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It is Quite Another Electricity -

Transmitting by one wire and without grounding

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“It cannot be, because it can be never”

Anton Chekhov

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1. Introduction from history point of view

The War of Currents (sometimes, War of the Currents or Battle of Currents) was a series of events surrounding the introduction of competing electric power transmission systems in the late 1880s and early 1890s including commercial competition, a debate over electrical safety, and a media/propaganda campaign that grew out of it, with the main players being the direct current (DC)-based Edison Electric Light Company and the alternating current (AC)-based Westinghouse Electric Company.

The method of AC received large impetus after invention of three phase system. (See US Patent Publication number US427978 A Publication date May 13, 1890 Inventors Michael Von Dolivo-Dobrovolsky)

We are using three phase system essentially for last 120 years after Dolivo-Dobrovolsky’s invention, Russian engineer from my city Sankt Petersburg.

Dolivo-Dobrovolsky

The first triumph of the three-phase system was displayed in Europe at the International Electro-Technical Exhibition of 1891, where Dolivo-Dobrovolsky used this system to transmit electric power at the distance of 176 km with 75% efficiency.

The intensive implementation of three phase system begins from this time. The major part of electrical energy generates and distributes by three phase systems till today.

But efficient generator and efficient motor maybe the only advantage of three phase system.

These technologies has changed in the last 120 years.
Three phase systems did not change significantly. It is now clear that this system has many problems. It has only one advantage. It allows implementation efficient generators and engines.

But it has the following disadvantages:

- Many expensive wires (three or four);
- Large expensive supports for wires;
- There are intermediate stations sometimes every 30 km;
- Underground and underwater three phase system are very expensive
- Strong negative environmental impact;
- Large number of wire breaks
- Large energy losses

The following parts of this book will show that it is possible today to make electrical system without these disadvantage and implement three-phase generators and motors.

These deficiencies contributed in recent years, to development and implementation of high-voltage DC systems (HVDC).
For very long-distance transmission, HVDC systems may be less expensive and suffer lower electrical losses. For underwater power cables, HVDC avoids the large current requirement to charge and discharge the cable capacitance during each cycle. For shorter distances, the higher cost of DC conversion equipment compared to an AC system may still be justified, due to other benefits of direct current lines (https://en.wikipedia.org/wiki/High-voltage_direct_current).

The main disadvantages of HVDC are in conversion, switching, control, availability, and maintenance. The required converter stations are expensive and have limited overload capacity.

Operating an HVDC circuit requires significant number of spare parts to be kept, often exclusively, for one system. In contrast to AC systems, realization of multi-terminal systems is complex (especially with line commutated converters), as well as expanding existing circuits to multi terminal systems. The grounding systems in DC circuits are more complicated and have higher resistance.

Is it a time to implement the method, first proposed by the great Tesla? (See patent Single-wire electrical energy transmission by Nikola Tesla (1890) [US Patent number 1,119,736])

Nikola Tesla

“Transmission of electricity requires at least two wires” - this statement has been ingrained in the consciousness of engineers for over 150 years. How else, after all any battery and any coil of a generator have minimum two terminals. Any loads for electrical energy have minimum two terminals also. Therefore electrical circuit must have minimum two wires. Usually in books, articles or lectures authors explain the work of an electrical circuit as the process of current flowing from the generator to the load, and then back to the generator. So we need minimum two wires. And nevertheless the necessity always to have two wires (two channels) is not so obvious [1].

Actually, during more than 100 years the mankind transmits the information and the energy over from transmitter to receiver by means of the electromagnetic field. Here we deal with one channel.
If it is necessary to reply over ether, the other channel is used, but once again it is a single channel. These channels are separated in time or in frequency, or they are distinguished by means of a special code. Somebody may say that at this kind of radio-communication there are two channels, as the electromagnetic field has two components: electrical and magnetic one. Indeed, at the point of reception there are a magnetic and electric fields. Relation between the fields is $120\pi$. Knowing level of one of these fields and radiation resistance (or current value or effective isotropic aperture) of the receiving antenna, we can compute the active power reaching the receiver. Therefore, we are dealing with a one-way system.

The other example of a one-way system is the communication by means of fiber-optical lines.
From one end of globe to another one optical cable is laid, which transfers huge volume of the information. No return cable is required. The other cable is used only in case of the necessity to transmit some additional information or as a backup. It is worth mentioning that the electrical energy for feeding of the optical signal amplifiers, which are being installed over certain distances, usually is transferred over the single wire too.

One more example of single-channel system of the energy and information transmission is a waveguide, which is being widely used today in the communication technology.

The waveguide is the channel of natural or artificial origin, providing the propagation of wave of a certain nature along some axial line or axial surface having relatively small attenuation and limiting the existence of this wave by the region of space which is located near this axis or the axial surface.

But let us revert to wire electrical system, about which the majority of specialists and amateurs have the firm opinion that it should be multi-wired. Here it is necessary to give notice that the author of this book is not a physicist and he has no intention to give scientific proof for some new theory of electricity. In this part
he only would like to pay attention to some widespread absence of logic in explanations of electrical processes.

Today there are many people are not satisfied with widely accepted description of the processes occurring in an electric chain. This description is based on a model in which electrons (or other charges) move inside of the conductor. Sometimes it is even presented as that the electrons do not move, but push one another, as in the known “domino effect.
But such an explanation is not plausible. Electrons are the mechanical particles having some mass. They cannot be moved or push each other with the speed of light. But the electrical signal is being transferred exactly with the speed of light.

And there is one more contradiction. When the operation of the most popular monopole antenna is being described, the current at the end of the monopole should be equal to zero as it has no way to go any further. But then the question arises: where electrons that arrive to the end of the antenna, disappear.
The transmission should be stopped, but the antenna nevertheless operates.

One more contradiction is the explanation of processes in grounding systems. In the grounding systems the current enters into the earth. What happened is that at the depth of a few meters it is impossible to find out any traces of this current. Where has it got to? There are many attempts to explain these processes. And all these explanations are different. Some people write that the earth is a huge capacitor. But, first, the capacitor should have the second plate. And, secondly, inside of the capacitor should be dielectric. And the earth cannot be a dielectric. The others explain the processes in grounding as current absorption. But absorption cannot be infinite. Any sponge, when it will be filled with water, will stop it to absorb. There are also other explanations, but all of them cause new questions.

However it is habitual and comfortable to use the term current, even if there is no flow.
Let us return to the question of the continuity of the current in an electrical circuit. It is difficult to speak of continuity of the current, if the circuit uses transformer.
But still more difficult to talk about it, if there is a capacitor between the plates of which there is a perfect insulator. Insulator does not let current through, but the circuit works properly and in accordance with Ohm's law. While creating the electromagnetic theory, Maxwell had introduced the concept of displacement current.
In addition to the conductivity current, the displacement current is a quantity appearing in Maxwell's equations that is defined in terms of the rate of change of electric displacement field. Displacement current has dimension of electric current density, and it has an associated magnetic field just like as the actual currents do. However it is not an electric current of moving charges, but a time-varying electric field. In materials, there is also a contribution from the slight motion of charges bound in atoms - dielectric polarization.
The idea was conceived by James Clerk Maxwell in his 1861 paper On Physical Lines of Force in connection with the displacement of electric particles in a dielectric medium. Maxwell added displacement current to the electric current term in Ampère's Circuital Law. In his 1865 paper A Dynamical Theory of the Electromagnetic Field Maxwell used this amended version of Ampère's Circuital Law to derive the electromagnetic wave equation. The displacement current term is now seen as a crucial addition that completed Maxwell's equations and is necessary to explain many phenomena, particularly the existence of electromagnetic waves.

Thus, we can assume that the current is a mathematical variable equal to \( V \) divided by \( Z \). It is convenient for the analysis of electronic circuits.

So, probably, one cannot consider that the electric wire is a pipe along which something flows. Probably such an understanding had taken roots because of the meaning of the word “current”. And maybe the concept “current strength” is in principle not necessary even though it is convenient. But everyone knows that current strength is potential difference divided by resistance and perhaps it is quite enough to use these two concepts. Certainly, the concept of current strength is convenient for calculations, simulations and substantiations of various laws.

But we know some other examples when the terms or values which do not exist in the nature but are convenient for analysis are applied. For example, in the theory of transformation of signals the concept of negative frequency is widely applied, but though frequency cannot be negative. Taking in account these and other contradictions, the author had come to the following assumption:

Evidently, no “flowing” of the electrical current takes place. The source creates a potential difference. These potentials, owing to magnetic field existing around the wire, are prorogated along its outer surface with the speed of light. (Hereupon, the well known Skin Effect arises). If the potential difference meets a resistance, it produces a work.

It is well known that the active energy does not return from load to source. And it means that the second channel is not necessary. True, the second wire nevertheless may be necessary, because it is necessary to transfer not a potential, but a potential difference. But to this issue we will return in following section, where it will be shown that an energy and information can be transferred on any frequency, including a direct current, over one wire.

There were earlier attempts to perform electrical energy transmission by means of one wire. There is Goubau line, or G-line for short, which is a type of single wire transmission line intended for use at UHF and microwave frequencies [2]. There was AFEP experiment based on the Russian patent application filed on May 10, 1993 by Stanislav and Konstantin Avramenko (PCT/GB93/00960) [3, 4].

This is also a straight-forward application of the single-wire electrical energy transmission based on the principle of longitudinal electrostatic waves as it was described by Nikola Tesla in 1890 [5]. These and other known resonance methods use increase in frequency. In case of large power, these systems must have noticeable losses due to radiation.
There is and have been used for a long time, so called, single wire earth return (SWER) system [6]. In such systems one port of the source and one port of the load connected to the ground. It will be shown later that these systems have large reactive power, due to inherent unbalance. This circumstance will be proved in detail in following sections. Assuming that the active energy does not return from load to the source, we can attempt to construct a single-wire electrical line. The line should not use the ground for the energy transfer from the source to the load. The current, as a matter of fact, will not be entered into the earth. It should not change frequency of source and not have additional losses as compared with conventional two-wire or three-phase lines. The author is sure that the future electrical systems will be single-wire lines being laid under the earth.

In the following sections, the single-wire balanced electrical system B-Line or SLE (Single Line Electricity) or One-wire System (all these are synonymous) is presented [7, 8].

2. Explanation and Check of the Main Idea

Conventional electric A-line (see Fig.1 the left part) is a combination of the generator and the load connected by two wires, in which phases of currents are opposite (differ by \( \pi \)).

![Conventional two wires circuit (A-Line) and proposed B-Line circuit.](image)

It is obvious, that if we unite these two wires, we get short circuit. But if we nevertheless want them to unite, it is necessary to change phase in one of these wires to the opposite one. But the amplitude in both wires should be identical.

This can be achieved by inserting phase shifter in one line. It is known that the voltage or current phase in an electrical line changes on the opposite one through a time interval equal to half of the period. For instance, 10 ms (half period) delay line can be used for signal with frequency of 50 Hz. Below it will be shown that on low frequencies the phase shifter in form of a transformer with opposing coils is more convenient. After the phase shifter, phases and amplitudes of the currents in both lines are identical and both lines can be combined into one. But the load requires a potential difference and not a single potential. Then in order to provide the normal load functioning a phase shifter can be inserted before the load in one of the wires. As a result, the two wire system turns into one-way B-Line system (see Fig. 1 the right part). That is, the generator and load will “see” the previous (which have existed before the phase shifters insertion) condition. In other words “from the point of view of the generator and load” nothing had changed.
The same results can be obtained by inserting phase shifters in both lines and shifting the phase in one line by $\phi$ and in another line by $-(\pi-\phi)$. This can be achieved by means of delay line, transformer with opposite coils, filters or another phase shifters, for example Hilbert transformation. If delay line is used as a phase shifter, then its delay time must correspond to half period. In the case of low frequencies, use of delay line is practically impossible, since the wire, which corresponds to half wavelength at 50 Hz, should be 3,000 km long. At low frequencies, it is convenient to use transformer with reversed coils as a phase shifter. For high frequencies, delay line is a quite suitable solution.

All above-stated can be summarized as follows:
(1) There is a two-wire line, where the currents in the wires have opposite phase;
(2) The phase of the current in one wire is changed by 180 degrees ($\Box$), or the phases of the currents in both wires are changed: in one by plus 90 degrees and in the other by minus 90 degrees;
(3) Since amplitude and phase are the same in both wires now, these wires can be combined;
(4) The current is being split into two currents before load. The phase one of the current is inverted or phases of both currents are shifted as in item (2)

Let us consider the results of simulations at frequency 50 Hz.

The proposed idea was checked many times using ADS program. Series of simulations with different phase shifters and various resistance lines were carried out. Each simulation was carried out for the A-Line and the B-Line. For clarity, the figures below show the conditions and the simulation results including polarity and magnitude of currents. Fig. 2.2 shows one of the simulations for the Ohm’s law verification in the proposed circuit. This is the A-Line circuit with the current in the line of 90 $\mu$A.

![Fig. 2.2 Conventional two-wire circuit (A-Line) as a prototype for B-Line](image)

In this circuit the resistance of each wire should be equal to 1 kOm. In the proposed B-Line circuit, we added phase inverters at the input and at the output, and combined two lines. As a result, a line resistance became 0.5 kOm.

The simulation shows that the currents at the input and output have not changed (see Fig. 2.3). The polarity of the load current depends on where the inverters are located: at the top or at the bottom.
Fig. 2.3 B-Line version of A-Line in Fig. 2.

Fig. 2.4 shows simulation results of B-Line corresponding to the circuit shown at Fig. 2.3.

The phase of the current in one wire can be inverted with the help of a transformer with reversed coils. The lower ends of the coils should not be connected, otherwise the current will flow from one coil into another.

As it was mentioned above, in practice it is difficult to create a delay line at frequencies 50 and 60 Hz. But one can apply a transformer with opposite wired coils (see Fig. 2.5).
Such a phase inverter requires a zeroing of the middle point potential, around which phase turn takes place. In other similar cases, zeroing is usually performed with the help of the grounding.

As it will be shown below, the grounding in this case does not take part in the process of energy transmission from the generator to the load. Moreover, it will be shown that the zeroing can be performed and without the entering of the current into the earth.

The simulation results in a circuit with ideal 1:1 transformers are shown in Fig. 2.6.

![Fig. 2.6. B-Line in which transformers are used as invertors.](image)

In this circuit the current in the common wire corresponds to the Ohm law. Therefore no other current (for example, in the ground) can be.

If the B-Line is used in a system with an increasing or decreasing voltage, the transformers must be used at the beginning and at the end of the line. An example of such a system with voltage in the line 6 kV is described in the section “Experimental systems” [7, 8].

**DC B-Line**

Implementing the inverter (phase shifter) in a DC circuitry requires a different solution then the aforementioned transformers. According to the main idea of the B-Line, it is proposed to use two capacitors and corresponding switches to implement the inverter as shown with respect to Fig. 2.7 in the source side and correspondingly at the load side.

In this circuit we will designate as “period A” the state, when the keys are closed in the points A, and as “period B”, when the keys are closed in the points B.
Fig. 2.7 DC B-Line example

Each of the inverter operates as follows: In period A, the first capacitor is charged and the second is discharged. In period B, they change the functions. The charge current has one direction, and the discharge current has reverse direction.

As a result, the summed current in the common wire will have the polarity of the current, which does not take part in the charging of the capacitors.

In this example, in line current has one direction, positive or negative. In fig.2.7 the direction is positive.

The charging and discharging times of the capacitors one can set taking into account the value of load resistance. Such a DC B-Line system can be implemented in an electrical railway system (i.e., tram). In this case, it is possible to transmit electrical power only in the wire or only in the rails.

In the circuit shown on fig.2.7 a serious problem exists, which is connected with zeroing of potentials. This problem is caused by larger difficulty making grounding for direct current than for alternating current. This is well-known in systems of electric transportation and in single-wire power supply systems of amplifiers for optical lines.

However, even for this case, an acceptable decision has been found. It is described in section 5.

In the end of this section it is necessary to notice that the current in single-wire system twice higher than in two wire system. It means that resistance of a wire should be twice lower. However one wire with linear resistance R/2 is cheaper, than two wires with linear resistance R. In addition, the transmission towers will cost much less. Possibly biggest advantage of single-wire systems is possibility of cost effective energy transfer underground or under water (see about it in section 9).
3. **Zeroing without the current injection into the ground. Nullifier Zeroing for AC systems**

An electrical ground system should have an appropriate current-carrying capability in order to serve as an adequate zero-voltage reference level. In electric circuit theory, a "ground" is usually idealized as an unlimited current source or the charge absorber, which can absorb an unlimited amount of current without changing its potential [11].

![Image](image-url)

**Fig 3.1**

The linear resistance of ground (between two points on the surface) is great (50 - 1000 Ohms per meter). Therefore energy cannot be transmitted between two points through the ground.

Potential zeroing is the main objective of the grounding in the systems for electric power transmission over considerable distances. As it shown in various sources, if the grounding is made properly, it is impossible to find out any current traces on depth more than 10 m [9 - 11].

However, in many simulation programs, such as ADS, there is only one ground bus. Therefore, it is impossible to separate the transmitting and receiving parts of the system, since they have joint ground (common grounding).

Grounding in B-Line is intended for potential zeroing only. However, zeroing can be made by other methods too, not by using ground. For example, if two B-lines with opposite phases are remote from a source, you can combine both points designed for zero potential. In this case, you don’t need grounding as shown in section 6. It shall be noted, that this method is quite acceptable in practice as the high power stations often have several outputs.

However a necessity of potentials zeroing exists almost in all electric systems. It can be the grounding for protection systems or zeroing of the neutral line in three-phase system, or zeroing in the asymmetrical antenna, for example, monopole, or potentials zeroing in single-wire system, for example, SWER or SLE.
The zeroing is necessary also in some systems, working with direct current, for example, in the electrical transport facilities or in the power supply system for optical cable amplifiers.

Today zeroing is made by means of grounding. Usually the grounding is a metal pin having about 1.5 m of length inside the ground.

If resistance of grounding results in the unacceptably high energy losses, one can use several groundings, which are connected in parallel and located at distances not less than 10 m between them (See Fig 3.2).

Usually the grounding creates many problems. These problems are connected with instability of ground parameters with change of weather conditions. In addition to it, the grounding often demands large area. Besides, in some countries it is possible to use grounding only for protection, as they are afraid that the electric current can do harm to animated beings and to plants in the ground.

Today there are no universally recognized explanations for grounding operation. See about it in the introduction (Section 1).

Below another explanation of the zeroing process is given and the new device for realization of zeroing, which we name “nullifier”, is offered.

**AC zeroing system – this is an antenna.**

The current which is being injected into ground is divided into the great number of weak currents. When ground depth increases, the quantity of currents grows and, hence, the amplitude of each current decreases to zero. Let us consider protection grounding of electrical cabinet.
Potential difference is necessary for the current to flow. But we have here only one potential (V), not difference of potentials like it is in a broken wire. Can current flows through broken wires? Yes, it can, for example, in a linear antenna.

In case of electrical antenna like a dipole or monopole, the current stops at the ends of radiators but its energy converted into the energy of the electromagnetic field. It means, the energy path is not interrupted.

Now we can imagine a lot of ground connected at the input of very short monopoles. It is known that monopole with height h, where h \(<<\) \(\lambda/4\) has radiation resistance equals [12]

\[
R_{\text{rad}} \approx 14(mh)^2 \Omega, \quad m = \frac{2\pi}{\lambda}
\]

This resistance tends to become zero with a decrease of h compared to the \(\lambda/4\). Decreasing radiation resistance leads to decreasing of radiating power because

\[
P_{\text{rad}} = R_{\text{rad}} \cdot I_{\text{rms}}^2
\]
So we can say that monopole with $h \approx 5 - 10$ m at frequencies 50 or 60 Hz has zero resistance and zero radiation field density.

The monopole with height much less than the quarter of wavelength has a capacitive component [14]. But parallel connection of monopoles results to decreasing capacitive resistance also.

In other words one can tell that grounding is an aerial consisting of a considerable quantity of monopoles, with length much smaller than quarter of a wavelength. If this hypothesis is correct, it is possible to make “Nullflier” in the form of a device isolated from the earth and other conductive objects.

This nullflier can consist of the electro-conductive rod with length about 0.5 - 2 m out of which the set of wires or thin rods of approximately 2 - 5 m sticks out and connected to the central pin. Supports made from non-conductive material. An example of the nullflier, where electrical wires are used as a line, is shown In Fig.3.5.

One can make the nullflier by taking the isolated volume (Fig. 3.6) filled with a semiconducting material of soil-type or with soil itself. It can be a concrete pipe of round or rectangular cross section, 3 - 10 meters long and with cross section of 10-15 square meters. As well as in case of usual grounding, the conductive rod about 1,5 meters long is being inserted into this volume.
The real nullifier of such type is shown on Fig. 3.7.

For implementation of such nullifier in an experimental single-wire 6 kV system a ditch by 3 m depth and 5 m long has been dug (see section 6). Walls and bottom of the ditch have been covered by no conducting fabric of nylon type. The results of this nullifier implementation are given in Section 6. If resistance of a nullifier is not low enough for a high-current system, it is possible just like in usual grounding to connect several nullifiers, as shown on fig. 3.8
The same idea of the nullifier resistance decrease can be applied also in case of the 
“air” nullifier usage, shown on Fig. 3.5. Then we get a design, shown on Fig 5.9. If the 
number of wires, which was used to make the nullifier, shown on Fig. 5.9, was not 
enough or the volume of the nullifier, shown on Fig. 3.7, was not enough large, the 
nullifier will have too large capacitance resistance. In this case the capacitance 
resistance can be compensated by way of incorporation of an inductance L between the 
point, which requires the zeroing and the nullifier, as shown on Fig. 3.9

This method has been checked at the frequency of 1 MHz (The programs, which we 
know, do not make it possible to do antenna simulation on frequency 50 Hz). 
At first, the monopole, which height (12 mm) is much less than quarter of wavelength, 
had been checked (see Fig. 5.9)
In this case active resistance will be 0.65 Ohm and reactance – 453 Ohm. Then the additional „rays“ were added (Fig 3.11)

In this case, the active resistance was equal 0.8 Ohm, and reactance - 60 Ohm. Then between the source and the input of “antenna” an inductance was incorporated. In this case the active resistance has proved to be 1.0 Ohm and the reactance – 1.98 Ohm. Thus, such a circuit is completely suitable for the zeroing of potential.

**Single frequency nullifier**

We propose here a zeroing using a device that does not contain ground also, in order to resolve this problem in ( ) simulations. Its functioning is clear from the figure shown in Fig. 3.12
Here zeroing takes place by addition of two currents of the same amplitude but with the opposite phase.

This method of zeroing (or this nullifier) works only at frequency: \( F_0 = \frac{1}{2\tau} \) or at all other frequencies satisfying the condition: \( F_n = \frac{1}{(2n + 1)\tau} \), because on all these frequencies the delay \( \tau \) gives phase shift 180°.

The method shown on Fig. 3.12 in practice can be implemented only at high frequencies because there the realization of the delay line is not a problem. At low frequencies (50 - 60 Hz) this method is suitable only for simulations.

In section 2 in Fig. 2.5 the circuit of an inverter being intended for transformation of two-wire signal into single wire signal and in which middle point demands (the) zeroing is given. The application of a nullflier which is described here, allows making zeroing, without current injection into the ground (Fig. 3.13).

![Fig. 3.13 Inverter with single frequency nullifier](image)

As it was noted above, in many countries at request of "Greens" it is allowed to inject a current into the ground only (at systems) for protection against short circuits. The decisions presented here in the form of "Nullflier", allows satisfaction these requirements without any harm to efficiency of electric systems. Besides, the systems of zeroing isolated from the earth, have important advantage as these systems do not depend on weather conditions.

Let us consider the effect grounding resistance of the Nullflier. Here is an example. Let us assume that it is necessary to supply 2.2 MW of electrical power in a city. The main voltage in the city is 220 V. It means that the consumption current is 10000 Ampere and the load resistance is 0.02 Ohm.

We shall supply electrical energy with voltage of 220 KV. It means that a step-up transformer will “see” \( 0.02 \cdot 10^6 = 20 \) kOhm.

In order to get one-wire line, let us apply an inverter shown in Fig.3.13.

But this circuit will not operate because both currents go towards each other and create an infinite resistance.
In order to get the single-wire line, which really operates, let us apply an ideal inverter, i.e. the inverter, in which the wires resistance is equal to zero and the grounding or zeroing is ideal. Now the currents flow and there are no losses.

Let the resistance of grounding or nullifier to be equal to 10 Ohm; it means that the useful current will flow not only through the 20 KOhm but also through the resistance 10 Ohm. It is obvious, that the losses will be negligible.

One can believe that the zero point of grounding is a point inside of ground, where the current is equal to zero and the resistance of grounding is negligible.

The proposed nullifier operates quite in the same way. The current in the antenna end is always equal to zero and the radiation resistance (impedance) of a short (as compared with wavelength) antenna is very close to zero. The “air” nullifier can have a capacitive resistance, but, first, it can be compensated like in Fig 3.9.

The idea of nullifier implementation as an antenna was checked experimentally. For this purpose a system insulated from the ground was built (see the photo Fig.3.14).

![Fig. 3.14 Real air nullifier](image)

The common length of 5 layers of wires the is about 1270 m. Point of the device, which requires zero potential is connected with the bottom point of the rod with a length of 1.5 meters. Two to five meters wires from, extend from the rod to the sides and upwards.
The measurements of this nullifier have shown that it needs compensation of a capacitive component by means of inductance.

The above-mentioned allows to suggest that grounding it is an antenna consisting of the great number of shorter monopoles. The ground is a conducting granular substance. Currents flow between granules going over the distance of several meters. One can believe, that it is very short monopoles (quarter of wavelength at frequency 50 Hz is 3000 km). It means that these monopoles have active radiation resistance equal to zero and large capacitive resistance. But because there are a lot of such monopoles, the capacitive resistance is very small too. Such an antenna practically radiates nothing.

One can have a question: Why the currents flow through in ground not deeper than 10 meters? This phenomenon one can explain in the following way. Let us assume that we applied a potential to a usual ground. At the first moment the length of currents will be small and the quantity of currents will be small. In this case the capacitive component of the grounding impedance will be large and there will be no zeroing of potential. And soon comes the moment, when the grounding resistance will be close to zero. The zeroing of potential begins at this moment and the increasing of the length and quantity of currents therefore ceases.

**Zeroing Grounding? in DC systems**

The problems, which are being created by direct current flowing in ground, include:
- Electrochemical corrosion of the long metal objects lay in ground, such as pipelines.
- By using sea water as the second conductor, the current flowing in sea water can produce chlorine or somehow differently affect water structure.
- The current in water can lead to appearance of a magnetic field, which can affect performance of magnetic navigation compasses of ships sailing over the underwater cable.
- Another serious problem is the wandering currents.

The sources of wandering direct currents usually are ways of electric trains, groundings of direct current lines, installations for electric welding, systems of catholic protection and installations for deposition of galvanic coverings. The example of an appearance of wandering direct current is a tram line, where steel rails are used for current return to generating station.

Owing to bad contact of rail joints and insufficient isolation from ground, a part of the current enters into soil and finds ways through objects of low resistance, for example, through underground gas pipes and water pipes. If the pipe is protected by a nonmetallic covering, it aggravates the corrosive destruction, because in this case all wandering currents leak through defects in the pipe coating which causes the current density increase on the in areas with the limited surface and accelerates pipe destruction.

Many sources, for example http://forca.ru/stati/energetika/osnovnye-nedostatki-setey-vysokogo-napryazheniya-postoyannogo-toka.html, Indicate that grounding of a direct
current transmission line is connected with complicated and labor-intensive installation, as it is necessary to create the reliable and constant contact with ground to provide the correct work, and for elimination of possibility of occurrence the dangerous "step voltage". The application examples of single-wire DC systems are power supply systems of amplifiers of optical cables, including and the amplifiers for underwater lines. For zeroing in the coastal zone the drilling of some deep boreholes to reach ground waters is performed. After that rods with good electric conductance are being inserted into these boreholes. More difficult circuits exist too. The example given in <http://forca.ru/stati/energetika/osnovnye-nedostatki-setey-vysokogo-napryazheniya-postoyannogo-toka.html> shows, that for the current of 225 A it is necessary to use a rod of 33.54 m long.

In various sources it is indicated that resistance of grounding for alternating current can be of the order 10 Ohm

The zeroing system for DC

No antennae works on direct current. But groundings are necessary for zeroing of potential as well as for static electricity removal. In the presence of grounding, the charges of static electricity are being led away into ground and are not being accumulated up to such a magnitude, at which sparks it are possible. The grounding device consists of steel pipes with length of 2-3 m which is dug in the earth in such a way that their top ends were below an earth surface for a half-meter. These pipes are connected to surfaces of protected objects using steel strips. Devices, cars, pipelines required grounding.

The following hypothesis can be made from above mentioned data and variety of other sources. For DC potential zeroing it is possible to get rid of static electricity connecting the necessary point to the big metal object. The cylinder (pipe) made of conducting material of certain length and thickness obviously can be such a device.

For estimation of the possible sizes of cylinders, the following simulation has been performed: a cylinder, which is located above a conducting surface (as it's shown on Fig 3.15, was taken.
The impulse with duration of half of millisecond was used as an input signal. After At the end of the impulse the current flowing via resistor 10 kOhm was measured. It can be suggested that if, at the end of the impulse, the current is not equal to zero; it means that the potential, which is an equivalent of static electricity, remains on the cylinder. During the simulation the different sizes of the cylinder, which made it possible to decrease the magnitude of the current, were being chosen. If the magnitude of the current is less, it means that a part of the potential has discharged. Some results of the simulation are shown in Fig 3.16.

Repetition of above

While taking into account the results of the simulation one can suggest that an acceptable zeroing can be achieved by means of one or several cylinders with length of 1-3 meter and with thickness of walls 10-30 cm. The material of the walls must
not have very high conductivity. It can be aluminum or a cylinder inserted in a box filled with ground.

The rod, to which constant voltage is applied, represents the cylinder over which surface a charge is regularly distributed. This charge possesses potential energy. ?? If all points at the cylinder’s surface connect using resistors of to points which are located at a great distance from the cylinder where electric potentials are equal to zero, the current will begin to flow through resistors. If parallel resistance of all the resistors will be close to zero, the electric potential of the cylinder will be close to zero as well.

In our case the soil in which the zeroing rod is inserted, is all these resistors... As resistance of soil can be very big, the chosen rod should be long enough. This rod is many times longer than the rod being used in AC systems. That is why comparing AC and DC systems, the complexity of manufacturing and operation of system for zeroing is the important factor in favor of AC systems.

There are different sources that indicate that the resistance of grounding of direct current may be of the order of 100 Ohm.

4. Balanced and Unbalanced Single Wire systems, SWER System

Unfortunately the words balanced and unbalanced are used in two different cases.

First, there is transmission lines balanced or unbalanced with respect on zero potential.

Second, there is three phase systems balanced or unbalanced with respect on equality or no equality between loads.

Considering this below we will use words balanced and unbalanced for first cases. But for second cases we will use words load balanced and load unbalanced.

Fig. 4.1 illustrates the normal construction of balanced and unbalanced lines. Balanced lines are used more for transmitting information signals. This allows decreasing the noise influence and interferences [9].
In an electronic and electrical circuit theory, a "ground" is usually ideal sink or source of an infinite amount of charge, which can absorb an unlimited amount of current with potential of the grounding point equal to zero \([9, 10]\). More details about grounding one can see in section 3, where it is shown that, the energy cannot be transmitted between two points through the ground. However, grounding can help transmit energy through single wire.

One can show, that all three circuit circuits, shown in Fig.4.2 (a, b and c) are equivalent, if the distance between a source and a load is much less than wavelength. In practice, if two points of the circuit, for example 3.2 a, have identical (zero) potential, these points can be connected (see Fig 4.2b).
Fig. 4.2 Equivalence of balanced and unbalanced circuits

By not using both zeroing (groundings) in the circuit in Fig. 4.2b, the magnitudes of the currents will not change. In circuit on Fig 4.3d in both wires there are currents which correspond to Ohm law. In circuit on Fig 3.2a and 3.2b the current there is only in one wire. But in these cases potential in working line is above of zero level. Therefore load will receive the same power as in case of Fig.3.2c.

In other words, from the point of view of energy transfer, the two-wire balanced circuit and the single wire circuit of SWEP type are equivalent. However, as it already was specified, this conclusion is fair only if the lines have length that is much less than wavelength. This fact is the main problem of unbalanced systems, for instance, SWER.

This unbalanced line must transmit all the energy and all signals from Tx to Rx. Potentials of grounding in the both points are the same (zero). However, potentials in points A and B (on transmitter output and on receiver input) in Fig. 3.2a are different due to a signal delay and Tx and Rx signals have a different phase. It shall be noted, that in the balanced circuit in case of active load the potential difference on receiver input does not depend on signal delay, as potentials on the ends of both wires change equally by a delay.

This situation can be likened to problems similar to reactive load. In case of a reactive load, there is reactive energy, namely, the source must produce active and reactive energy. And in case of long lines, this system loses a large amount of energy. The problem of the appearance of reactive power in unbalanced circuits is well known [3]. This statement can be illustrated by the example of the SWER system.

About SWER system

The authors of this system claim that in their system only one conductor as well as the current return path through earth (see Fig 4.3) is employed as an electricity distribution method. [6]
Emergence of reactive power in a real SWER system can be shown with the help of a simulation (Fig. 4.4a). In this case the phase shift in a line is \( \cos \varphi = 0.65 \), which corresponds to a line length of 450 km. It is equivalent to the load shunting by a reactance, which must result in increase of the current of generator. In this case the generator current has appeared more than twice higher than the current in the load (Fig. 3.4b).

Fig. 4.3 The **circuit** of SWER system

Fig. 4.4 SWER simulation circuit – a and simulation results - b
Compensation of the reactance, which emerges owing to misbalance, creates the problems due to instability of the load, as well due to the possible losses in compensating filters.

Figure 4.3 illustrates that the SWER system is a usual unbalanced circuit. Therefore some losses of energy can be expected. However these losses are not caused directly by the fact, that the low points of transformers are connected to the earth. On the contrary, as it was shown above, the zeroing leads to losses.

Here, it is clear that the generator must produce a current that is greater than the current in the load. This problem cannot be solved by means of compensation using series or parallel inductivities or capacitors. The reason is that the phase shift of these filters depends on the value of the resistive load, which, typically, is not constant. These filters have significant losses, which considerably complicates the implementation of phase compensating circuit.

**Balanced one wire (B-Line) system**

The author proposes a new single-wire system (B-Line) [4]. The single line method operates as follows. Phase-shifting devices in both wires of two-wire line or in three wires of three phase lines set equal magnitude of the phase in all wires. Therefore, the wires can be combined. Prior to loading a single wire split into two or three wires, and they restore the required phases. The generator in the B-Line circuit produces exactly the same two currents as in the usual balanced two-wire circuit. For this reason, B-Line circuit can be considered balanced. Figure 4.5 illustrates the circuit and results of the simulation of a B-Line system for comparison with the results of the SWER system (see Figure 4.4).

In the case of B-Line, the current of the generator almost equals to the current in the load.
The selected parameters of the delay line correspond to the required phase shift of the load current. The main advantage of B-Line circuit: its ability to transfer a differential (balanced) signal by a single-wire.

5. Three phase system by a single wire

The well-known three-phase system is a combination of three single-wire systems. If all three phases have the same load (balanced circuit), the current in the common wire will be zero. In this case, the fourth wire is not necessary. A problem arises if phase loads change unequally. The main advantage of three-phase systems is in using three or four wires instead of six lines for transmitting three signals, since a three-phase signal is better for some electrical motors and generators. The disadvantages of the three-phase system are: the necessity to use three or four wires for transmitting one signal for a three-phase load, the presence of large distance between wires in many cases, the necessity to use intermediate stations, more expensive transmission line towers and a higher line voltage, which by 1.73 times greater than the phase voltage.

We can demonstrate that the signal being transferred by three-phase system, can be transmitted over one wire. Unfortunately, to change a phase by 120 degrees is not a simple task. The simple one-level filter can change phase less than by 90 degrees. The usage of more complex filters in power systems is complicated and can cause significant losses.
However the task of the three-phase signal transformation into a single-wire signal can be achieved by a more simple method which is being offered by the author. The solution of a converter application for this task is shown in Fig. 5.1a. In this case the phases of two signals are shifted by 60 degrees by means of simple filters. The phase of the third signal is changed by 180 degrees with the help of an inverter.

The same method allows to transform a single-wire signal in three-phase one (Fig 5.1b).

The inverter here is an 1:1 ratio transformer with the opposite connected windings. All three elements determined by given voltage and current.

The values of C and L together with load resistance R must provide the phase shift equal to 60 degrees. Therefore, ratio \( X_c \) and \( R \) must be 1.73. The resistance R can be found from known full load power.

As a result, the converter circuit looks as it is shown on Fig.5.2
Fig 5.2

The circuit and the simulation results of the proposed converter are shown on Fig. 5.3

Fig. 5.3. The circuit of the converter 1 to 3 for three phase B-line circuit and simulation results
Note that this circuit does not need an additional wire even in the case of three different load resistances (phase unbalanced circuit).

In practice the load in the system can change. Therefore it is necessary to change the values of capacity C and inductance L accordingly.

It can be made using feedback from current value changes, which change inversely with a load value. Currently, in order to support the constant voltage level with variable load resistance, the so called “Tap-changing-under-load (TCUL) transformers” are used. But this transformer also does not solve completely the problem of the load resistance change with the attempt to keep the necessary phases. In single wire case, one must increase L and decrease C proportionally to decreasing current (as it shown on Fig.5.4) 

The values of capacitors and inductors can be selected in accordance with the value of voltage change steps in transformer. As a source for feedback signal any non-contact sensor can be used..

Fig. 5.4 Converter 3 to 1

The system of the phase adjustment can be automatic.

In this case the system consists of two parts. The first part is the control part. The feedback signal can be obtained by the known contactless method as is shown on Fig. 5.5.
Fig 5.5. Contactless removal method of measuring the amount of current values

The second part includes relays, variable inductors and capacitors. This part will be different in all systems. The system developer will prepare table with recommendation for these elements.

The practical implementation of this circuit can be not difficult. (see Fig 5.6 a,b). The inductance set is one choke. The capacitors set are set of identical capacitors. There are no gaps, when the current is switching. This inductance with taps and the set of identical capacitors should not be very expensive.
As one can see on Fig. 5.6 a, b in these circuits there is no current interrupt. There is only the current increase or decrease.

Thus we have shown that Single Line Electricity allows transmit from a source of three phase signal to a receiver of three phase signal by one wire instead of three or four wires. But there are two important advantages as well

First. Let there are three phases with wires resistances 1 Ohm, current 1 A and phase voltage 1 V. The power creating in wires (power loss) will be PL = 3 * 1² * 1 = 3 Wt. The same result can be obtained by voltage 3 * (1² /1) = 3 Wt.

But linear voltage in this system is 1.7 V. Let us make single line system with voltage 1.7 V also. For getting the same PL we must have resistance 3W / (1.7)² = 1.0 Ohm.

So instead of three wires of 1 Ohm we will use one wire of 1 Ohm.

Owing to what such a big gain is being achieved? Just three phase system is poor transformer, in which the voltage is increased by 1.7 times, and the current is not lowered.

Second. The normal long three phase line creates reactive power. This is result that this system is unbalanced. The potential of load terminal which connected to line is being changed in case of distance changing. The potential of another load terminal is constant and equals zero. And this equivalent to presence inductance in load. The circuit for simulation three different distances one can see on Fig 5.7
The results of simulation with three different delays there are in Fig 5.8

We can see that with distance increasing (delay increasing) reactive power increases. Here K is ratio between current in generator to current in load.
6. Experimental systems

220 V single line

In addition to conducting simulations and experiments, it was decided to built experimental lines. The first working single line was made between two campuses in Lev Academic Centre (JCT). The transmitting part (source) was located in the first building. The first receiver (light bulb 60 W) was located in another building (See Fig. 6.1).

The second receiver (the same bulb) was located in the first building, but in a different room. These buildings have different grounding points. The wires between the source and receivers are 300m long. 220 V voltages are supplied to the source. The source has one single-wire output for each receiver.

The middle points of the invertors in the both lines have opposite polarities and therefore their connection provides the necessary potentials zeroing. Thus, the source and its inverters are not connected to the earth (see circuit in Fig 6.2).
That is, there is a grounding of both lines in the receiving ends only. One of the buildings has a separate ground for the B-line.

These lines were twice checked by a specialist sent by Israel Department of Energy, which has confirmed that the system operate as single wire line and does not insert no additional losses.

To demonstrate that the ground is not involved in the transmission of the electrical signal, another experiment was carried out at a frequency of 300 kHz (See Fig. 6.3). In this case it is possible to make inverter as a 500 m long line (half period delay line) without any connection to the ground.
**6 kV single Line**

After demonstration of the first experimental line the author has got many remarks, such as "It is not possible", "You use in simulations ideal elements, in real system it will not work", “There is grounding for zeroing, so there ground is another line”, “220 V is not practical system” and so on.

Therefore one more experimental line was built in the center of Israel (in township Tal Shahar). This line works at voltage of 6 kV.

In the beginning was made a simulation of proposed circuit (see Fig 6.4)

![Fig. 6.4 The circuit and the simulation of the experimental 6 kV system](image)

At first the system was checked in a laboratory conditions. The both parts of the system (transmitting and receiving) are shown on Fig.6.5.
At the first stage of tests the zeroing in transmitting and receiving parts have been made by means of grounding.

Next this system was deployed over the length 200 m, making use wire intended for high-voltage.

To this purpose, close to the Transmission Compartment we inserted by hammer a copper rod of 18 mm of diam. and 150cm of length, for grounding. The rod was connected to the grounding terminal of the Transmission Compartment (See Fig 6.6)
One of the big advantages of the SLE system is the possibility to use underground and underwater lines in small cross section pipes with no need of tunnels. Therefore about 20m of the line is an underground line. This segment is inserted into a 1.5" plastic pipe to enable later electromagnetic fields measurements.

The poles (metallic pipes) are strengthened with ropes to the cactus plants to prevent failure by wind blow. The first high voltage SLE moves to the Receiving Compartment (See Fig 6.7)
On fig 6.8 one can see measurement results, which correspond to the results of measurements in the laboratory that are listed above (on Fig 6.4).

![Fig 6.8 Magnitudes of the currents in an air single wire line](image)

After that we decided to show that there is no energy transmission between two grounded points.

To this purpose we have switched off the grounding from the transmitting part and have switched on the nullifier, which is shown on Fig. 5.6. The magnitudes of all the currents have not changed.

One more experiment was carried out in the receiving part of the system. Into it we have added the converter which is shown on Fig. 4.2. As a result the three-phase signal has been obtained. The amplitudes and the phases of all three currents corresponded to the necessary magnitudes.

These experiments have shown that SLE system with 6kV voltage and on 50 Hz frequency is working and gives no additional losses. This system can work without real grounding, but with Nullifier. Therefore ground is not the second line. The load and source of single line system can be three phase system.

7. Single Line Green Energy System

Common two-wire structure

Nowadays the majority of the systems of the „green“ (environment safe, renewable) energy are being built as the systems of direct current and all the sources are being connected with an energy storage device by means of two-wire lines. The systems of wind energy are being built in the same way, though every source (wind generator) generates the alternating current (Fig. 7.1). The main reason for usage exactly of the
direct (but not alternating) current is the synchronization problem of all the sources. Therefore at output of every source a rectifier is used

![Diagram](image)

Fig. 7.1 Common two-wire structure

Below a single-wire method of the energy takeoff from the „green” sources is given. As it is follows from the previous sections, the convertors 2 to 1 and 3 to 1 as well as the nullifiers are easier to perform on the alternating current. And they are still simpler, if the frequency of the current is more than ten kilohertz. As it was shown below, in this case the converter can be performed as a bifilar line. But the synchronization problem is remained.

For solution of this problem it was decided to use not direct current but quasi direct current

Proposed here system does not include inverters AC - DC and DC - AC, batteries, groundings and synchronization blocks inside of system. The system consists of blocks sources and block for collecting. Each block source includes source and generator on frequencies for example100 kHz. The source, which contains a generator, is being built in accordance with the single-wire method described in the section 2, using delay line on half wave. Let us name such a source One Pole Source (OPS). On these frequencies delay line can be made as a bifilar coil.

The transition from a direct current source to the sources of quasi direct current is shown on Fig.7.2
The converter or the delay line can be performed in the form of the known bifilar line (see Fig. 7.3).

The half of the sources generates the current of positive polarity and the other half of the sources – of negative polarity. The energy storage system gets both quasi alternating currents.

In this case the Single Line Green Energy System looks, as it is shown on
Simulations

As a basis for rectifier in collecting block we can use normal balanced single-phase full-wave rectifier (see Fig. 7.5)

\[
U_{op} = \frac{2 \cdot U_{max}}{\pi} = 0.636 \cdot U_{max}
\]

Fig 7.5. Rectifier and its output current

The simulation of system with one block source was made by circuit on fig 7.6.
This is not ideal DC signal. But it is quasi direct current or one pole signal. After summing with many the same signals with different delay we can get correct DC signal. These delays create due to different distances between bloc sources and collecting block.

The simulation of system with five blocks source was made by circuit on fig 7.7.
Each signal of the source blocks has different delay correspond to distances from 0.1 till 1 km. The results of simulations – quasi constant signal one can see on Fig. 7.8. It is obvious that if to connect low frequency filters to both inputs of the storage device (a battery or a generator), we get the normal two-wire signal of direct current.

It shall be noticed, that we use two times less wires, more simple system of conversion in the energy sources and we have excluded grounding problems in direct current system.
8. Interference and loss

Electric field and corona effect

High voltage between wires creates an electric field and corona effect. In addition to the possible harmful effects on the environment, these factors lead to additional losses. Remember that a linear voltage in a three-phase system in a square root of three times more than voltage in each phase.

As a result of high voltage, the ionization rate increases, and, consequently, current crown and loss of energy are increasing. This regime is called bipolar corona (see the right part of Fig 8.1).

Appearance of corona creates not only the additional losses in wires, but creates also such additional distortions of the initial sinusoidal form of the current, which are not acceptable for the alternating current networks which are now in use.

This problem almost does not exist in the B-Line system (see Fig 8.1 the left part).

Possible options for short circuits

Wire breaks and short circuits are a serious problem in many regions of the world. Nowadays the servicing of two-wire system is rather expensive. The author is sure, that the future systems of electric-power transmission will be single-wire systems. On Fig. 8.2 one can see, that the number of short circuits at transition to single-wire method will be sharply reduced. Less wires - less short-circuits - fewer accidents.
The number of wire breaks should decrease at the same extent. At usage of the single-wire method the single wire will be laid underground or under water (see section 9).

**Power losses**

The main advantage of single-wire system is the use of one wire instead of two or four, which leads to a drastic reduction in the cost of the electrical system [16].

Another important advantage is the decrease of losses in the transmission of electrical energy. The calculations and simulations show that the mutual influence of the two relatively closely spaced conductors with currents of opposite polarity, results in an increase in resistance of both wires (See Fig 8.3).

![Fig. 8.3 Tho wires mutual influence](image)

This problem is studied in detail with regard to the cables under the name “twisted pair”.

These cabling is a type of wiring in which two conductors of a single circuit are twisted together for the purposes of canceling out electromagnetic interference (EMI) from external sources; for instance, electromagnetic radiation from unshielded twisted pair (UTP) cables, and crosstalk between neighboring pairs. Attenuation of crosstalk’s on CAT5 channel: (A Channel may consist of up to 90 meters of horizontal cable, one or two transition connectors on each end of the horizontal cable, and up to 10 meters of user patch cables for a total maximum length of 100 meters.) [13]

In the three-phase systems of electrical energy transfer the method of phase splitting is being applied. It means, that the energy is being transmitted by three separate wires. It provides not only decreasing of losses due to corona and more convenience at installation and mounting of the line, but it has one more important advantage relating to decreasing of the line inductance. Owing to it, as it is known, the transmission capacity is being increased, that is especially important for the lines of extra-high voltages which are purposed for transfer of very large powers. At increasing of the distance between wires, the inductance of the line per unit of length monotonously
decreases and therefore a small departure from the optimal distance results in very small increase of the maximal field intensity. This problem does not exist at usage of the single-wire method.

**The influence of electromagnetic field on human being**

There is serious problem with assessment of the impact of radiation of high voltage electric lines and transformers on human health. There are norms, recommendations and measurement methods for parameters like Electric field strength, Magnetic field strength and Magnetic induction. However, these parameters do not allow to estimate the power level, which enters into the human body.

The opponents of a single-wire method often say that in case of usual two-wire or Three wire methods, the electromagnetic field being created by several wires, is being mutually compensated. But if there will be only one wire the influence of the field created by it will be more. However, probably, these dangers are exaggerated.

One can consider that the electric wire is a transmitting electric aerial, and the human body is the receiving antenna. From the theory of aerials it is well-known, that efficiency of the aerial is very low, if the length of the aerial is much less than quarter of wavelength. Here we have just that very case. The wire above the head of a human being and all the more the height of human body is many times less than quarter of wavelength. It shall be noticed that the wavelength on frequency of 50 Hz is equal to 6000 km.

The powerful transformers which use windings with great number of turns, as well cores with high magnetic permeability can create the strong electromagnetic field. Such transformers can represent a magnetic antenna with large effective height.

On Fig. 8.4 one can see an entrance of electric energy in an apartment house in the centre of Jerusalem, using step-down transformer.
Evidently those transformers shall be in many-wire systems as well as in single-wire systems. But the single-wire method allows supplying the electric energy underground. In this case the transformers or switching devices can be located on the ground level or lower than this level, but not in front of the windows of an apartment house.

9. Underground and underwater single line systems

Two problems of underground three-phase system

First, between wires of three phase system must be a distance and decreasing of this distance causes the large additional losses. For decreasing these losses one needs to build very expensive tunnels (Fig 9.1).
The second problem is cable capacitance per unit length [14].

This capacitance of each wire is increasing in presence of other wires. This capacitance causes large reactive power. In order to prevent it in extended systems the intermediate stations are used, which provide reactive power compensation.

Another solution is the transmitting electrical energy by DC. This solution can solve these problems, but it is very expensive.

The reactive power in electrical system is well known problem. Let us show it by next simulation (Fig. 9.2). We will take capacitor and connect it parallel to load.

There is a huge reactive power (input current increased from 200 mA to 800 mA). The same currents are obtained, if the second wire connected to ground.
But in single-wire system the same capacity creates much smaller reactive power (Fig. 9.3)

![Fig. 9.3 The simulation of a single-wire system with capacitance being connected in parallel to loading](image)

The largest influence has the linear or charge capacitance. In the large degree it is the capacitance between either cables or between the cable core and cable braiding. (Fig. 9.4 from [15])

![Fig. 9.4 The second wire influence on the cable capacitance](image)

Usually it is implied that the cable transmits one-phase signal. One pole of phase is connected to cable’s central core and the second one is connected to cable’s braiding. The cable’s braiding can be grounded at input and as well at output, but between the input and the output the wire is not grounded.

In the single-wire system there is not (or almost not) linear capacitance, therefore, it is possible, there is no need to compensate anything. That is, in this respect the single wire system does not differ from the DC system.
In the single wire system there is nothing to connect to braiding, even if it will be grounded, it becomes no two-wire system.

After our useful for me discussions, I would like to formulate reactance compensation problems. They are source of reactive power. In general, reactive power appears, if a reactance is connected in parallel to load. Serial reactance gives phase shift and additional losses. We would like to talk about reactance compensation problems. In high voltage airlines, there is large capacitance between wires i.e. parallel to load. Therefore, there are compensation devices in intermediate stations.

One of important advantages of SLE is absence of capacitance between wires, but capacitance between wires and ground very small. Therefore, it is maybe no need in intermediate stations. In underground and underwater lines, there are capacitance between wire and ground. So we need to use intermediate compensation devices. I think it is not big problem. It is possible to develop small devices like an amplifier in optical line system (something similar to connecting coupling, (see Fig 9.5).

![Reactance compensator](image)

**Fig 9.5** Possible underwater zeroing

One must add wire nullifier. In underwater system, this compensator will be in salt water on the bottom.

At the request of the one of electric company we made the simulation of a single-wire system for the transmission of electrical energy (1.3 MW) in line, which consists of three sections 300 – 400 - 500 km

We made the simulation of this system and we have showed that using a serial inductance and parallel capacitor we can eliminate the reactive power (Fig 9.6 a and b).
Thus, at application of a single-wire method for the overhead (air) systems, the intermediate stations for reactive power compensation, probably, will be not necessary. In the case of underground or underwater systems the small compensating elements can solve the problem conditioned by the influence of running inductance and linear (charge) capacity.
10 High Frequency Single Line System, Antennas

Line on high frequency

We will now illustrate, that the idea of the B-line is also correct for high frequency. First, we compare a normal long line with a characteristic impedance of 300 Ohm with B-Line on a frequency of 1.1 GHz.

On high frequency, it is possible to produce a inverter as a delay line where its length equals half wavelength [15] or a one-port strip line, see Fig 10.1

![Fig. 10.1 One-port strip line structure](image)

A simulation of one long wire line was conducted using this strip line, which is normally equivalent to a 300 Ohm long line. The circuit A-Line (mode 1) and B-Line (Mode 2) are shown in the graphs in Fig.10.2 and 10.3. As a load is implemented source with resistance 300 Ohm and no voltage. On the same figures one can see parameters S11 and S21.
Fig 10.2 Normal long line and its S parameters

Model 1

Fig. 10.3 Proposed one line and its S parameters
The matching long line has infinite bandwidth. This has an advantage, but also a disadvantage. The advantage is that you can pass through a long line of multiple signals with different frequencies. However, in a real system there is always some noise. Even if the noise is weak, in an infinitely wide band, the noise will still be infinitely large (this is true, of course, only if the noise is white). Although you can, of course, apply a filter at the input of the receiver, but often it is problematic. The filter introduces loss and increases the noise factor.

The proposed single-wire system (B-Line) is a selective system. The disadvantage of the B-Line is a need to change the delay line in case of change of frequency. The B-Line is compatible with the source and load, and in this sense it has no difference from the usual long line. It is selective, but rather broadband. It has no requirements referring to symmetry, which is often a problem in the prior-art systems when using long line inside the apparatus, where there can be different influences on each wire.

**Using B-Line on antenna construction**

B-Line principle allows to build a monopole with dipole parameters (MB antenna [16]). This idea is clear from this Fig. 10.4

![Fig. 10.4 Single line idea and MB antenna](image)
MB antenna described in detail in [16]. It is shown that the MB exhibit higher gain and efficiency, compared to a dipole. The enhanced performances of the MB is attributed to the fact that the MB is based on a shorted two-wire line approach, which is in contrast to the conventional linear antennas with open ended arms.

One important advantage of the MB antenna lies in the fact that its promising characteristics are achieved while removing the need for a separate antenna to be implanted in a mobile unit.

Another advantage of MB is its circular radiation pattern.

Improving the MB gain by 3 dB in the transmitting mode and by 3 dB in receiving mode allows doubling the communication range.

The conventional dipole is a balanced antenna, so that its arms are connected to the leads of a balanced source. In this case, the currents on the dipole arms are in anti-phase, and since the arms are in opposite directions, the emissions from the arms add constructively.

In the case of the MB antenna, the leads of the balanced source are both fed into a single radiator. The currents from the leads are made in-phase by means of an inverter (180° phase shifter) inserted in the path of one of the source leads. In this manner, the current in the (single) radiating element of the MB antenna is doubled, compared to a dipole antenna.

The PCB of mobile handsets can be used as the radiating element of the MB antenna. In this case, one has merely to add a phase shifter of 180 degree to one lead of the signal source, The MB antenna actually removes the need for a separate antenna such as PIFA to be installed on the PCB, and consequently it eliminates any potential adverse effects of the PCB on the antenna performance.

The MB antenna can be designed for multi-band operation, and can provide very broad bandwidths. In addition, the idea behind the MB antenna can be applied to transparent antennas of large areas. These properties make the MB antenna a promising antenna for energy harvesting applications.
Fig 10.5 Connection of source and radiator in MB antenna

There are some problems in cases of using antenna PIFA in small transducer (see Fig 10.6)

Fig. 10.6. Far field distribution of PIFA
Using antenna MB one can make transducer without antenna. As a radiator will be PCB (Fig 10.6)

![Fig 10.6 MB antenna in cell phone](image)

Example and parameters of MB antenna one can see on Fig 10.7

![Fig 10.7 Simulation results of MB antenna on Fig. 10.6](image)
MB antenna principle allows developing telephone in watch like on Fig 10.8, (but not in the pocket via Bluetooth).

Fig 10.8. Very small MB antenna

On Fig 10.9 and 10.10 one can see this model simulation results.

Fig 10.9 E-field simulation of MB antenna on Fig. 10.8
So MB antenna is a new type of antenna. It is not dipole and not monopole. It consists of one metallic surface as the radiating element and a phase shifter. In cellular handsets, the existing PCB can be used as the radiating element so that only a phase shifter is needed. The characteristics of MBA are similar to those of a dipole and even better.

**Conclusion**

The SLE system was proposed and checked. Now in Israel two SLE systems are working on 220 V and 6 kV. SLE can operate at all frequencies, including 50 Hz, 60 Hz and as well DC, with all power, with all voltages. Electrical energy in SLE AC system is not transmitted through the ground.

SLE (B-Line) method allows:

- to realize as Single Line System (SLE) any electrical system, including smart systems;  
- to connect three phase generator and three phase motor with one wire only;  
- to make SLE AC system without input of electrical current to the ground surface;  
- transmit electrical energy from place of generating up to place of implementation by using cheaper system, as in many cases it will be more profitable to produce.
electricity at the place of gas production and transfer it to the place of consumption using single wire under the ground;
- to reduce significantly the number of wires on the globe;
- to reduce significantly the cost of construction of high-voltage electrical systems;
- to use of underground and underwater power lines for energy transmission without intermediate stations;
- to reduce number of accidents associated with electrical systems;
- to reduce losses in transmitting by one wire instead of three phase common wires;
- to build new antenna (MB antenna), which allows to create the receiving transducer without antenna

A separate conclusion concerning the problem of zeroing:

The proposed method of zeroing gives a hope to create the AC systems without electrical current inserting into ground surface.
In section 3 on page 15 it has been shown that in the future power plants, operating in single wire systems, the zeroing can be at all not required.
Some conducted researches had proved, that the danger for living creations because of current injection in earth is strongly exaggerated.
In section 3 on page 24 an example is given, in which current strength in a line (and consequently magnitude of current which requires the zeroing) are 10 A. It is known that the ground space within which one can detect a current represents is a cylinder of 10 meters diameter and 10 meters of depth. That means that its volume is approximately 800 cubic meters. And if resistance of grounding will be even 10 Ohm, the power which is emitted by the current of 10 A will be 1000 watt, and it means that average power in one cubic meter will be 1.25 watt and, in addition, as it is being supposed in the section 3, this power is mainly spent for creation of a very weak electromagnetic field

All information about SLE method, including articles, presentations and films in YouTube one can find on website: www.ofdma-manfred.com Technical questions please send to bankmichael1@gmail.com and questions referring to the possible collaborations to larry@sleint.com

Gratitudes:

The author sincerely thanks all who expressly or by implication promoted the development of the single-wire method. The majority of these people was, and probably is against this idea. But they have helped too, because the author knew that it is necessary to explain and on what question to answer.
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