Investigation of 20 kW, 6,8 kV, 80 mkm Single-Wire Electric Power System

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Abstract

20 kW, 6.8 kV, diameter 80 mkm, 6 m long electric power transmission line was tested. There was demonstrated appearance of specific current density 600 A/mm^2 and specific electric power density 4 MW/mm^2 without overheating of copper single-wire line of 80 mkm diameter.

The electric technique of 20 kW single-wire electric power system (SWEPS) with two Tesla transformers [1] is developed (see Fig. 1). Results of 10 kW SWEPS testing are given in [2]. For increase of transmitted capacity more powerful condensers in resonant circuits were installed and parameters of a low-voltage winding of the step – down transformer (Table 1) are changed. On Fig. 2 and on the cover page there are shown photos of SWEPS and the high-frequency transformers made in VIESH.

On Fig. 3 results of measurements of volt-current characteristics of step-down transformer are submitted. The measurement has been made in the period from October 27 till November 1, 2002. Measurements were made at wire with diameter of 1 mm, 100 microns (the area of section, $S=7.85\cdot10^{-3}$ mm^2) and at wire with diameter of 80 microns, $S=5.024\cdot10^{-3}$ mm^2. It have been shown, that parameters did not depend on diameter of a wire. Voltage internal resistance of a low-voltage winding of the step-down transformer was equal to 1.34 Ohm at U = 6 kV. At measuring the inclination volt-current characteristics was applied to an axis.

For wires with diameter of 80 - 100 microns intensive mechanical movement of wires was observed in a cross direction ("dancing" of wires). In some cases this resulted in a mechanical separation of an 80 microns wire. It was also a result of the presence of repeated bend in a place of fastening of a wire at isolator.

The frequency converter operates on the second harmonic and conditions of a resonance correspond to a line voltage of 6 – 7 kV. Experimental values of voltage 360 V and 406 V were measured at 8 Ohm load. Line voltage was equal to 6 kV and 6.8 kV. Using these experimental values, there were determined factors **A** and **n** in the equation $P = A\cdot V^n$, which describes dependence of transmitted capacity **P** (kW) on a line voltage **V** (kV):

$$A = 0.54113,\ n=1,896 \quad P=0.54113\ V^{1.896} \quad (1)$$

On Fig. 4 dependence P=f (U) according to (1) in a graphic kind is submitted. Experimental data practically coincide with results of calculation for voltage 5– 6.8 kV (Table 2). Small difference of calculation and experiment for V=3.2 - 4 kV is connected with deviations of frequency from resonant value. Results of SWEPS tests are submitted in tables 3 and 4. It follows from the equation (1) and Fig 4, that electric capacity of 50 kW may be transmitted at a voltage 11 kV using existing Tesla transformers and the frequency converter of the increased capacity. As a result of tests it is shown, that the copper wire with a diameter of 80 microns and cross section of $5.024\cdot10^{-3}$ mm^2 at a voltage of 6.8 kV is not overheated up to 20.52 kW of transmitted electric power density. At room temperature effective specific transmitted electric power is 4 MW/mm^2 and specific current density is 600 A/mm^2. SWEPS electric parameters in two hundred times exceed parameters of a usual two-phase or three- phase ac line or dc line and may be achieved for existing methods of electric energy transmission only at use of special materials in a mode of low temperature superconductivity.

Thus, property of a single-wire line to transfer active power without essential losses on line resistance is experimentally confirmed. High-frequency transformer Tesla at the beginning of a line is operating as the effective powerful electrostatic charges generator. These charges are flown down under action of a gradient of concentration along a line to a resonant circuit of step-down Tesla transformer and through the rectifier they are removed to loading. The resonant mode and high good quality of the system (Q = 105) determines low losses in circuits. The electrostatic nature of charges transfer with a displacement current in the space, which surrounds a line, is not effected by Joule Law for the description of losses in a line. Irradiation losses at low frequency 3.4 kHz are small. In single-wire power system the 80 microns wire plays a role of directing system for an electromagnetic energy flow, which runs from the generator to the load.

Table 1
Parameters of windings of the transformer and resonant circuit of 20 kW SWEPS

Parameters Step-up transformer	Step-down transformer	
Internal diameter, mm	590	590
Length of a winding, mm	400	400
Number of turns of a high-voltage winding	952	952
Number of turns of a low-voltage winding	19	27
Capacity, μF	14	12
Resonant frequency, kHz	1.852	1.852

Table 2
Dependence of SWEPS electric capacity on a line voltage, R=8 Ohm

U_l, kV	3.2	4	5	6	6.8	8	10	11
P, kW, calculation	4.91	7.49	11.45	16.17	20.506	27.9	42.6	51
P, kW, experiment	5.565	8.8	11.25	16.2	20.503	-	-	-

Table 3
Results of tests of an electric equipment of 20 kW SWEPS

Parameters of a network on an input of the frequency converter	Parameters of the rectifier of the frequency converter	Parameters of a single-wire line	Parameters of loading on an output of the bridge rectifier
I_f = 52.6 A	I = 62 A	L = 6md = 0.08 mm	I_H = 54 A
V_f = 214 In	V = 490 V	V = 6.8 kV	V_H= 380 V
P_a = 32.83 kW		L_{1kHz} = 8.1 μH	
		R_{1kHz} = 14.29 Ohm	P_H = 20.52 kW
Q = 2.137 kVAp			
f = 49.9 Hz		f_l = 3.4 kHz	
φ = 3.60			

Table 4
Results of tests of 20 kW single-wire power system

1.	Electric capacity on loading	20.52 kW
	Current	54 A
	Voltage	380 V
2.	Voltage of a line	6.8 kV
3.	Frequency of a line	3.4 kHz
4.	Diameter of a wire of a line	80 microns
5.	Effective current density on unit of the area of cross section of a conductor	600 A/mm^2
6.	Specific electric capacity	4 MW/mm^2

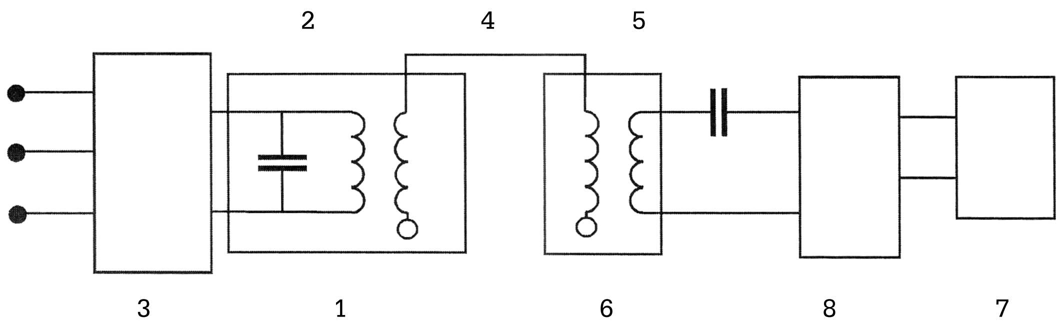

Fig. 1 Electric circuit of SWEPS (explanations in the text)

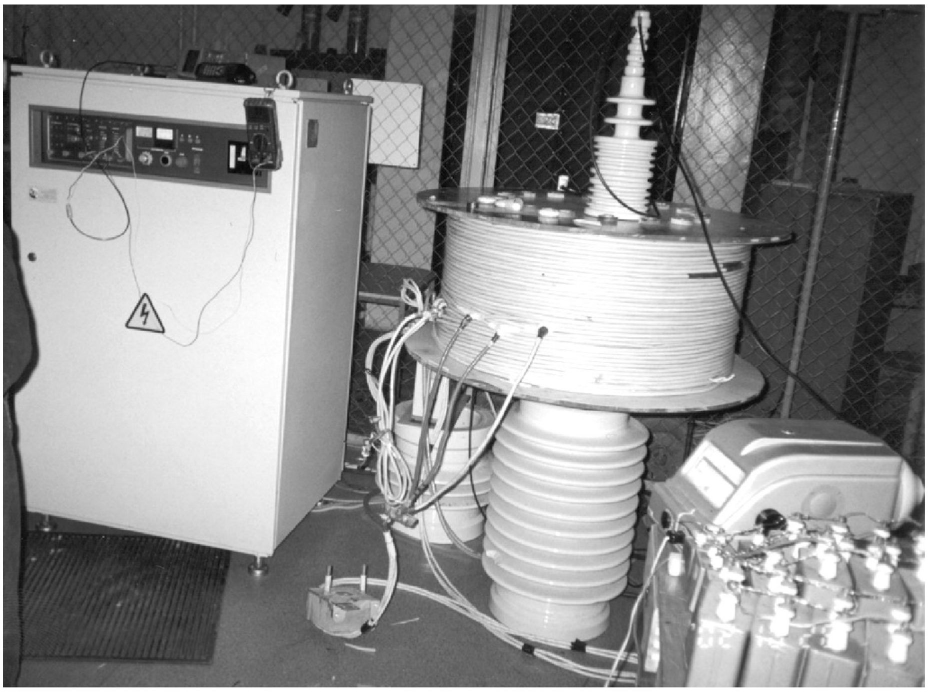

Fig. 2 Frequency converter and a resonant circuit of step-up high-frequency transformer

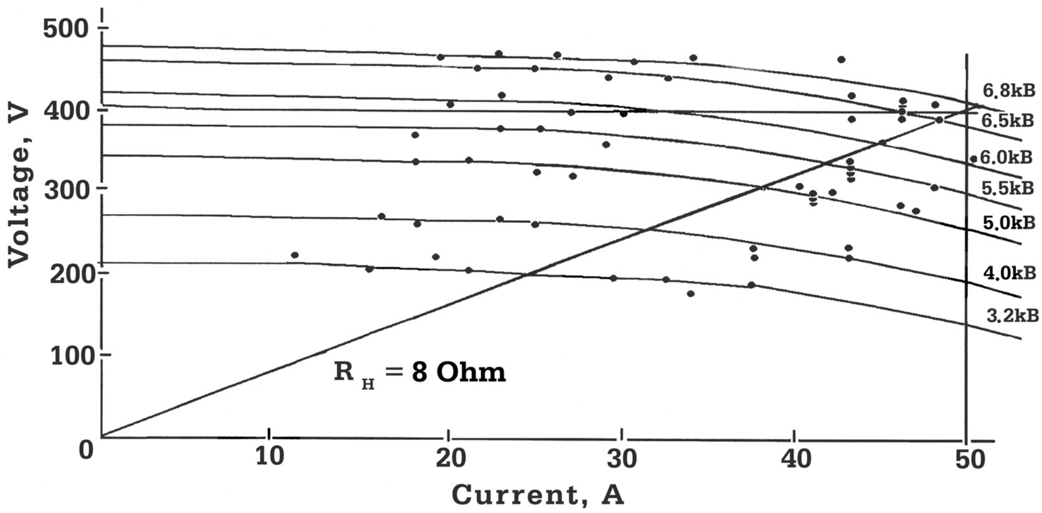

Fig. 3 Experimental volt-current characteristics of the step-down transformer and load

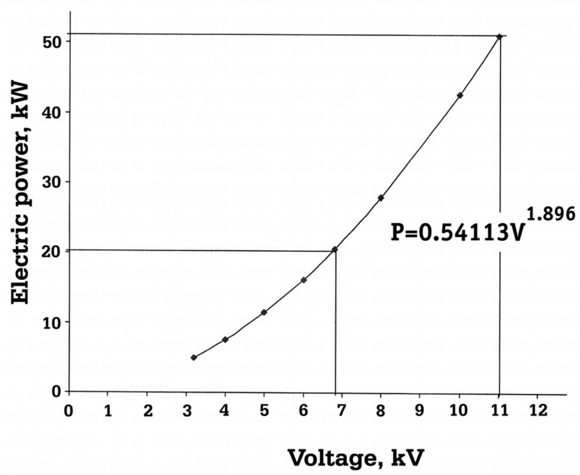

Fig. 4 Dependence of SWEPS electric power on a voltage of a line

References

1. Tesla N. Apparatus for transmission of electrical energy. US Pat N 349621, 15.05.1900
2. D.S. Strebkov, S.V. Avramenko, A.I. Nekrasov, O. A. Roshchin. New Results of Development and Testing of Single-Wire Electric Power System. New Energy Technologies, 2002, N 5 p. 17-19