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Conceptual Design Development of a Pulsed Discharge Device for Water Treatment

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Abstract

Water is called the life of all living beings and it is well known that almost ninety percentage of human body is made up of water. The consumption of pure wateris very necessary and primary things related to human life from its heath point of view. With the rapid increase in population, there is a demand for large amount of consumable pure water to satisfy everyone's primary need. Although, there exists so many water treatment facilities, but most of them have some inherent drawbacks either in terms of realise in toxic chemical or in efficiency. In the recent years, pulsed discharge was studied by various groups of researchers around the globe. This system finds importance due to its superior advantages like directly generated active species (ozone, OH radical etc.), ultraviolet and shock wave treatment of water. In our present paper, we are planned to report the design and develop part of a table top pulsed discharge device in our laboratory for the treatment of water samples. We will play with different parameters of the system to optimize the device and have a high efficiency rate. Moreover, we will analyse all the results of treated water samples at different experimental conditions and those will be compared with existing conventional water purification processes

Key words: *Pulsed discharge, water, active species*

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1. Introduction:

In the recent years, the availability of the clean water has become a critical issue all over the globe. The existing water purification techniques are unable to meet with the present-day demand due to rapid increase in the world population. It has reported [United States Environmental Protection Agency [EPA], 2009] that, in developing countries the cause of death of around 35% people have directly related to the consumption of unsafe water. There are numbers of reasons for which the water becomes unsafe to consume. Out of these, some of important causes are addition of chemical pollutants, organic pollutants, inadequate treatments, deficient or failing water treatments, untreated bacteria and viruses with the consumable water etc. But the existing popular water treatment facilities namely chemical treatments, ultraviolet radiation and ozone injection technologies etc. aremainly based on the procedure of inactivation of the bacteria only. Simultaneously, these technologies are also not free from drawbacks,for examples chemical treatments are resulting with portable toxins, whereas ultraviolet radiation and ozone injection technique are less effective and require a periodic maintenance. As a result of which, the present-day researcher are in search of some new and advance technology to overcome these difficulties for the improvement of water treatment quality relatively in a small-time span and low cost.

As an effort of this, many new techniques based on the Advance Oxidation Processes (AOP) has been reported in the literature [Chaplin, 2014]. The advantage of these techniques lies in the basic principle that it can able to dissociate even a very stable molecular structures, which is not possible by using the conventional techniques. The high-voltage electrical discharge that share the family of AOP have achieved an additional interest due to the advantages like ability to deplete or destroy almost all the impurities starting from the organic compounds [NicolaeBogdan, 2008; Magureanu et. al., 2010], the deactivation of bacteria and viruses [Yong et al.; Sun et al., 2006], the oxidation of inorganic ions

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[Sridharan et al., 2007] etc. Moreover, in case of pulsed electric discharge, the treatment reactions are carried out simultaneously at a time by different species namely UV radiations, shockwaves, intense thermal load etc. Keeping all these benefits in mind, in this proposal we are planned to develop a table top pulsed discharge device to study the treatment of water samples with varying experimental conditions.

2. Methodology:

As mentioned earlier, in this proposal we are planned to develop a portable pulsed discharge device which will be used for treatment of water. The pulsed operation of the device will enable us to obtain higher discharging voltage by using a smaller amount of energy. The pulsed mode of operation of this device is based on the simple concept of storing the electrical energy in one storage device and discharging the same in between electrodes using a pulse forming device and a switch. The block diagram of the pulsed system is shown in the Figure 1. The components of the pulsed power system will be so chosen that it can able to deliver a output pulse of discharge voltage 25 kV with a lifetime of 10 microseconds.

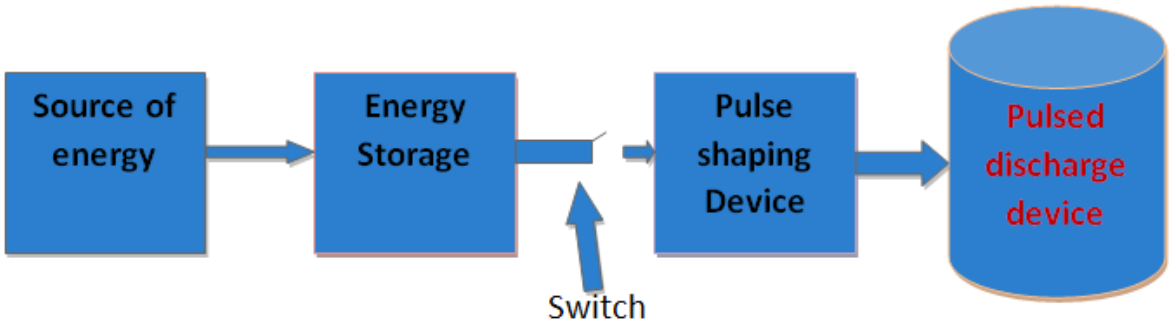


Figure1: Block diagram of pulsed system

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The pulse power device, which drive the pulsed system will mainly comprises of a high voltage power supply, a capacitive storage, a spark gap switch and low inductance transmission cable. The simple circuit diagram for the pulse power system is shown in the Figure 2.

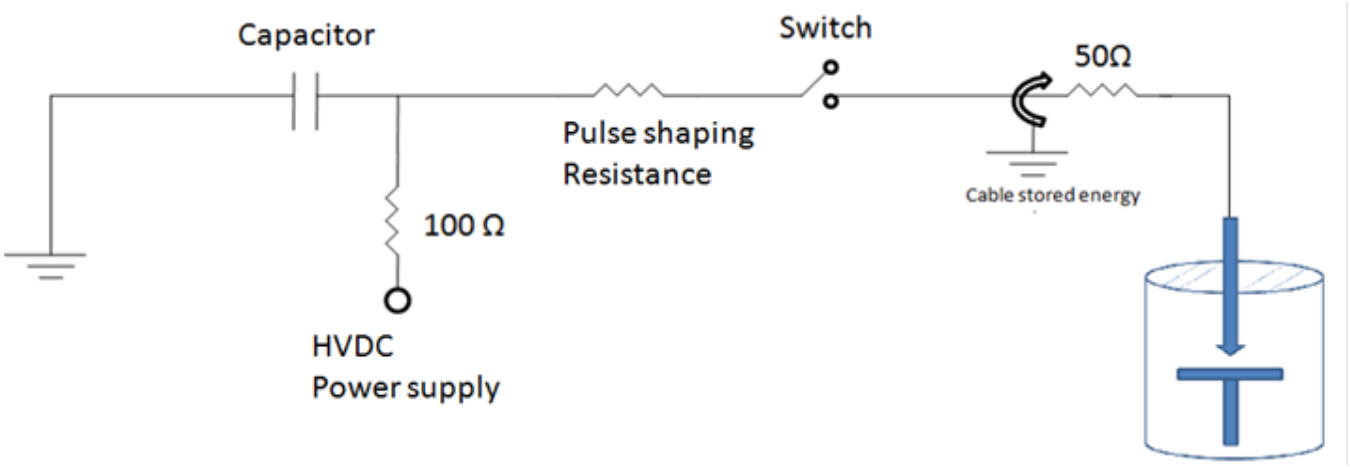


Figure 2: Circuit diagram of pulsed power driver with system

As depicted in the circuit, the voltage rating and capacitance of the capacitor is responsible for obtaining the discharge voltage of 25 kV that means by playing with these two parameters of the capacitor, we can able to adjust the output pulse voltage. On the other hand, the output pulse lifetime will be depended on both capacitance of the capacitor and value of pulse shaping resistor as shown in Figure 2. Therefore, in our experiment, we will select all the technical parameters of circuit components based on the fact that we are going to produce a 10-microsecond output pulse having discharge voltage of 25 kV.

In the main pulsed discharge chamber an assembly of two electrodes (a point to plane electrode system) will be housed inside as shown in the Figure 3. The spark discharge will be produced directly on the water between these two electrodes. A water tank will be attached with the chamber as shown in Figure 3. The system parameter like high discharge voltage and current will be characterized by using voltage probe and current probe, respectively. By optimizing the discharge parameters, the

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power will be deposited in to the samples of water that prepared in the laboratory by adding some of the known impurities (such as organic dye). The water samples will be then treated for different numbers of pulses that is at different experimental conditions. After experimentation, the reference as well as all the treated samples will be characterized by using different types of characterizing tools such as ultra violet spectrometer, mass spectrometer, inductively coupled Plasma-Atomic emission spectrometer, etc. to study the chemical and quantitative behavior. The results will also be compared with the finding of different conventional water treatment processes.

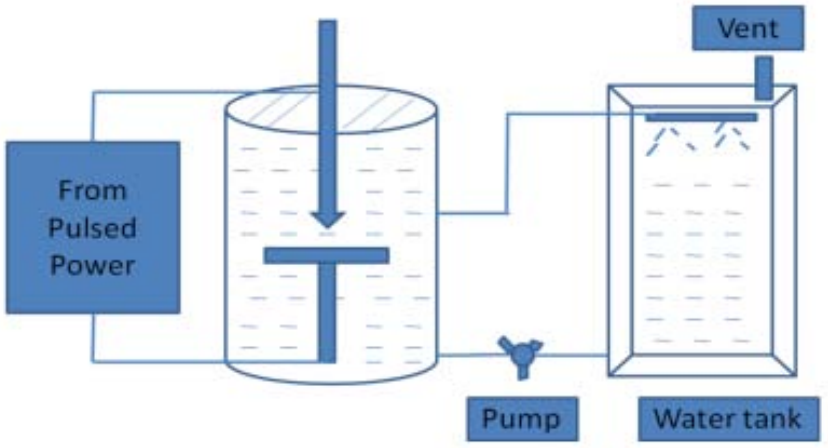


Figure 3: Pulsed discharge device with water tank and water sample.

3. Result and discussion:

As an initial stage of the development process various important parameters are calculated theoretically using different standard laws. Depending upon this calculations and taking the concern of

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golden rule and worst condition of operation the technical specification of various major parts of pulse power driver are computed which are listed herewith (Table I, II and III)

Table I

Specification for High Voltage EnergyStorage Capacitor (40kV)

Attribute	**Specification**
Type	Energy storage, plastic case
Capacitance	7.1 μF
Tolerance	±10%
Voltage rating	40kV
Maximum peak current	~7 kA
Maximum current (rms)	~ 7 A
Duty cycle	1000 pps
Dielectric	Paper/Castor oil
Inductance	~100-100 nH
Voltage reversal	20% or better
Operating temperature	5-35 degree Celsius
Operating humidity	Upto 80% RH

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Table II
Specification for 40 kVDC coaxial cables

Attribute	**Specification**
Nominal Voltage between conductor and shield	40 kV DC
Nominal current through conductor	10A DC
Shield	Shield copper shielding coverage 90%
Approximate Cable capacitance	100 pF/m
Characteristic impedance	50 ohms +/- 2ohms

Table III
Specification for solid state high voltage switch

Attribute	**Specification**
Switch type	Solid state switch type (Thyristor/MOSFET based.)
Maximum operating voltage	40 kV DC
Maximum turn on peak current	Better than 10A
Trigger pulse voltage range	3-6 VDC
Maximum switching frequency	Better than 10 Hz
ON TIME DURATION	~100µsec fixed
Turn on jitter	1 ns or less
Rise time , Fall time	Hundred of ns

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As a pilot experiment to our design and development of pulsed discharge device, we have carried out experimentation on dye degradation by a very simple plasma treatment process by a continuous 15 kV plasma discharge device. The schematic of the experimentation is illustrated in Figure 4. Here the experimental set up consists of a commercial Neon Sign Transformer maximum rating of 15 kV, a variac, a pointed SS electrode. The Methylene blue dye is mixed with water in a beaker and then electrode is placed on the surface of the water.

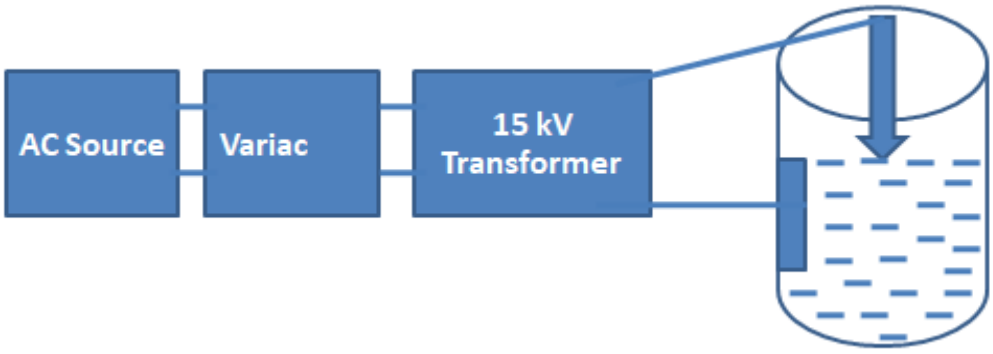


Figure 4: Continuous discharge device with water beaker filled with water sample.

After the plasma treatment at different time such as 10, 20, 30 and 40 minutes it is observed visually that the deep blue colour of the water samples goes on fainted accordingly. We have characterised the treated and untreated samples with the UV visible spectroscopy and record the position of most intense absorption peak at 664 nm. Further, from these results we have calculated the concentration of all the water samples by using Beer- Lambert's law. Knowing the concentration of untreated solution C_0 and concentration of treated solution C_I the desorption rate is calculated as,

$$D(\%) = \frac{C_0 - C_I}{C_0} \qquad (1)$$

In Figure 5, a graph is plotted with treatment time versus desorption rate which clearly shows the efficiency of the treatment process for removing the organic dye.

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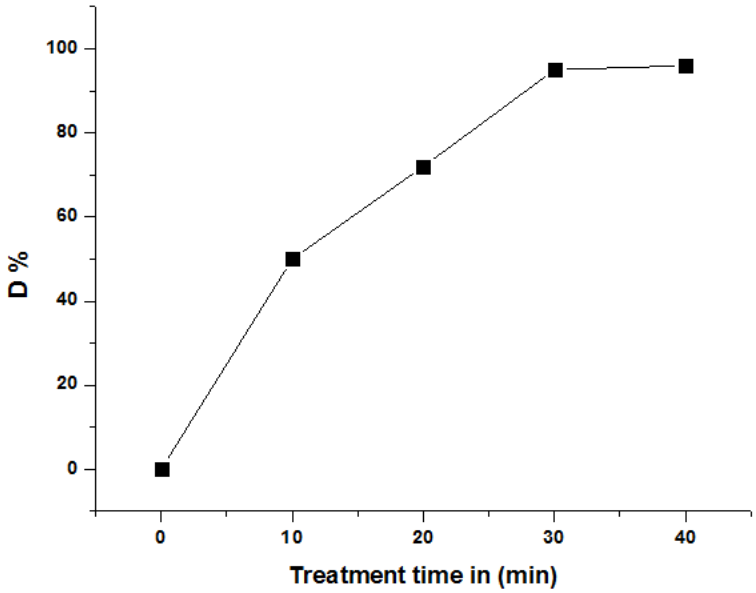


Figure 5: Variation of desorption rate with plasma treatment time

4. Conclusion:

Here in this paper, we have discussed the design criterion of a pulsed discharge device for water treatment. As a pilot experiment we have performed an initial experimentation with continuous source at atmospheric condition which provides a satisfactory result in the degradation of Methylene blue dye. It is observed that the continuous source can able to desorption of dye in a longer time frame (~ hour) and a relatively small amount (few liters) as in this condition relatively a small voltage (~ 10-15 kV) is applied. Hence to use this experimentation in commercial point of view we have to use relatively a large voltage (~ 30-50 kV) and this high voltage operation is possible only in pulse mode. In connection to this the proposed design provides an opportunity to purify the drinking water in a very large scale but at affordable price and short span of time. The device will be developed at Tihu College, Tihu, Assam and in the near future the same set up will be modified to treat the waste water also.

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