

# Electrical Energy Transmission by Several Wires and Reactive Power Problems

Michael Bank

Jerusalem College of Technology, Jerusalem, Israel  
Email: bankmichael1@gmail.com

**How to cite this paper:** Bank, M. (2018) Electrical Energy Transmission by Several Wires and Reactive Power Problems. *Engineering*, 10, 329-335.  
<https://doi.org/10.4236/eng.2018.106023>

**Received:** May 27, 2018  
**Accepted:** June 26, 2018  
**Published:** June 29, 2018

Copyright © 2018 by author and Scientific Research Publishing Inc.  
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).  
<http://creativecommons.org/licenses/by/4.0/>



Open Access

---

## Abstract

The main goal of this article is to compare traditional three phase system with one wire three-phase system. There are several obvious advantages of one wire system, for example cost, reliability and other. But there is a problem as well, connected to reactive power in both systems. This article proposes explanation of reactive power emergence in systems SWER, three-phase and in their one wire versions.

## Keywords

Three-Phase System, SWER, Single Line System, Reactive Power

---

## 1. Introduction

It is common knowledge that electrical energy can be transmitted using a different number of wires. In common three-phases use three, two or one wire. This document discusses transmitting on low frequency (50 or 60 Hz). All these systems can divide on balanced and unbalanced. In each wire of electrical system the phase of signal depends on distance but in balanced system the difference between phases remains a constant.

Below we will try to define the main differences between systems with different amount of wires.

The suggested references are new systems running on a single wire balanced system as described in [1] and [2] and in patents [3] [4].

Following we will discuss each of these systems, pay attention to the comparative cost of system, losses including depending from reactive power and the influence on nature.

## 2. System Classification

All different schemes for transmitting electrical energy, by different number of

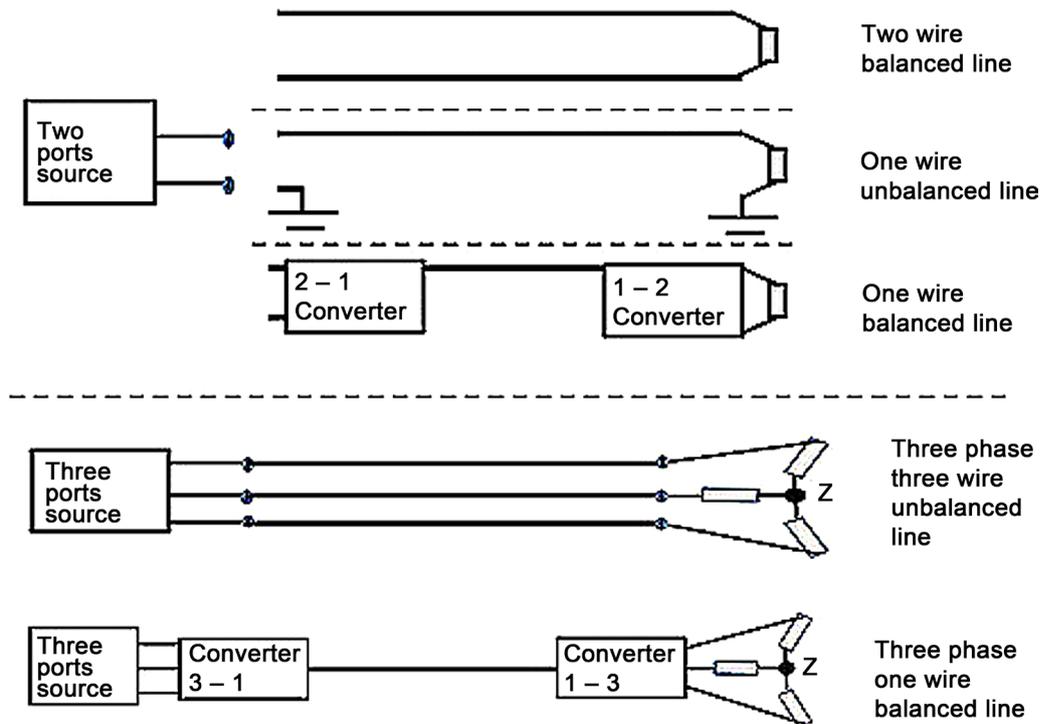
wires, can be shown on **Figure 1**.

It is obvious that source of two wires line gives one phase signal and a source of three-wires line gives three-phase signals. All systems on **Figure 1** can be balanced and unbalanced. There's the possibility that the combination of words "one wire" and "balanced" sounds odd but it is important what does the load see, but not what exists in wires.

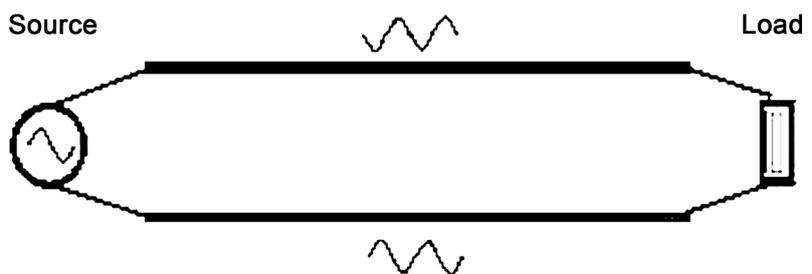
### 3. Classical Symmetrical Two-Wire Line

**Figure 2** illustrates the normal construction of a classical two wires balanced lines.

The energy is transmitted by two wires. The signals polarity in the wires is opposite. The wires resistances are smaller than the load resistance. The wires are absolutely identical. The phases of the signals are changing along the wires. But in a symmetrical balanced line the phase difference will always be 180 degrees therefore in this system there is no issue with changing of phase's difference.



**Figure 1.** Proposed system classification.



**Figure 2.** Two-wires balanced line.

#### 4. Unbalanced One-Wire Line

Here we are discussing a single-wire line in which one of two ports of the source and of load have zero potential (see **Figure 3**). It is unbalanced scheme.

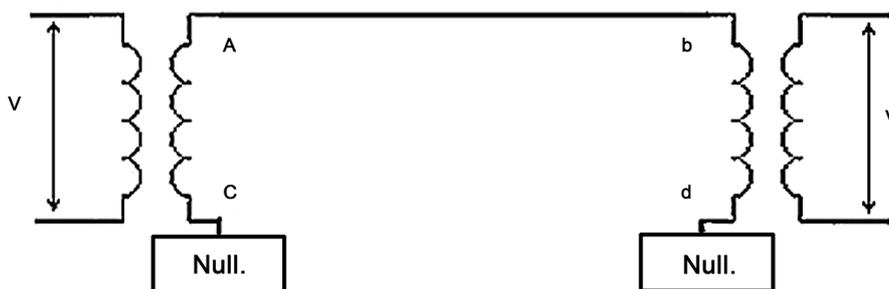
For the potential zeroing one can use nullifier [1] (on **Figure 3** it showed like Null.). Common practice for zeroing uses grounding but it is not always possible.

As it shown in [1] in a one unbalanced wire of line we can transmit all needed energy just like in a two wire line. Obviously that phase of potential in end of single line (load port) depends on distance. But the phase of the second port potential is always zero. Therefore the phase difference in the load does not equal to source phase difference (180 degrees).

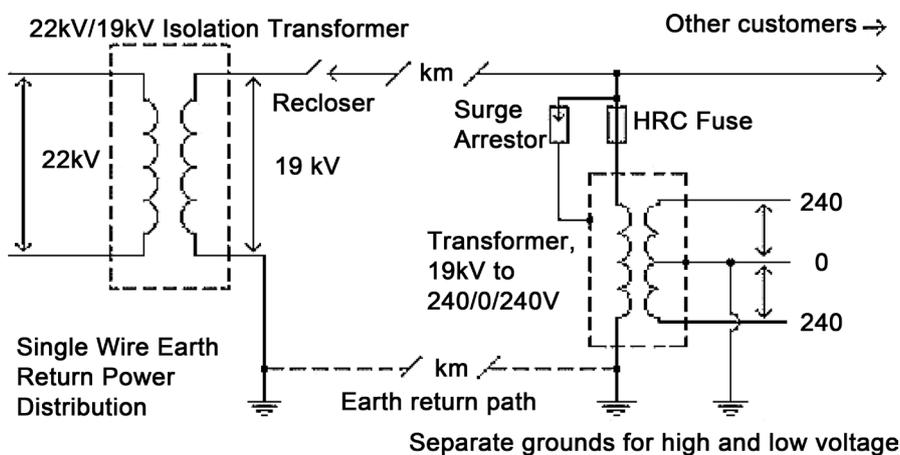
Let us consider the influence of this fact by explore the following real example. There is Single-Wire Earth Return (SWER) system (see **Figure 4**), which is used in several countries [1]. The SWER scheme on **Figure 4** is the proposal drafted by the authors of the SWER system.

In this scheme the grounding generates potentials in points C and d zero. However, the potentials in points A and B in **Figure 3** are different due to a signal delay in single line. This means that the phase difference in points b and d will not be 180 degrees.

This situation can be likened to challenges similar to a reactive load. In the case of a reactive load, there is reactive energy, namely, the source must produce



**Figure 3.** One wire unbalanced line.



**Figure 4.** The circuit of real SWER system.

active and reactive energy. And in the case of long line, this system must lose a large amount of energy.

The losses due to reactive power in real SWER system can show using the following simulation (Figure 5(a)).

The influence of line length 450 km on Figure 5(a) is showed by delay line, which gives the phase shift correspond to  $\cos\phi = 0.65$ . It is equivalent to the load shunting by a reactance, which must result in an increase of the current of the generator. In this case the generator current has appears to be more than twice higher than the current in the load (Figure 5(b)). In this simulation we generate zeroing in receiving part using nullifier. This nullifier type [1] makes zeroing in needed point by connecting this point with output of delay line, which is length equals to half wavelength (10 ms for frequency 50 Hz).

Here, it is clear that the generator must produce a current that is greater than the current in the load, and that this larger current creates additional losses due to wires resistance.

This challenge cannot be fully solved by means of compensation using a 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.

It is needed notes that ground can't transmit energy [1]. Each grounding point makes zeroing but for transmitting energy there must be a potential difference not equal to zero. Therefore, the expression "Earth return path" is not exactly accurate.

### 5. One Wire Balanced Line

One wire balanced line was proposed in [2] and presented in [1]. Its main idea is shown on Figure 6.

In this scheme the source and the load see the same as they see in two wires

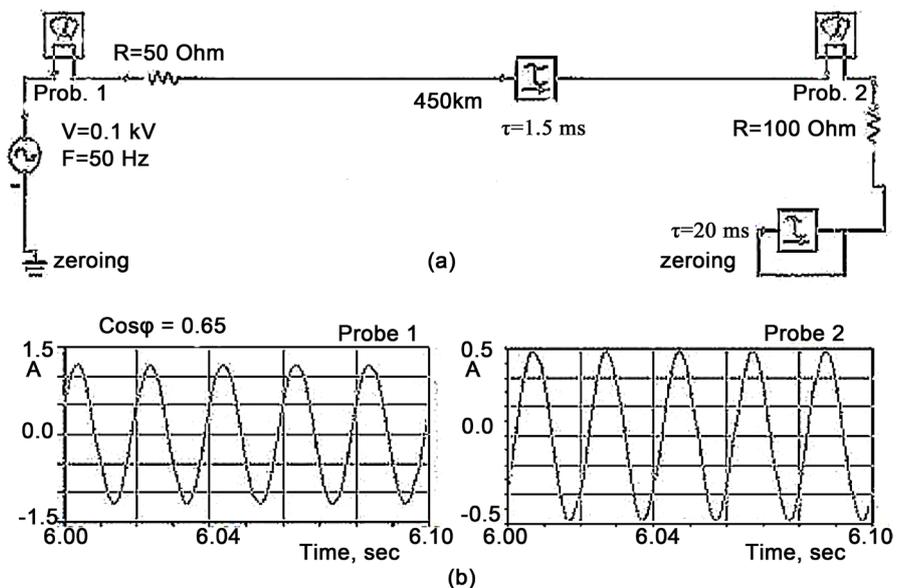


Figure 5. SWER simulation circuit (a) and simulation results (b).

scheme. In one common wire flows double current. But in equivalent two wire scheme we have double length of wires.

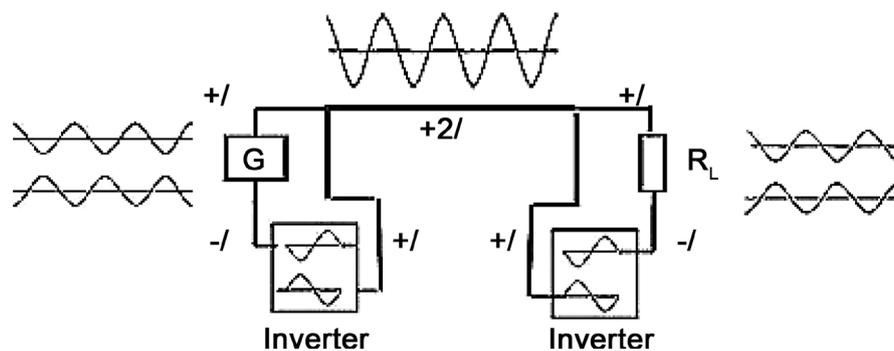
In the case of an active load in this scheme does not reactive power, because phase difference on load equals 180 degree and does not depends on line length. The inverter can be made by a transformer with opposite windings. The simulations and measurements results are presented in [1].

## 6. Three-Phase (Three Wires) Unbalance Line

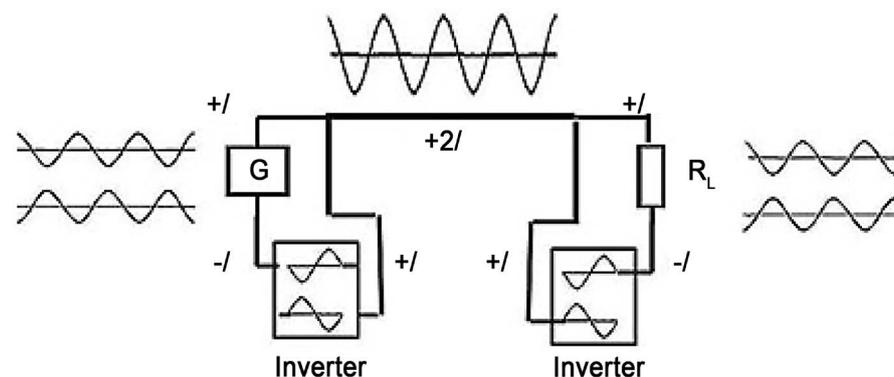
Three-phase scheme is well known and well studied. The principle of this system is shown on **Figure 7**.

The following shortcomings of the three-phase three-wire system can be noted.

- If all three loads are identical and active, the potential in point Z equals zero. We can state that this scheme is actually a connection of three SEWER systems. Therefore there is accumulation of reactive power, for the compensation of which it is necessary to use expensive intermediate compensators;
- Many expensive wires (three or four);
- Large expensive supports for wires;
- For laying three-phase lines, larger areas of useful areas are required;
- Underground and underwater three phase system is very expensive;
- Strong negative environmental impact (Corona Effect);
- Large number of wire breaks and short circuits;
- Large energy losses due to phase's misbalances and reactive power.



**Figure 6.** The principle of one wire balanced scheme.



**Figure 7.** Simplified version of three-phase circuit.

As shown in [1] in Fig. 5.3, the point Z in **Figure 8** may not be grounded. It is connected to the output of a single-wire line through an inverter.

Let us explain in more detail the question of reactive power. One port of each load of the three-phase system receives a signal at the end of the line. The phase of this signal depends on the length of the line. The signal phase of the second port in balanced scheme is always zero. That is, the phase difference in the load is not 180 degrees and it depends on the length of the line. This phenomenon is equivalent to the presence in the load of reactive resistance and, consequently, the appearance of reactive power. That is why there are in long three-phase systems there are intermediate stations, sometimes every 30 km.

One wire method allows transmit three phase signal by one wire and without these disadvantages.

It is known that sum of three currents of three-phase system equals zero.

Therefore in one wire three-phase system for summing we make currents with needed phase shifting (see below).

## 7. Three Phase Signal by One Wire Transfer

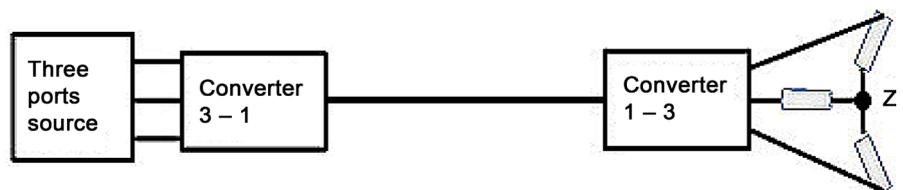
All the above disadvantages of the three-wire system are not inherent in the single-wire method of transmitting the three-phase signal [1] and [3].

To build such a system, it is necessary to change the phases of each of the three signals so that they are the same. Then we can get the sum of these signals. Such a conversion can be conducted with phase shifters and inverter, or by vector summing all three signals. In the diagram in **Figure 8**, such a converter is designated as Converter 3-1.

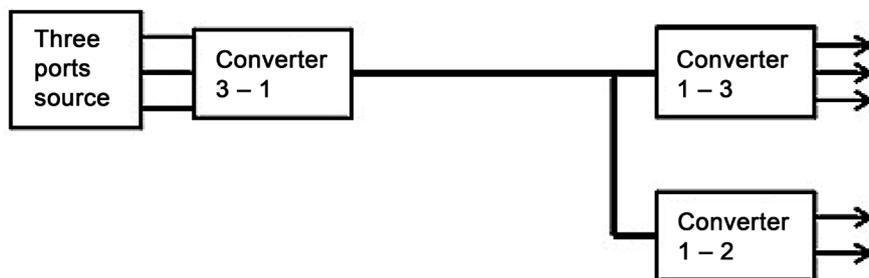
For transforming a one wire signal to a three phase signal a converter is needed 1-3. This converter is an analogue of converter 3-1, but it transforms in opposite sequence.

This scheme is balanced, and it does not create reactive power if the line length increases. In [1] we also present that in a one wire version we can use the same type of wire like each wire in three phase prototype. But for this voltage in one wire system must be equal to linear voltage in three phase system.

The main problem in three phase systems is possible unbalance of loadings. The base cause of this is often situation when each phase is working with different loads. And these loads can change differently.



**Figure 8.** Three phase one wire balanced line.



**Figure 9.** One wire system with two outputs.

One wire method allows delete and this disadvantage too. For this one wire can have two outputs one for one phase systems and second for three phase systems (see **Figure 9**).

All one phase loads must connect to one phase output. In this case the unbalance in three phase part cannot be.

## 8. Conclusions

It is shown that all systems for transmitting electrical energy can be made by one wire method.

This method allows significantly decreasing systems cost and losses including losses due to reactive power.

## References

- [1] Bank, M. (2016) It Is Quite Another Electricity—Transmitting by One Wire and without Grounding. Partridge Publishing, Singapore.
- [2] Bank, M. (2012) Single Wire Electrical System. *Engineering*, **4**, 713-722. <https://doi.org/10.4236/eng.2012.411092>
- [3] Patent US 9608441.
- [4] Patent US 9246405.