

Lightning Risk to Alternative-Current Electricity Meters

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Abstract— Article presented the basic information about the lightning risk to alternative-current electricity meters, which are connected directly or indirectly to power system. It was proved, that on electricity meter, in the case of direct connection, can affect some part of lightning current and all types of overvoltages from low-voltage power system. In order to attain the estimation of lightning risk in indirect connection, overvoltages transfer through instrumental transformer to secondary sides were measured. Additionally the protection against surge current and voltages was considered.

Index Terms— Lightning, overvolatages, current and voltage transformers, alternative-current electricity meter, lightning protection.

I. INTRODUCTION

Failure-free working states of electronic, multifunctional alternative-currents electricity meters was possible to achieve limiting the current and voltage surges in electric power systems to required levels.

Selection and arrangement of surge protective devices SPD required the information about the surge risk in power system and the resistibility of ac electricity meters to voltage and current surges.

II. SURGE RESISTIBILITY OF ELECTRICITY METERS

One of the basic requirements of ac electricity meter is the fulfils the appropriate dielectric properties in cases when different impulse disturbances appeared in power systems.

For presentation of surge risk, the meters were tested [12] by surge voltage with peak value 6000 V and shape $1,2/50 \mu s$. The range of surge resistibility investigations were presented in Tab.1.

III. SURGE EXPOSURE OF ELECTRICITY METERS

Electricity meters can be connected:

- directly to low-voltage power system,
- half directly by current measuring transformers to voltage power system,
- indirectly by current and voltage measuring transformers to high or medium voltage power systems.

In dependence from arrangement of connections in power

systems, on electricity meter can affect some part of lightning current and different types of overvoltages.

Table 1. Break-down s	strength tests	s for ac electricity	/ meters
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Tests	Ranges of tests	Remarks	
Tests for circuit's insulation and insulation between circuits	Tests for individual circuit, which is insulated from other circuits.	Terminals of not tested circuits were connected to the earth.	
	Common tests for currents and voltage circuits.	When these circuits are connected together.	
	Tests for current circuits – impulse voltage between every terminal and earth.		
	Tests for voltage circuits – impulse voltage between every terminal and earth.	Voltage and current circuits are separated and each has the separate insulation.	
	Tests for auxiliary circuits – the same tests as voltage circuits.		
Tests for insulation between circuits and ground	All terminals in electric meter are connected. Impulse voltage between all terminals and earth.	Terminals of auxiliary circuits were connected together with terminals of others circuits.	

A. Surge exposure in low-voltage power systems up to 1000 V

In building with lightning protection system LPS lowvoltage power system and electricity meters connected directly to this system can be affected by some part of lightning current. Such risk appeared during direct lightning stroke into the air-terminal system of LPS.

In this case, according the recommendations in standards about lightning protection of structure [6][7][8] and requirements for SPD [5], 50% of lightning current is discharged through the earthing system of structure and odd part is distributed in the connected conductive systems (power system, metal piping, etc. - according to Fig.1.).

In the worst situation, it is possible to accept the following conditions:

- only the low-voltage power system is connected and it will be loaded by 50% of lightning current,
- lightning current with peak value 200 kA and shape 10/350 (values for the I lightning protection level),
- TN-C system (phases L1, L2 L3 and PEN),
- insulation break-down in low-voltage power system caused by voltage differences between L1, L2, L3 and PEN connected to earthing systems.

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In this case the lightning current of 25 kA will be loading per conductor of low-voltage power system.



Fig. 1. Lightning current distribution during direct stroke to LPS.

For typical buildings, smaller value of lightning current (12,5 kA, 10/350) per conductor is recommended.

In all cases the electricity meter connected at the entrance directly to power system will be in danger caused by potential difference between conductors and earthing system (PEN conductor). Voltages increased up to insulation breakdown (Fig. 2.), with high probability that this breakdown occurred in electricity meter. Next lightning current flows in phase conductors.



Fig. 2. Lightning current distribution in low-voltage power system: a) current only in PEN, b) currents in all conductors after insulation break-down.

Considerably often ac electricity meters are exposed to voltage surges from power system supplied building. In lowvoltage electric installation inside the structure overvoltages may be classified in the following main categories:

- lightning overvoltages,
- switching overvoltages,
- temporary overvoltages.

Measurements in power systems, laboratory tests and theoretical calculation indicated that these overvoltages have double-exponential or damped oscillatory waveshapes.

The rate of occurrence of surge voltages varies over wide limits and prediction of this rate for particular installation is always difficult or frequently impossible.

Data collected from many overvoltage measurements have led to the plot the curves, which presented the probability of surge voltages exceeding specific values in form of low, medium or high exposure (Fig. 3.).



Fig. 3. Rate of surges occurrence versus voltage levels for different exposures [5].

On basis of accessible dates it was possible to accept, that in urban areas the overvoltages in range 1000 V - 5000 V occurred about some times per year.

In rural areas the relative probability of overvoltage occurrence is some times greater than in urban areas.

B. Surge exposure in medium-voltage power system

For the medium-voltage (MV) systems direct lightning discharge to overhead line is the dangerous case. The frequency of lightning flashes to overhead line depends on local lightning discharges density, dimensions of line and possible shielding effects of the surrounding.

The number of direct stoke per year can be defined by:

$$N = A \cdot N_g \cdot 10^{-6}$$

where: A – effective area in m²,

 N_g – flashes per km and per year in area with MV line. In such cases on MV and LV lines flashover will usually occur between line conductors and earth. The value of overvoltages appears on the inputs of current and voltage measuring transformers dependent on:

- flashover voltages on insulators,
- voltage on inductance and earthling resistance of poles, on which flashover followed.

Considerably smaller values achieved overvolatages induced in overhead lines. Generally they have double-

exponential or damped oscillatory waveshapes.

Induced lightning overvoltages U between conductors and earth can be estimated from equation:

$$U = 30 \cdot (H/d) \cdot I \quad [kV]$$

where: I - lightning current [kA],

- *H* height of suspension of line above the ground [m],
- d distance among line and place of hitting of lightning [m].

Possibility of assessment the number of induced overvoltages in the function of amplitudes, parameters of line and local flash density is defined by:

$$N_{i} = 1.9 \cdot 10^{-6} \cdot N_{g} \cdot H \cdot L \cdot \left[3.5 + 2.5 \cdot \log \frac{30 \cdot (1 - c)}{U}\right]^{3.75}$$

Where N_i - number of induced overvoltages, N_g , HL and U are as presented in previous equations. Coefficient c defines reducing factor due to earthed neutral or earth conductor (c= 0, in absence of this conductor and c = 0,7 or 0,9 in dependence from earthing of conductors).

Lightning risk in half-directly and indirectly connection of electricity meters will be presented on examples of measure circuits in power stations, in which control buildings with meters were in considerable distances from the places of instrumental transformers. In these situations, in secondary circuits are necessary signal cables about a few hundred meter lengths. In such arrangements overvolatages transferred from primary sides to secondary windings by inductive, capacitive and impedance (galvanic) couplings.

When the secondary windings were earthing in one point (for example at instrumental transformers), these couplings caused that in the places of measurements (in control buildings) in secondary circuits appeared the overvoltages between conductors and between conductors and earth.

Dates presented in literature and author's measurements show that overvoltages between conductors and earth can achieve values to some kilovolts and in the case of impedance (galvanic) coupling even to 20 kV.

C. Results of measurements

The main purpose of the research was the investigation of overvoltages transferred in instrumental transformers from medium-voltage to low-voltage networks with electricity metres.

During measurements, the unidirectional voltage surges were introduced at the primary sides between terminal of winding and earth and overvolatages in secondary windings were recorded (Fig.4.).

Observations have been carried out in the following arrangements:

- voltage between secondary windings and between terminals of windings and earth (secondary winding are insulated from earth),
- voltage between terminals of windings and earth (secondary windings were earthed).



Fig. 4. Measurements of transfer overvoltages in instrumental transformer.

The voltage surges were produced with high-voltage impulse generator UCS 500M6B, which delivered a $1,2/50 \ \mu s$ voltage surge up to 6600 V (at open-circuit) and a $8/20 \ \mu s$ current surge up to 3300 A into a short circuit.

Some results of overvoltage transferred to secondary windings (insulated from earth) in current transformer are presented in Fig.5.



Fig. 5. Voltages at: a) the primary side of current transformer, b) between secondary windings and between secondary winding and earth.

Miscalculation of measurements results to real overvoltages proved the possibility of insulation damages in secondary, considerable length circuits.

IV. OVERVOLTAGE PROTECTION OF ELECTRICITY METERS

In case of direct connection of electricity meters to lowvoltage power system, protection against lightning current and limitation of overvolatages to adequate level assured SPDs type I with voltage protection levels below 4000 V. SPDs with discharge spark gap are recommended [3].

For the protection against lightning current (Fig.2.), arrangement of SPDs shall be installed near the origin of the installation on the supply side of electricity meter (Fig. 6.).



Fig. 6. SPDs on the supply side of electricity meter.

Protection against lightning (caused by indirect lightning strokes) and switching overvolatages is provided by installations of SPDs type II (varistor and spark gap in series connection).

In indirect connection of electricity meters and considerable distance between instrumental transformers and control building, potential differences between earthing systems can be dangerous for insulation of measurement circuits.

The solution is earthing the secondary windings in control building. In this case in control room we avoid the potential of earthing mesh from HV Station. In such arrangement the protection against potential differences between secondary windings and earth at the instrumental transformer is possible to occurred using gas discharge tubes with impulse flashover voltage below 6000 V (Fig.7.).



Fig. 7. Protection against potential differences in secondary windings.

Gas discharge tubes should be installed in control building when the secondary windings are earthed at instrumental transformer.

V. CONCLUSION

Creation of conditions to failure-free work of electricity meters require:

- analyse the lightning and overvoltages risk in places of theirs installations,
- compare this risk with the surge resistibility level of meters,
- install the protective devices with adequate protection level.

Surge protective devices can't influence onto works of meters.

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