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A PROTOTYPE MODEL FOR PURIFICATION OF HARVESTED RAINWATER USING SOLAR POWERED PULSED CORONA DISCHARGE

Abhishek Mandal[1*]

[1]Department of Electrical Engineering, Dr. B. C. Roy Polytechnic, Durgapur-713206 West Bengal, India, Email ID: abhishek.mandal@bcrec.ac.in

Abstract: ***Nowadays we all are suffering from lack of water. In this circumstances rain water harvesting system is one of the most feasible and viable options to overcome the crisis. In this system the rain water is collected from rooftop through rain pipe and is being stored into a reservoir. Then the water is filtered and distributed for drinking and irrigation purpose. In this study the filtration system has been proposed using pulse corona discharge. At the time of water purification with the help of Pulsed Corona Discharge (PCD) technique water is allow to run into a reactor where the atmospheric air or oxygen is available and simultaneously a short duration high voltage pulse creates a Corona discharge. Consequently high voltage discharges are produced by the equipment which is as little as hundred nanosecond in duration and it can be said that it is equivalent to the duration of a lightning strike. This work bears a noble propose to implement the use of Pulsed Corona Discharge and it endeavours to develop a solar fed filtration system so that one can use it off grid as well.***

Key words: ***Pulsed corona discharge (PCD), pulse generation, water treatment, multilevel converter, rain water harvesting, water savings.***

1. INTRODUCTION

Though people waste water in their daily life one cannot deny its invaluable importance in our life. Our body temperature remains normal as we drink water. Even it helps us to lubricate and cushion our joints and protects our spinal cord and other sensitive tissues. Drinking water is the best way to keep hydride our body. Not only that but also water is used widely for various application in our daily life. There are various sources of water like Oceans and Seas water, Rainwater, Glacial, Surface Water, Ground Water etc. Among this ample source of water we have very few for drinking purpose. The water which has less than 500 parts per million (ppm) of dissolved salts is called the fresh water or drinking water. The pH of the drinking water is 7. Almost 3/4$_{th}$ of area is covered by water in the earth among them only 2.5% to 2.75% is useable water it includes 1.75% to 2% of ice and snow, 0.5% - 0.75% of water from ground and soil wetness and less than 0.01% of it as surface water from lakes. Less than 3% of the planet's water exists as freshwater. Among them two third of the freshwater in our glove is not even liquid, it is in the form of ice in glaciers like Antarctic and

Greenland. The main source of freshwater is groundwater. But if we consider water pollution then these ground water is also is in danger. Especially in industrial area the level of water pollution is very much since maximum industrial waste are deposited into the nearby river or pond. So it's our duty to think about the alternative source of drinking water. Rainwater harvesting is one of most feasible and viable process by which we can properly utilize the rainwater as drinking purpose as well as household purpose.

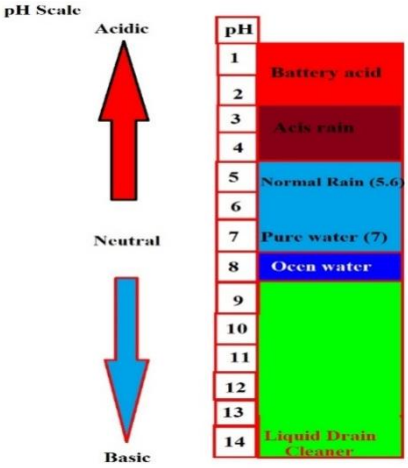

Figure 1 pH scale of various types of water

1.1 Literature Review-A lot of research work has already been done related to rainwater harvesting system. M. S. Nasif et al., 2016 studied that the optimized size of rainwater tanks of storage for different types of roof materials. They also discussed about the run-off coefficient for various roof material [1]. M. F. Colom-Reyes et al., 2017 discussed about the water expenditure in household and try to minimize the misuse [2]. Subhajyoti Samarddar et al., 2008 worked with the rainwater harvesting technology based on Social Network Threshold model in a small city of coastal Bangladesh, suffers from arsenic [3]. Fayez A. Abdulla et al., 2008 also discussed about the water scarcity in Jordan and recommend the rainwater harvesting technique to provide the clean water supply [5]. B. Helmreich et al., 2008 discussed about the various opportunities in rainwater harvesting system. Depending on the precipitation intensity, rainwater constitutes a possible source of drinkable water [8]. Mohammod kebriaei et al., 2015 discussed about the water treatment using Pulsed Corona Discharge, its advantages and procedure [11]. Petri ajo et al., 2015 proposed a PCD reactor model and studied about the various parameters of the pulse, its power requirement etc [12]. M. A. Elgenedy et al., 2017 proposed a new technique for generation of sharp voltage pulse from a relatively low voltage DC input using nano crystalline transformer. They have also proposed their topology and working principle [13]. In 2006 Grabowski, L.R investigated the

applicability of a pulsed corona discharge for waste water cleaning [15]. Tomio Fujii et al., 2008 discussed about the behavior of the pulsed corona discharge over the water surface [16].

2. WATER PURIFICATION USING PCD

There are few traditional methods to purify the dirty water as well as rainwater for use it as a drinking water. Existing methods too expensive have unwanted byproducts or simply don't work so it cannot be used all the time. Pulsed corona discharges are such a technology. In recent past the PCD technique has become an important subject for research and this technique has beenperformed on alarge scale. In this Pulse Corona Discharge technique there is a reactor in which high sharpvoltage pulses of short duration and keen rise time are given across two terminals. These high voltage pulses energize and accelerate free electron which collide with each other ionized, excite the surrounding molecules. This process produces number of free electrons and lastly an electron avalanche creates which is known as streamer. This streamer initiate in the bubbles created by locally heated of the liquid or in pre-existing bubbles, since in liquid phasethe average free path is longer than in gas state. Splitting of the ambient molecules helps to produce more freely moveable radicals, e.g. H_2O split into the H• and OH•. The bubbling of the oxygen gas between the discharge gap of the electrode helps to produce O• by separation ofO_2 and the rate of creation of HO and OH• also boosted by this process. Interaction of the freely moveable radicals, such as Ho, OH•, O•, etc. with each other and with surrounding molecules also producesthe O_3andH_2O_2. The chemical active species that's mean these high energy electron, OH•,H•,O•, O_3, H_2O_2, neutral molecules in a energized state and ionic species created by this corona discharge attack and spoil toxic organic compounds in the water. This method is analogs to that which is happen into an atmospheric water droplet. Electrical discharge also produces ultra violet radiation shock waves and supercritical water conditions in water.These products by electrical discharge create the surrounding more compatible for the putrefaction of toxic organic compounds present in water. The electrically discharge, mainly pulsed corona discharges (PCDs) seems to be the most suitable technique for water and gas cleaning because of some benefits like, PCD can able to oxidize a large types of poisonous organic compounds in water and in air, A large number of harmful microbial contaminants in water can be killed Pulsed electric fields and the technology is simple for this process and the installation cost is also lower.

2.1 High Voltage pulse generation from a low voltage DC input-A converter is needed which has a high gain of voltage to create large voltage from a respectively lower voltage source. In this generation solid state device is more preferable than conventional method

because solid state device has more reliability, durability and it is more cost effective than conventional method. In this sharp a high voltage pulse generation using Capacitor Diode Voltage Multiplier (CDVM) has been described because of its couple of advantages. Their small size, light weight, high efficiency and reliability are the main advantages of the voltage multiplier [17].

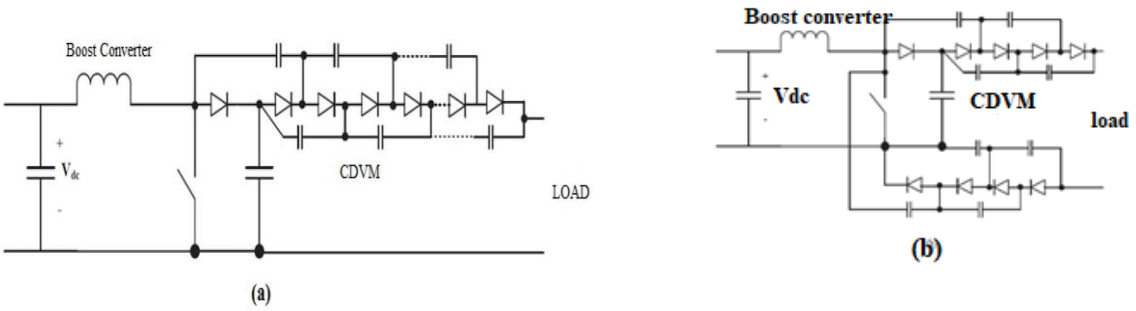

Figure 2 Boost Converter with CDVM [17]

The high voltage pulse generator is shown in fig. 2. Here all the capacitor gets the same amount of voltage and the diodes keep the capacitor voltage level equal. The CDVM feeds from the boost converter centrally i.e. CDVMs are distributed uniformly on the both ends of the output terminal. This type of connection helps us to improve the thermal loss distribution as it reduces the fluctuation of current in the CDVM stages as compared to the first proposed method. The output voltage is the summation of the top and bottom CDVM groups. The boost converter's inductor is choose to give uninterrupted current mode as it inductor core losses. To follow aparticular reference voltage the converter is controlled by regulating its duty cycle. A conventional proportional integral (PI) controller is utilizes to control the duty cycle of the boost converter. The output terminal voltage response isgiven by (1), where V_{out} is the high voltage DC output,V_b is the voltage of the capacitors used, m is the number of stages in top and bottom CDVM,V_{dc} is the DCinput voltage, andD_b is the boost converter duty cycle [17].

$$V_{out} = (2m+1)V_b = \frac{(2m+1)}{(1-D_b)}V_{dc} \quad (1)$$

The duty cycle equation is shown by equation the (2). Number of voltage multiplier can be chosen by the equation (2). It provides operation within a medium range of duty cycle of the converter.

$$D_b = 1 - \left(\frac{(2m+1)}{V_{out}}V_{dc}\right) \quad (2)$$

To get the sharp voltage pulse of the generated high voltage (V_{out}) a high voltage controlled switch is needed at the out terminal. The series combination of switches with dynamic voltage balancing can be used to implement the high voltage switch [17].

2.2 Prototype model of solar powered Water Purification Technique using PCD-

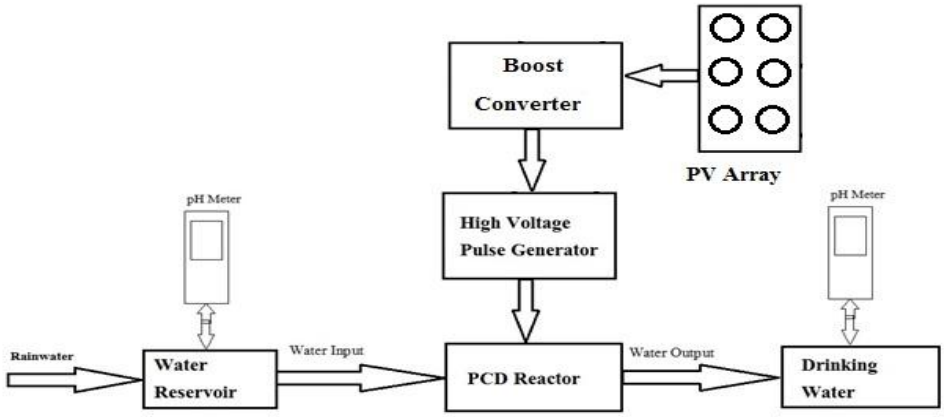

Figure 3 Prototype model for solar powered water purification system using PCD

A proposed model for solar powered purification system using PCD is shown in Fig 3. In this system the rainwater is stored into a water reservoir, and then this water goes through the PCD reactor where a high voltage corona discharge is occur and the purified water comes out from the reactor. The PCD reactor is fed from a sharp voltage pulse generator. This high voltage pulse generator is takes a low voltage DC input from a solar PV array and generates a high voltage pulse which is used in PCD reactor. There is a pH meter in the unpurified water reservoir to get the pH value of the unpurified water and another pH meter is in the drinking water tank so that we can also measure the pH value of the purified water. By comparing the two pH value we can verify the quality of the drinking water. The pH value of drinking water is around 7.

3. PROPOSED RESULT & DISCUSSION

With the proposed model for water purification it is expected to get around 3.5KV voltage spike and 3.5A current within a very short time interval when the system is fed from a PV array of around 1500w/m^2 irradiation at 40^o C with maximum power rating of around 250 W and the CDVM with ten capacitor (approx. 0.5µF each) & eleven diodes having near about resistance 0.01 ohm, forward voltage 0.08V, snubber resistance 750 ohm & snubber capacitance 300 µF. From these result it is expected to get the sufficient voltage and current spike so that it can be used in the proposed solar powered Pulse Corona Discharge water purification system.

4. CONCLUSION

A solar powered based purification system of harvested rainwater using pulsed corona discharge has been proposed in this dissertation. The necessity of and scarcity of water has also been discussed here. In this circumstance rainwater harvesting is one of most viable and feasible option to mitigate the scarcity of drinking water. Here the proposed purification system is solar powered so it can be used off grid also, not only that, where the electricity is not available there also it can be used. As it is solar powered so it totally based on clean energy and pollution free.

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