New Results of Development and Testing of Single-Wire Electric Power System

Prof. Dmitry S. Strebkov, Eng. Stanislav V. Avramenko, Dr.Aleksey I. Nekrasov, Eng. Oleg A. Roschin

(See photos on the cover page)

The All – Russian Institute for Electrification of Agriculture.
Address: VIESH, 1-st Veshnyakovsky proezd, 2, Moscow109456, Russia
Phone: 7 095 1711920 Fax: 7 095 1705101 E-mail: viesh@dol.ru

Abstract

10 kW, 3 kV, diameter 100 mkm, 6 m long electric power transmission line was tested, demonstrating specific current density 428 A/mm^2 and specific electric power density 1,28 MW/mm^2 without overheating of copper single-wire line with diameter 100 mkm.

Scientists of the All-Russia Scientific Research Institute of Electrification of Agriculture (VIESH) Academician D.S. Strebkov, Eng. S.V. Avramenko, Dr., A.I. Nekrasovym, by post-graduate student O.A. Roschin developed a new method and the equipment for transmission of electric energy on a single-wire line using resonant idle operation mode and reactive capacitive currents for transmission of active electric power. There is created the experimental sample of single-wire electric power system (SWEPS) with 10 kW electric capacity and 3000 V voltage. A single-wire line is made from a copper wire, which has 100 microns diameter and 6m length. At room temperature there was a specific transmitted electric capacity of 1280 kWt at effective density of a current of 428 Amperes on one square millimeter of the area of cross section of the single wire line.

Obtained SWEPS electric parameters a hundred times exceed parameters of a usual two-wire or three-wire alternative and direct current line. It could be achieved for existing methods of electric power transmission only at use of special materials in the mode of low temperature superconductivity.

With use of SWEPS technology VIESH scientists developed:

- the new method and the equipment for single-trolley electric transport (electric car, a trolley bus, a tram, an electric train), **the patent of the Russian Federation - 2I365I5, 26.08.1998**;
- electric power supply of mobile electric units on a single-channel superthin cable (a tractor, an air balloon, the helicopter), **the patent of the Russian Federation – 2158206, 15.04.1999**;
- method for transmission of electric energy on the isolated sites of the ground, water, pipelines, carbon strings and films made of oxides of metals on fiber optic communication lines, **the patent of the Russian Federation – 2172546, 24.01.2000**;
- method for wireless transfer of electric energy in atmosphere of the Earth on a laser beam, **the patent of the Russian Federation - 2143775, 25.03.99** and outside an atmosphere on an electronic beam, **the patent of the Russian Federation – 2163376, 03.07.2000**; with use of the Earth and conducting channels in ionosphere , **the patent of the Russian Federation -2I6I650, 14.07.1999**;
- cold plasma coagulator for veterinary science and medicine, **the patent of the Russian Federation – 2100013, 11.04.1995**.

Practical value of SWEPS consists in an possibility to develop:

- reduction of both aluminum and copper consumption in wires and cables in 100 times with their replacement by steel wires with the copper anticorrosive covering, used in wire radio and telecommunication;
- significant (50 %) economy of motor fuel and improvement of ecological conditions (reduction of emissions in 10 times) due to usage of single trolley private and public transports in large cities and of electrotractors with thin (1 mm^2) cable;
- creation of wireless transmission of electric energy on the Earth and in Space, and also between objects on the Earth and in Space;
- creation of essentially new electrotechnological installations and plasma generators.

Experimental results

The method of electric energy transmission on a single-wire using operation mode and reactive capacitive currents for transmission of active electric power has been developed. The equipment with capacity of 20 kW has been designed. The equipment comprised Tesla transformers, which were connected to the line with two resonant circuits, and adjusted to the resonant frequency f_0, where 100 Hz < f_0 < 100 kHz. Placed in the beginning of a line the resonant circuit consists of the primary winding, the step-up high-frequency Tesla transformer and condensers battery, which were connected in parallel to the primary winding. The parallel resonant circuit was connected to the static frequency converter. As a load there were used 24 filament lamps (220V, 1 kW) that were arranged in 12 parallel groups, each consisted of 2 connected in series lamps. The lamps were connected to a step-down Tesla transformer through a 400V/25kW bridge rectifier.

A three-phase *Petra-0115A* thyristor converter (input: 25 kW 220/380V, 50 Hz, output: 400 V, 2.5-7 kHz) was used as a static frequency converter. A 6 m long, 100 mkm diameter copper solid wire in 10 m thick enamel isolation was used.

The parameters of the single-wire line were defined by RLC mether *ELC- 1310*. The parameters of the electric equipment were measured with the use of the following devices:

At the input of the frequency converter: by the electronic energy meter **"Energy – 9" STSK3-10 Q1H6P**, designed for measurement of active and reactive capacity and energy, phase currents and voltage, frequency and power factor.

The **panel-board ampermeter and voltmeter M42301**, class of accuracy 1.5 with measurement limits 150A and 600V were used in the rectifier circuit of the frequency converter.

Load current and voltage at the output of the rectifier bridge were measured by a **DC ampermeter M38I**, class 1.5 with maximum current 75A, the shunt of 75 mV, 0.035 Ohm and a **DC voltmeter E59**, class 0.5 with measurement range of 75, 150, 300 and 600 V.

The single-wire line voltage was measured by means of **kilovolt-meter C196** with measurement limits of 7.5 kV, 15kV and 30kV.

The line frequency was measured with a **digital multi-meter *Protek 505***.

Since January till October 2002, more than 100 tests of the electric equipment and single-wire electric power transmission lines with various types of transformers and frequency converters have been carried out.

In the Table 1 and 2, the results of tests of electric equipment 1 dated 27.09.2002 are given. Test results show that a copper wire with 100 m diameter (cross-section is $7.85 \cdot 10^{-3}$ mm^2) is capable to transfer electric capacity of 10.08 kW under 3 kV voltage without over heating of power line. For a conventional or three-phase line, these parameters (power density of 1.28 MW/mm^2 and current density of 428 A/mm^2 and line voltage of 3 kV) could not be achieved, using standard equipment (Fig 1).

Thus, the ability of a single-wire line to transmit active power without considerable Joule losses in the line is experimentally proved. The losses in this electric power transmission technology occur mainly in the converter as in DC high-voltage lines. These losses can be reduced to a level acceptable for industrial application owing to improvements of electric and mechanic design.

Table 1

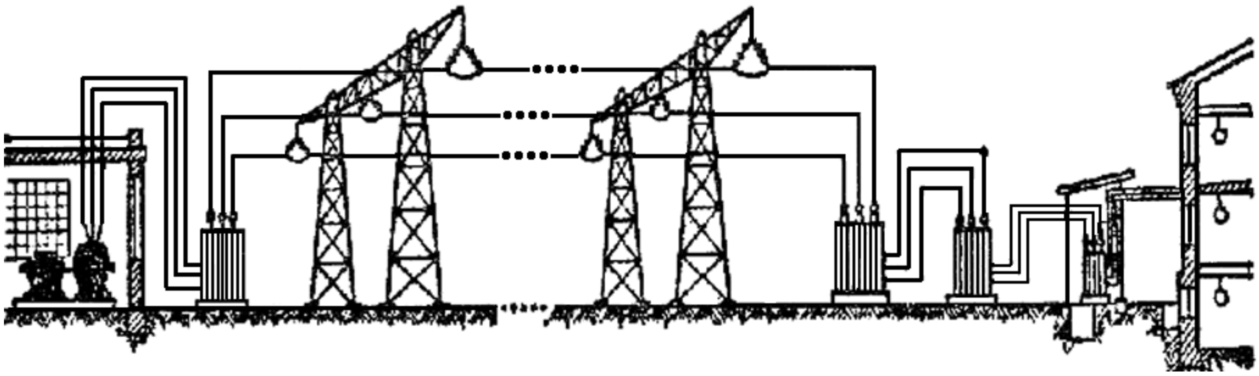
Test results (2002-09-27) for single wire electric power transmission line equipment

Main parameters at the input of the frequency converter	**Parameters of the rectifier of the frequency converter**	**Single wire line parameters**	**Parameters of DC load at the output of the bridge rectifier**
I = 22.1 A	I = 25 A	L = 6 m d= 0.1 mm	I_L = 40 A
Vph = 225 V	V = 520 V	V = 3 kV	V_L = 252 V
Pa = 14.9 kW		L_{1kHz}= 2.9 μH	P_L = 10.08 kW
Q = - 0.692 kVAr			
f = 50.0 Hz		f = 2.647 kHz	
φ = 3° (power factor = 0.9986)		R_{1kHz}= 9.54 Ohm	

Table 2
Results of tests of 10 kW single-wire electric power transmission system (SWEPS)

1. **Electric capacity on loading**	10 kW
Operating current	40 A
Operating voltage	252 V
2. **Parameters of the single- wire power line:**	
Voltage of the line	3 kV
Frequency of a line	2.647 kHz
Diameter of copper wire	100 mkm
Effective current density	428 A/mm^2
Specific electric power	1.28 MW/mm^2

CONVENTIONAL ELECTRIC POWER SYSTEM.



1 2 3 4 5 6

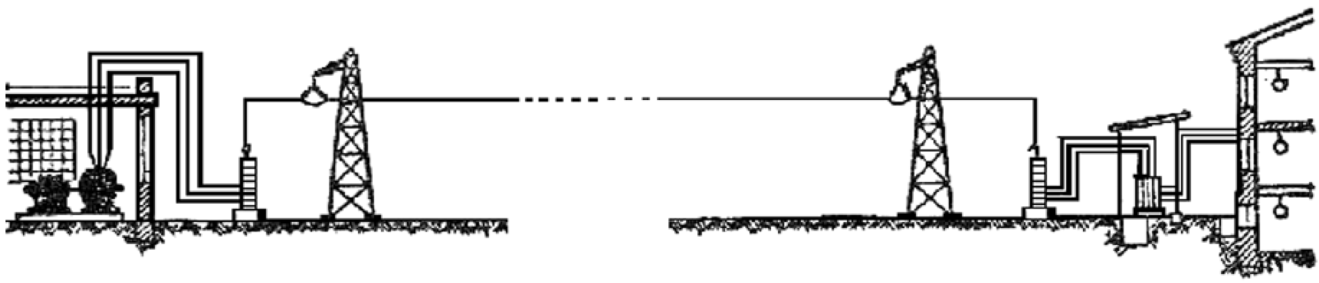
1 – Electric station generator 6 kV, 50Hz;

2 – Step-up transformer 6 kV/ 110 – 500 kV, 50Hz;

3 – Three phase electric transmission line 110 – 500 kV, 50Hz;

4, 5, 6 – Step-down electric transformer 110 – 500 kV/36/10/0,38 kV, 50Hz

SINGLE – WIRE ELECTRIC POWER SYSTEM.



1 2, 3 4 5 6

1 – Electric generator 6 kV, 50Hz, 1-10 kHz;

2 – Frequency converter (is not necessary if frequency of electric generator 1-10 kHz);

3 – Step-up transformer 6 kV/ 110 – 500 kV;

4 – Single – wire power transmission line 110 – 500 kV;

5 – Step-down transformer 110 – 500 kV/10 kV, 0,4 kV;

6 – Inverter 1-10 kHz/50 Hz. Output: The conventional electric grid of customer's standards.

Fig 1.
Comparisons of SWEPS and conventional 3-phase transmission line

THE TRANSMISSION CAPACITIES:
1 W – 1 GW

THE ADVANTAGES:

- High electromagnetic stability due to the resonance mode of operation;
- Considerable decrease in resistance losses due to the idle mode of the power transmission and the use of reactive capacitive current for transmission of active power;
- Considerable decrease in investment due to simple design of pillars and the significant decrease in wire materials consumption. Wire diameter is 3-5 mm, material is steel, instead of copper or aluminum, and wire diameter is 10 - 20 mm;
- Independence of operation mode and frequency for different parts of electric grid.