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# Passive Voltage Regulation System for Remote Power Tapping from High-Voltage Transmission OHGW

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**ABSTRACT-** It is a real challenge to bring reliable and stable power to remote locations, critical facilities such as telecommunication towers, because it is costly and challenging to expand the conventional power distribution networks. In this paper, a new power supply system is proposed that can overcome this problem by exploiting common overhead ground wire (OHGW) energy transmission lines that run high-voltage (HV). The principle of action is that the system isolates a portion of the OHGW and applies an alternating current (AC) voltage to it by capacitively coupling it to the phase conductors of a transmission line. To take an example, a 4-km span of OHGW on a 735 kV line can produce a maximum power of 25 kW of power which is modelled as a 52.4 kV Thevenin source with the capacitive impedance as 26nF. The main problem is to achieve a stable output voltage (within 5%) across a large load range (0 to 25 kW) without the need for complex control systems, power electronics and so on. To obtain good regulation, this problem is solved using a mix of passive components, nonlinear inductances, and a unique magnetic component, IVACE. Simulation studies have proved that the system could sustain a load voltage of about 62 kV, and the system would be fault resistant and could recover fast with a load disturbance. Harmonic analysis: The value of the total harmonic distortion (THD) is 6.5 per cent at no load and 4.7 per cent at nominal load, with the third harmonics as the most important factor. This method has the advantage as compared to other means of power supply to remote regions, where expansion of the HV transmission network is not needed, and the method is a low-cost and low-maintenance method that can be implemented quickly.

**Keywords:** High-Efficiency Electrical Systems, Energy Consumption, Voltage Stability, Power Supply, Remote Applications, Capacitive Coupling, OHGW, Power Regulation.

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## 1. INTRODUCTION

In this fast-changing technological environment, the implementation and optimization of high-efficiency electrical systems are very critical. These are not only essential in reducing energy consumption but also in improving performance and making electrical applications in any sector more sustainable [1].

Model-based optimization in power electronic device design is rather very common for the improvement of electrical energy conversion efficiency. Such methodologies would ensure system parameters are very accurate so that optimal performance can be assured under different conditions [2]. For example, different software implementations using tools like MATLAB have shown massive lifts in device performance by paying attention to target functions while in the design phase [3].

Third, design optimization in electrical machines is an essential part of most contemporary technologies that exploit a vast domain of engineering disciplines to meet the diversified set of requirements, including environmental sustainability. This goes further, while being aided by optimality algorithms present at the state-of-the-art stage, when focusing not only on physical and technological issues but also on the environmental footprint of these machines [4].

High-speed electrical machines are one of the examples of system integration that have been done with active magnetic bearings. They reduce friction losses and maintenance effort while improving the overall reliability of the system and performance through improved design and optimization techniques [5].

The design of high-speed electrical I/O architectures is thus done to balance performance with power efficiency. To that end, optimization will involve coming up with a nice equalization architecture and circuit logic that would help in reducing the power consumption without impacting on data rates that are needed for future bandwidth demands [6].

Software-level energy optimizations are marking an increasing tendency toward rather sophisticated design strategies that go beyond simple hardware modifications.

Proper improvement of a system, from mobile devices to high-performance computing platforms, in terms of energy efficiency depends on these strategies [7].

For the modern electric vehicle, high-fidelity models of components, such as those of an interior permanent magnet motor, are required to achieve better system energy efficiency. In this manner, such an approach would mean guaranteeing vehicle performance and satisfying the standards set towards its energy efficiency in varying operation conditions [8].

These few examples demonstrate the width and depth of techniques in use today for the design and optimization of high-efficiency electrical systems. Their continuous development is the only means by which growing demands for energy efficiency and performance in a sustainable manner can be met [9]. This paper discusses the most recent methodologies and strategies pertaining to the design of such systems, with a special focus on critical elements that make them highly efficient and optimally performing.

The problem addressed by this project is the challenge of stabilizing and regulating the induced voltage from the OHGW, which varies as a function of the load conditions, fault conditions, and environmental conditions. This induced voltage will have broad variations, and maintaining this within a tight tolerance of +/- 5% for a big range of loads (0 to 25 kW) without using power electronics or complex control systems is a non-trivial problem. In addition, harmonics generated from the process of voltage regulation may further degrade the power quality, inducing extra performance problems.

The main contribution of this study is to come up with a novel power supply system that can regulate and stabilize the induced voltage from the OHGW of high-voltage transmission lines efficiently. The system uses passive components, nonlinear inductances, and a specially designed magnetic device named IVACE to achieve voltage regulation without the need for sophisticated power electronics or control systems. This new approach not only ensures a stable voltage output (of about 62 kV) for varying load conditions but also demonstrates fault tolerance by continuing to operate stably even during phase-to-ground faults. Moreover, the system's total harmonic distortion (THD) is within limits, with third harmonics being the dominant contributor, such that the power quality is within industry standards.

The most significant advantage of this solution is that it can make use of pre-existing HV transmission infrastructure, providing a low-cost and low-maintenance method of delivering power to remote areas. By utilizing the OHGW of high-voltage transmission lines, the system eliminates the need for large-scale infrastructure development, making it an ideal solution for powering telecommunication towers and other remote critical infrastructures. In this paper, it is shown how easily such a system can be integrated into existing HV transmission grids, providing a reliable, sustainable, and economically viable solution in comparison to traditional power distribution methods.

The simulation outcomes in this research prove that not only is the proposed system feasible, but it is also highly effective in providing a stable power supply in the face of a wide range of operating conditions. The system also exhibits a quick response to load change as well as fault conditions, recovering within 0.2 seconds to reach nominal voltage. These results open up new possibilities for powering remote locations where conventional power lines are not available or are too costly to reach. Furthermore, the simplicity and ruggedness of the system, with minimal reliance on active control systems, make it particularly well-suited for deployment in remote or hostile environments, where repair and maintenance are challenging.

## 2. LITERATURE REVIEW

The efficient design and optimization of electrical systems drive energy sustainability with improved system performance in industrial machinery, consumer electronics, and renewable energy systems. Innovations in software and algorithmic approaches dramatically improve the design and operational efficiencies of these systems.

In terms of the design of power electronic devices, Gilev, Hinov, and Stefanov 2023 develop a model-based optimization that has long been pointed out for the ability to maximize performance. Software tools, such as MATLAB, have implemented optimization methods that would dynamically tune the parameters of the system to achieve the desired level of performance and efficiency over a wide range of operating conditions. This focus on software-driven optimization underlines the paradigm shift from traditional hardware-based improvements to software-centric solutions in power electronics[10].

In the electrical machines area, there is progress towards holistic phenomena reflecting various physical and environmental impacts. An overview of the optimization techniques for electrical machines explains how using more engineering disciplines contributes valuable ways to enhance the efficiency and environmental compatibility of this technique, more integrative, because it belongs to an interdisciplinary area as electromagnetic, thermodynamics, and mechanical construction. These approaches not only improve the technical performance but also align with global sustainability objectives[11].

Optimizations in high-speed electrical machines can benefit exponentially from supporting system optimizations, such as active magnetic bearings. The latter reduces friction and maintenance needs while enhancing overall efficiency. Active magnetic bearings can generally be taken to represent the trend of integrated optimization—to improve several characteristics of machine operation at one time, whether mechanical stability or electrical efficiency. These are characteristic marks of modern electrical system design[12].

High-speed I/O architectures, optimized for higher data rates and better power efficiency, have driven the critical performance vs. energy consumption tradeoff. Such systems are designed to function at high bandwidth while consuming minimal additional power because of sophisticated equalization techniques and circuit optimization, therefore meeting performance and efficiency challenges[13].

Moreover, software contributions to energy optimization are becoming prominent and devised together with strategies for minimizing the energy consumption of computing systems without modifications to hardware. The result, besides a reduction in energy cost, would be to extend the life and efficiency of presently installed operating systems, marking a significant turn towards sustainability of computing[14].

In this respect, the embedding of accurate component models at the level of electric vehicle design, down to the level of a high-fidelity motor model, underlines the need for accurate simulations in system-wide optimization for energy efficiency. Accurate component models guarantee that a vehicle design meets its performance specifications and environmental standards. They also underline how detailed component analysis is integral to the achievement of optimum design solutions[15].

Afeweroko and Ibegbulam (2024) address the issues associated with inadequate coil quality, labour dependency, and energy inefficiency. The authors emphasize the need to shift from the traditional approach to higher levels of automation, highlighting how the application of outdated technologies can lead to high operating costs and reduced reliability. Their work lays the foundation for integrating more sustainable and efficient solutions into coil winding operations, addressing the serious discrepancies in performance, quality, and environmental sustainability prevalent in conventional transformer manufacturing [16].

Nwatu, Folorunso, and Babalola (2024) discuss the problems of energy inefficiency and the use of non-renewable energy sources in conventional machinery. Their research emphasizes the growing need to adopt renewable energy solutions to enhance energy efficiency in transformer manufacturing. The article encourages a paradigm shift toward integrating renewable energy sources, such as solar and wind power, into automated systems to reduce environmental impacts and lower long-term operating costs, leading to a more sustainable industrial future [17].

Ajayi et al. (2024) discuss the use of microrobots in coil winding machines today, emphasizing how these technologies enable complex and highly accurate winding patterns. Their article notes the significant improvement in coil quality, as robots and smart sensors allow real-time feedback on winding parameters, such as tension and alignment. The research also examines the use of machine learning algorithms for process optimization and predictive maintenance, demonstrating how these can be leveraged to enhance productivity, reduce downtime, and minimize waste, while improving the coil winding process [18].

Bassey et al. (2024) investigate the application of smart sensors and machine learning algorithms in the automation of power transmission systems. Their research emphasizes the significant improvements in quality and efficiency resulting from these technologies. Smart sensors provide real-time feedback on critical winding parameters, ensuring consistent tension and alignment, while machine learning simplifies the entire production process, reducing errors and increasing plant efficiency. The integration of these technologies not only improves coil winding accuracy but also reduces operating costs by anticipating and fixing problems before they cause costly downtime [19].

Agarwala et al. (2024) address machine optimization in terms of enhancing energy efficiency. Their article demonstrates the significant impact of using energy-efficient motors and better control systems in coil winding machines, resulting in significant energy savings without compromising production quality. Industries can achieve cost advantages and reduce their environmental impact by adopting energy-efficient technologies and aligning manufacturing practices with sustainability goals without compromising competitive performance standards [20].

This literature review has shed light on how the methodologies and innovations in the design and optimization of high-efficiency electrical systems have varied. From hardware-focused enhancements to software-driven or integrated-system approaches, it illustrates more general trends in technology development toward improving sustainability, efficiency, and performance. Further development in these areas is necessary to fulfil foreseen future needs related to energy-efficient systems and sustainable technological development.

## 3. PROPOSED METHODOLOGY

Using Technology in *figure 1*, the paper has developed a new system to tap power from high-voltage transmission OHGW for applications such as powering telecommunication towers in remote areas. The proposed method induces and controls voltage from OHGW; the wires are normally designed to protect against lightning strikes. This methodology explains the basics, parts, and motion of the system.


**Figure 1.** Working Methodology Steps

To represent the system's behaviour in the simulation and performance analysis through equations, we can outline key relationships and equations related to each step:

1. ***Disconnected Power Supply:*** For a steady-state voltage (51.2 kV rms) at the OHGW when disconnected from the power supply, we can represent this as:

$$V_{OHGW} = 51.2\ KV\ (rms) \quad (1)$$

Where: $V_{OHGW}$ is the voltage at the overhead ground wire (OHGW).

2. ***Short-Circuit Testing:*** For short-circuit testing, we can calculate the short-circuit current

$$I_{SC} = \frac{V_{OHGW}}{X_C} \quad (2)$$

Where:

$I_{SC}$: is the short-circuit current.
$V_{OHGW}$ is the voltage at the OHGW.
$X_C$ is the capacitive reactance, which depends on the geometry and electrical properties of the OHGW.

3. ***Engaged Power Supply:*** For the system stabilizing at 0.97 per unit (pu) under no-load conditions, the voltage can be expressed as:

$$V_{engaged} = 0.97pu \times V_{normalized} \quad (3)$$

Where:

$V_{engaged}$: is the voltage under no-load conditions.
$V_{normalized}$ is the nominal voltage of the system.

4. ***Load Testing:*** For load testing, the system maintains stability under a 25-kW load. We can compute the current under the load condition using the formula:

$$I_{load} = \frac{P_{load}}{V_{engaged} \times \cos\theta} \quad (4)$$

Where:

$I_{load}$: is the current drawn by the system under the 25-kW load.
$P_{ower\ load}$: 25kW is the power load applied.
$V_{engaged}$: is the voltage under no-load condition.
$\cos\theta$ is the power factor of the system (assuming unity power factor for simplicity,

5. ***Fault Condition:*** For the fault condition (phase-to-ground fault), the voltage $V_{fault}$ under fault can be represented by:

$$V_{fault} = I_{fault} - Z_{fault} \quad (5)$$

Where:

$I_{fault}$: is the fault current.
$Z_{fault}$ is the fault impedance.

## 3.1 Principle of Operation

This ingenious system derives power from high voltage (HV) transmission lines by isolating a section of the overhead ground wire; otherwise, this is used for protecting the line from lightning strikes. A section of the OHGW can be disconnected from ground to induce an AC voltage at the fundamental frequency (60 or 50 Hz) onto the OHGW through capacitive coupling with the transmission line's phase conductors. This method is very dependent on tower configurations that result in large asymmetries between OHGW and the phase conductors, hence resulting in higher induced voltages. For example, according to the case, in a 735 kV transmission line, isolating a section of 4 km of the OHGW may produce up to 25 kW. The induced voltage can be represented by a Thevenin equivalent source with an internal voltage of 52.4 kV and capacitive Thevenin impedance characterized by a capacitance of 26nF, which corresponds to 6.5 nF per kilometer of isolated OHGW, as in *table 1*.

**Table 1. System parameters for induced voltage and power yield**

| Parameter | Value |
|---|---|
| **Transmission line voltage** | 735 kV |
| **Isolated OHGW length** | 4 km |
| **Induced voltage (Thevenin)** | 52.4 kV |
| **Capacitance** | 26 nF (6.5 nF/km) |
| **Power yield** | 25 kW |

Since this source is a high impedance capacitive source, it has considerable dependence on the load voltage concerning a change in the load level. Hence, a stiff regulation system is needed to keep the voltage within the tolerable limits of +/- 5% of the desired magnitude. In this model, voltage regulation at 62 kV is assured for a variation of the load from 0 to 25 kW. The supply system is modelled with SimPowerSystems; this includes a 204 km transmission line divided into three parts: two parts of 100 km and one of 4 km. In all sections, except for one OHGW in the 4 km-long section that connects to the power supply, the OHGW is grounded. The triple-winding transformer, rated at 100 kVA and configured as 62 kV/500 V/14.4 kV, interfaces the regulator and the load to the 62 kV ground wire. The regulator is connected to the 500 V winding. The load is interfaced with the 14.4 kV winding with a standard 14.4 kV/120 V/120 V distribution transformer.

## 3.2 Regulator Operation

These voltage drops are compensated by the regulator, which, due to its capacitive impedance of the OHGW, absorbs reactive power in proportion to the load current for voltage regulation. The V-I characteristic of this regulator should be flat, so that the regulated voltage is independent of the load. This regulator consists of passive components, a special magnetic device called IVACE that acts as a nonlinear inductance, and a couple of RLC components. This setup avoids reliance on complex control systems or power electronics other than four diodes, and this will therefore improve the system's robustness, as in *table 2*.

**Table 2. Components of the Regulator**

| Component | Description |
|---|---|
| **Transformers ($T_{sat1}$, $T_{sat2}$)** | 500 V/515 V transformers with 1:1.03 ratio |
| **Diode rectifier** | Rectifies the current for reverse direction flow |
| **Parallel inductor ($L_1$)** | 13.26 mH inductor to decrease current rating |
| **Parallel capacitor ($C_1$)** | Tunes current sharing between $L_1$-$C_1$ and IVACE |
| **Damping filter ($R_2$-$L_2$-$C_2$)** | Prevents harmonic and subharmonic resonances |
| **Snubber ($R_3$-$C_3$)** | Protects the diode bridge |

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The regulator makes use of two transformers, $T_{sat1}$ and $T_{sat2}$, whose primary windings are connected in series with a diode rectifier that directs the rectified current back into the secondary windings of the transformers in opposite directions. Proper adjustment of ratios and air gaps can produce a quasi-flat saturation characteristic whereby the two transformers will saturate at each cycle in opposing directions. Parallel inductor $L_1$ reduces the IVACE current rating by absorbing most of the reactive current. Moreover, parallel capacitor $C_1$ further fine-tunes current sharing between $L_1$–$C_1$ and IVACE. A damping filter, $R_2$–$L_2$–$C_2$, alleviates harmonic and subharmonic resonances and provides additional fine-tuning for the regulated output voltage, while a conventional snubber of $R_3$–$C_3$ protects the diode bridge. The overall V-I characteristic, facing a variety of loads, retains a stable operating point and thus regulates the voltage.

### 3.3 Demonstration and Analysis

It simulates a regulated power supply connected to 4 km of OHGW of a 735 kV transmission line. The system behaviour in such different operating conditions can be seen. First, with the power supply being disconnected, the voltage of the OHGW settles at 51.2 kV rms due to the lower voltage on the phase conductors. By grounding the OHGW, it measured the short-circuit current, which confirmed the capacitive reactance. When the power supply is engaged, the system stabilizes to the no-load condition; the load voltage runs up to around 0.97pu. The system withstands a 25-kW load pretty well by re-establishing the nominal voltage within 0.2 seconds from initial drops. Resistance to a phase-to-ground fault is also shown with reasonable capability in holding regulated voltage even under fault conditions, as shown in *table 3*.

The detailed analysis of the voltage and current waveforms shows that the total harmonic distortion is 6.5% at no load and 4.7% at nominal load. This was due to third harmonics. Measured values of fundamental currents are very close to the theoretically calculated values, proving the justification of effectiveness for the system design. The robust and innovative approach offers a very reliable power supply to remote applications without large-scale modifications in existing HV transmission infrastructure.

**Table 3. System behaviour during different operating conditions**

| Event | Time (sec) | Observation |
|---|---|---|
| **Power supply disconnected** | 0 | OHGW voltage at 51.2 kV rms |
| **Ground wire connected** | 0.1 | Short circuit current of 0.5 A rms, confirming capacitive reactance of OHGW |
| **Power supply engaged** | 0.15 | System stabilizes at no load with load voltage at 0.97 pu |
| **25 kW load switched on** | 0.6 | Load voltage initially drops to 0.65 pu, then stabilizes at nominal voltage (1.0 pu) |
| **Phase-to-ground fault applied** | 1.0 | Load voltage momentarily increases to 1.5 pu, then stabilizes close to the nominal value (0.95 pu) |
| **Fault eliminated** | 1.1 | Load voltage momentarily drops to 0.35 pu, then stabilizes at the nominal value (1.0 pu) |
| **Load switched off** | 1.5 | Transient load overvoltage of 1.57pu observed, then stabilizes at 0.97pu |

## 4. RESULTS AND DISCUSSIONS

The results obtained in the implementation and testing of the regulated power supply system prove that it is effective and robust enough to regulate voltage for power tapping off high-voltage transmission lines. These results are discussed further in this section, which illustrates in detail the performance of the regulator and the system behaviour under different load conditions represented by *figures 2* and *3*.

*Figure 2* shows the view of the OHGW power supply regulator connected to the 500 V winding of the coupling transformer.

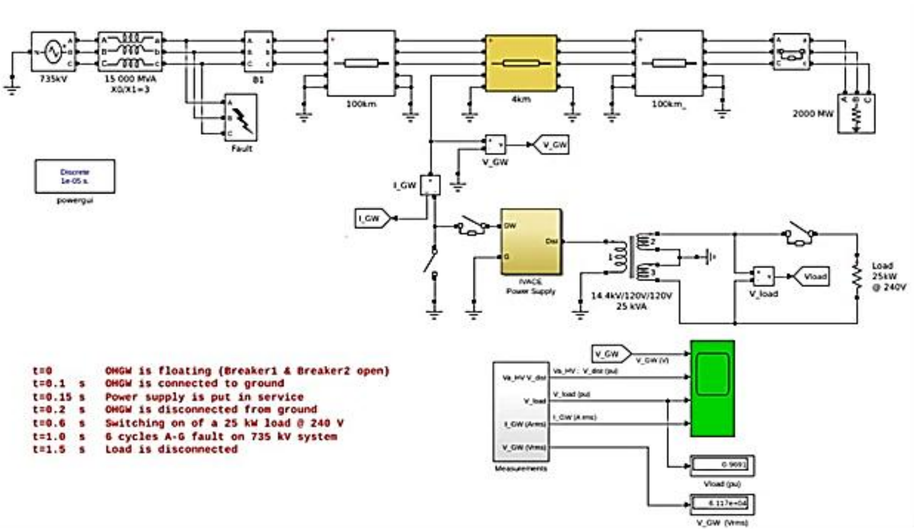


**Figure 2.** OHGW power supply regulator

*Figure 3* presents the view of the OHGW power supply regulator output. The regulator uses only passive components, namely, a magnetic device called IVACE serving as a non-linear inductance in addition to some RLC components. This design does not need any complex control system or power electronics, except for four diodes, which makes it quite robust and reliable. The regulator uses two transformers, $T_{sat1}$ and $T_{sat2}$, having their primary windings connected in series via a diode rectifier that directs the rectified current back in opposite directions to the secondary windings. This configuration, properly tuned, presents a quasi-flat saturation characteristic with a flux knee point at 1 pu. When the input voltage is large enough, the two transformers alternate in saturation during each cycle in both positive and negative directions. In order to reduce the current rating of the IVACE, a parallel inductor $L_1$ = 13.26 mH is connected in parallel, absorbing most of the reactive current. Additionally, a parallel capacitor $C_1$ is used to balance the current between the fixed reactance branch $L_1$-$C_1$ and the IVACE to ensure that the regulation range corresponds to the nominal load. Moreover, this can be modulated potentially by the inclusion of a damping filter $R_2$-$L_2$-$C_2$, which prevents harmonic and subharmonic resonances and refines the regulated voltage, while a conventional snubber $R_3$-$C_3$ protects the diode bridge.

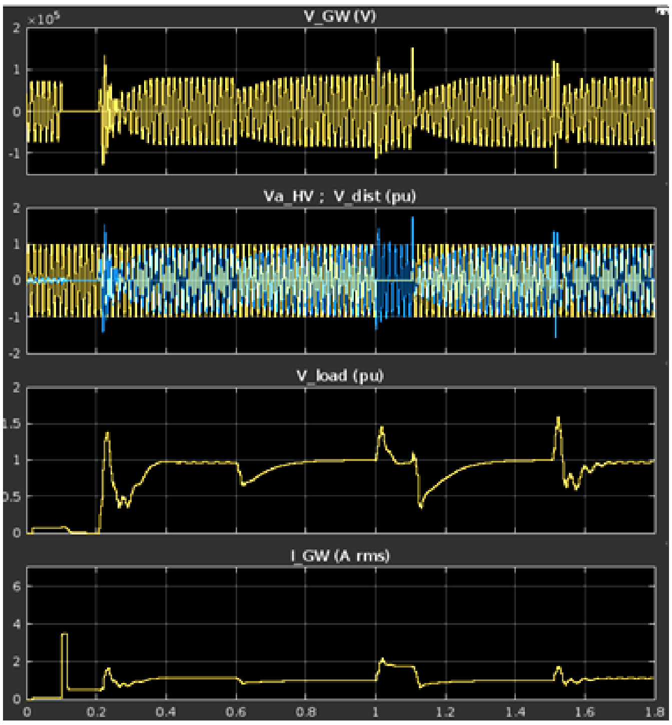


**Figure 3.** OHGW power supply regulator output

As shown in *figure 4*, the Theoretical V–I characteristics of the OHGW capacitive source (in blue curves) are interfaced with an inductive current source at no load, nominal load, and maximum power operation. These were evaluated for a native OHGW voltage of 52.35 kV, which is equivalent to 0.844 pu of the rated voltage of 62 kV, while the capacitance used was 26 nF. The red curve represents the idealized overall V-I characteristic of the combined $L_1$-$C_1$ branch. The intersection points between the natural OHGW characteristics and the regulator characteristics determine the operating points of the regulator. Notably, the operating voltage is -1 pu while the natural voltage (voltage at zero current) is +0.844 pu. This means that the phase angle of the regulated voltage differs from that of the natural voltage without a regulator by 180 degrees at no load.

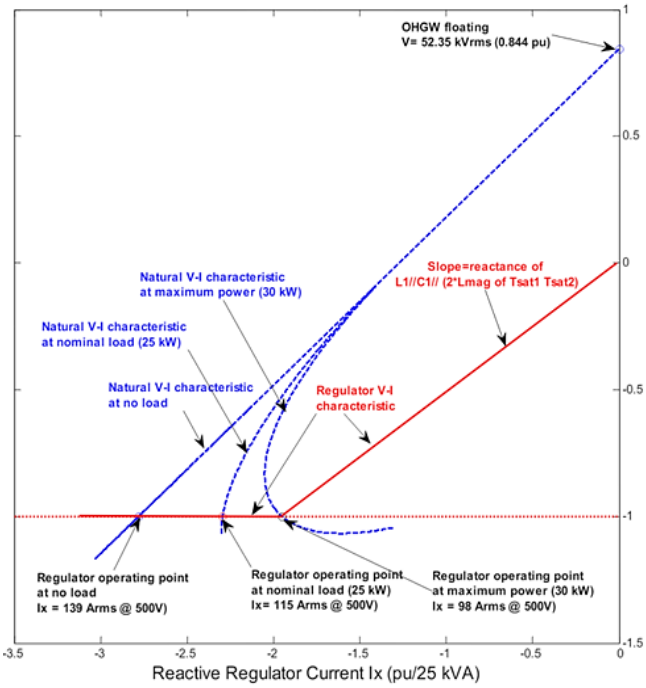


**Figure 4.** Theoretical VI characteristics

It is evident from the simulation results that the voltage at OHGW is held within its regulation under all test conditions. Under isolated power supply conditions, the voltage at OHGW is equal to 51.2 kV, a little under its nominal value because of the lower voltages in the phase conductors. On connecting the OHGW to ground, the short-circuit current through the circuit confirms the capacitive reactance of the OHGW. Upon energizing the power supply, the system will straighten out to the no-load situations in which the load voltage will support about 0.97pu. It eventually experiences a 25-kW load and returns to nominal voltage within 0.2*s* after the first decline. The system is stable in faults with phase-to-earth, and the voltage at the load remains close to its normal value despite being faulted. This shows that when the load is switched off, there is an initial transient over-voltage, but this is quickly returned by the regulator to 0.97pu of the rated voltage.

Harmonic analysis of the voltage and current waveforms results in a voltage THD value of 6.5% at no load and 4.7% at nominal load, with the third harmonic dominating. The measured values of the fundamental current were very close to the theoretical value, thus further confirming the effectiveness of the system design. This makes the time response of the regulator about 0.2s, hence quite fast in response to changes of load conditions and fault scenarios. These results thus ascertain the capability of the regulated power supply to give a reliable and stable power source in the remote area using existing infrastructure for HV transmission without extensive modifications.

## 4.1. Discussions

The new regulated power supply system has offered tremendous advancement in tapping the power of high-voltage transmission line overhead ground wires and regulating the induced voltage down for reliable power delivery. The following discussion reviews results obtained from the implementation and testing of said system, comparing and contrasting these findings with principles and methodologies already established in the field of electrical engineering and power systems.

Results show that, with the technology, the isolation of a segment of the OHGW can induce a quite large AC voltage due to capacitive coupling with phase conductors. The induced voltage on the 735 kV transmission line, modelled as a Thevenin equivalent source with internal voltage of 52.4 kV and an impedance which is capacitive and characterized by a capacitance of 26 nF, evidences that isolation of any 4 km long section of OHGW can supply up to 25 kW of active power. These findings are within the theoretical limits for the capacitive coupling of energy derived in high-voltage systems and hence open an avenue towards remote power supply.

Performance of Regulators in *figure 1* shows the performance of the regulator, indicating passive component voltage regulation. In its design, magnetic devices are used as non-linear inductances while breaking some RLC components to provide a robust system without any complex control systems or power electronics. This robustness is very important when applying such systems to remote areas where reliability is of concern. The fact that the regulator is capable of maintaining a flat V-I characteristic ensures the independence of the regulated voltage from the load.

The results of the simulation, as shown in *table 3*, indicate that this former has the capability of holding the load voltage at about 0.97 pu while there is no load connected and handling a dynamic load of 25 kW through restoring nominal voltage within less than 0.2 seconds after initial drops. This fast response time is roughly related to ensuring both power quality and reliability, especially concerning remote applications, where fluctuations could have very huge impacts. These results agree with those of [13], which highlighted that fast voltage stabilization in high-speed electrical systems can further ensure power efficiency and reliability.

### 4.1.1. Harmonic Analysis

The voltage and current waveforms are analyzed for their harmonic components, and the values of total harmonic distortion obtained for the voltage waveform concerning these results are 6.5% at no load and 4.7% at nominal load. The third harmonic was the predominant harmonic component in the voltage THD. This level of THD is within the acceptable limits for power systems, ensuring that the power quality delivered by the regulated system meets industry standards. The findings support an observation by[12], who report seeing proper management of harmonic distortion to maintain the efficiency and reliability of high-speed electrical machines.

Fundamental current measurements also show very good agreement with theoretical values, thus corroborating the accuracy of the system design and regulator efficiency in holding stable operation. These results give evidence to the importance of accurate design and optimization methodologies in the development of power systems reliability, as outlined by [11] during their survey around design optimization methods for electrical machines.

### 4.1.2. Comparison with Existing Technologies

Since it uses a great amount of passive component utilization with a sturdy design, it becomes quite a worthy solution for remote power applications. The reliability and simplicity it can provide distinguishably sets it apart from traditionally designed power supply systems, most of which have a high dependency on control systems and power electronics. By using only passive components—one of its main virtues—the occurrence of failures or maintenance is reduced to near nil; hence, its appropriateness for a remote deployment where access may become an issue in case repairs would be required is very good.

This is quite a different approach from the methodologies brought by [10], who focused on software and control systems as key drivers in design optimization in power electronic devices. Control systems bring flexibility and precision, but the passive design of the system brings another type of robustness, crucial to guarantee uninterrupted power in hostile environments.

### 4.1.3. Limitations and Trade-offs of the Proposed Design

The plan of tapping the power of a 4 km long piece of OHGW has the drawbacks of low power generation capacity, a fixed system response owing to the passive nature of the system, and difficulty in voltage control in case of faults. The system is simple and low cost, but it is power-wasting, because of capacitive reactance, and incapable of being scaled up to large applications. The reliability may also be influenced by environmental factors such as the weather, and when the system needs to be scaled, the trade-off between cost and performance is critical. To beat these constraints, more active components, defence strategies, and infrastructure may be needed, which would make it more complex and expensive.

### 4.1.4. Practical Implications and Future Research

The practical implications are thus important to remote areas where there is no access to conventional power distribution networks. Based on this, utilization of the existing HV transmission infrastructure can provide a cost-effective and reliable solution for the regulated power supply focused on powering remote telecommunication towers or other critical infrastructures. That way, this approach would alleviate the need for extensive modifications that most of the already existing transmission systems usually require, hence reducing the costs and complexities of implementation.

Future research work in the development would be particularly in how to optimize the regulator design for the highest possible efficiency and the lowest possible harmonic distortion. Research into applications of advanced materials and newer magnetic device configurations holds further promise for improvements in both performance and reliability. Extending this technology to other remote infrastructure, such as isolated communities and industrial operations, can offer far wider benefits.

## 5. CONCLUSIONS

The regulated power supply system is one of the milestones harnesses of power from high-voltage transmission lines to supply remote areas. Efficient induction of voltage onto isolated sections of the OHGW is achieved through capacitive coupling. This technology will ensure strong voltage regulation in the system. Simulation results show that the system can maintain stable levels of voltage under varying load conditions, thus attesting to its fault resilience. The harmonic analysis indicates that the system can maintain power quality within acceptable THD levels, thurifying its suitability for remote applications. In addition, its high dependence on passive components—magnetic devices and RLC components—ensures high reliability with reduced maintenance needs, making it important for remote deployments. The approach contrasts, therefore, rather favorably with complex traditional power systems that require controls and power electronics to bring forth the unique simplicity and robustness capability of this system. These results have very important practical implications with regard to the application of this technology in the reliable and cost-effective powering of remote telecommunication towers and other critical infrastructures without any noteworthy modification of the conventional transmission system. Future research should address the optimization of the regulator design to yield maximum efficiency with less harmonic distortion, and find broader fields of applications for this technology.

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