50 years University of Mining and Geology "St. Ivan Rilski"
Annual, vol. 46, part III, Mechanization, Electrification and Automation in Mines, Sofia, 2003, pp.113-115

INVESTIGATION AND ESTIMATION OF HIGHER HARMONICS IN POWER NETWORK OF CHARGE STATION IN UNDERGROUND COAL MINE "IVAN ROUSEV"

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ABSTRACT
Electricity consumption of electrical transport with accumulator electrical locomotives is about 10% of the total electricity consumption. The total installation capacity of charging stations on thyristor devices is commensurable with the capacity of charging transformer. Amplitudes of higher harmonics in electricity supply network of underground charging station in mine "Ivan Rousev" are measured." Measurements are realized by using of the network analyser Multiver – 3SN.An attempt for analytical calculation of influence of non-linear load of the charging stations on the other consumers is made.

INTRODUCTION

One of the quantity indexes of electrical energy (BDS 10694-80) is the coefficient of non-sinusoidality of current or voltage, that express degree of distortion of current or voltage sinusoid. The maximal legitimate value is 5%. Distorted sinusoid could be presented as a sum of regular sinusoids with determined frequency, amplitude and initial phase, which are termed harmonic components or higher harmonic of the current or voltage.

An occasion for appearance of higher harmonic is presence of electrical consumers with non-linear current-voltage characteristic. Charging stations for accumulator locomotives are this kind of consumers because are constructed of thyristor converters. Electricity consumption in charging stations is about 10% of the total consumption.

OBJECT OF INVESTIGATION AND DATA FROM EXPERIMENT

In mine "Ivan Rousev" are constructed two charging stations- one underground and one overground. Because of technological reasons experimental measurement is made in overground charging station. The charging devices in both stations are the same. The value of current higher harmonic generated from one charging device is measured. The value of higher harmonic in underground station with n working charging devices and its influence on the rest consumers in the network are estimated on the base of obtained results. Only the harmonics of current are measure. The voltage harmonics are different for overgroun and underground stations because of different capacity of power transformers that supply the charging device. Electricity supply of underground charging system is realized by a sectional transformer substation (STS) with ТКШВП-180 кVA, located near the substation and electricity supply of overground charging station is made by transformer station with transformer TM-750 кVA.

STS "Underground charging station" supplies also two drainage pumps and a fan. One-linear circuit of electricity supply of consumers is shown on fig. 1 and data for installed powers age given in table 1

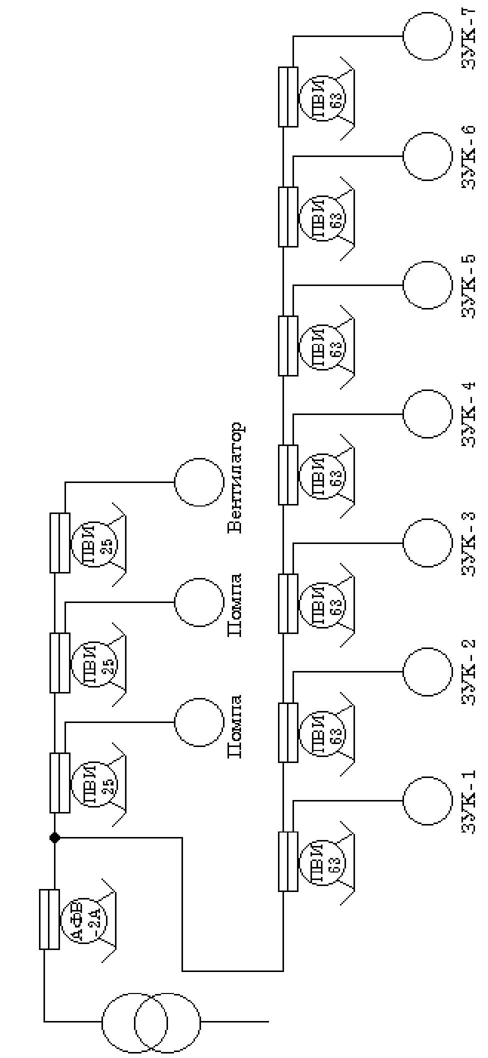
Table 1. Data about consumers.

Kind of consumer	Quality	Power кW	cosφ
ЗУК155/230/У5	7	15	0,76
Pump	2	5,5	0,86
Fan	1	5,5	0,86

Using electrical analyser Multiver - 3SN we made the record of levels of higher harmonic, generated from a current charging device. Measurements results show, that in the network are generated higher harmonics only with numbers 5 and 7 and their percentage concerning the main (first) harmonic is given in table 2.

Table 2. Values of measured and calculated currents.

$I_{изм.}$,A	I_1 ,A	I_5 ,%	I_7 ,%
42,35	34,95	42	18,8



ТКШВП – 180/6/0,4 СВБТ 3х50, L= 800м

Figure 1. One-linear circuit of STS "Underground charging station".

CALCULATIONS OF COEFFICIENT OF NON-SINUSOIDALITY BY ANALYTICAL METHOD (E. DANKOV, 1991)

Using the obtained results and data about electrical network and consumers in underground charging station is calculated the degree of distortion of voltage sinusoid.

This is made for the most unfavourable real variant when three charging device and three induction motors are working simultaneously, as well as for theoretical variant when seven charge devices are working.

The equivalent circuit of the electrical network is constructed for this purpose and is shown on fig. 2 (for the first variant).

The coefficient of non-sinusoidality is determined by formula (E. Dankov, 1991):

$$K_{нс} = \frac{\kappa_{\psi} . \kappa_{\partial} . I_{н} . x_{e} . \sqrt{n_{\nu}}}{U_{н}} .100 \text{, \%} \qquad (1)$$

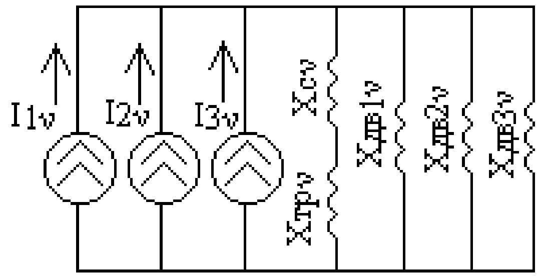


Figure 2 Equivalent circuit of the electrical network for v harmonic.

where:
κ_{ψ} = 0,9 – is the coefficient, that gives non-coincidence of phases of the harmonics;
$\kappa_{д}$ = 1,3 – coefficient of presence of abnormal harmonics;
$I_{н}$ – sum of nominal current of valve converters, A;
x_e – equivalent resistance of the electrical system, Ω;
$U_{н}$ – nominal linear voltage of the network, V;
n_{ν} – number of serial harmonics, in which the coefficient of non-sinusoidality is determined (n_{ν}=2);

Obtained from calculations results are given in table 3.

Table 3. Calculated values of inductive resistances of the network and coefficient of non-sinusoidality.

X_c, Ω	$X_{тр}$, Ω	$X_{дв}$, Ω	X_e, Ω	$K_{нс}$,%
0,005	0,028	2,1	0,0314	1,74

The coefficient of non-sinusoidality 4,14 % is obtained as a result of calculation for the second variant with seven simultaneously working charge devices.

DETERMINATION OF ADDITIONAL LOSSES AND ACTIVE POWER CAUSED BY HIGHER HARMONICS.

Higher harmonics cause considerable damages as a result of: increase of losses of active power and energy, wearing and ageing of electrical isolation.

Additional loss of power in the windings of induction motors and transformer, caused by higher harmonics are determined by the formula (E. Dankov, 1991):

$$\Delta P = 3\sum_{\nu=3}^{n} I_{\nu}^{2} . R_{\nu} \qquad (2)$$

where: I_{ν} – is the effective value of the current of v harmonic;
R_{ν} – active resistance for the v harmonic.

$$R_{\nu} = R.\sqrt{\nu} \qquad (3)$$

R– is active resistance of the main harmonic.

Results from calculation of active resistance of the network elements and losses of active power, caused by the fifth and seventh harmonic and total losses by higher harmonics are given in table 4 and table 5.

Table 4. Calculated values of active resistances of the motors, transformer and equivalent of the network for 5 and 7 harmonic.

	Harmonic number		
	1	5	7
$R_{дв.v}$	3,11	6,95	8,23
$R_{тр.v}$	0,00427	0,00955	0,0113
$R_{екв.v}$	-	0,00955	0,0113

Table 5. Losses of active power caused by 5 and 7 harmonic and total losses from harmonics.

ΔP_5, W	ΔP_7, W	$\Delta P_{v\Sigma}$, W
55,57	1,545	57,02

DETERMINATION OF VOLTAGE OF N HARMONIC

The following formula is used for determination of levels of higher harmonics of the voltage (N. Vasilev 1991):

$$U_v = I_v \,.\, Z_v, \quad V \qquad (4)$$

Z_v – is impedance of the electrical network v harmonic, Ω;

$$Z_v = \sqrt{R_v^2 + X_v^2}\ ; \qquad X_v = K_x \,.\, X_2 \,.\, v \qquad (5)$$

K_x – coefficient of influence of surface effect of the current;
X_2 – inductive resistance of the negative sequence, Ω;

Calculation results for inductive and total resistance of network elements concerning 5 and 7 harmonic and the value of harmonics on voltage are given in table 6.

Table 6. Calculation results for X_v, Z_v and U_v.

	Harmonic number		
	1	5	7
$X_{2\,дв.}$ Ω	2,37	-	-
$X_{2\,тр.}$ Ω	0,031	-	-
$X_{дв.v}$ Ω	-	9,24	12,94
$X_{тр.v}$ Ω	-	0,137	0,174
$Z_{дв.v}$ Ω	-	11,56	15,34
$Z_{тр.v}$ Ω	-	0,137	0,174
$Z_{\Sigma.v}$ Ω	-	0,132	0,168
U_v, V	-	5,29	3,32

Using the obtained results for higher harmonics on voltage is calculated the coefficient of non-sinusoidality by the voltage of higher harmonics.

$$K_{нс} \approx \frac{\sqrt{\sum_{v=2}^{7} U_v^2}}{U}.100, \ \%$$

$$K_{нс.} \approx \frac{\sqrt{(5{,}29)^2 + (3{,}32)^2}}{380}.100 \approx 1{,}64 \ \% \qquad (6)$$

The difference 0,1% between values of $K_{нс}$, determined by classical method (table 3) and by the voltage of higher harmonics (when working three charge devices) allow to consider that the precision of obtained results is high. The coefficient of non-sinusoidality of the voltage when 7 charging devices are working simultaneously, calculated in the mentioned above method is 3.99%, I.e. the error is about 4 % concerning the analytical method and it is in the admissible norms.

CONCLUSIONS

1. Form calculations considered in the report is seen that when both with three and with seven working simultaneously charging device the harmonics of voltage do not exceed the admissible norms of standard BDS 10694 – 80, i.e. the charging station is designed according to the standard BDS concerning $K_{нс.}$.
2. Initiated power losses, caused by higher harmonics are insignificant comparing with the power, consumed in underground charging station.
3. In mines except the charging stations there are another power consumers of electrical energy with non-linear current-voltage characteristic as some lifting devices, contact electrical locomotives etc. and their influence on the rest consumer and coefficient of non-sinusoidality of the voltage should be estimate.

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Recommended for publication by Department of Electrical Engineering, Faculty of Mining Electromechanics