IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 10, Issue 1 Ver. I (Jan – Feb. 2015), PP 23-28
www.iosrjournals.org

Study of Characteristics of Capacitors, Having Non-Traditional Conical Electrode Shapes, For Charge Distribution, And Surface Current Sharing Density

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Abstract: *The objective of this paper is to study and discuss on the different characteristics, like charge distribution over the surface area of the electrode of a capacitor, surface current sharing density per unit height of the electrode, having non-traditional conical electrode shape in comparison with the traditional typical parallel plate capacitors, particularly used with power frequency of 50 Hz. The study shows that the nontraditional conical shape of a capacitor creates the nonlinear, exponential or polynomial functionality. It develops logarithmic polarization-distribution in the dielectric medium. This offers usan exponential / polynomial reactive power distribution along the surface.*

Keywords: *Conical Shaped Electrodes, Capacitor, Charge distribution, current sharing. (Cup= capacitance with unit differential height of a parallel plate electrodes,)(Cuc= capacitance with unit differential height of conical electrodes)*

I. Introduction

This paper has a discussion on the study of characteristics of a capacitor having nontraditional conical electrode shape.The focus of study is on charge distribution over the surface area of the capacitor electrode, surface current sharing density per unit height along the capacitor electrode, in comparison with the typical traditional parallel plate electrode capacitor. The initiation of this study taken place, when the capacitor bank failure problem in the industry, brought forward, by the Managing Director of M/s. Chaitanya Electromagnets, the registered vendors of M/s Siemens Ltd. Aurangabad. The

power capacitor banks in their industrial set up observed repeated and random periodic puncture in any one of the capacitor plates in the power capacitor bank consisting of power capacitors, as shown in fig.1. These three phase capacitor bank formed by three parallel capacitors per phase. Whenever there happens a spike / harmonic current of high amplitude, more than sustaining capacity of the electrode plate thickness, that capacitor got punctured. The time-varying nature of electric arc furnace (EAF) gives rise to voltage fluctuations, which produce the effect known as flicker [1].

The problem of flicker has become quite acute [2]. During the Melt-down period the furnace operation the variations in system is very erratic, and violent, based on the large inductive load variations affect the power and reactive kilovolt amperes variations, and in load currents [3].

The location of puncturing of one of the parallel capacitors at different locations, and at different instants in M/s Chaitanya Electromagnets, is shown by plain rectangles in the fig.-1. The diagnostic testing and openings of the punctured capacitors did not shown break down of dielectric medium, but surprisingly every time, the melting of a portion of an electrode metal film found. However, progress from surface charging to the flashover has not been clarified sufficiently [4]. This compelled to think for safe passage of the high peak current density. One should provide the proper relation between that current density with area of cross section for conduction to the current spike. The situation can be understood from the fig. -1.

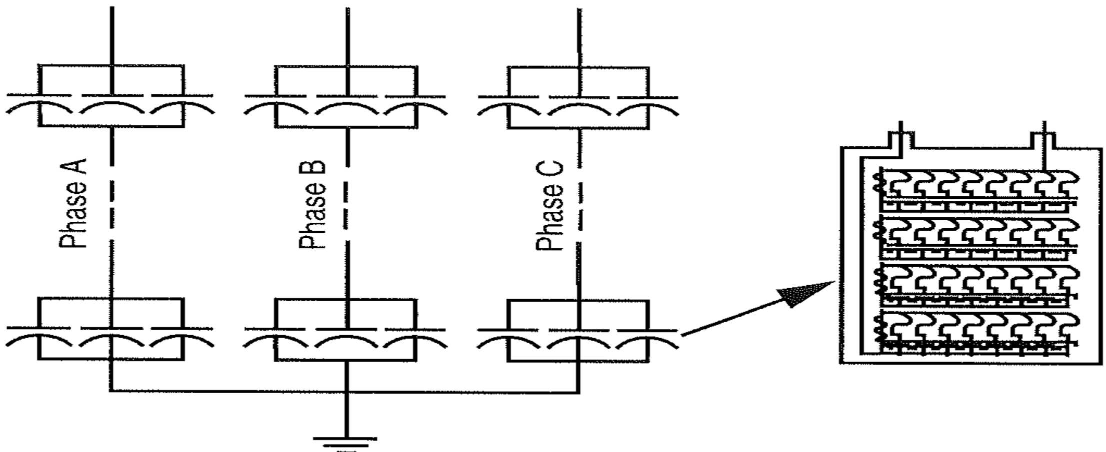

Fig.1-capacitor banks in industry having puncturing of electrode problem

The capacitance 'C' is defined as C= $\varepsilon r \varepsilon 0$ A/d.—[5].
(sponsors) M/s Chaitanya Electromagnets, Vendors of Siemens Ltd. D1/1
MIDC Aurangabad[Maharashtra State] INDIA. -431136

When a parallel plate capacitor is considered as shown in fig.-2, the total capacitance of the plate is a parallel combination of all individual differential capacitors developed between small unit height surface areas of the plate, can be found by the relation capacitance of parallel plates ΣCunit = Σ ε * Aunit /(distance of separation between parallel surface areas). This distance of separation is filled by the insulating dielectric material, like gaseous-air, SF6- or liquid – transformer oil- or solid- paper, mica and so on. The permittivity of that dielectric material is indicated as 'ε'. This ε- is a product of relative permittivity 'εr' and the absolute permittivity 'ε0'.

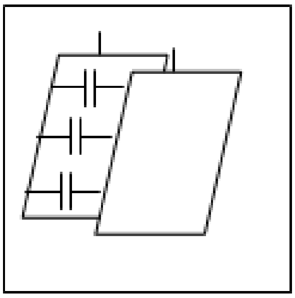

Fig.2- parallel plate cap.

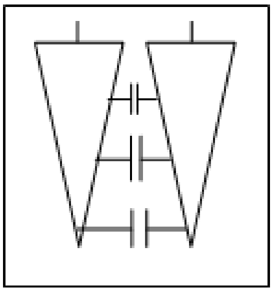

Fig.3-conical electrode Shape capacitor

Since all the unit height areas have same dimensions, same distance of separation, the value of each individual capacitor is same for all 'n' capacitors considered along the height. Hence total capacitance of the parallel plates is just = n* Cup. Whereas application of same logic for the capacitor having nontraditional cone shape electrodes, the individual capacitance of conical shapes Cuc has different values for each one, fig.-3. In such case the characteristics for both types of capacitors are studied and the charge distribution and surfacecurrent sharing by each individual Cunit is found and compared.

II. Selection Of Samples For Study

The each cone shaped electrode is chosen, having maximum radius 12.5 mm or 0.0125 m. Height of the cone is 50 mm or 0.05 m and slope length 51.54mm or 0.05154 m. The total cone area facing each other to form capacitor is 0.001256004 m2. The square root of this area value provides the dimensions of the equivalent parallel plates. The radius increment is differentiated in 100 equal parts; and as well the height. The cone surfaces are separated by 0.5 mm at their maximum radius side. The distance between two parallel plates is 0.000358996 m to have same capacitance, as that of the cone faces are developing. The dielectric medium is taken with two mediums; Air as a dielectric and Transformer oil as a dielectric, for both electrode shapes.

III. Mathematical And Graphical Analysis

The graphical outcome, indicating development of capacitance found is compared; as shown in fig.4 and 5; for parallel plates and fig.6 and fig.7 for conical shaped electrodes. The parallel plate capacitors follow the linear relationship of a straight line, y= mx+c, and making linear trend of making approximately 45 0 angle with reference axes. The capacitor development in conical electrodes, show the exponential/ polynomial type, capacitor development trend. This is a non-linear behavior of the conical arrangement.

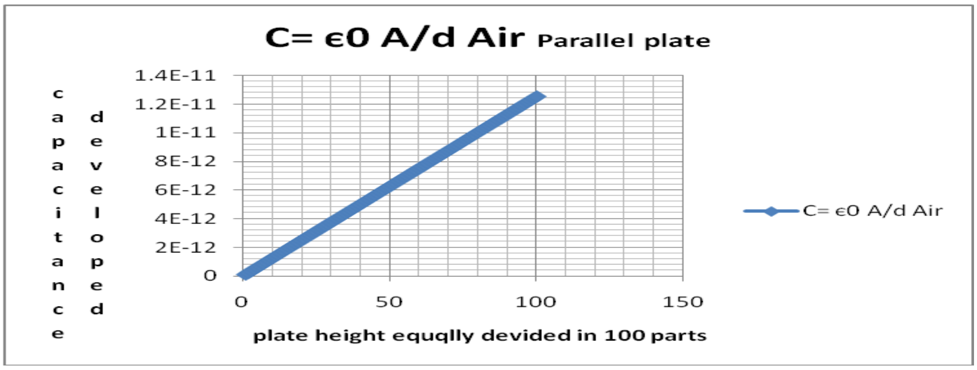

Fig.4 capacitance development in parallel plates-air

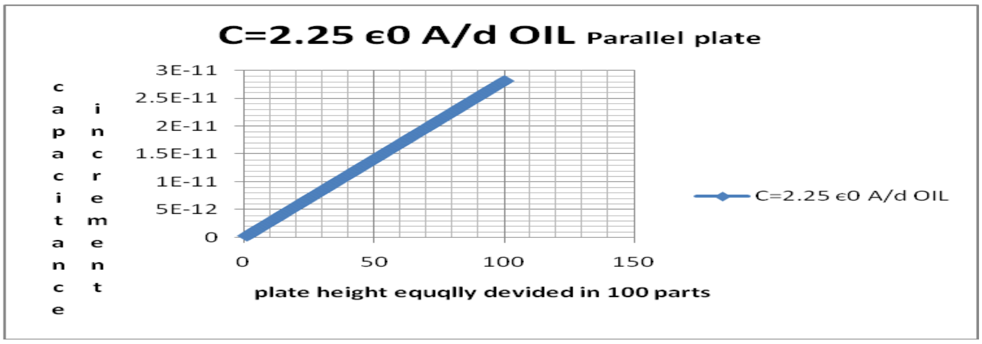

Fig.5 capacitance development in parallel plates-oil

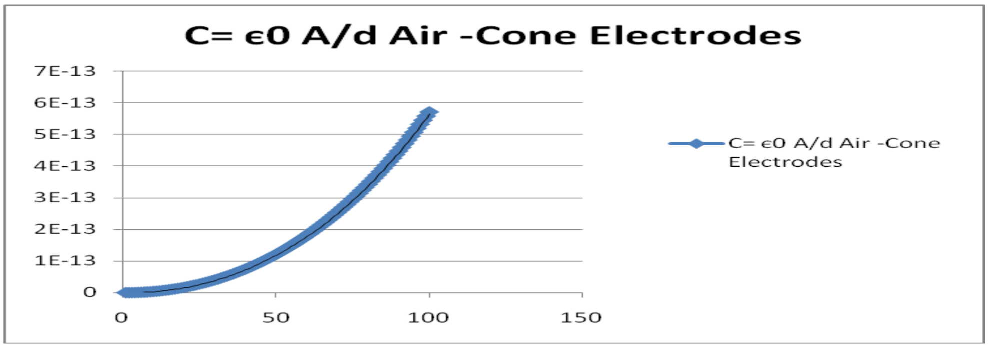

Fig.6 capacitance development in conical electrodes-air

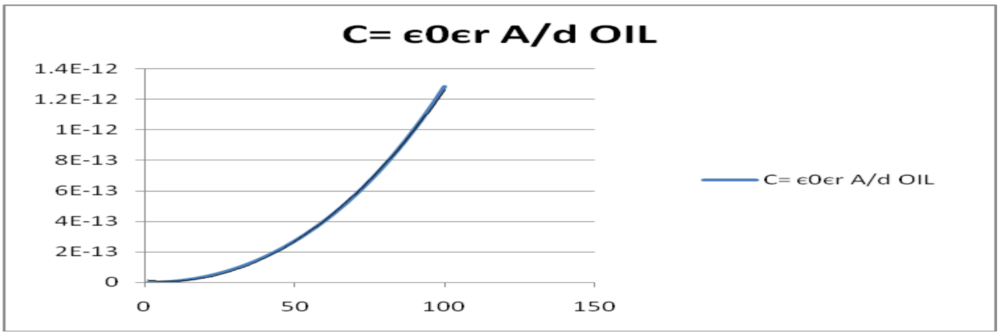

Fig.7 capacitance development in conical electrodes-oil

These curves obtained from conical electrode shaped capacitor are further studied in various angles, like current share by each of the differential capacitors of unit height in parallel, and development of high current carrying sustainability of the capacitor, in both parallel plate and conical electrode capacitors. Referring to the Fig. 1 and 2, the current passing from one electrode to second electrode is obviously a sum of all currents passing through the differential capacitors connected in parallel between two electrodes. This condition is same for both electrode shapes. Thus the current carried by each differential electrode pair, making a differential capacitor, depending on the capacitive reactance xc of that individual differential capacitor. The value of each individual differential capacitor and their x_c is uniform or same for all the differential capacitors considered for the parallel plate capacitor. Hence the current share taken by each individual differential capacitor is also uniform, in this case. Now applying same logic on conical electrode capacitor, we get that each individual unit height differential capacitor, has different value of capacitance, having related different value of xc, which exhibits proportional different current carrying share of total current flow, from one electrode to second electrode. This current share characteristic does not show uniform and linear shape but it has a non linear exponential or polynomial shape.This can be seen from the graphs shown in Fig. 8 and 9. From this, it shows a way for thinking, to provide a variable area of conducting electrode, as well as variable capacitance, offering

variable xc in a same pack.The current share distribution depends on the charge density distribution, and hence the study is extended to that factor of consideration and the observed charge density distribution or 'Charge Spread' over the surface. The graphs plotted for the said 'Charge Spread' over or along the capacitor electrode are also found showing the similar, straight line versus exponential or polynomial characteristics. These graphs are shown in Fig.-10 and 11. The charge distribution over the parallel plate capacitor electrodes is uniform; hence it is making the uniform effect on the dielectric medium between them, for making polarization of the dipoles. The accumulated charges are of a serious concern, as it would further lead to system failure. The static charges on the surface of the insulator causes local field enhancement which influences the pre-discharge development and subsequent flashover [6]. Whereas the charge distribution in case of conical shaped capacitor electrodes does not have linear relationship, it exhibits an exponential or polynomial type charge distribution. Non-uniform electric field distribution along the electrode surface is also found at the location around electrode-ends, joints [7].

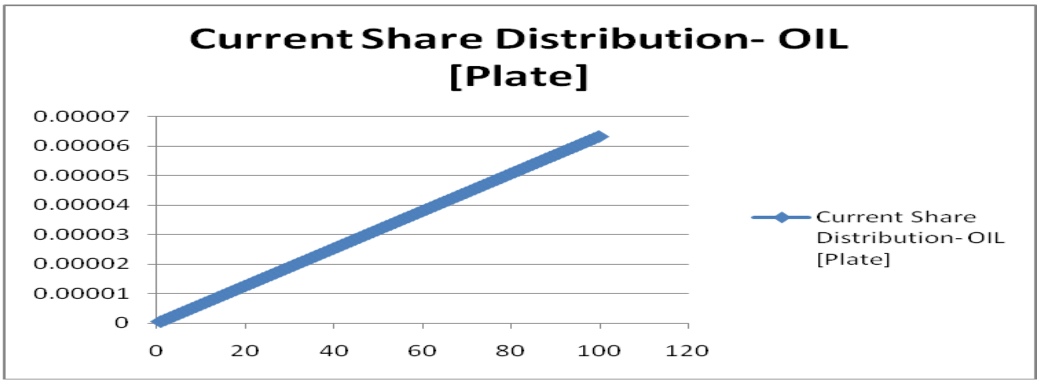

Fig.8 current share distribution in parallel plate capacitor –oil

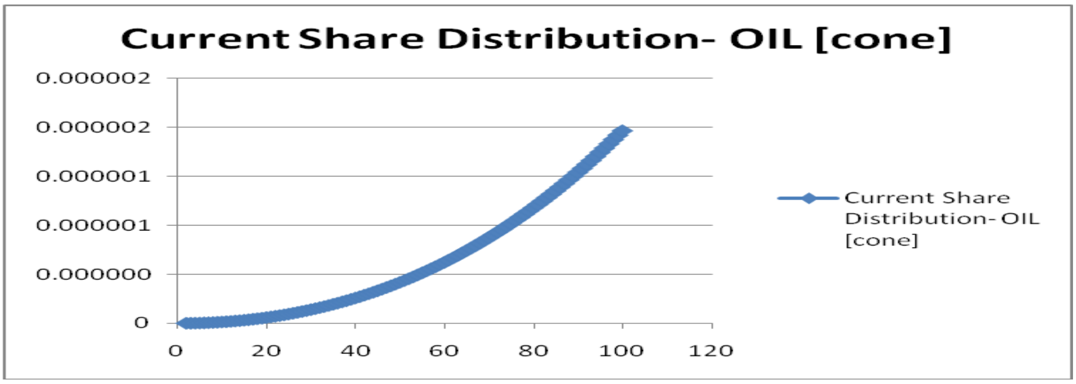

Fig.9- current share distribution in conical shape electrodes-oil

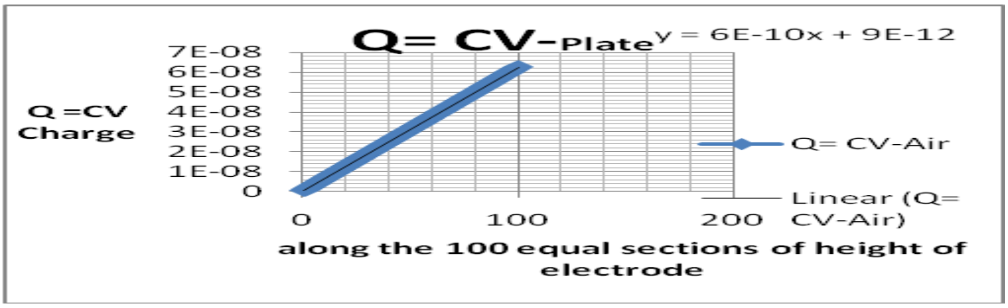

Fig.10- charge distribution with parallel plate capacitor.

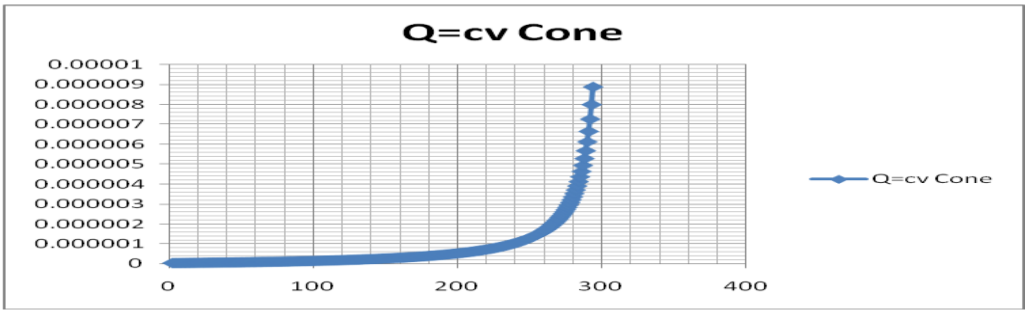

Fig.11-charge distribution with conical shaped electrodes.

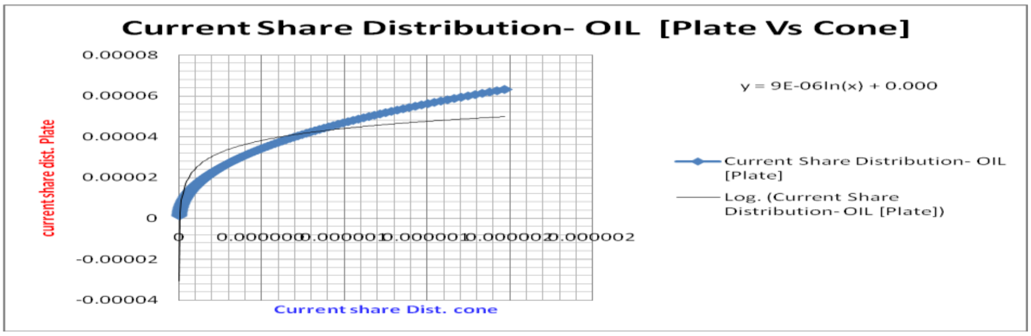

Fig.12- Relationship between current shares of both capacitor types.

The current share distribution trends exhibited by both electrode shapes have shown some sort of logarithmic relationship between them, as shown in Fig.-12. The relationship between the current share trends, may guidethe application and selection of an electrode shape for a particular purpose. The current flowing through the capacitor as an element definitely has an impact of actual flow of energyon the conductor material properties of the electrode. This effect can be moderated by selection of the shape of it. High resistivity electrodes and heavy edge had a negative impact on overall performance [8]. The data represented by the graphs, as shown in Fig.-13 and 14, and even assessment of conical electrode capacitors is capable to suggest the thought for use ofthe capacitor having electrode shape of conical nature, in series connection or for shunt connection of that capacitor, orfor the tuning of variable nonlinear inductance of viz. an arc furnace, with a suitable capacitor for that circuit.

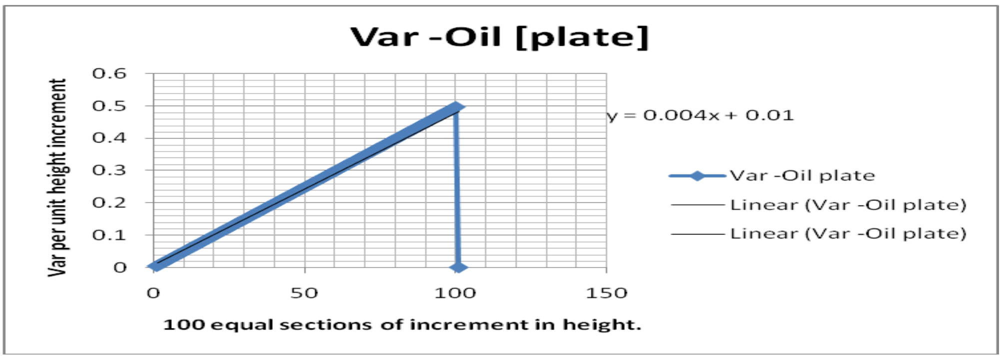

Fig.13- VAR compensation by parallel plate capacitor.

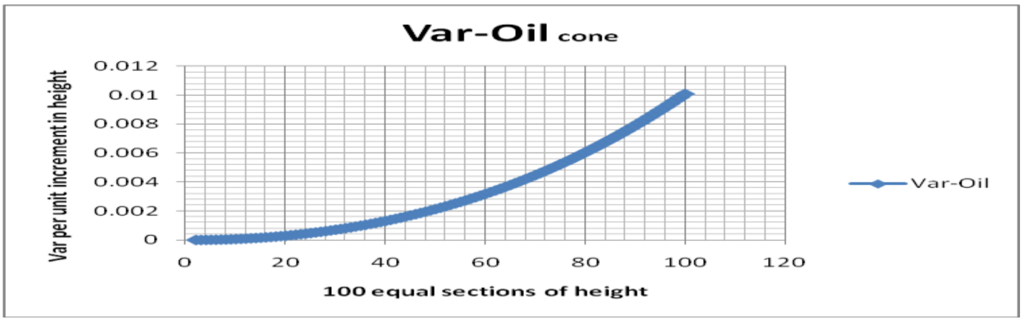

Fig. 14- VAR compensation by conical electrode.

The reason for the series capacitor system is to supply reactive power to the load that is directly proportional to the magnitude of the load [9].For conical shape electrode capacitors it is required in view of possibility and their capability to work as flying capacitor[10], or High energy density, energy storage capacitors used in launch applications require capacitors that can withstand extreme levels of acceleration[11].

IV. Conclusion

From past so many years, till present days, people had taken significant efforts in developments in parallel plate capacitors of different kinds; with innovative materials for electrodes as well as dielectric materials. In this paper, it is proposed to pay the attention towards the non traditional and non conventional electrode shapes like conical electrode. The study shows that this offers all the characteristics studied, are of similar nature.

Even with air-gas, and transformer oil-liquid, type different dielectrics, that shows non linear exponential or polynomial type particular behavior. These characteristics lead towards the study the VAr compensation by both the types of capacitors. The data represented by the graphs, as shown in Fig.-13 and 14, in the discussion and even assessment of conical electrode capacitors is capable to suggest the thought for use of the capacitor having electrode shape of conical nature, in series connection or for shunt connection of that capacitor, or for the tuning of variable nonlinear inductance of viz. an arc furnace, with a suitable capacitor for that circuit.

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