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Multipoint's cylinder corona reactor new design

***Abstract**. This paper aims to develop new designs of multipoint-cylinder corona reactors. The current-voltage characteristics of the discharge are studied experimentally and are examined for both positive and negative polarities depending on the arrangements and the number of tips. The experimental study is completed by numerical calculations of electric field using Comsol Multiphysics. The tip arrangements double the current when the number of needles doubles and maximum current can be obtained with minimum energy without passage to electric arc.*

***Streszczenie**.Celem pracy jest opracowanie nowych konstrukcji wielopunktowych reaktorów koronowych. Charakterystyki prądowo-napięciowe wyładowania są badane eksperymentalnie i badane pod kątem polaryzacji dodatniej i ujemnej, w zależności od układu i liczby końcówek. Badania eksperymentalne uzupełniają obliczenia numeryczne pola elektrycznego przy użyciu programu Comsol Multiphysics. Układ końcówek podwaja prąd, gdy liczba igieł się podwaja, a maksymalny prąd można uzyskać przy minimalnej energii bez przechodzenia przez łuk elektryczny. (**Nowy projekt cylindrycznego reaktora koronowego firmy Multipoint**)*

Keywords: High Voltage, Corona reactor, Electric Discharge.
Słowa kluczowe: Wysokie napięcie, Reaktor koronowy, wyładowanie elektryczne

Introduction

Pollution is one of the problems facing the environment at the heart of acclaimed industrial development. Many different types of discharges may be used as reactors for pollution control [1]. Many reactor designs use electrodes such as small diameterwires, needles or sharp edge metals that promote strong electricfields. Corona reactor, which by applying high voltage between two types of well-chosen electrodes obtains corona discharge. Depending on the type and configuration of the electrode, there are several models of corona reactors, either; wire plate, wire cylinder, cylinder -cylinder, multi-point on plane [2-4].

The electrode configuration commonly used is the point-plane configuration for its simplicity of study and analysis [5-7]. Multipoints plane configuration is practically important allows drawing a more powerful current and expand the treatment area [8-11]. Multi wire cylinder configuration and coaxial cylinder wire are preferred because they offer symmetric structure and ensures uniform electric field [12].

Mingjiang et al [13] Show the investigation of the wire cylinder configuration for the realization of an electrostatic precipitator Back corona discharge, it should be noted that BCD results in an increase in the power consumption of the ESP for all stages. Kantouna et al [14] Show that a cylinder-wire-cylinder electrode configuration with the right cylinder closer to the wire produces efficiency relatively higher than a typical wire cylinder arrangement.

Results obtained by Sahraoui et al [15] using a cylinder point electrode configuration show the influence of the geometrical and electrical parameters on the corona discharge, so that the adopted values of these parameters provide a sufficient electric field to initiate the corona discharge and give maximum current and optimum power consumption. multiplication of the number of points, using a multi-point cylinder "2p, 4p" electrode configuration, where the points are arranged in a symmetrical manner with respect to the cylinder increase the current and optimize the power, avoiding the transition from the corona discharge to the electric arc.

To obtain a higher current and further optimize the power we propose a new multipoint cylinder configuration. Points are arranged in a symmetrical and parallel way, the number of points is twelve. The electric field computation at the points is done by Comsol based on the finite elements method.

This theoretical study helps providing means to test different geometries and parameters to determine their relevance and feasibility. In this work, we calculate the electric field using the voltage value applied at the moment of the appearance of the filament at the top of the needle. The value of the electric field is the maximum value indicated at the needle head, corresponds to the ignition voltage of the corona discharge. The electrode configuration is simulated in 3D electrostatics. The electrode dimensions are the dimensions quoted in experimentation: The boundary conditions are the outer limits at zero, the peak in potential U, the cylinder is grounded.The resolution is based on the finite element method. The current I, the minimum voltage and the optimal power $P = UI$, belong to the most important factors in the optimization of a corona reactor [16].

Experiment set up

The experiment set up is shown in Fig.1. The high voltage DC power supply have both positive and negative output polarities and 30kV maximum output voltage, the maximum current is 10mA. The multipoints cylinder configuration consists of a cylinder "cathode" which is a copper tube; diameter D= 22mm connected to ground, and the needles "points" connected to the high voltage electrode "anode". Each needle radius of curvature is r_c = 0.002mm placed perpendicularly with gap distance d from the cylinder. A high voltage probe for multimeter is placed at the high voltage electrode.

To measure current with a multimeter, a measuring resistance R_m=110 kΩ, is plugged in series with the ground electrode. The resistance R_p = 10 kΩ is used to limit current.

While serial circuitry is built, the experiment planning consists of preparing a test program according to positive and negative polarity. We took as values: inter electrode distance d=5mm, the distance between points by moving vertically h =5mm, number of points equals twelve. The electrical parameters voltage and current are indicated on the front panel of the multimeters. Angle between points is either α=120° or α=90°.

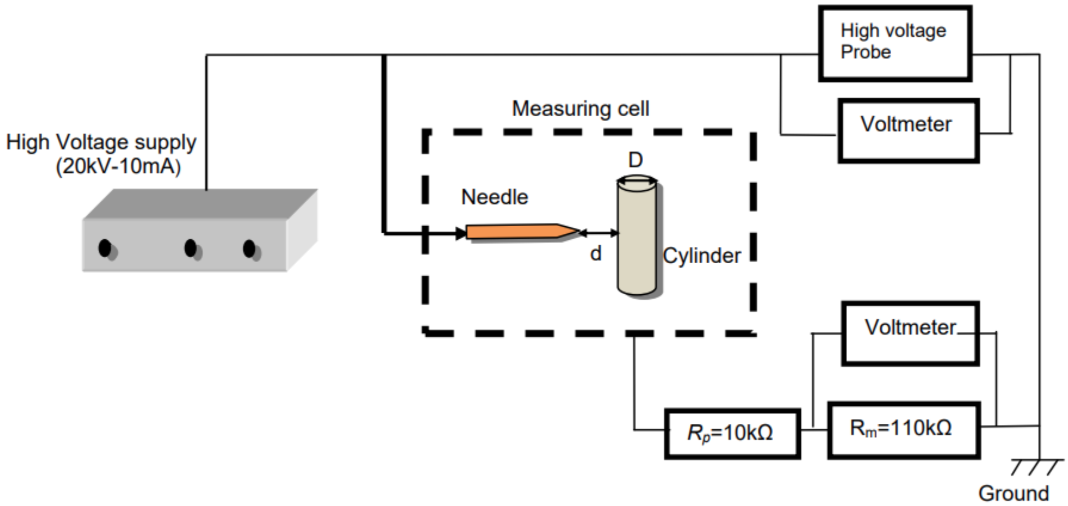

Fig1**:** Simplified schema of the Multipoint's cylinder system

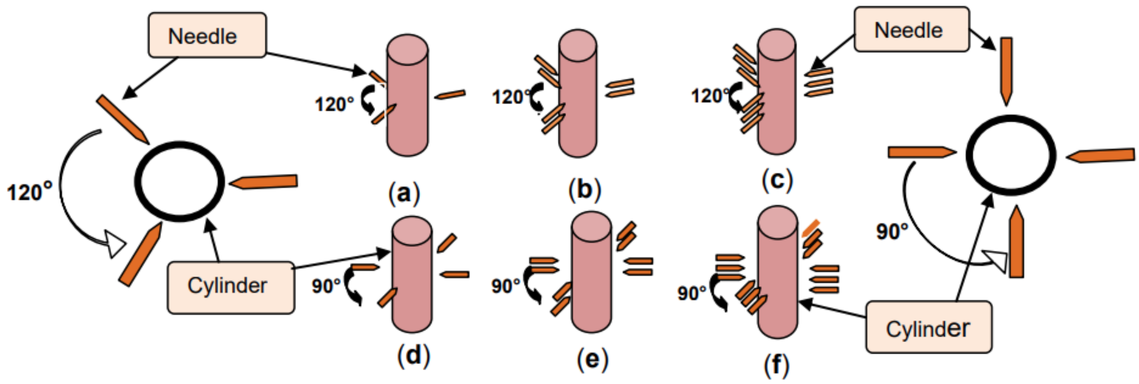

Fig2: Scheme of the arrangement of the cylinder multipoints

Result and discussions

Twelve needles connected to a high-voltage electrode, are laid symmetrically in relation to the cylinder. The cylinder of diameter *D*=22mm is connected to the ground electrode as shown in Fig.2"a, b, c, d, e, f". Points are disposed in triangular angle α=120° see Fig. 2 "a,b,c", or in quadrature see Fig. 2"d,e,f". The taken values of " *d*" and " *h*" are the optimum as they make the electric field homogeneous at the level of points, and the discharge developed uniform.

Current and voltage measurements are done while multiplying the number of points with negative and positive polarity.

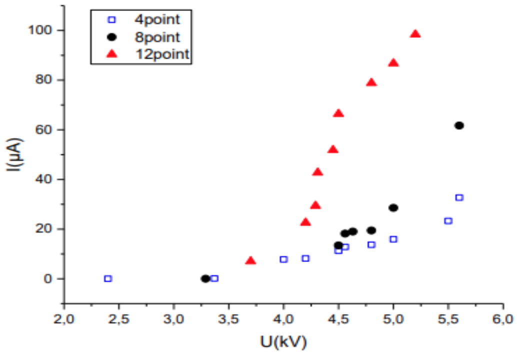

Fig 3.. Current variation as a function of the applied voltage for four and eight, twelve points in quadrature and parallel with respect to the cylinder, positive polarity

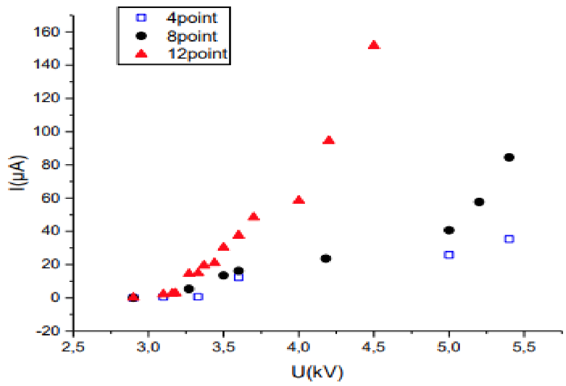

Fig.4. Current variation as a function of the applied voltage for four and eight, twelve points in quadrature and parallel with respect to the cylinder, negative polarity

The obtained results presented in Figs. 3- 4, illustrate the influence of the number and parallel arrangement of the points for the angle α=90° see Fig.2"d, e, f" on the variation of the current, in positive and negative polarity. We notice that the current increases with the number of points and the applied voltage.

The multiplication of the number of points[15], using a multi- point cylinder "2p, 4p" electrode configuration, where the points are arranged in a symmetrical manner with respect to the cylinder, makes it possible to increase the current and to optimize the power, avoiding the transition from the corona discharge to the electric arc.

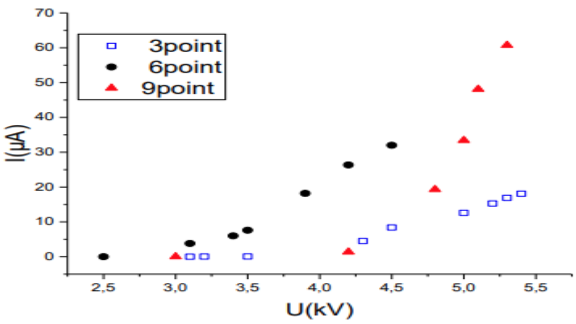

Fig 5. Current variation as a function of the applied voltage for tree and six, nine, points in triangular and parallel with respect to the cylinder, positive polarity

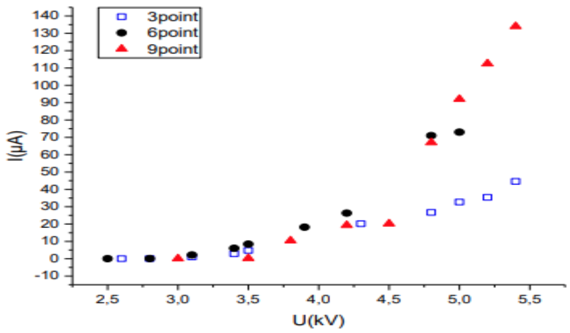

Fig 6. Current variation as a function of the applied voltage for tree and six, nine, points in triangular and parallel with respect to the cylinder, negative polarity

The voltage current characteristic show the maximum current of the corona discharge doubles from one floor to another for almost all the configurations carried out. Table 1 shows the maximum current values.

The current obtained doubles as the needles multiply from one floor to another with quadrature configuration " 4,8,12" points and triangulair configuration " 3,6,9" .
The current for each stage is given by:
$I_{2\ floor}=2I_{1\ floor}$; $I_{3floor}=3I_{1floor}$.

The points are arranged in triangular and parallel in symmetry of angle 120 ° with respect to the cylinder see Fig.2 "a,b,c". The results presented in Fig. 5 -6 show that the current increases with increasing number of points and voltage decreases with increasing number of points for both positive, negative.

At negative polarity, the corona current is important compared to the positive polarity, this is the property of the negative polarity.

Many works have focused on the study of negative and positive polarity, in particular: The work of [17, 18] shows that the current of the negative polarity is important than that of the positive polarity for this reason the negative polarity is preferred in the corona discharge investigations.

The computation of electric field strength at the points for an angle of symmetry respectively 90 ° , 120 ° shown in Tables 2 and 3.

Table 1: Maximum current values for Multi Needles configurations quadratic,Triangular (positive and negative polarity)

Quadrature Needle configuration			
Positive polarity	One stage, four needle in quadrature Fig .2a	Two stages, eight quadrature needle Fig.2b	Three stages, twelve quadrature needles Fig.2c
Imax (µA)	32	62	100
Negative polarity	One stage, four hands in quadrature Fig.2a	Two stages, eight quadrature needle Fig.2b	Three stages, twelve quadrature needles Fig.2c
Imax (µA)	35	84	152
Triangular Needle configuration			
Positive polarity	One stage, three triangular needle Fig.2d	Two stages, six triangular needle Fig.2e	Three stages, nine triangular needles Fig.2f
Imax (µA)	18	32	61
Negative polarity	One stage, three triangular needle Fig.2d	Two stages, six triangular needle Fig.2e	Three stages, nine triangular needles Fig.2f
Imax (µA)	44	73	134

Table2 **:** Electric field at the points for an angle of symmetry 90° level with respect to the cylinder for a fixed applied voltage and inter-electrode distance.

E (kV/cm) 4point(Fig.2a)	E (kV/cm) 8Point(Fig.2b)	E (kV/cm) 12point(Fig.2c)
6155	5547	5289
6184	5534	5055
6151	5568	5344
6223	5543	5209
	5595	5106
	5583	5259
	5500	5282
	5688	5229
		5385
		5297
		5123
		5316

We noticed that for the same applied voltage and the same inter-electrode distance, the electric field takes almost the same values for each configuration of the points either in quadrature or in triangular.

The position of the needles limits the variation of the field, which makes the field proportional to the change of the number of needles for the same position.

Table3: Electric field at the points for an angle of symmetry 120° with respect to the cylinder for a fixed applied voltage andthe inter-electrode distance.

E (kV/cm) 3point(Fig.2d)	E (kV/cm) 6point(Fig.2e)	E (kV/cm) 9Point(Fig.2f)
6212	5652	5070
6245	5509	4985
6126	5590	4931
	5628	5066
	5658	4836
	5541	50131
		5110
		4879
		5109

The symmetrical arrangement of the points with respect to the cylinder Fig. 2 "a, d", limits the variation of the field, this one is uniform at the level of the points, under these conditions the corona discharge is stable and uniform. Results gives similar and varied values in a narrow interval, which means that the field is uniform.

If we double the number of points Fig. 2 "b, c, e, f", the current doubles too. We notice that the current increases and the voltage decreases with the increase in number of

Table 2 and table3 indicate that the angle of symmetry between the points influences the field variation as well as for the same applied voltage, if we decrease the angle between the points the field decreases.
Ppoints and the decrease in the angle of symmetry between the points.

Conclusion

This work was devoted to an experimental and theoretical study of the corona discharge in air in order to adopt an optimal electrode configuration characterizing an optimal corona reactor. The results obtained using a cylinder points electrode configuration, show the influence of the the number of points and the manner in which points are disposed with respect to the cylinder on the corona discharge, in positive and negative polarization.

Multiplying the number of points, using a multipoint electrode configuration twelve points, the points are arranged symmetrically with respect to the cylinder. The

points are placed in superposition with respect to the angle cylinder 90 °, 120 °, this arrangement of points makes it possible to design two models of corona reactor. The negative polarity quadrature dot pattern pattern gives a large current.

This study gives the possibility of adopting an optimal electrode configuration that allows the design of a multi-points corona reactor optimal cylinder.

This study will be continued for the realization of a corona reactor with optimum parameters, experiments will be conducted for other configurations.

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REFERENCES

[1] J. Moon and J. Jung, "A wire-plate type nonthermal plasma reactor utilizing a slit dielectric barrier and a third electrode", Int. J. Plasma Environ. Sci.Technol, vol.1, No.1, pp7. March 2007.
[2] A.Susan, M. Nur and M. Widodo, "Study of the mobility of charge carriers in the multi-point to plane corona plasma reactor with 841 points",Advanced. Sc. Letters, vol 23, No.7, pp. 6601-6604(4), July 2017.
[3] H.Ren, N.Lu, K.Shang, J. Li and Y. Wu, " Oxidation of ammonium sulfite by a multi-needle-to-plate gas phase pulsed corona discharge reactor", J. Phys. Conf. Ser. 418(1), 8. Doi: 101088/1742- 6596/418/1/012128, 2013.
[4] J. Jiang, Z.Yang Luo, L.Zhao, J.Y Xuan, M.X. Fang and X.Gao, "Detection of OH radicals generated in wire–plate pulsed corona discharge by LIF",IEEE Trans. Plasma Sci.Vol 43.No.5,pp1747- 1757,May2015.
[5] M S Moss, K Yanallah, R W K Allen and F Pontiga, " An investigation of CO2 splitting using nanosecond pulsed corona discharge: effect of argon addition on CO2 conversion and energy efficiency", Plasma Sources Sci. Technol. (18pp), 2017.
[6] L. Liu, M. Becerra, " An Efficient semi-Lagrangian algorithm for simulation of corona discharges: The position-state separation method", 0093-3813 IEEE.pp1-10, 2016.
[7] E Sasmita, E Yulianto, M Restiwijaya, A W Kinandana, S H Pratiwi, F Arianto and M Nur, " Characterization of electrical property and ion mobility in positive corona and dielectric barrier discharge with point to plane configuration", J. Phys. Conf. Ser. 1170 012022I, pp7, 2019.
[8] E.M. Bazelyan, Y. P. Raizer, N. L and Aleksandrov, "Non-stationary corona around multi-point system in atmospheric electric field: dischargecurrent and vertical electric field profile", XV Int Conf on Atmospheric Electricity, Norman, Oklahoma,U.S.A.pp1-13.15-20 June 2014.
[9] Med Ali Kouidri,D.Mahi, "Study and realization of an electrostatic precipitator device ",Modelling Measurement and controlC,vol,79,No,4,December,2018,pp235-241.
[10] Lucian Dascalescu, Senior Member, IEEE, Adrian Samuila, Dan Rafiroiu, Alexandru Iuga, Senior Member, IEEE,and Roman Morar, Senior Member, IEEE," Multiple-Needle Corona Electrodes for Electrostatic Processes Application ',IEEE, VOL. 35, NO. 3, MAY/JUNE 1999,pp543-548.
[11] J.Koller.L.Aubrecht.J.PLocek,"Properties of multipoint corona discharge ",Czechoslovak journal of physics ,vol.62(2002)pp1-6.
[12] M.Abdel-salem, A Hashem, and E.Sidique , " characteristics of Negativecorona Disharge in Single-Needle and Multi Needle to plane configurations" ,International Journal of Plasma Environnement Science technologiy,Vol.7.No.2.pp121-135. .July 2013.
[13] Mingjiang Ni, Xihui Wang, Gang Xiao, Kunzan Qiu , Guang Yang, Xiang Gao and Kefa Cen," Development of back corona discharge in a wire- cylinder electrostatic precipitator at high temperatures", Power Technology 286 (2015) 789–797.
[14] K. Kantouna g.p. fotis k.n. kiousis l. Ekonomou g.e. chatzarakis," Analysis of a cylinder-wire-cylinder electrode configuration during corona Discharge " , Latest Advances in Information Science, ircuitsand Systems, ISBN: 978-1-61804-099-2.pp204-208.
[15] F. Sahraoui, S. Flazi, A. Mimouni, Y.Meslem, "Optimization of a multi points-cylinder corona reactor", CNHT'19, 29-30 April2019,Oran,Algeria,pp1-6.
[16] R.Balek, M. Cervenka , " Stabilization of Multi-needle-to-Plate Electrical Discharges in a High-intensity Sound Field", Proceedings of 20th International ., Sydney, Australia ICA .pp1-4. 23-27, August2010.,
[17] A. Bendaoud, A. Tilmatine, K. Medles M. Younes, O. Blejan, L. Dascalescu," Experimental Study of Corona Discharge Generated in a Modified Wire-Plate Electrode Configuration for Electrostatic Processes Applications",IEEE Trans Ind,Vol.46.No.2,pp666-669,March/April2010.
[18] Sabah I. Wais, Dunia D. Giliyana " Sphere-to-plane electrodes configuration of positive and negative plasma corona discharge", American Journal of Modern Physics.Vol. 2, No. 2, pp. 46-52, 2013,