operation, keeps the historical book, manages display presentation and carries out other regulatory and managing functions of the meter.

Real time internal clock /RTC/ - is a standard equipment of modern meters of any configuration and purpose. RTC generates metering period for power metering, control of tariff registers pursuant to defined tariff programme and daily, monthly, seasonal and annual calendar including certain holidays. Optionally, meters may be also equipped with inputs for receipt of command from ripple control receiver - module or time switch.

Measured values – meters register individual values per each of three phases and cumulative value for three phases and enable calculation of the following values:

- active energy in two directions of flow (import/export) in all tariff registers and as a total,
- reactive energy in two directions of flow (import/export) in all tariff registers and as a total,
- apparent energy per tariff registers and as a total,
- active, reactive and apparent power per tariff registers,
- 4-quadrant metering of billing values and combined per quadrants (for instance I + II, III + IV),
- load curve i.e. registering of average maximum power in time intervals of 5 to 60 minutes and selected time of duration,
- effective values (RMS) of voltage, current and power per phases,
- power factor, distortion factor, content of over-harmonics, etc.

Communication ports – For the purpose of meter reading i.e. programming and load management, modern meters are equipped by standard with two communication ports

- optical IR port through optical head enables connection with terminal /HHU/ i.e. with PC/LAPTOP.
- electrical output is used for automated meter reading /AMR/ needs, meter programming and load management. Interfaces for communication may be built in the meters or prepared for subsequent installation of appropriate modem for connection with some of communication routes for data transmission – PLC/DLC, RF, GSM/GPRS, PSTN/ISDN, KTV.

Meters are also equipped for the purpose of reading, programming and load management with appropriate protocols, usually according to the IEC 62056-21 mod C and IEC 62056-31 standards or by DLMS protocol.

Metering integrity – It is usual that the meters are equipped in such manner to enable registering of certain events by the time they happened and state of billing registers in the moment, such as: opening of terminal cover, meter parameter change, certain values reset, indication of state of presence of voltage to neutral i.e. phase disconnection etc.
Some commands and access to the meter should be protected by appropriate password at a few levels.

Other technical characteristics – are determined by appropriate standards or are specified by the user.
The requirements of the state regulations relating to the accuracy and quality of metering and billing of electrical energy are also important

III BASIC FUNCTIONAL REQUIREMENTS FOR ELECTRICITY METERS

In the electric power industry and in the distribution activity as well modern electricity meters play very significant role as from the aspect of functioning of the entire electric power system as well as in electricity market regulation.
With regards to the technical capabilities from one side and electric power requirements on the other side, it is very important to define basic functions of the measuring devices with reference to the rationality of a solution and overall cost-effective approach.
Respecting the requirements emerging from power distribution praxis and taking into consideration possible scenarios in the area of electric power activities in the coming period, basic requirements can be catagorized as per following functional and technical structure:
- measurement of basic accounting and other values,
- remote reading and data transfer,
- consumption control and complex functions.

Accounting measurement function. As afore mentioned, the modern processor-based meter enables measurements and display of a series of energy values / active and reactive electric power, peak load of actual and mean electricity values, voltage and power, power factors and other, but the functions of a meter should most often be limited to measurement of values required by the actual tariff system.
However, a meter is primarily an instrument through which the functions of accounting, measuring and charging for the goods called electric power are performed and following the regulation acting upon supplier / customer relationship.
In that sense, this measuring instrument is under special state control for the purpose of relationship regulation between seller and buyer as in the broadest sense.
Especially from electricity distributor point of view of, the approach of definition and rationalization of the technical functions of the measuring instrument at the side of custormers within the broadest category is very significant, and we refer to households and other low voltage consumers equipped with meters of the mass category accounting for up to 90% of the total number of the units.
Functional requirements of tariff system are significantly lower than measuring features of the modern meters, even than requirements specified for meter procurement for the need of electric power utilities
For example, tariff system in Serbia defines two-rate tariff , namely low and high day rates, for all consumption categories, without any weekly or season-based charging. The significant portion of consumer is with only one rate. Peak load is measured and calculated for consumption categories of so called "high voltage", "medium voltage", "low voltage" levels, while the peak load within the category of so called "wide consumption" is determined as fixed payment amount. Reactive energy is calculated and measured only in one tariff rate at consumption categories of HV, MV and LV levels where the mean maximum 15-minute power is measured. Meter accuracy classes are defined by the volume of annual consumption as well as by voltage level at which connection is made. Only meters designed to measure consumption of HV-connected customers need to include the feature of two-way communication. Tariff system established in Slovenia is similar and the accounting of consumed electricity for the biggest

number of consumers of household category is carried out on the basis of measuring active energy in two or even one tariff rate, but during Saturdays, Sundays and holidays the consumption is registered in a lower tariff rate. Reactive energy is not calculated, and maximum load is charged through the same fixed payment.

The method of accounting and frequency of reading in a year have high impact in determining choice of solution and configuration for meters.
Some electric power utilities (e.g. VDEW –Germany) have defined and implemented rational options of meter functions both for households and for industrial customers.
On the basis of this reviewes/observations, the conclusion emerges that it is necessary to avoid ''hypertrophy'' of measurement functions, especially when it comes to residential customers.
Undisputable fact that meters in this category should not (except in a small number of cases) measure and display values such as current, voltage, actual power, power factor, reactive energy and reactive power, maybe also maximum mean active power in all tariff registers, with mandatory recording of certain events and long time to store specific data and similar.
Quite different approach is used to specifiy functions of meters installed with customers having larger electricity consumption or HV-based consumption, or where multifunctional metering sets are used or where in addition to accuracy class, reliability is required too, as well as capability of measuring and displaying other energy values for the needs of producing consumption analysis, load control and other requirements set by the user and/or the electricity supplier.
Quantity of such units, namely the number of specific customers on the electric power network is relatively small, but those customers regularly register electricity volumes up to 60% of total supplies, hence this way of treating them is technicaly and economicaly logical.

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Remote meter reading. Remote meter reading (AMR) systems were introduced in early 1990's in operational usage solely for remote reading of meters for the purpose of accounting, one-way communication mainly via radio network. The new state-of-the-art AMR systems use bi-directional communication which eneables beside meter reading, remote adjustments of their parameters and measuring configuration respectively. The system makes it also possible to control demand that is a load of network, as well as change of electricity supplier in de-regulated electricity market.
The effects of applying remote reading system are as follows:

- Remote reading and monitoring of meter,
- Reduction of costs, time required for reading and meter inspection,
- Opportunity of implementation of more flexible tariff system,
- Increase of collection rate along with reduced time for producing invoices and improvement of financial balance of supplier,
- Contracting of absorbed peak power and total consumption,
- Identification of maximum load of network and monitoring individual and aggregated load of customers,

- Selective disconnection of customers and/or electricity-consuming devices,
- Identification of certain type of failure, controls and loss reduction and theft of electricity,
- Supply system and power facility control improvement
- Remote reading of other measuring instruments (water consumption meters, gas meters, calory meters and similar),
- Better customer awareness on consumption status and more rational electricity utilization.

From technical point of view, AMR unit operates by means of following sub-systems:
1. electronic meters; 2. telecommunication unit; 3. control centre with proper software.
In AMR unit data transfer buses as well as data number and structure are the factors which determine the unit and its communication perfomances. Selection of communication system that should enable two way communication generally with each metering point is, for the time being, the biggest problem against faster implementation of AMR system.
At the moment there are two outstanding data transfer systems as from engineering and economic point of view the most appropriate solution:

1. LV network of supplier, (PLC/ DLC) though it is not built for data transfer due to a number of limitations to quality of communication (interruptions, overvoltages, higher harmonics, diversity of networks), however it shows that it can be used for the need of AMR systems – usually for one transformer area.
2. GSM/GPRS technology, already the most spreaded transmitting medium and of the highest quality, but which use is getting cheaper every year, many indicators say undoubtly that this is the optimal way of transfer in the near future.

In considerable amount one can find method of data transfer via radio network (RF), telephone network (ISDN/PSDN), or combination of these technologies (for example PLC-GPRS).
In defined system technical parameters are identified for operation such as: protocols, frequencies and other, mainly in accordance with the international standards in this area.
Complete specification for selection of telecommunication ways, protocols and data access, could significantly influence meter design and following typification and rationalization of solutions for the distribution activity in this area.

Demand management. Use of meters which are based on microprocessor technology and remote reading extends the opportunity to use this system for consumption management and for the needs of system and as logistics support by planning and maintenance of the electric power system and increase of work efficiancy of technical departments at electric power distribution utilities. By applying AMR system with a meter in which is installed proper output relay, that is a bistable single-pole or three-pole circuit breaker is added/ attached, that would enable various functions from the area of consumption management such as:

а) consumption restriction or power limitation to a contracted
б) remote on/ off switching of power installations in case of pre-paid (subscribed) arrangements or for the purposes of interventions/ actions in cases of non-paying for consumed electricity
ц) remote on/off switching of part of the power installations and certain (for example thermal) electricity - consuming devices/units, or in order to dedicate a real consumption to pertinent tariff register.
A basis for operating management of distribution network as well as definition of basic information for investments activities is created through data monitoring and selection from measuring points and data concentrators – values of currents, voltages, load curve registers, events logs. It is necessary to emphasize that application of demand management in a broadest sense still has not found large-scale and mass use in electric power distribution activity, because the effects can be achieved by application of other actions such as: possibility to overload the system, capabilities of electricity generation capacities, decreasing the cases of unauthorized access to electricity meter and prevention of electricity theft by applying other methods of managing distribution companies, proper price- and tariff-related policy, optimal construction of electric power facilities, application of energy efficiency actions, and etc.
Data compiled from implemented pilot projects which were focusing on consumption management indicate that invested resources in this area are the ones with the slowest result-effectiveness.

IV FINAL REVIEWS

1. It is a definite appraisal that breakthrough made by electronic micro processing units onto the field of measuring of electricity can be in certain way observed as revolution-like from the technical point of view and that it is a cause of change of conventional solutions, when we start looking from the replacement of electromechanical mesuring devices and all the way up to the setting up of specific measuring system in the environment of deregulated electricity market.
2. It is obvious that the process and scope of application, conditions of usage, and technical solutions as well are not final in the overall electricity measurement system therefore requiring analytical handling when choosing practical solutions in the field of electricity measuring within power distribution activity.
3. It is especially important to provide, in addition to economic reasons, high requirements of reliability of measuring system, which are the basis for accounting and charging of consumed electricity, since the conditions for reliable work of fundamental functions are disturbed or are achieved in a very difficult way due to increase of the functions and infrastructure for data aquisition, processing, storage and application

4. In these circumstances, by decision-making and typification of measuring devices and selection of metering functions, it is necessary to set rational approach and take a close view to what extent the additional functions unnecessarily burden the system operation, namely how they impact reliability, price and optimal costs in investment and maintenance

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