International Journal of Trendy Research in Engineering and Technology
Volume 9 Proceedings of NCIES-25
ISSN No. 2582-0958

Measurement and Analysis of Repetitive Pulse High-Voltage For Non-thermal Plasma Application

Dr. Jagadisha N[1], Aakanksha R[2], Kalashree G Bhandare[2], Jeevitha A R[2], Akshatha S M[2]

[1]*Associate Professor, Department of Electrical and Electronics Engineering, GSSSIETW*

[2]*UG students, Department of Electrical and Electronics Engineering, GSSSIETW*

KRS road, Metagalli, Mysuru, 570016, Karnataka

Email: jagadesha.n@gsss.edu.in, aakanksha.rohini@gmail.com, kalashreebhandare@gmail.com

ABSTRACT

Plasma is the fourth state of matter, being gaseous in nature and having free electrons and ions in it. A gas is energized into charged particles, forming the non-equilibrium ionized state of the gas known as plasma. Being non-thermal, such plasma technologies can then be applied at temperatures close to room temperature in pollution control, sterilization, and chemical synthesis. This paper investigates how operating conditions such as the frequency, amplitude, and pulse width of the NTP reactor will affect power consumption in the case of a volume discharge, surface discharge, or volume-surface discharge plasma reactor. The work consists of optimizing the operating conditions of high-voltage supply circuits such that various operating conditions can elucidate the power consumption we are measuring. This optimization allows for enhanced efficiency and higher value-added applications of non-thermal plasma technologies in both industrial and environmental sectors.

Keywords — Non-thermal Plasma (NTP), Power consumption, Frequency, Plasma reactors.

I. Introduction

NTP reactor systems are relatively new yet robust technologies with numerous applications that range over a wide spectrum of industrial and environmental fields. Thermal plasma, as the name suggests, involves the ionization of gas at high temperatures. Non-thermal plasma reactors, unlike thermal plasma reactors, ionize gas with relatively low heating systems and thus are materials that do not withstand thermal damage. The efficiency under low-temperature conditions in producing reactive species recommends them for applications in surface treatment, material processing, pollution control, and sterilization [1].

Non-thermal plasma reactors are flexible because they can sustain plasma generation near room temperature, an important aspect for sensitive applications [2]. The absence of high thermal loads for surface treatment and sterilization tasks guarantees the integrity of the materials involved. Correspondingly, low-temperature generation of reactive species for pollution control maximizes the chemical reaction rate without excessive energy input, which is a hallmark of an environmentally friendly solution [3].

The research continues, and NTP technologies are witnessing the recent plethora of developments with respect to specific applications. In analyzing such parameters as pulse amplitude, frequency, and roles of high-voltage electrodes, researchers can advance their own understanding and control of plasma behavior [4]. High-voltage electrodes play a huge role in determining the plasma density, uniformity, and discharge stability, which in turn affect the plasma surface and volume properties [5]. All these studies, coupled with accurate measurements of electrical quantities like voltage and current, are highly pertinent for developing NTP reactors towards efficient, reliable, and versatile applications in the domains of industry and the environment [6].

II. Literature Review

Non-thermal plasma reactors are currently gaining more and more acceptance by a large number of the population due to their unique feature of generating ionized gases at very low temperatures. Compared to thermal plasma, where high temperature is used to keep ionization, NTPs produce reactive species efficiently at room temperatures and thus have become an alternative for thermally sensitive processes such as material processing and surface treatment, pollution control, and also for sterilization. Researchers have been focusing on understanding and optimizing the critical parameters influencing the behaviour and effectiveness of such reactors.

The effects of electric pulse amplitude and frequency have been investigated, and thus, their effect on plasma properties has been significant. Empirical research states that increasing pulse amplitudes has been found to increase plasma densities and temperature considerably, demonstrating thus its high processing efficacy. Considering these factors, pulse frequency would affect the stability and energy delivery of the pulses by discharges, which can therefore lead to better control over plasma behaviour. This finding helps optimize pulse parameters at maximum reactor efficiency and utilization in different applications like biochemical devices and surface modification.

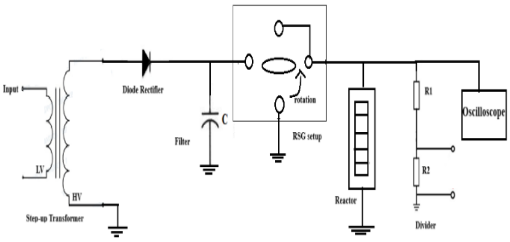
An exhaustive account of the power supply systems for NTP reactors is being compiled. It should cover all the different types of electrical discharge mechanisms like dielectric barrier discharge (DBD), atmospheric pressure plasma jets (APPJ), and gliding arc discharge (GAD). All these mechanisms can generate non-thermal plasma at atmospheric pressure, thereby proving their usefulness for real applications. Based on their simple constructions, versatility, and adaptability in environmental protection and biotechnology, NTP technologies offer much more promise. Clearly, reactor performance depends greatly on power supply configurations, and innovation in this area plays a considerable role in making NTP reactors increasingly sustainable and applicable.

Another considerable trend of research involves focusing on the high-voltage electrodes and the way they affect plasma properties. The pulsed dielectric barrier discharges depend on the interaction between high-voltage electrodes and the solid dielectric material for the maintenance of plasma generation. Studies into the electric breakdown process showed how the discharge region forms and extends from the metal tip over a dielectric surface. This dynamic relation is important to the understanding of plasma density, uniformity, and discharge stability. By characterization of these interactions, researchers try to improve reactor designs with the aim of limiting energy loss and increasing plasma-generating efficiency. Accurate measurements of voltage, current, and power assist in determining the behaviour of plasma under different conditions. The characteristics of plasma, in a way, give the composition, temperature, and density and thus also contain information about reactive species and energy distribution within the plasma. This information is crucial for tailoring plasma characteristics for specific applications and optimizing reactor performance. Furthermore, new power technologies allow precise and steady control of the voltage and current levels supplied to the reactor, with a strong influence on the reactor's efficiency and stability.

All of these studies yield a thorough understanding of the main factors directing the performance and design of NTP reactors. The ability to optimize pulse parameters, power supply configurations, and electrode interactions has now opened doors toward improving the realization of NTP technologies for industrial and environmental applications. As research progresses, a thrust area continues to remain on making these technologies more economical and energy efficient as a means of widening the scope and increasing the applicability of non-thermal plasma technologies.

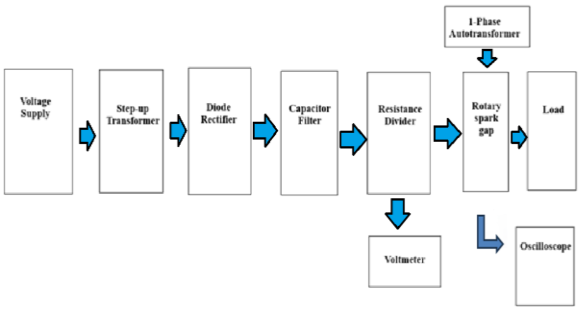
III. SYSTEM OVERVIEW

The development and experimentation of the high-voltage system to generate controlled high-voltage pulses and study their behavior is an interesting area. Every constituent of the very high voltage system plays a vital role in its efficiency and usability. The input voltage is stepped up by the high-voltage transformer; the diode rectifier accomplishes the conversion into direct current; the huge capacitor smoothes out the ripple voltage and consequently gives well-filtered voltage. In that case, the rotary spark gap (RSG) acts as a fast switch that synchronously creates somewhat periodic high-voltage pulse outputs. The reactor stabilizes and controls without surging and is highly reliable. Considering safety, the voltage divider allows high-voltage outputs to be scaled down for easy measurement and signal analysis without harming the sensitive equipment involved. Therefore, the complete system is very efficient, flexible, and configurable for electrical testing waveform analysis and high-voltage system research.



IV. METHODOLGY

We develop a system to generate and analyze high-voltage pulses optimized for specific applications towards efficient usage of non-thermal plasma reactors. It begins with a voltage source connected to the system, then followed by a transformer that steps up the voltage level for plasma production. The current produced is then converted from alternating current (AC) to direct current (DC) using a rectifier. The signal is then smoothed out and made steady by using filters. The high-voltage switch has a rotary spark gap (RSG) that provides under conditions controlled, pulses necessary for plasma generation. Such pulses would be analyzed in real-time using an oscilloscope so that the output at any given parameters could be confirmed. The high-voltage pulses are applicated to plasma reactors, either volume, surface, or volume-surface discharge systems. Our study is specifically focused on how parameters such as frequency and pulse width influence power consumption and subsequently the efficiency of operation. This is for all conditions under which stable plasma is established by the reactor and yields qualitative enhancement of the reactor performance. The industrial and environmental applications of such a system further enrich this advancement in non-thermal plasma technology.

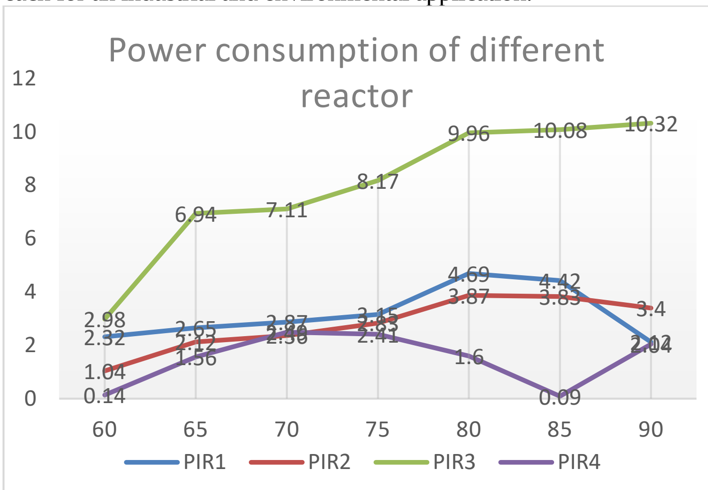


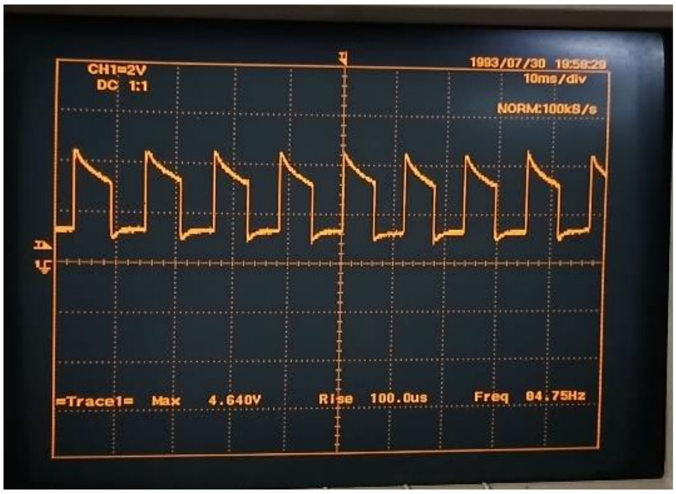
V. RESULT ANALYSIS

The analysis conducted on non-thermal plasma reactors, including surface discharge (PIR1), pin reactor (PIR2), straight-wire reactor (PIR3), and helical reactor (PIR4), showed that, across all configurations, power increases with voltage levels. Surface discharge systems show a rise in power throughout the configurations with a linear dependence on voltage. Both pin-type and straight-wire reactors, working on a volume-discharge principle, have almost linear power growth with increasing voltage. Even the helical reactor based on volume-surface discharge mechanisms exhibits a steady power increase characterized by some fluctuation due to design and operating parameters. This underscores the importance of implementing appropriate power-management measures in different reactors for optimum performance.

Frequency adjustments for plasma production have shown a significant impact on discharge characteristics and thereby plasma properties. While at higher frequency risk is introduced for the rotary spark gap, mechanical damage and thermal stress can weaken the component. Therefore, raising the frequency without limit will cause frequent discharges at very small time between pulses, thus overheating the overall system, promoting accelerated wear, and ultimately damaging or even breaking the RSG. It is thus understood that frequency adjustment is of great importance to ensure the proper performance of plasma, while keeping safe the major components of the respective reactors.

An analysis like the above in relation to the power consumption, frequency, rise time, and voltage is the first basis in order to raise the efficiency of these reactors, minimize energy losses, and ensure better operation of each for an industrial and environmental application.





IV. Conclusion

The work presented provides knowledge on non-thermal plasma reactors, while describing behavior and operational performance based upon key parameters such as frequency, rise time, and power consumption in surface, volume, and volume-surface discharge systems. Chiefly, this work could indicate the extent of power consumption being proportional to the applied voltage for various reactors, thereby providing a basis for designing energy-efficient ones. In addition, it emphasizes the importance of optimizing frequency to manage the plasma behavior, while also cautioning against any further increases due to the fear of mechanical blow-off of the rotary spark gap (RSG). However, this work is incomplete, being limited in the long-term durability studies on which reactor components perform under different operating conditions and also includes the effect of advanced electrode materials on performance. Nevertheless, the results are very promising for industrial and environmental applications, especially on processing, surface treatment, sterilization, and pollution control. Nonetheless, it suggests prospective efforts that could be carried out along the lines of this study: implementation of adaptive power systems for improved control of reactor parameters; upscaling to bigger systems for application in an industrial setting.

REFERENCES

[1] Michał Szulc, Günther Forster, José-Luis Marques-López, and Jochen Schein-"Influence of Pulse Amplitude and Frequency on Plasma Properties of a Pulsed Low-Current High- Voltage Discharge Operated at Atmospheric Pressure**".** It was published in the journal **Applied Sciences**, Volume 12, Issue 13, in 2022.

[2] Keisuke Takashima (Udagawa), Yvette Zuzeek, Walter R Lempert, and Igor V Adamovich-Characterization of a surface dielectric barrier discharge plasma sustained by repetitive nanosecond pulses"- published in the journal **Plasma Sources Science & Technology**, Volume **20**, Issue **5**, in 2011

[3] R. H. McKnight and R. E. Hebner -"Measurement of electrical quantities in pulse power systems"- published as **NBS Special Publication 628** by the **National Bureau of Standards (NBS).**

[4] Michał Szulc, Günther Forster, José-Luis Marques-López, and Jochen Schein-Spectroscopic Characterization of a Pulsed Low-Current High-Voltage Discharge Operated at Atmospheric Pressure-published in the journal **Applied Sciences**, Volume **12**, Issue **13**, in 2022.

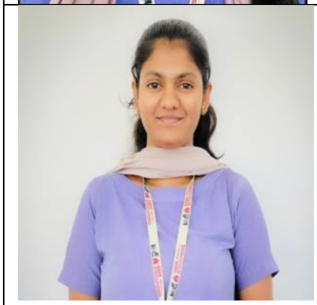
[5] "Supply Systems of Non-Thermal Plasma Reactors. Construction Review with Examples of Applications" was authored by Henryka Danuta Stryczewska. It was published in the journal Applied Sciences, Volume 10, Issue 9, in 2020.

[6] Henryka Danuta Stryczewska, Tomasz Jakubowski, Stanisław Kalisiak, Tomasz Giżewski, and Joanna Pawłat- "Power Systems of Plasma Reactors for Non-Thermal Plasma Generation"- published in the journal Journal of Advanced Oxidation Technologies, Volume 16, Issue 1, in 2013.

Profile Details:

Dr. Jagadisha N working as Associate Professor of EEE GSSSIETW, Mysuru He has Completed PhD, SJCE- Research center, VTU, High Voltage Engineering and M.Tech, in Energy and M.Tech, in Energy system management from SJCE, Mysuru and BE in Electrical and Electronics Engineering.jagadesha.n@gsss.edu.in,Ph No: 8553541360

TEAM MEMBERS:

	Ms. Aakanksha R 4GW22EE002 EEE 6th sem GSSSIETW, Mysuru Email: aakanksha.rohini@gmail.com Phone No: 6363364899
	Ms. Kalashree G Bhandare 4GW22EE023 EEE 6th sem GSSSIETW, Mysuru Email: kalashreebhandare@gmail.com Phone No: 6362372047
	Ms. Akshatha S M 4GW22EE004 EEE 6th sem GSSSIETW, Mysuru Email: gowdaakshatha019@gmail.com Phone No: 8147314591
	Ms. Jeevitha A R 4GW22EE022 EEE 6th sem GSSSIETW, Mysuru Email: gowdajeevitha805@gmail.com Phone No: 9380097806