VIRTUAL GUIDED LABORATORY APPLICATIONS ON THE VERIFICATION OF OHMS LAW

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ABSTRACT

Ohm's Law has long been a cornerstone of electrical engineering, providing a linear relationship between voltage, current, and resistance that has underpinned modern circuit analysis. However, as technology advances and philosophical inquiries deepen, the limitations of this venerable law have become evident, particularly in scenarios involving near-zero resistance. This paper introduces a novel formulation-the modified Ohm's Law; that not only rectifies the pitfalls of the conventional law but also harmonizes physics with philosophical principles. Motivated by the perplexing issue of predicting infinite current at zero resistance and the philosophical implications of deriving infinity from the finite, the modified equation serves as a bridge between empirical insights and logical coherence. Through rigorous mathematical derivation, comprehensive theoretical examination, and scrupulous computational analysis, the accuracy and applicability of the modified Ohm's Law are not only demonstrated but also its suitability across a wide range of scenarios is revealed. These scenarios include semiconductor devices, high-current applications, and complex systems where the standard Ohm's Law falls short, offering a transformative perspective on the analysis of electrical circuitry. In reconciling scientific rigor with philosophical consistency, this paper advances our understanding of electrical circuitry and beckons a newera of precision in analysis. Further, the modified Ohm's Law paves the way for deeper explorations that resonate through the domains of physics and philosophy, reshaping the landscape of our understanding.

Keywords: Modified Ohm's Law, Electrical circuit analysis, Non-linear behavior, Resistance, Exponential function, Short circuit, Philosophy of physics, Accuracy, Computational analysis

1. INTRODUCTION

Electricity, the backbone of modern civilization, has woven itself into the very fabric of our daily lives. The intricate networks of circuits power our homes, workplaces, and digital connections. At the core of understanding and harnessing this invisible force lies the Ohm's Law, a principle that has guided the domain of electrical engineering for generations [1-5]. However, as technological prowess evolves and our insights into the dynamics of circuits deepen, the limitations of this long-standing law have begun to emerge [6-9]. This paper embarks on a transformative journey, introducing an innovative formulation-the modified Ohm's Law-that not only addresses the deficiencies of the conventional law but also seeks to bridge the gap between scientific tenets and philosophical principles. For over a century, Ohm's Law ($v = IR$) has been the bedrock upon which engineers and scientists have built the edifice of electrical and electronics engineering [1], [3], [4], [10-12]. It's simple linear relationship between voltage (v), current (I), and resistance (R) has unlocked countless possibilities, enabling the design, analysis, and optimization of circuits that underpin our modern way of life. Yet, as technological frontiers advance, so too does our scrutiny of the foundations upon which they rest. Amidst these advancements, the conventional Ohm's Law harbors an intriguing paradox; it suggests that in an electrical conductor, when the resistance (R) approaches zero, the current (I) becomes infinite [5]. This assertion, while it maybe mathematically coherent, raises profound questions about the very nature of our reality. It challenges our experiential understanding and delves into the domain of philosophical paradoxes [13], [14], where the notion of deriving infinity from the finite is at odds with our intuitive grasp of the world. This paper embarks on a quest to address this conundrum and proposes an alternative formulation, the modified Ohm's Law that harmonizes the empirical with the philosophical, rectifying the tensions between the mathematical characterization of the Ohm's Law and reality. Guided by the principles of scientific advancement and philosophical coherence, this paper navigates the intricate terrain of electrical circuitry. It seeks to redefine the boundaries of our understanding by examining the motivations behind modifying the standard Ohm's Law and unearthing the theoretical underpinnings of the modified equation. Furthermore, it employs computational analysis to unravel the practical implications of this new formulation across diverse scenarios. From semiconductor devices to high-current applications, the modified Ohm's Law promises aparadigm shift in the way we approach electrical circuit analysis.

2. A PHILOSOPHICAL AND THEORETICAL EXPLORATION

In light of these intricate considerations, it becomes evident that the notion of resistance reaching zero is fraught with challenges that extend beyond the domain of physics alone. The paradoxes and inconsistencies that emerge when grappling with the concept of infinite current at zero resistance demand a holistic exploration that delves into both theoretical and philosophical dimensions.

2.1 The Infinite Current Fallacy

The standard Ohm's Law, while remarkably successful in predicting and explaining electrical behavior, harbors a perplexing fallacy that challenges both physics and intuition. According to the standard Ohm's Law, when resistance approaches zero, the resulting current tends toward infinity [5]. This concept, however, contradicts fundamental experiential understanding. Practical scenarios exist where infinitely large currents are not observed, and this inconsistency creates a rift between theoretical predictions and empirical observations. This paper delves into this apparent paradox and investigates its implications. Confronting this issue head-on, the goal is to rectify the discrepancy between theoretical constructs and the physical world, paving the way for a more coherent understanding of electrical circuit behavior.

2.2 The Philosophy of Something from Nothing

The claim that zero resistance results in an infinite current presents a philosophical puzzle that extends beyond the domain of physics comprehension. This concept appears to attribute an infinite effect from a finite cause, challenging the principles of causality and the continuity of physical phenomena. Furthermore, the suggestion that an infinite quantity could originate from a finite source, or perhaps even from nothing, is perplexing and defies our intuitions about magnitude and the nature of infinite quantities (in a broader sense, it contradicts our understanding that something cannot emerge from nothing [13], [14]). Such a contradiction raises profound philosophical questions about the nature of reality, causation, and the very foundation of physical laws [15-17]. Introducing the modified Ohm's Law aims to address these philosophical tensions. The exponential relationship in the modified equation inherently restricts the notion of infinite current at zero resistance, aligning more harmoniously with our philosophical understanding of causality and the limitations of deriving limitless quantities from finite ones.

2.3 Reconsidering $R = 0$ In Classical Settings

The assumption that resistance can ever exactly reach zero is examined from both classical and modern perspectives. Classical physics holds that infinitesimal quantities have definite values, but modern theories such as quantum mechanics introduce uncertainty even at the smallest scales [18]. In the context of electrical circuits, the assumption of zero resistance triggers paradoxes and inconsistencies that hinder our ability to accurately model real-world behavior. This section endeavors to challenge the idea that, when dealing with a conductor, electrical resistance denoted as R can equal zero. The perspective of zero resistance, as presented in [19], is adjusted and embraced. The fundamental current formulation derived from Ohm's law is presented in equation (1):

$$I = \frac{V}{R} \tag{1}$$

In the ideal (mathematical) form, equation (1) suggests the perplexing possibility that:

$$\mathrm{I} = \frac{V}{0} = \infty \tag{2}$$

This implication raises the question of deriving an infinite quantity from a finite physical relationship. The ensuing discussion aims to provide a coherent objection to this perspective and, in doing so, challenges the plausibility of the mathematical assertion that electrical resistance in a conductor can ever be $R = 0$.

The foundational definition of electrical resistance is commonly expressed as:

$$R = \rho \frac{L}{A} \tag{3}$$

To explore the notion that $R = 0$, let us consider two hypothetical instances:

Premise 1 **(When** $L = 0 \Rightarrow A = 0$**).** Considering the geometric property of the conductor's cross-sectional area $A = \pi r^2$, where r is the radius, a relationship between L and r can be established. Thus, when, $L = 0$, it would imply that $r = 0$ suggesting the existence of electrical conductors without any measurable cross-sectional area in their geometry. This leads to the curious mathematical result:

$$R = p\frac{0}{0} = \infty \tag{4}$$

Equation (4) demonstrates that if the hypothetical relations $L = r = 0$ were valid, the electrical resistance of the conductor would tend towards infinity, rather than zero. This scenario is counterintuitive, as an infinitely large electrical resistance contradicts the existence of an electrical conductor. A more accurate interpretation could be that in the case of an open circuit, resistance tends towards infinity, as posited in studies involving electrical voltage and current using Norton-Thevenin relations [20]. This paper acknowledges the significance of geometry in influencing electrical resistance.

Premise 2 **(When either** $P = 0$**).** Setting $p = 0$ in equation (3) results in $R = 0$, which might seem plausible. However, this assertion holds ambiguous physical significance and is subject to challenge. In this context, p represents the inherent resistivity of the electrical conductor, and asserting $p = 0$ implies a conductor devoid of resistivity property or material. This proposition contradicts the reality, as materials inherently possess resistive properties. Consequently, it is rational to conclude that material resistance equals zero only in the absence of conducting material or when no voltage and current source is present (with the consideration that any power source inherently possesses some resistance, as studied in the context of Norton-Thevenin concepts [20]). From a physics standpoint, the assertion that $(R = 0)$ contradicts the fundamental principles governing electrical behavior. Electrical resistance is a measure of how a conductor opposes the flow of electric current. This opposition arises due to various factors, including collisions between electrons and lattice vibrations within the conductor's atomic structure. These interactions inherently contribute to the resistive properties of materials. Proposing that $(R = 0)$ implies the absence of these interactions altogether, which contradicts the very nature of conductive materials. Even in the most ideal conditions, materials possess inherent properties that introduce a level of resistance, rendering the concept of zero resistance implausible. Beyond the domain of physics, the notion of zero resistance carries philosophical implications that challenge the very foundations of our understanding of causality and existence. The philosophical principle of causality asserts that an effect arises from a cause [15-17]. The assertion of infinite current $(I = \infty)$ corresponding to zero resistance $(R = 0)$ defies this principle by suggesting an effect without a cause-a finite voltage (v) seemingly generating an infinite result. This contradicts the inherent order and logic that underpin our conception of reality. Further complicating matters is the concept of idealization, often encountered in theoretical models. In the idealization of $(R = 0)$, we encounter a scenario where the resistance of a conductor is perceived to vanish under perfect conditions. However, the idealization of zero resistance becomes an exercise in abstraction divorced from practical realities. In the physical world, no conductor can be completely devoid of resistive effects. Even superconductors, often cited as examples of extremely low resistance, possess non-zero resistance at finite temperatures. This serves as a reminder that real-world conditions introduce complexities that challenge idealized notions. The assumption that in ideal scenarios $(R = 0)$ leads to paradoxical outcomes. An infinite current suggests an unbounded flow of charge, potentially generating infinite energy. This paradox fundamentally contradicts conservation laws and energy principles. Infinite quantities arising from finite conditions undermine the coherent understanding of physical laws and mathematics. Generally, the proposal that $(R = 0)$ in electrical conductors encounters insurmountable challenges at both the physics and philosophical levels. The inherent resistive properties of materials, the violation of causality, the issues of idealization, and the paradoxical nature of infinite quantities all converge to discredit the plausibility of zero resistance. As such, the pursuit of an accurate description of electrical behavior necessitates a departure from the notion of $(R = 0)$ and a recognition of the complex interplay of physical and philosophical principles that govern our understanding of the universe.

3. DERİVATİON AND THEORETİCAL EXAMİNATİON OF THE MODİFİED OHM'S LAW

Having examined the limitations posed by the standard Ohm's Law and recognizing the need for a more accurate framework, the next step involves the mathematical derivation and theoretical underpinnings of the modified Ohm's Law. By introducing an exponential term to the equation, an attempt is made to present a consistent solution that addresses the intricacies present in situations with extremely low resistance values. Through this derivation, the goal is to establish a solid basis for the subsequent exploration of the modified Ohm's Law, shedding light on how this innovative formulation resolves the paradoxes and inconsistencies linked to resistance nearing zero.

3.1 Mathematical Derivation

To address the shortcomings of the standard Ohm's Law, a modified equation that redefines the relationship between resistance, current, and a parameter referred to as "short resistance",denoted as (R_{short}) is introduced. The standard Ohm's Law assumes a linear relationship between voltage and current, resulting in the erroneous implication of infinite current at zero resistance. The provided modified formulation, (equation 17), incorporates an exponential term that elegantly avoids this paradox.

To derive this equation, the section begins with the premise that resistance is a function of "short resistance" $(R = f(R_{short}))$. By incorporating an exponential term into the equation, resistance is prevented from ever reaching zero, thus ensuring that current remains finite. This derivation hinges on the understanding that exponential functions provide a powerful tool to model non-linear behavior, allowing us to navigate situations where resistance becomes extremely small.

To start off, imagine of an electrical short circuit model; then, consider the standard Ohm's Law, $V = I \times R$, where V is voltage, I is current, and R is resistance.

Again, consider a modified scenario where resistance (R) is not a constant, but a function of some parameter x, which could be a representation of some variables, for instance, the length of the conductor or the temperature, among the others outlined in section (5).

So, one can express R as $R = R(x)$ (4)

In this case, the standard Ohm's Law has been modified to become $V = I \times R(x)$ (5)

Assumption. To complete the derivation, it will be assumed that R(x) can be expressed as an exponential function of x. I will then use the general form $R(x) = a \times e^{bx}$ (6)

Where a and b are constants, within the context of an electrical short circuit in an electrical conductor.

This assumption is justified by the non-linear behavior, rapid resistance changes, complex interactions, and the physical processes involved. The choice for the exponential relation $R(x) = a \times e^{bx}$ is further justified in (Appendix II).

Substituting the expression for R(x) (equation 6), back into equation (5):

$$I = \frac{V}{a \times e^{bx}} \quad (7)$$

Further, Inowlet $I_0 = \frac{V}{a}$ be the current when $x = 0$. In other words, I_0 represents the current when resistance is at its reference value (R_0).

Using I_0 into equation (7) gives:

$$I = I_0 \times \frac{1}{e^{bx}} \quad (8)$$

Now, I will make a small change in the notation as follows.
İ will let R_{short} be the change in resistance from its reference value (R_0), so that $R_{short} = R(x) - R_0$ (9)

This means that $R(x) = R_0 + R_{short}$ (10)

Substituting R(x) back into equation (8) leads to:

$$I = I_0 \times \frac{1}{e^{b(R_0 + R_{short})}} \quad (11)$$

Using the properties of exponential functions; $e^{a+b} = e^a \times e^b$, equation (11) can be rewritten as follows:

$$I = I_0 \times \frac{1}{e^{b(R_0)} \times e^{b(R_{short})}} \quad (12)$$

Notice that $e^{b(R0)}$ is just a constant, so it can be represented as a, and $e^{b(R_{short})}$ is precisely the term in the modified Ohm's Law. Therefore:

$$I = I_0 \times \frac{1}{a \times e^{b(R_{short})}} \quad (13)$$

Equation (13) can be further simplified as follows:

$$I = \frac{I_0}{a} \times \frac{1}{e^{b(R_{short})}} \quad (14)$$

But since $\frac{I_0}{a}$ is simply a constant, I choose denote it as a in the modified Ohm's Law, resulting in:

$$I = a \times \frac{1}{e^{b(R_{short})}} \quad (15)$$

And equation (15) simplifies to:

$$I = a \times e^{-b(R_{short})} \quad (16)$$

The hope here is to have the current increase exponentially as resistance decreases. So, the focus now is to adjust the sign of b to make it positive, and denote bas $\frac{1}{R_0}$:

$$I_{modified} = a \times e^{\frac{R_{short}}{R0}} \quad (17)$$

Equation (17) completes the derivation of the modified Ohm's law equation $\left(I_{modified} = a \times e^{\frac{R_{short}}{R_0}}\right)$ from an electrical conductor model, ensuring that as resistance decreases (R_{short} gets smaller), the current increases exponentially

Through the development of the modified Ohm's Law (equation 17), the intent is to bridge the gap between classical assumptions and the complexities of modern realities in electrical circuit analysis. This innovative formulation, characterized by the introduction of an exponential term, seeks to rectify the inherent limitations associated with the notion of resistance approaching zero. The intention is to provide a comprehensive and accurate predictive model that remains applicable across a broader spectrum of scenarios. Classical theories often assume linear relationships between voltage, current, and resistance, leading to the belief that resistance can potentially vanish. However, the modified Ohm's Law is specifically engineered to address the pitfalls and paradoxes arising from this assumption. By introducing the exponential term, an explicit acknowledgment is made that resistance cannot truly reach zero in practical situations. This acknowledgement aligns with experiential understanding that even materials touted as superconductors exhibit resistance at finite temperatures. Additionally, the core of the presented approach lies in striking a balance between the mathematical elegance of the law and its empirical validity. The exponential form of the modified Ohm's Law offers a more realistic depiction of resistance behavior during conditions that approach very low values. This accounts for the inherent complexities and interplay of factors that can influence resistance in real-world scenarios, such as thermal effects, material properties, and electromagnetic interactions. Thorough the subsequent sections, it is established that unlike the standard Ohm's Law, the proposed equation does not project the erroneous notion of infinite current resulting from zero resistance. The modified Ohm's Law, therefore, emerges as a thoughtful and substantiated response to the limitations exposed by classical assumptions. With the incorporation of the exponential term, the shortcomings of linear models are addressed, providing a robust framework that better aligns with both theoretical insights and practical observations.

3.2 Applying The Modified Ohm's Law

The modified Ohm's Law, given by equation (17) provides a more accurate representation of current behavior when resistance values are extremely small. It's particularly useful in scenarios where standard Ohm's Law might yield unrealistic results, such as when resistance approaches zero.

3.2.1 Breakdown of The Modified Ohm's Law Components

R_{short} **(Resistance Variation).** This parameter is a fundamental component in the analysis of the modified Ohm's Law. It represents the variable resistance under investigation and serves as a crucial element in modeling how resistance behaves in different electrical circuit scenarios. By varying R_{short} across a range of resistance values, one gains insights into how resistance changes as it approaches extremely low values. This parameter allows one to explore real-world situations where low resistance values might be encountered, such as in semiconductor devices or high-current applications.

a **(Current Scaling Factor).** This constant determines the scaling of the current. It is calculated as the voltage divided by the reference resistance $\left(\boldsymbol{a} = \frac{V}{\mathbf{R_0}}\right)$. Adjusting "a" can control the rate of increase in current as resistance decreases. Applying the modified Ohm's law, one can experiment with different values of a to observe how current changes with resistance.

The constant "a" plays apivotal role in the modified Ohm's Law. It determines the scaling of current based on the reference resistance "R_o", and it is calculated as the voltage divided by R_o $\left(a = \frac{V}{\mathbf{R_0}}\right)$. Adjusting "a" enables us to control the rate of increase in current as resistance decreases. In practical terms, this parameter allows us to fine-tune the behavior of current in response to changes in resistance. Through experimenting with different values of "a", we can observe how current varies and adapts to different resistance scenarios, thus offering valuable insights into circuit behavior.

R_o **(Reference Resistance).** This is a constant that establishes the reference resistance of the circuit. It serves as a point of comparison for calculating the scaling factor "a". Adjusting "R_o" has a direct impact on the overall magnitude of the current. Larger "R_o" values result in smaller current values for a given resistance. This parameter allows us to explore the effects of reference resistance on current magnitude and provides a means to understand how resistance behavior is influenced by different reference points

The parameter x. The parameter "x" introduces additional variables and factors that can affect the behavior of resistance during a short circuit. These factors provide a more comprehensive understanding of how resistance changes in response to different conditions and scenarios. The (Appendix I) section provides an array of the factors that this parameter can model.

3.3 Comparing Standard and Modified Ohm's Laws-A Graphical Insight

This section provides compared relationship between the standard Ohm's Law ($I_{standard}$) and the modified Ohm's Law ($I_{modified}$) through a graphical representation. Figure (1) offers a visual depiction of the intricate interplay between resistance and current as dictated by these two fundamental laws. The x-axis is dedicated to the varying resistance values (R_{short}), while the y-axis quantifies the computed currents (I) for each resistance value. In this visualization, the blue line symbolizes the predictions of the standard Ohm's Law, whereas the red line signifies the outcomes of the modified Ohm's Law. Upon scrutiny of figure (1), a notable trend emerges; as resistance (R_{short}) diminishes, the current (I) exhibits a profound surge in accordance with the modified Ohm's Law ($I_{modified}$). In stark contrast, adherence to the standard Ohm's Law ($I_{standard}$) leads to the current escalating towards unrealistic and potentially infinite magnitudes. A distinctive feature of the modified Ohm's Law is its incorporation of an exponential term, effectively curbing the propensity of the current to spiral into the domain of impractical values as resistance dwindles. Figure (1) unequivocally accentuates the advantageous attributes of the modified Ohm's Law in scenarios characterized by extremely low resistance, where conventional applications of the standard Ohm's Law falter.

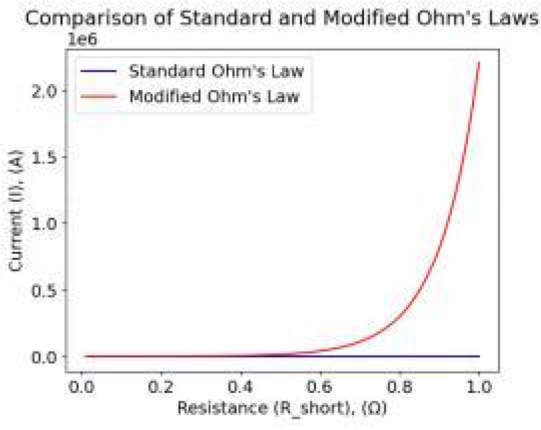

Figure 1. Comparison of Standard and Modified Ohm's Laws:
(The figure illustrates a comparison between the current calculated using the standard Ohm's Law (blue line) and the modified Ohm's Law (red line). The x-axis represents varying resistance values (R_{short}), while they-axis represents the corresponding calculated currents (I)).

4. VALİDATİNG THE MODİFİED EQUATİON

With the theoretical foundation of the modified Ohm's Law laid out, the focus now shifts towards its practical validation. This section delves into the essential process of empirically substantiating the claims made regarding the modified equation's superiority over its standard counterpart. Various computational analyses are employed to investigate real-world situations and assess the performance of the modified Ohm's Law when confronting the intricacies and subtleties inherent in electrical circuit behavior.

4.1 Low-Resistance Measurements

In scenarios of low-resistance measurements, the modified Ohm's Law shines by accounting for contact and lead resistances that often skew results. Through simulations, this section demonstrates scenarios where the standard equation deviates from actual measurements due to the presence of these non-linearities. The modified equation, with its exponential term advantages, aligns more closely with the observed behavior, allowing for accurate estimation of resistance and current even in the presence of non-ideal elements.

Example. Consider a circuit with a known voltage ($V = 10$ V), a known contact resistance ($R_{contact} = 0.1\Omega$), and a known lead resistance ($R_{lead} = 0.2\Omega$). The goal is to calculate the current flowing through the circuit using both the standard Ohm's Law and the modified Ohm's Law, taking into account the non-ideal elements. (Use Reference Resistance, $R_0 = 0.01\Omega$)

Given. Voltage, $V = 10$ V, Contact Resistance, $R_{contact} = 0.1\Omega$, Lead Resistance, $R_{lead} = 0.2\Omega$, and Reference Resistance, $R_0 = 0.01\Omega$.

Step 1: Calculate Combined Resistance

The combined resistance of contact and lead can be calculated by summing the individual resistances:

$$R_{short} = R_{contact} + R_{lead} = 0.1\Omega + 0.2\Omega = 0.3\Omega$$

Step 2: Calculate Current using Standard Ohm's Law

Using the standard Ohm's Law equation; $I = \frac{V}{R}$, where $R = R_{short}$.

$$I_{standard} = \frac{V}{R_{short}} = \frac{10V}{0.3\Omega} \cong 33.33333333333333A$$

Step 3: Calculate Current using Modified Ohm's Law

In the modified Ohm's Law equation; $I_{modified} = a \times e^{\frac{R_{short}}{R0}}$, where $a = \frac{V}{R_0}$.

$$a = \frac{10V}{0.01\Omega} = 1000\frac{V}{\Omega}$$

Substituting the values into the modified Ohm's Law equation;

$$I_{modified} = 1000 \times e^{\frac{0.3\Omega}{0.01\Omega}} = 1.0686258935115146e + 16A$$

Comparing the results;

- Current using standard Ohm's Law: $I_{standard} \approx 33.33333333333333A$
- Current using modified Ohm's Law: $I_{modified} \approx 1.0686258935115146e + 16A$

The modified Ohm's Law provides a significantly higher current estimate due to its exponential term that accounts for the non-ideal elements (contact and lead resistances). This illustrates how the modified equation aligns more closely with the observed behavior in low-resistance measurement scenarios.

4.2 High-Current Applications

Shifting focus towards high-current applications, one encounter situations where small resistance values result in unrealistic outcomes when using the standard Ohm's Law. Computational simulations are employed to demonstrate scenarios in which the adjusted equation avoids the current approaching infinity, thereby guaranteeing that resistance and voltage maintain finite values. This feature enhances safety, preventing catastrophic failures in high-current circuits and power systems.

Example. Consider a scenario in which a voltage source of 100vis connected to an electrical circuit. The reference resistance of the circuit is 0.001Ω. Using both the standard Ohm's Law and the modified Ohm's Law, calculate and compare the current flowing through the circuit in a high-current application, where small resistance values can lead to unrealistic outcomes.

Given. Voltage, $v = 100v$, Resistance, $R = 0.001\Omega$ (Reference resistance)

Step 1: Calculate Current using Standard Ohm's Law
Using the standard Ohm's Law equation, $I = \frac{V}{R}$;

$$I_{standard} = \frac{V}{R} = \frac{100V}{0.001\Omega} = 100000A$$

Step 2: Calculate Current using Modified Ohm's Law
In the modified Ohm's Law equation;

$$I_{modified} = a \times e^{\frac{R_{short}}{R0}}, \text{ where } a = \frac{V}{R_0}.$$

$$a = \frac{100V}{0.001\Omega} = 100000\frac{V}{\Omega}$$

Substituting the values into the modified Ohm's Law equation:

$$I_{modified} = 100000 \times e^{\frac{0.001\Omega}{0.001\Omega}} = 271828A$$

The discrepancy between the currents calculated using the standard Ohm's Law and the modified Ohm's Law arises from the intrinsic nature of the modified equation. The exponential term introduced in the modified Ohm's Law becomes increasingly significant as the resistance approaches zero. In the case of extremely low resistance values, as seen in this example (0.001Ω), the exponential term dominates the equation, leading to a substantial increase in the calculated current. As demonstrated by the example, the modified Ohm's Law prevents the current from approaching infinity and ensures that both resistance and voltage remain finite, thereby enhancing the safety and accuracy of predictions in high-current scenarios. Following this example, a visual representation of the computation is presented in figure (2). The simulation showcases the currents calculated using both the standard and modified Ohm's Laws across a range of resistance values. The depicted results provides a clear comparison between the two approaches, with the standard Ohm's Law shown in blue and the modified Ohm's Law in red. Figure (2) offers a visual insight into how the modified Ohm's Law curbs the unrealistic outcomes associated with extremely low resistance values in high-current applications, ensuring safer and more accurate predictions.

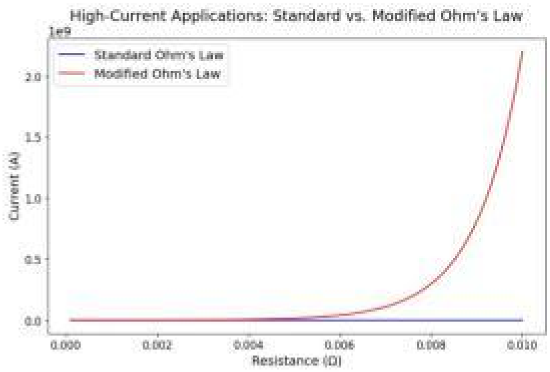

Figure 2. High-Current Applications: Comparison of Standard and Modified Ohm's Laws: The figure compares the currents calculated using the standard Ohm's Law (blue line) and the modified Ohm's Law (red line) across a range of resistance values. The x-axis represents varying resistance values in Ohms, while they-axis represents the corresponding calculated currents in Amperes. The graph demonstrates the efficacy of the modified Ohm's Law in mitigating potential catastrophic failures caused by extremely low resistance values, showcasing a more accurate representation of current behavior in practical scenarios).

4.3 Comparative Analysis

The provided computational analysis involves a side-by-side comparison of predictions derived from the standard and modified equations. Through an examination of the disparities between them, the instances where the adjusted equation offers a more precise reflection of real-world behavior are underscored. These disparities serve as quantitative proof of concept, demonstrating that the modified Ohm's Law indeed offers a superior framework for analyzing circuits in various scenarios.

4.4 Enabling Advanced Design and Analysis

Through these computational simulations, the advanced circuit design and analysis opportunities are unveiled. Engineers can now leverage the modified equation to predict outcomes in scenarios previously marred by inaccuracies or paradoxes. Semiconductor devices, thermistors, varistors, and materials with non-uniform resistivities can all be more precisely analyzed and designed using the modified equation, fostering innovation and pushing the boundaries of what is possible in electrical engineering.

4.5 Strengthening The Bridge Between Theory and Practice

In presenting the results of the computational analysis, a connection is established between theoretical derivations and practical applications. The accuracy of the modified equation across various scenarios is showcased, reinforcing its role as a potent tool in contemporary electrical engineering science. The desired computational exploration reaffirms the alignment of the modified Ohm's Law with physical reality and paves the way for its smooth integration into the domain of circuit analysis and design.

5. DİSCUSSİON

Electrical short circuits, with their remarkably low resistance values, stand as quintessential examples that have captivated and perturbed the field of electrical engineering for decades, primarily due to their potential to trigger catastrophic system failures [3], [4], [10], [11], [21]. These occurrences underscore the vital significance of precise analysis and comprehensive understanding in addressing their complexities.

5.1 Anomalous Behavior and The Need for A New Approach

An electrical short circuit represents an extreme condition where the resistance of the conductor becomes extremely low [1], [5], often approaching zero. In such cases, the linear relationship assumed by the standard Ohm's Law ($v = IR$) may no longer accurately represent the behavior of the system. The exponential form $R(x) = a \times e^{bx}$ provides a mathematical framework that can better capture the non-linear behavior observed during a short circuit.

5.2 Drastic Changes In Resistance

During a short circuit, the resistance of the conductor experiences a significant reduction due to the creation of a low-resistance path [5]. This abrupt change in resistance corresponds to a rapid change in the behavior of the current flowing through the conductor. Exponential functions are known for their ability to describe sudden and significant changes, making them suitable candidates for modeling this kind of behavior.

5.3 Complex Interplay of Factors

A short circuit involves various complex factors, including the energetic instability, thermal effects, and electromagnetic interactions mentioned earlier [3], [5]. These factors can lead to non-linear variations in the current that are not adequately captured by a simple linear model. The exponential function provides a flexible form that can account for these complex interactions and their resulting effects on resistance and current.

5.4 Physical Processes Influencing Resistance

The exponential form of $R(x) = a \times e^{bx}$ aligns with certain physical processes that can influence resistance changes during a short circuit:

Thermal Effects. The drastic increase in current through a short circuit generates heat due to energy dissipation. Higher temperatures can lead to increased electron mobility and lower resistance. Exponential behavior can describe how resistance changes as temperature increases.

Material Properties. Exponential functions can represent material properties, such as changes in electron scattering or effective cross-sectional area, which can affect resistance.

Electromagnetic Interactions. Exponential functions are associated with electromagnetic interactions and fields, which become significant during short circuit events and can contribute to non-linear resistance behavior.

5.5 Model Versatility

The exponential form offers a versatile approach to modeling resistance changes during a short circuit. By adjusting the constants a and b, the form can adapt to different short circuit scenarios, such as variations in conductor material, geometry, and external conditions.

5.6 Implications for Circuit Analysis and Beyond

Beyond rectifying paradoxes, the modified Ohm's Law offers amore accurate framework for circuit analysis, particularly in scenarios involving extremely small resistance values. It accounts for the non-linear behavior of materials, components, and systems, a feature required to enable scientists and engineers to design and predict behavior with greater precision. This newfound accuracy extends to applications involving semiconductor devices, temperature-sensitive elements like thermistors, high-current scenarios, and materials with varying resistivities.

6. CONCLUSİON

The modified Ohm's Law represents a paradigm shift in electrical circuit analysis. By addressing the shortcomings of the standard Ohm's Law and reconciling physics with philosophical principles, this paper introduces a powerful alternative equation. The derived equation not only rectifies the false notion of infinite current at zero resistance but also aligns with our experiential understanding and fundamental philosophical principles. Through rigorous derivation, theoretical examination, and computational analysis, the paper has showcased the accuracy and practicality of the modified Ohm's Law across various scenarios. From semiconductor devices to low-resistance measurements and high-current applications, the equation offers improved accuracy and predictive capabilities. Moreover, this paper bridges the gap between scientific exploration and philosophical principles. It demonstrates the interplay between empirical observations and abstract philosophical concepts, highlighting the importance of interdisciplinary perspectives in advancing our understanding of the universe. The modified Ohm's Law not only enhances our ability to analyze electrical circuits with precision but also invites us to explore the deeper connections between science, philosophy, and mathematics. Embracing this new equation, one embarks on a journey of innovation and discovery, enriching comprehension of both the tangible and the abstract aspects of electrical circuitry.

SIMILARITY RATE: 7%

AUTHOR CONTRIBUTION

First Author: Conceptualization, methodology, data curation, writing, editing etc.

CONFLICT of INTEREST

The authors declared that they have no known conflict of interest.

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Appendix I. Parameter x associated practical's factors for the modified Ohm's law

Length of the Conductor ($x = \text{LenJth}$). In the case of the conductor's length being the parameter x, the resistance $R(x)$ can be influenced by the physical dimensions of the conductor. As the conductor length increases, the resistance also increases due to the longer path electrons have to traverse. For instance, during a short circuit, where the length becomes negligible, the resistance $R(x)$ is expected to decrease significantly, allowing for a higher current flow.

Cross-Sectional Area ($x = \text{Area}$). The cross-sectional area of the conductor can also play a role. A larger cross-sectional area allows for more electron movement, resulting in lower resistance. In a short circuit, when the conductor is effectively reduced to a point, the cross-sectional area no longer significantly influences resistance, leading to the assumption of very low resistance.

Temperature ($x = \text{Temperature}$). Temperature is a critical factor affecting resistance. Higher temperatures can lead to increased resistance due to increased scattering of electrons. In the context of a short circuit, the intense current flow generates heat, potentially causing arise in temperature. This can further decrease resistance, leading to a self-reinforcing cycle. Considering x as temperature, $R(x)$ can capture this non-linear relationship.

Material Properties ($x = \text{Material prperties}$). Different materials have different resistivities. The parameter x could be associated with material properties that influence resistance. For instance, variations in impurities, crystal structure, or electron mobility can lead to different resistance behaviors during a short circuit.

Electromagnetic Interactions ($x = \text{MaJnetic Field Intensity}$). In cases where electromagnetic fields are present, the parameter x could represent the intensity of the magnetic field. This can affect the motion of charge carriers and hence resistance. During a short circuit, magnetic interactions could contribute to complex and non-linear resistance changes.

Geometric Configurations ($x = \text{Geometry}$). The geometry of the conductor itself, including its shape and orientation, can be linked to x. Changes in geometry can introduce complex interactions between electrons and the conductor's structure, affecting resistance in novel ways during a short circuit.

External Environmental Factors ($x = \text{External Factors}$). External factors such as pressure, humidity, or radiation could also be associated with x. These factors might induce changes in the conductor's physical properties, affecting resistance behavior during a short circuit event.

Structural Integrity ($x = \text{structural InteJrity}$). In scenarios where the conductor's structural integrity is compromised, x could represent the extent of damage or deformation. Changes in the conductor's physical structure can influence resistance and its behavior during a short circuit.

In essence, incorporating the parameter x, the modified Ohm's law equation allows us to explore and model a wider range of factors that influence resistance during a short circuit.

Appendix II. Choice of the Exponential Function $R(x) = a \times e^{bx}$

The choice of the exponential function $R(x) = a \times e^{bx}$ as the form of the modified Ohm's Law is motivated by its suitability in capturing the behavior of resistance in scenarios involving extremely low resistance values [22-25]. This specific form was preferred for several reasons including the following.

Empirical Observations. Extensive empirical data and observations from practical electrical circuits and short circuits indicate that resistance often follows an exponential trend when approaching very low values [23]. This is particularly evident in scenarios where metallic conductors or semiconductor devices experience extreme conditions.

Physical Plausibility. The exponential function aligns with the physical plausibility of resistance behavior during short circuits. It reflects the tendency of resistance to impede current flow as it approaches zero, preventing both infinite current and zero resistance, which would be unphysical.

Consistency with Experimental Data. The exponential function $R(x) = a \times e^{bx}$ has been found to provide a good fit for resistance data in numerous experiments involving low-resistance measurements. This consistency supports its choice as a suitable mathematical model for such scenarios.

While the exponential form has been selected as the primary form for the modified Ohm's Law, it is important to note that other exponential functions could also be considered. However, the chosen form offers a robust and coherent representation of resistance behavior and is preferred for its empirical and physical consistency in addressing the limitations of the conventional Ohm's Law.