

SINGLE WIRE EARTH RETURN (SWER): APPLICATION IN BRAZILIAN ENVIRONMENT CONDITIONS

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Abstract – This paper presents some preliminary considerations on the application of Single Wire Earth Return distribution systems for energy delivery in rural areas, in Brazil.

1 - INTRODUCTION

Presently, the restrictions on financial resources are limiting the expansion of projects for energy delivery to rural areas, in Brazil

Also some other factors contribute to disturb the policies of investment in such projects, increasing their costs. Besides the vast total rural area in the country, most of the Brazilian rural properties to be electrified are small, or their owners have very poor economical condition. Low density of connections is expected and also a reduced energy demand by consumers. Therefore, in general, the expectation of investment return for rural electrification is practically null.

Another important factor, which influences directly the projects costs, is that the techniques employed by the energy utilities for rural electrification is basically an extension of the urban distribution ones. Usually, the same standards of network adopted for densely populated areas are applied in rural areas. Therefore, the costs for implementation and maintenance are relatively high.

These aspects suggest the adequacy to apply dedicated and low cost technologies for supplying rural properties in Brazil. In this respect, the adoption of Single Wire Earth Return (SWER) system seems an attractive alternative solution. The program "Light for All", created by the Federal Government, aims to supply 100% of the Brazilian rural properties. This program includes alternative solutions, such as the SWER, that is able to reduce installation costs. This has direct effect on the final value of resources for attendance of the electrification projects in areas with energy deficit and also allows a larger number of connections.

On the other hand, in rural areas an unexpected occurrence is taking place presently: the stealing of neutral conductor in conventional existent distribution networks. This is happening for both: three-phase feeders or single two conductors branches (phase and neutral),

harming the quality of energy supply and also determining risks of generating dangerous potentials in the soil surface next to the structures where the distribution transformer is installed. In the last case, non-intentional SWER systems are been created, which are not designed for this purpose. The costs for replacing the stolen conductors are very high and, sometimes, they are stolen again just after replacement. Therefore, a better solution is to modify the system to make it an well designed SWER system.

In general, the adoption of SWER in Brazil is very limited in relation to other standards applied in rural networks in the country. This picture is usually justified by the typical high value of distribution system's grounding resistances, due the high resistivity of the Brazilian soils.

The authors have been working on evaluating the potentiality for efficient implementation of SWER systems for the Brazilian environmental conditions. This paper consider some preliminary aspects of their study.

2 – DEMANDS OF BRAZILIAN RURAL PROPERTIES

Brazilian rural area has a low demographic density (0,1 to 0,5 consumers for kilometer or 3,0 KVA/km²) [13]. It is verified that 19 of 20 electric loads installed in rural areas can be attended by a 5 kVA transformer, and 9 of 10 could be attend by a 3 kVA transformer. In general, simultaneous maximum demand (30 minutes) varies from 0,3 to 3,0 kW. This range of loads indicates that single-phase system is sufficient to attend the rural area.

3 – BASIC ASPECTS OF SWER SYSTEMS

The SWER system is specially efficient for supplying small loads in areas of reduced population density. It uses the ground as path for returning current, from load to source. Some other associated practices may improve the economical advantages of its application, such as the use of wood pole and steel wires, the increase of spans between poles, etc.

This may reduce the costs of such system to about 48% in relation to conventional single-phase system with neutral conductor (multi-grounded) [17].

3.1 – BASIC CONFIGURATIONS OF SWER SYSTEMS

The characteristic of the SWER system depends on several aspects, such as: the nature of the existing electrical system, the needs of the protection system, the profile of the load to be supplied and the local soil resistivity. This determines different configurations for the SWER.

a. Single phase system without isolation transformer

As shown in figure 1, in this configuration, an only metallic conductor is directly connected to one phase of an three-phase line. The return current flows through earth to the substation earthing. At the consumer entrance, a distribution transformer has its primary winding connected between such single conductor and the ground. This system is usually adopted for feeders that originated from substations, whose transformer has a grounded neutral point at the secondary winding.

The configuration may be considered a simplification of conventional single-phase multi-grounded system, where neutral conductor and the grounding along the line were suppressed. Certainly, this is the cheapest version of the SWER systems.

b. Single phase system with isolation transformer

In this configuration, an isolation transformer is connected to two phases of three-phase system and has one conductor of secondary winding connected to earth, as shown in figure 2. The secondary circuit is closed by the current return through the soil.

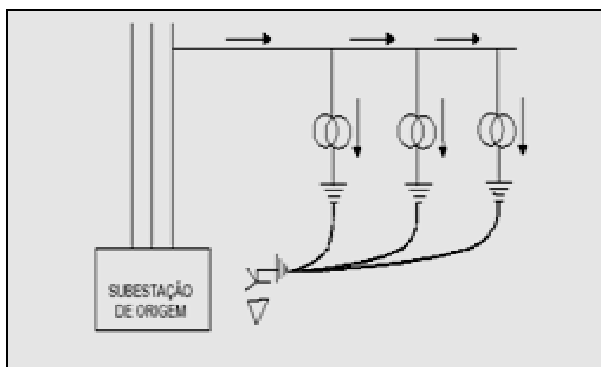


Fig.1 – S.W.E.R. system without isolation transformer

The use of isolation transformer allows some improvements: (i) to adjust the voltage of SWER system (to standard nominal voltages), (ii) to raise the voltage level in order to supply longer lines, (iii) to limit the circulation zone of return current, (iv) to prevent the improper performance of protection device for high impedance phase-ground faults and (v) finally to limit short-circuit currents.

However, it also presents disadvantages, such as, the limitation of branch power to the nominal power of isolation transformer, the need of a very low grounding resistance for the isolation transformer and the additional cost of such transformer.

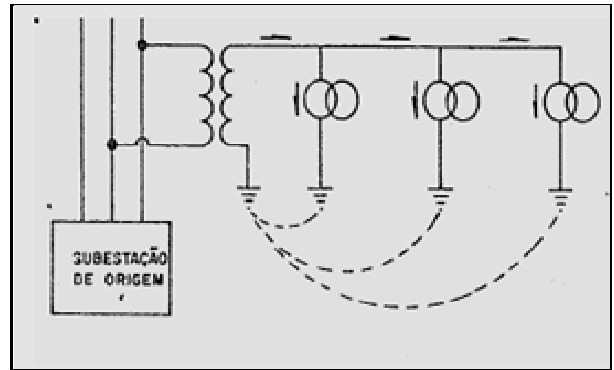


Fig. 2 – S.W.E.R. system with isolation transformer

c. SWER system with neutral conductor partially connected

In this configuration, the groundings of SWER of all transformers are connected by an additional conductor (fig. 3). It is presented as single-phase system with neutral conductor (multi-grounded). The difference is that the neutral conductor is not connected to the substation. It is used as a solution to use SWER in high resistivity soils, when it is difficult to get low values for grounding resistance of transformer, inside the limits established in the project [09, 23]. In this system, the connection of the transformer to ground makes only one ground-mesh, contributing to lower the value of the equivalent ground resistance in each point.

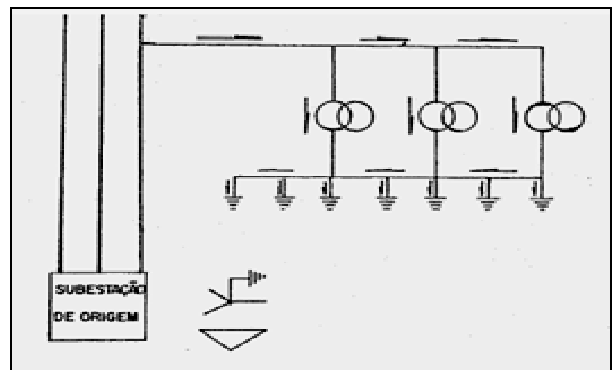


Fig. 3 – S.W.E.R. system with partially connected neutral conductor

3.2 – LIMITATIONS OF SWER SYSTEMS

Due to the low demand, it is possible to use lower cost materials and components that those employed at networks of urban distribution systems. However, the usual specification of conventional SWER systems presents limitations, usually associated to the characteristic of the employed low cost components:

- ✓ High resistivity of the zinc steel conductor (about seven times bigger than the aluminum conductor) that limits the capacity of energy transport;
- ✓ High electric losses in zinc steel conductor;
- ✓ High voltage drop along spans;
- ✓ Grounding: it is an active element of circuit. All load current is injected into the ground. It is necessary to take care on its connection and the measurement of the grounding resistance to hinder accidents caused by voltage gradients over the soil surface;

- ✓ additional costs due to isolation transformer (when employed);
- ✓ Load balance: It is necessary to assure load balance on derivations of branches from three-phase feeder.

3.3 – SYSTEM PERFORMANCE

The performance of the electric equipment is related with the voltage regulation of the distribution networks, which is obtained using voltage regulators, capacitors banks or reactors, in three-phase systems.

For SWER systems, the solution is limit the maximum current, the length and the power to be supplied by the system, assuring that certain limits of voltage drop are not exceeded.

The standardized voltages of these systems are derived from the three-phase one: $13,8/\sqrt{3}$, $23,1/\sqrt{3}$, $34,5/\sqrt{3}$ kV (system line to ground).

As the main objective of a SWER system is the reduction of costs, the definition of the voltage level as well as of the type of conductor are basic for a acceptable voltage regulation, inside of the established limits. IN Brazil such limits are determined in 505 of ANEEL (National Agency of Electric Energy) Resolution.

The report RER 07 of Eletrobrás presented a study of new conductors used in SWER systems, and five conductor types are recommended: CAA 4AWG, the CAW 3x2,59; the CAZ 3x2,25; the CAW 1x3,26 and the CAZ1x3,09 (measured in millimeters).

The use of these conductors results in cost reduction of rural electric networks, not only by lowering components costs but also due to the reduction of the number of structures. This reduction reflects on the construction, operation and maintenance costs of these networks.

3.4 – GROUNDING FOR SWER SYSTEMS

In single-phase systems with earth return, all the load currents of distribution transformers pass necessarily and continuously by their grounding electrodes, demanding special attention for it.

Many grounding criteria are adopted by the Brazilian energy utilities, which use SWER system. Some of them analyse previously the soil, before defining the construction of SWER systems. However, other ones consider that high values of soil resistivity do not make impracticable SWER system, choosing solutions that prioritize the values of potentials in the surface instead of limiting grounding resistance values.

Over the soil surface surrounding the transformer structure, the gradients of potential in the ground must be kept low enough to prevent risks for people and animals. The connections to the ground must be solid and have suitable resistance values, as single-phase networks have their performance determined by safety conditions that are directly influenced by their earth terminations characteristics.

Amongst the grounding systems, two philosophies are applied. One of it is single grounding and the other one is independent grounding. Single grounding consists on providing for each distribution transformer, a single grounding where the points of the primary circuit are connected, as well as the points of the secondary circuit (neutral of low voltage etc.). Such practical ties, however, the maintenance of conditions of security in the case of disruption of the grounding conductor, due to the existence of other groundings in the net of low voltage, as the equivalent resistance is usually smaller or equal to the maximum permissible value for the grounding of the transformer. This philosophy of grounding becomes suitable for the cases, which, from secondary terminals, a net for attendance to a set of consumers is derived. The validity of its adoption is inversely proportional to the values of soil resistivity at the region. This conception also allows the injection of atmospheric surges derived from the primary circuit to the secondary circuit through the grounding system. Independent Grounding requires the implementation of two separate groundings for each transformer. One of them, the Primary Grounding, is connected. The other grounding, called Secondary Grounding, is destined exclusively to the connection of the neutral of the net of low voltage. The main advantage of this alternative is the maintenance of the security conditions when the grounding conductor break up, independent of any complementary requirement of the secondary groundings values of resistance (of net and consumers). This practice is recommended in the cases of distribution transformers feed a single load. Although the transference of atmospheric surges can occur through the electromagnetic coupling between the primary and secondary circuits, some utilities recommend keeping at least 25 meters between the grounding systems to prevent the transference of surges derived from the primary circuit to the secondary one through the grounding system.

Concerning the fact of the interconnection or not of the groundings of the primary and secondary circuits, the subject is controversial. Some concessionaires demand the minimum distance cited of 25 meters between the grounding systems. However, it has a modern trend of establishing connection of groundings. Under that aspect, in [11] it describes that, for the grounding of low voltage, the preponderant factor is the protection against overvoltages, being that, not having constant current drainings to the ground, it is not done in a discerning way. Thus, the grounding of low voltage must be understood as a simple bond to the ground, being able to be constructed with an only connecting rod, not mattering, in this case, the value of the grounding resistance. On the other hand, it always recommends the X0 terminal of the single-phase transformer to be tied to these groundings and never with the pole of the transformer, in order to prevent the transference of potentials from the primary to the secondary circuit (and, so, to consumer installations).

According to reference [01] the interconnection of low and high voltage circuits grounding systems is allowed only if the resultant grounding resistance becomes lower than 1Ω (condition almost impossible for usual soils in Minas Gerais State for typical grounding configurations). When this connection is performed, some Brazilian utilities, recommends the minimum distance of 25 meters between grounding systems [17].

The maintenance of separation between the grounding systems is justified by the fact that, in the hypothesis of their connection, if the secondary grounding system has larger or equivalent grounding resistance (in comparison to primary grounding) and a rupture down-conductor occurs, the eventual ground potential rise at secondary grounding may be transferred to the consumer's entrance and may result in casualties.

There is explicit definition about the convenience (or not) of connecting the neutral of the primary and secondary circuits, or the electric insulation of the down-conductor.

In Brazil, no utility that uses the system as archetype or in great amount has supported their practices by laboratorial or field researchs about alternatives of disposal of electrodes, types of more convenient electrodes, step voltages, touch voltages, distribution of potential in the ground, etc, that allowed the recommendation of a criterion in norms.

3.5 – OVERCURRENT PROTECTION

According to the usual insulation impedance values for the transformers (between 4 and 5%), the values expected for fault currents are lower than 250A near the feeder and around 30 to 50A for distant faults.

The philosophy of protection against overcurrents to be used in the SWER system is similar to that used in the conventional single-phase system, though in some specific cases changes are necessary.

In systems that adopt protection against line-to-ground fault of high impedance based on the return current to neutral wire, if SWER derivations from three-phase feeders branches are employed, it is necessary some criteria to balance the loads of the SWER systems among phases and to limit the load for each SWER branch. That procedure is justified by prevention of improper protection operation of relays against high impedance line-to-ground fault.

For SWER systems the short circuit is always phase-to-ground, observing no path low impedance path of current to source exists. This implies the need of care for the cases of wire rupture that, falling directly to the ground, leads to a high value of defect impedance. It is necessary the use of sensible protection devices against line-to-ground fault. This concern is not exclusive to SWER system.

4 – CONCLUSIVE REMARKS CONCERNING THE APPLICATION OF SWER FROM ENVIRONMENTAL CONDITIONS OF MINAS GERAIS

SWER systems are employed when it is desired to supply rural areas of low energy consumption and scattered populated. In this cases, the need to reduce costs of networks does not justify the utilization of voltage regulation devices, such as capacitors bank, reactors or even voltage regulators. The present solution is to limit the maximum current, the length and the power to be supplied by a SWER network in order to avoid exceeding established limits of voltage drop. The maximum allowed voltage drop, the maximum load current for derivation

and the maximum branch length are direct function of the conductor employed for energy deliver.

The grounding system, essential to the operation of the system, needs to attend at least one of this two criteria: maximum grounding resistance and control of touch and step voltage. Both criteria aim to keep the ground potential rise within established limits.

Another factors to be considered are the mechanical dimension of conductors and the coordination of overcurrent protection (high impedance line-to-ground fault for the cases of derivations SWER without insulation transformers). If the insulation transformer is used in the derivation, also it is limiting factor, as the branch has the maximum supply limited by insulation transformer power.

Concerning the possibility to increase the level of voltage supply to allow longer extensions of SWER networks, it is not a simple technical task and implies cost increase, is it demands the need to specify and acquire materials and equipments at non standardized voltage level for distribution network. If it is possible to supply the load by the SWER branch, observing the voltage drop and maximum current of the conductor limits and in the available standardized voltage level, this is the best and cheapest condition for adoption of SWER system.

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