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Particular Wire Earth Return Power Grids

[1]Prof. D.N.Pansande, [2]Prof. N.A.Salunke, [3]Prof J.H.Pawar,[4]Prof.R.A.Mule

[1]Assistant Professor, [2] Assistant Professor, [3] Assistant Professor [4]Assistant Professor

[1]Electrical Department,

[1]S.V.P.M.C.O.E.Malegaon.B.K, Baramti, Maharashtra

Abstract: This paper presents a novel approach to The Single Wire Earth Return (SWER) power distribution system addresses a crucial challenge in modern electrical engineering: delivering affordable, reliable electricity to rural and remote areas where traditional multi-wire grid systems are impractical due to cost, infrastructure, and geographical constraints. The significance of the SWER system lies in its ability to bridge the energy access gap, particularly in developing regions where rural electrification is a key factor for economic and social development.

Index Terms - Power Generation Source (Substation), Cost-Effective Rural Electrification, Environmental Benefits

I. Introduction

Single wire earth return (SWER) power distribution grids are a type of electrical distribution system used in rural and remote areas where it is not economically feasible to install a traditional two-wire power distribution system. In a SWER system, only one wire is used to carry the current, while the earth itself serves as the return path for the electricity.

SWER systems are typically used in areas with low population density and long distances between customers, as they are much cheaper to install and maintain compared to traditional power distribution systems. The single wire is usually installed on poles or towers, with grounding rods placed at regular intervals to provide a low-resistance path to the earth.

While SWER systems are cost-effective and efficient for powering remote areas, they do have some limitations. The single wire design can result in higher losses and voltage drops compared to traditional two-wire systems, and the earth return path can be affected by factors such as soil resistivity and moisture levels.

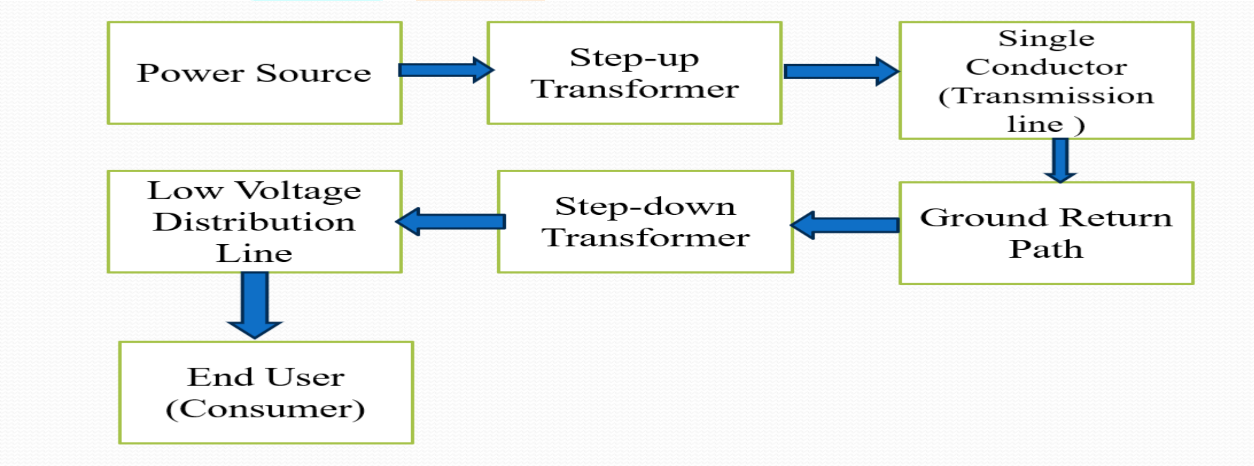
Overall, SWER power distribution grids are a practical solution for providing electricity to rural and remote areas where traditional power distribution systems are not feasible. They offer a cost-effective way to bring power to communities that would otherwise be without access to electricity.

Methodology

As stated earlier, it distinguishing feature is that the earth (or sometimes a body of water) is used as the return path for the current to avoid the need for a second wire (or neutral wire) to act as return path. It is supplied by a step-down isolating transformer rating between the range 200KVA to 300KVA. The transformer isolates the grid from ground or earth and changes the grid voltage (typically 33KV Line to line) to the Single Wire Earth Return Voltage (typically 19 KV line to earth). It can be stepped-down from 22KV to 12.7KV. Also, it can be from 11KV to 6.33KV (Balwinder S. S 1972). The stepping-down of

33KV to 19KV is all about the transformers turn ratio, as determined by the transformer designer. From the secondary of the step-down isolation transformer, only a single wire will be transmitted to the numbers of local distribution transformer along its length. In Single Wire Earth Return System, current flows from the line through the primary coil of a step-down isolation transformer to earth through the earth path, and from the earth path current eventually finds its way back to the main stepup transformer at the head of the line hence completing the circuit. By this description step-down isolation transformer is a complete circuit on its own and at the same time acting as conductor connecting another circuit in the distribution transformer. The Earth rod should be extra deep installed to prevent energy wastage that can result from high resistance of the soil. Another way to prevent the effect of high resistance of the soil is to add charcoal and salt to the soil or keep the surrounding soil of the earth electrode wet always (Gupta J.B 2006). If the soil resistance is high enough that insufficient current flows into the earth neutral, it causes the earth rod to float to higher voltage. Note, self-setting circuit breaker, reset due to difference in voltage between line and neutral, the reduced difference in voltage between line and neutral caused by the soil high resistance may prevent breakers from resetting. The connection to the customers from the local distribution transformer is either single phase (N-O) or split phase (N-O-N) according the appliance voltage in use. The O volt is in place for safety which carries no operating current.

II. BLOCK DIAGRAM



1. **Power Generation Source (Substation)**:
   This is where the electricity is generated, typically at a power station or substation. It supplies alternating current (AC) power, which needs to be transmitted to distant rural or remote areas.
   Generates electricity at lower voltage levels, which is stepped up to a high voltage for efficient long-distance transmission.
2. **Step-Up Transformer**:
   A step-up transformer is used to increase the voltage of the generated electricity to a higher level (12 kV to 33 kV) to minimize energy losses during transmission.
   Converts the low-voltage electricity generated at the substation to high-voltage electricity for transmission over long distances. Higher voltages result in lower current, which helps reduce power loss due to resistance in the transmission line.
3. **Single Wire Transmission Line**:
   This is the single high-voltage conductor (wire) that carries the electricity from the step-up transformer at the substation to the distribution point near the end-users.
   Transmits high-voltage AC power over long distances. Since only one wire is used, the return path for the current is provided by the earth, which completes the circuit.
4. **Grounding Electrode (At the Power Source)**:
   A grounding electrode system is installed at the power source end (substation) to connect the electrical circuit to the earth.
   Provides a secure and low-resistance path for the return current through the earth, completing the electrical circuit. Proper grounding is essential for system safety and performance.

5. **Step-Down Transformer (At the Load End)**:
   At the distribution end, a step-down transformer reduces the high transmission voltage (12 kV to 33 kV) to a lower, more usable voltage for local distribution (typically 240V or 120V).
   Converts the high-voltage electricity back into low voltage for safe usage in homes, farms, and other end-user applications.
6. **Grounding Electrode (At the Load End)**:
   Another grounding electrode system is installed at the load (user) end, ensuring the safe return of current through the earth.
   Completes the circuit by returning the current through the earth back to the power source. Grounding at the load end ensures the safety and reliability of the system.
7. **Load (End-Users)**:
   The load consists of consumers who use the electricity, such as households, farms, and small industries. These users are located in rural or remote areas.
   The final destination of the electricity. The load can include various electrical appliances, lighting, agricultural machinery, and other equipment.
8. **Surge Protection Devices**:
   Surge protection devices, such as lightning arresters, are installed at various points in the system to protect against surges and spikes caused by lightning or other faults.
   Protects the SWER system and its components from damage due to voltage surges, ensuring the safety and longevity of the system.

III. SOFTWARE SYSTEM

A. Arduino

The Arduino Integrated Development Environment (IDE) includes a code editor, a message area, a text console, a toolbar with basic operation buttons, and several menus. The software connects to the Arduino platform to upload programs and interact with the hardware. In the Arduino IDE, you can create programs called sketches, which are written in a text editor and saved with a .ino extension. The editor allows you to search, replace, cut, and paste text. The message section displays errors and feedback during saving and exporting. The console shows text output, including error messages. The bottom right corner of the window displays the serial port and selected board. The toolbar buttons let you verify, upload programs, open the serial monitor, and save sketches.

DETAILED DESIGN

The detailed design for a Single Wire Earth Return (SWER) power distribution grid must consider the technical, infrastructural, and operational aspects required to ensure efficient and safe power delivery. Below is a breakdown of the key components and design elements for the SWER system.

1. SYSTEM ARCHITECTURE

1.1 Overview

- Primary Objective: Provide a reliable, cost-effective electrical distribution system for rural and remote areas using a single wire for high-voltage transmission and the earth as the return path for current.
- Power Flow: The system steps up the voltage at the source (substation) for long-distance transmission, then steps down the voltage near the consumer's location for local distribution.

2. ELECTRICAL DESIGN

2.1 Voltage Levels

- Transmission Voltage: 12 kV to 33 kV for high-voltage transmission to reduce power losses.
- Consumer Voltage: Typically 240V or 110V, depending on local standards.

2.2 Transformer Design

- Step-Up Transformer:
  - Located at the power generation source or substation.
  - Increases voltage from the generation level (e.g., 11kV) to the transmission voltage (12-33kV).
  - Transformers are equipped with lightning arrestors and circuit breakers for protection.
- Step-Down Transformer:
  - Installed near consumer locations or distribution points.
  - Reduces high transmission voltage to consumer-safe levels (240V or 110V).
  - The secondary winding is connected to the local distribution system, with neutral grounded to ensure circuit completion through the earth.

2.3 Conductor Specification

- Material: Aluminum or copper wire is typically used, with aluminum being more cost-effective and lighter.
- Size: The conductor size depends on the power demand and distance. For rural grids, smaller sizes may suffice.
- Single Conductor: The system uses only one conductor for high-voltage transmission.

3. GROUNDING DESIGN

3.1 Grounding Electrodes

- Material: Copper-clad steel rods, conductive concrete, or grounding plates.
- Location: Grounding must occur at the substation, at each step-down transformer, and at regular intervals along the transmission line.
- Depth: Grounding rods are typically buried several meters into the ground to ensure low-resistance contact with the earth.

3.2 Soil Considerations

- Soil Conductivity: The return path's efficiency depends on soil conductivity. In areas with poor conductivity (e.g., rocky or sandy soil), additional grounding electrodes or conductive concrete may be required.
- Grounding Intervals: In low-conductivity areas, grounding points are placed closer together to ensure reliable current return.

4. TRANSMISSION LINE DESIGN

4.1 Poles

- Material: Wooden, steel, or concrete poles are used based on local availability and weather resistance.
- Height: Typically 8-12 meters tall, depending on voltage levels and the need to avoid obstructions like trees and buildings.
- Spacing: Poles are generally spaced 100-150 meters apart, though this may vary depending on terrain.

4.2 Insulators

- Material: High-voltage ceramic or polymer insulators are used to suspend the conductor and prevent current leakage.
- Installation: Insulators are installed on poles to isolate the conductor from the pole structure and ground.

4.3 Lightning Protection

- Lightning Arrestors: Installed at the substation, step-down transformers, and key points along the line to protect the system from lightning strikes.
- Surge Protectors: Additional surge protectors may be installed at consumer endpoints to safeguard appliances from voltage spikes.

5. PROTECTION AND CONTROL SYSTEMS

5.1 Circuit Protection
- Circuit Breakers: Installed at substations and step-down transformers to isolate faulty sections of the network in the event of an overload or short circuit.
- Fuses: Used in smaller sections of the system or at consumer endpoints for additional protection.

5.2 Reclosers
- Automated Reclosers: These devices automatically disconnect faulty sections and restore power after temporary faults (e.g., lightning strikes) are cleared.

5.3 Supervisory Control and Data Acquisition (SCADA)
- Monitoring: Real-time remote monitoring of the SWER system is possible using a SCADA system. This allows operators to quickly identify faults, overloads, or system imbalances.
- Control: Operators can remotely control key components of the system, such as circuit breakers and reclosers, to improve response time and minimize downtime.

6. CONSUMER CONNECTIONS

6.1 Low-Voltage Distribution

- Two-Wire or Three-Wire System: After stepping down the voltage, electricity is distributed using traditional low-voltage distribution systems to consumers.
- Neutral Grounding: The neutral wire is grounded near the transformer to complete the electrical circuit through the earth.

6.2 Consumer Safety Devices
- Meters: Smart meters are installed to measure consumer power usage and ensure accurate billing.
- Circuit Breakers: Consumer endpoints are equipped with small circuit breakers to protect against overloads and faults.
- Surge Protectors: Installed to protect household appliances from surges caused by system faults or lightning.

7. SAFETY CONSIDERATIONS

7.1 Ground-Fault Protection
- Ground-Fault Detectors: Integrated into the system to detect and isolate ground faults. These detectors protect both the system and users from potentially dangerous voltage levels caused by improper grounding or system faults.

7.2 Touch and Step Potential
- Design Mitigation: Proper grounding and pole placement are used to minimize dangerous voltage exposure to humans and animals.
- Insulated Poles: In some designs, insulated materials are used on poles or around grounding points to reduce shock hazards.

IV. SIMULATION

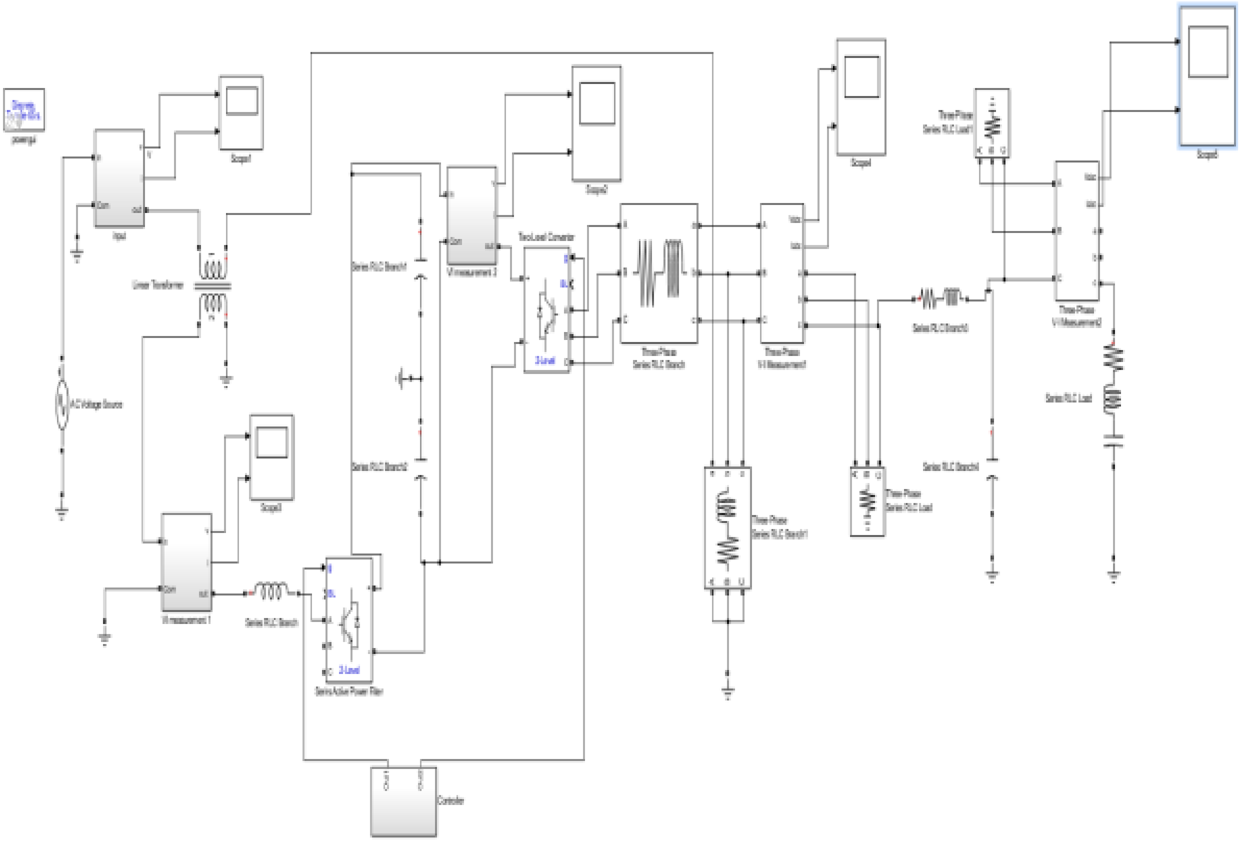
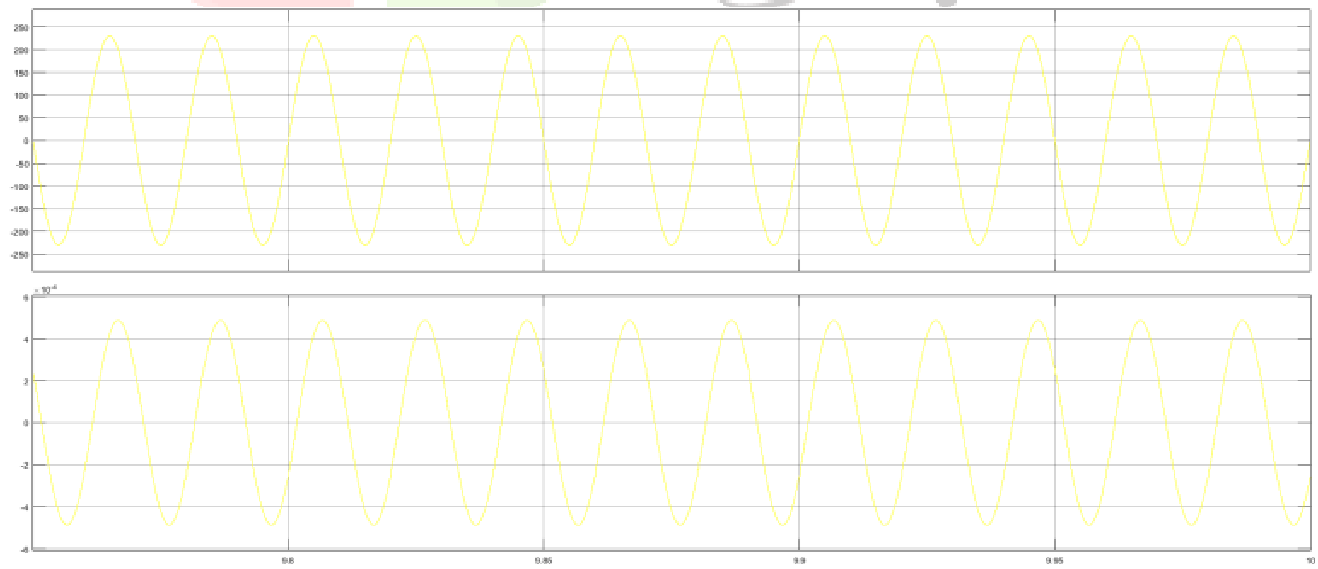


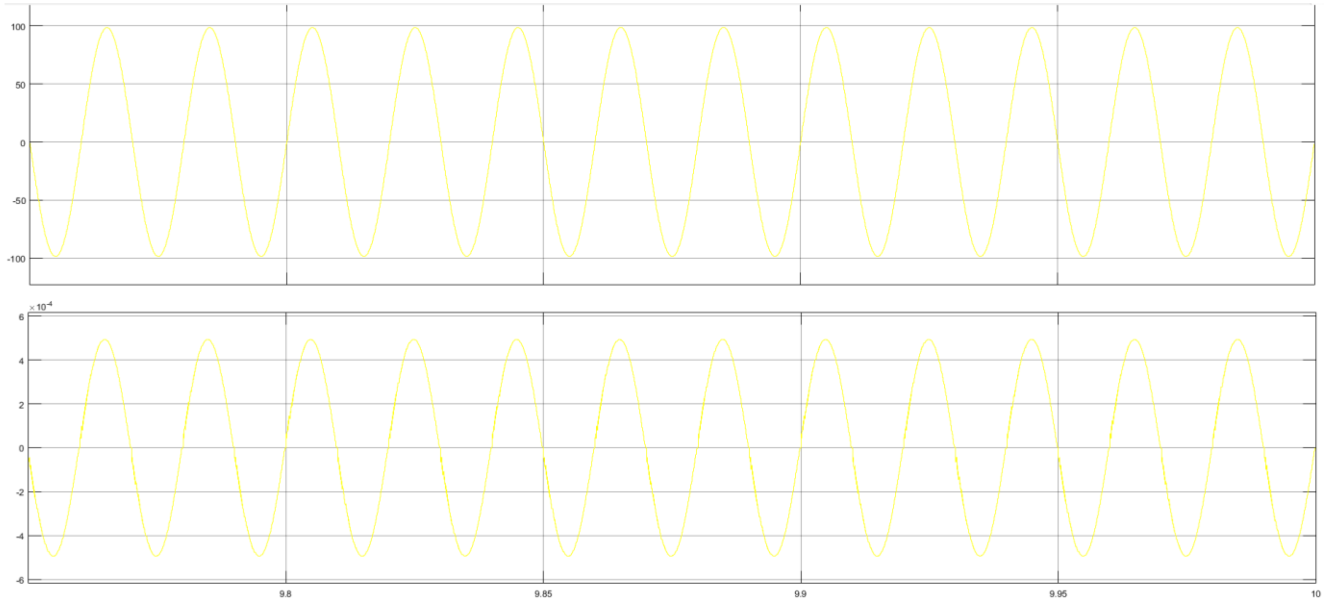
Fig. 3.Circuit Diagram of Transmitter Section

Output:

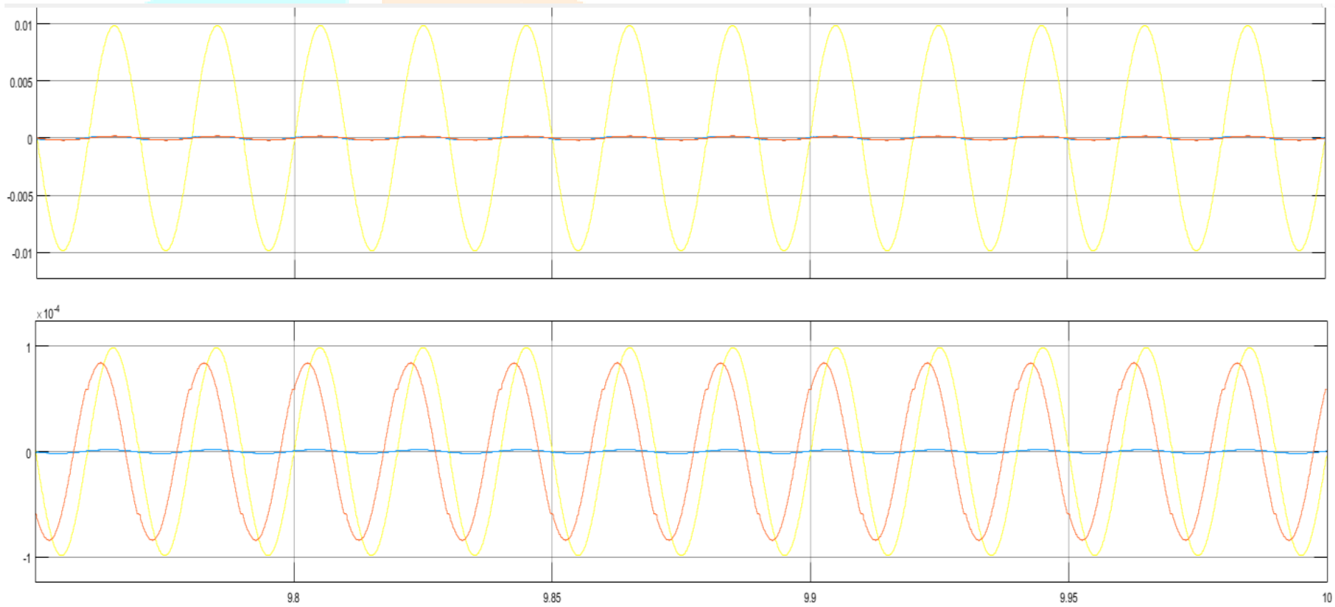
SCOPE 1



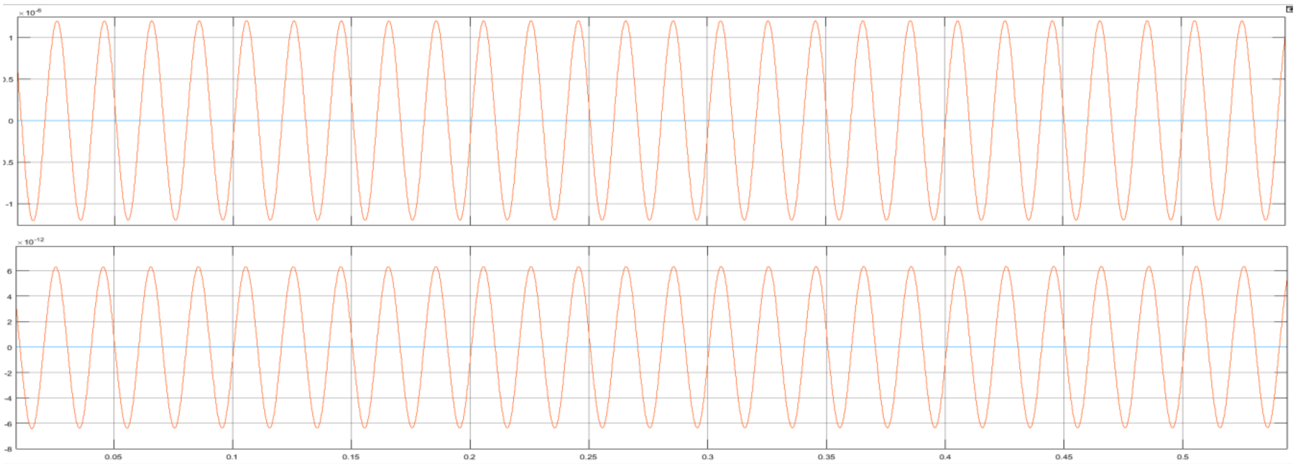
SCOPE2



SCOPE 3



SCOPE 4



V. PERFORMANCE PARAMETER

- Voltage Regulation

Measures the system's ability to maintain a consistent voltage level across all connected loads. Poor voltage regulation can lead to inefficiency and affect sensitive equipment.

- Power Losses

Total losses incurred due to resistance in the conductor and ground path. Minimizing these losses improves overall efficiency.

- Earth Return Path Resistance

The resistance of the earth return path impacts voltage drop and power losses. Low resistance in the earth path improves efficiency and power delivery.

- Line Capacity and Load Factor

The system's load factor is the ratio of average load to the maximum load within a given period. affects the system's ability to meet power demand without overloading.

- Voltage Drop

Voltage drop along the transmission line, especially over long distances, can reduce the voltage available to consumers and must be minimized for efficient distribution.

- Power Quality

Assesses the presence of harmonics, voltage fluctuations, and power factor. SWER systems often have lower power quality, which can affect connected equipment.

- Grounding Effectiveness

Proper grounding is essential to ensure that the return current flows safely through the earth. Ineffective grounding can lead to safety hazards and reliability issues.

- Safety Compliance

Ensures the system meets safety standards for personnel and equipment, addressing risks like electric shock or corrosion due to high earth currents.

VI. APPLICATION

Rural Electrification

- **Primary Use Case**: SWER systems are most widely used for rural electrification. In sparsely populated areas where the cost of constructing traditional multi-wire or three-phase transmission systems is prohibitive, SWER offers a low-cost solution.
- **Areas**: Farms, small rural communities, and remote homes benefit from SWER systems, providing them with access to electricity for lighting, heating, and small appliances.

2. Agricultural Applications

- **Irrigation and Water Pumping**: SWER systems are often used to power irrigation systems and water pumps on large farmlands. By supplying power to remote areas, SWER enables farmers to mechanize operations such as irrigation, significantly improving agricultural productivity.
- **Livestock**: In areas where livestock farming is dominant, SWER supplies electricity for electric fences, lighting, milking machines, and automated feeding systems.

3. Remote Settlements and Villages

- **Powering Remote Communities**: SWER is commonly used in remote or isolated villages, especially in mountainous, desert, or forested regions where traditional power grids are too costly or impractical.
- **Off-Grid Alternative**: For areas that are entirely off-grid, SWER can be a reliable and affordable alternative to more expensive solutions like diesel generators or solar systems with batteries.

VII. FUTURE SCOPE

1. Hybrid SWER-HVDC Systems For Efficient Long-Distance Transmission.
2. Intelligent SWER Grid Monitoring And Control Systems.
3. SWER-Based Microgrids For Rural Electrification.
4. Underground SWER Cables For Reduced Visual Pollution.
5. SWER Integration With Renewable Energy Sources.

VIII. SCOPE OF STUDY

The scope of a study on Single Wire Earth Return (SWER) power distribution grids can vary, but generally focuses on the design, implementation, and evaluation of SWER systems, particularly in rural areas or for cost-effective electrification. Key areas of investigation often include planning, voltage profile analysis, cost-benefit analysis, and the impact of SWER on telecommunication lines.

Conclusion

In this project demonstrates that SWER is a highly viable solution for rural electrification and remote power distribution. By addressing the needs of remote communities, small-scale industries, and isolated infrastructure, the SWER system plays a crucial role in bridging the electricity gap and fostering economic and social development in underserved regions. Future work could focus on integrating renewable energy sources into SWER systems and exploring ways to further enhance safety and efficiency, making it an even more sustainable and reliable power distribution method.

Despite these challenges, SWER systems are highly reliable when properly maintained and can provide electricity at a fraction of the cost of conventional two-wire or three-wire systems. It is especially valuable for rural electrification programs in developing countries, where extending the grid over large distances to reach low-density populations is often economically impractical.

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