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DISTRIBUTION SYSTEM PLANNING USING NETWORK RECONFIGURATION FOR LOSS REDUCTION

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Abstract - *This Paper presents effect of network reconfiguration on power losses in distribution system has been investigated. This technique is restructured of distribution system with an purpose to improve the power quality. The general objective of losses minimization, power quality along with related objective such as voltage unbalance and voltage sag are identified as the objectives of network reconfiguration. Every of the objectives are solved by the Branch exchange technique. It can be used as very an effective tool to improve the power quality of distribution system. The Distributed energy sources also have great effect on distribution system. Branch exchange has been applied in two stages - between the elements of the network under each substation, called intrazone branch exchange and between the elements of the networks under adjacent substations, called interzone branch exchange. Their location and size are found to have great importance on the power loss, and voltage unbalance. The effectiveness of the network reconfiguration on power quality issues have been studied on 33-bus unbalance radial distribution network with Distributed generator.*

Key Words: **Branch exchange, Distributed generation, Network reconfiguration, Power quality improvement.**

1. INTRODUCTION

Now-A-Days Electrical Energy Is Generated, Transmitted And Distributed In The Form Of Alternating Current. Alternating Current In Preferred To Direct Current Is The Fact That Alternating Voltage Can Be Conveniently Changed By Means Of A Transformer.

High Distribution And Distribution Voltages Have Greatly Reduced The Current In The Conductors And The Resulting Line Losses. The A.C. Distribution System Is The Electrical System Between The Step-Down Substation Fed By The Distribution System And The Consumers' Meters.

The A.C. Distribution System Is Classified Into

- Primary Distribution System.
- Secondary Distribution System.

1.1 Primary Distribution System.

It is that part of A.C. distribution system which operates at voltages somewhat Higher than general utilization than the average low-voltage consumer uses. The most commonly used primary distribution voltages are 11 kV, 6·6kV And 3·3 kV.

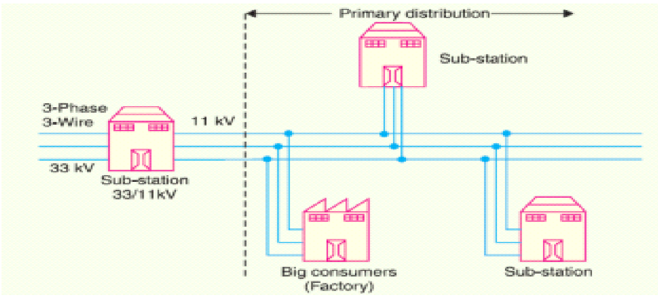


Fig.1.1 Primary Distribution System

Primary distribution is carried out by 3-phase, 3-wire system. Fig. shows a typical primary distribution system.

Electric power from the generating station is transmitted at high voltage to the substation located in or near the city. At this substation, voltage is stepped down to 11 kV with the help of step-down transformer. Power is supplied to various substations for distribution or to big consumers at this voltage. This forms the high voltage distribution or primary distribution.

1.2 Secondary Distribution system

It is that part of a.c. distribution system employs 400/230 V, 3-phase, 4-wire system. Shows a typical secondary distribution system.

The primary distribution circuit delivers power to various substations, called Distribution substations. The substations are situated near the consumers' localities and contain step down transformers.

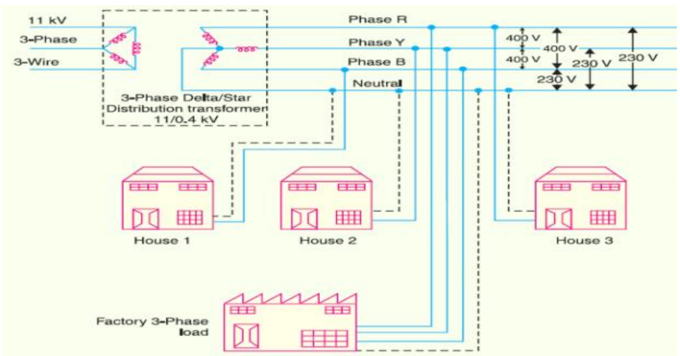


Fig.1.2 Secondary distribution System

At each distribution substation, the voltage is stepped down to 400 V and power is delivered by 3-phase,4-wire a.c. system. The voltage between any two phases is 400 V and between any phase and Neutral is 230 V. The single phase domestic loads are connected between any one phase and the neutral, Motor loads are connected across 3-phase lines directly.

2. PAPER REVIEWED

Priyesh Kumar at [1] have performed on Analysis of Network Reconfiguration Technique for Loss Reduction in Distribution System. An electric distribution structure plays a significant character in achieving satisfactory power supply. The quality of power is measured by voltage stability and profile of voltage. But because of losses in distribution system, its voltage profile affects. In this paper we analyze different techniques to reduce these losses in distribution system and examine the Network Reconfiguration method based on various parameters in detail and find out the optimum one.

S.K.Goswami at [2] have performed, Effect of network reconfiguration on power quality issues of distribution system has been investigated. The problem of network reconfiguration is reformulated with an objective to improve the power quality of the distribution system. Along with the traditional objective of loss minimization, power quality related objectives such as minimization of harmonic distortion of the voltage waveform, minimization of voltage unbalances at the nodes and maximization of sag voltages are identified as the objectives of reconfiguration. They has been Branch exchange technique used to establish each of the objectives.

Aboelsood Zindan at [3] performed, Distribution system reconfiguration for energy loss reduction considering the variability of load and local renewable generation. In this paper method based on GA (genetic algorithm) is presented to investigate the distribution system reconfiguration problem taking into consideration the effect of load variation and the stochastic power generation of renewable DG (distributed generators units). The presented method determines the annual distribution network reconfiguration scheme considering switching operation costs in order to minimize annual energy losses by determining the optimal configuration for each season of the year.

Sasan Ghasemi [4] performed on Balanced and unbalanced distribution networks reconfiguration considering reliability indices. Distribution system reconfiguration problem is a complex optimization process to find a structure with minimum losses in which the satisfaction of both sides, those are consumers and distribution system companies, need to be met. One of the most significant parameters in this regard is to increase the reliability of the system. This parameter, on one hand, increases the satisfaction of power consumption and on the other hand, improves the economic benefits of distribution companies. Distribution system reconfiguration, considering the reliability parameters, seems to make the attempts to solve the problem of optimization difficult. In this paper, a modified heuristic approach for distribution system has been presented. Also, in order to consider reliability indexes, a number of new formulas have been presented.

J.S.Saviar [5] performed on Loss allocation to consumers before and after reconfiguration of radial distribution networks. the research allocation of power losses to consumers connected to radial distribution network before and after network reconfiguration in a deregulated environment. Loss allocation is made in a quadratic way, which is based on identifying the real and imaginary parts of current in each branch and losses are allocated to consumers. Comparison of loss allocation after multi-objective approach based distribution network reconfiguration is made with those before reconfiguration. For network reconfiguration, multiple objectives are considered for minimization of system real power loss, deviations of nodes voltage, branch current constraint violation and transformer loading imbalance and they are integrated into an objective function through appropriate weighting factors which is minimized for each tie switch operation.

Distribution system reconfiguration for loss reduction was first proposed by **Merlin and Back** [6]. They have used a branch exchange and bound type optimization technique to determine the minimum loss configuration. In this method, all network switches are first closed to form a meshed network. The switches are then opened successively to restore radial configuration.

Vahid Farahani at [7] have performed on Reconfiguration and Capacitor Placement Simultaneously for Energy Loss Reduction Based on an Improved Reconfiguration Method. Network reconfiguration and capacitor placement have been widely employed to reduce power losses and maintain voltage profiles within permissible limits in distribution systems. Reconfiguration method proposed in this paper is based on a simple branch exchange method of single loop. In this simple method of branch exchange, loops selection sequence affects the optimal configuration and the network loss. Therefore, this method has been improved by optimizing the sequence of loops selection for minimizing the energy losses in this paper. Discrete genetic algorithm (GA) is used to optimize the location and size of capacitors and the sequence of loops selection. In fact, the capacitor sizes have been considered as discrete variables. Simulated annealing (SA) is also applied to compare the performance of convergence. The proposed algorithm is effectively tested on a real life 77-bus distribution system with four different kinds of load patterns.

Mohammad Hossein Karimi and Seyed Abbas Taher at [8] have performed on Optimal reconfiguration and DG allocation in balanced and unbalanced distribution systems. This paper investigates feeder reconfiguration in balanced and unbalanced networks and presents an efficient method to optimize practical distribution systems by means of simultaneous reconfiguration and distributed generation (DG) allocation. A precise and robust load flow algorithm is applied and a composite multi-objective function is formulated to solve the problem which includes: 1. voltage profile, 2. power loss saving, 3.current unbalance of the system, and 4. voltage unbalance. The genetic algorithm (GA) is utilized to search for optimal solution.

2. LOSSES IN DISTRIBUTION SYSTEM

The key role of an electrical distribution system is to deliver electricity to specific client sites. Distribution of electric power to various clients is completed with much minimum voltage point. The distribution of electric power from bases to the end levels is complemented with power losses at all times.

Power losses arise in distribution systems due to Joule"s effect which can calculation for as much as 13% of the produced energy[1,2]. Such major quantity of losses has a straight effect on the economic subjects and the total efficacy of supply utilities[1].

Distribution power losses can be shared into two[1]

- Technical losses.
- Non-technical losses.

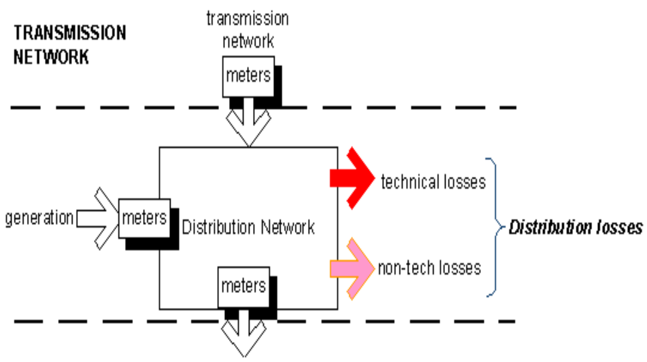


Fig. 2 Losses in Distribution system

3 LOSS REDUCTION TECHNIQUES[1] :

3.1 Network Reconfiguration: Network Reconfiguration is the procedure of operating switches to modify the circuit topology so that operational overloads and charges are condensed while sustaining the stated constraints[1].

3.2 Network Reconductoring: Network reconductoring is the technique in present conductor on the feeder is replaced by conductor of optimum size for optimum dimension of feeder. This technique is used when present conductor is no more optimum because of quick growth of load. This technique is good for the emerging nations like India where annual account growing rates are great and the conductor are selected to reduce the preliminary financial investment[1].

3.3 Distribution Transformers Locating and Sizing: Usually, DTs are not positioned centrally in the aspect of clients. Due to which the farthest customer sattain a very low voltage even though a reasonably high voltage level is retained at another transformer. This centrals to maximum losses in distribution system[1].

Fig. 3.3 Distribution Transformer

In this technique, distribution transformers should be located nearer to the load center as possible and replace large transformers by the transformers of small rating such that it serves small number of consumers so that optimum voltage level is maintained.

3.4 Automatic Voltage Booster (AVB): Automatic Voltage Booster increases the voltage at its point of site in distinct steps which in turn develops profile of voltage and minimize the losses in the sections outside its location point towards receiving. Generally, AVB boost voltage upto 10% in equal steps. Loss minimization is directly proportionate to voltage enhancement[1].

3.5 Reactive Power Compensation: It is described as the management of reactive power to increase the enactment of ac energy system. This technique clasp a diverse and wide area of both system and consumer difficulties, particularly related with power superiority subjects, as most of power QoS issues can be resolved with requisite control of reactive power. As the load is mostly inductive on the distribution system and requires large reactive power[1].

As, shunt capacitor provides reactive power compensation at its site, not dependent to the load and Series capacitor introduces negative reactance. It means series compensation alters the conduction or distribution system factors, while shunt compensation vagaries the corresponding impedance of the load. In both scenarios, the reactive power that flows through the system can be efficiently organized refining the performance of the overall distribution system[1].

3.6 Aerial Bunched Cables (ABC): These cables are new model for overhead energy distribution. It offers great safety and reliability, reduces power losses and final system budget by decreasing setting up, repairs and operational cost. This technique is perfect for rural distribution and especially striking for setting up in problem aticareas like mountain ous spaces, woodland parts, sea side zones etc[1].

3.5 Aerial Bunched Cables (ABC)

This is also measured as greatest selection for power distribution congested urban areas with fine lanes and by-lanes. ABC is the best choice in urban complex due to flexibility for switching lane as request by modifications in urban development design.

3.7 High Efficient of Transformers:

3.7 High Efficient of Transformers

The use of high efficient of transformers will also reduce losses, i.e. using amorphous core transformers instead of CRGO transformers. As it have high magnetic vulnerability, with less coactivity and maximum electrical resistance. As in transformers, minimum losses due to the high resistance by eddy currents[1].

3.8 High Voltage Distribution System (HVDS): This technique is most effective and efficient in minimizing the technical losses and refining the power quality in distribution system. In this technique, transformation of previous Low Voltage Distribution System to High Voltage Distribution System is done. This technique aims at extending high voltage lines as nearer to the load as possible and replacing large transformers with various small rating transformers. By using high this method, we can reduce the losses as current is low in high voltage systems[1].

4. Network Reconfiguration

Reconfiguration of distribution network has long been identified as a very useful method for the improved performance of the system. Merlin and Back were the first to propose the network reconfiguration technique for loss minimization of the system[6].

Later on many researches have been reported in the literature with the objective of loss minimization, load balancing, service restoration, voltage profile improvement. Initial attempts were restricted to the balanced radial networks. More recently, attempts have been reported to apply the technique on unbalanced networks as well.

Placement of shunt capacitors is an established technique for voltage and reactive power control in distribution system and researches on the placement and sizing of shunt capacitors have been reported extensively in the recent past, other form of 'VAr' compensators, like STATCOM are also being used[6,7].

Installation of small capacity Generating sources, popularly known as the Distributed Generation (DG) sources, in the low voltage distribution network is being encouraged during the recent years for several reasons. Network reconfiguration problem has been solved in association with the solution of the capacitor placement problem[7].

Reconfiguration technique has also been applied on distribution system having DG penetration. Some of the publications have formulated and solved the complexity of the DG and capacitor placement problem along with network reconfiguration[6,7].

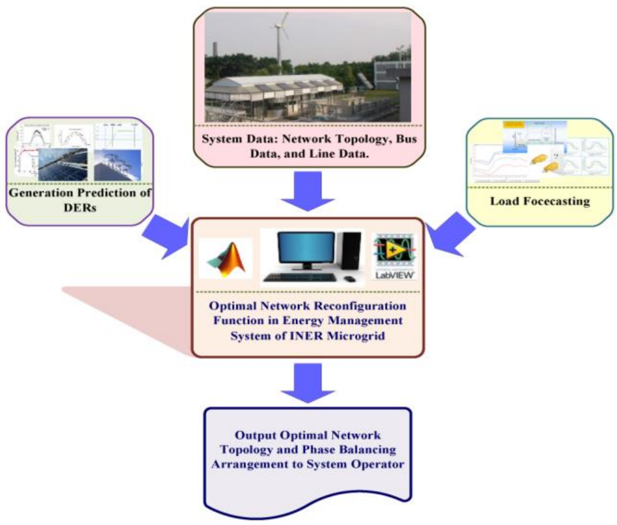


Fig.4 Network Reconfiguration

In recent years power quality issues have received considerable attention from the researchers and system engineers. Of the various power quality problems, voltage sag and harmonics issues are treated with fast attention because of the increased use of sensitive loads in the distribution system.

In this context the impact of network reconfiguration on voltage sag, harmonics and unbalance in distribution system has been investigated in this paper. Several researches have also been reported to have considered the network reconfiguration problem along with the power quality improvement problem[7].

In reconfiguration problem has been solved to minimize power loss and voltage sag problem. In , loss minimization, reliability and voltage sag enhancement are incorporated in the reconfiguration problem. In , and all the power quality issues are included in the formulation of the network reconfiguration problem along with the minimization of power loss[2].

In the present a new formulation of the problem has been presented. Branch exchange technique has been applied to determine the optimum reconfiguration strategy so as to minimize the effects of various power quality issues along with the networks losses. Simulation results performed on a 33-bus network has been presented to justify the proposed concept[2].

5. OBJECTIVE

Distribution network is radially configured for operational advantages. However, in medium voltage networks tie/sectionalizing switches are provided such that network configuration may be altered to satisfy some operational requirements. The change of the configuration alters the power flow path in the network resulting in altered line currents, node voltages, and degree of unbalances and also level of distortion of the node voltages in presence of harmonics. Since the impedance of the power flow path also changes due to reconfiguration, the voltage available at a node during a voltage sag condition is also liable to be changed[2].

As voltage sag may involve tripping of the sensitive loads, it is apparent that having an improved sag voltage has the potential to reduce the loss of the system under a voltage sag condition. Moreover, change in the effective impedance of the power flow path and the mutually induced voltage due to changes in the line current distribution will result in the change of the harmonic content of the node voltages. Thus, a better and more desirable reconfiguration scheme would take care of all these issues to maximize the benefit of network reconfiguration in distribution system.

Thus, the objectives of network reconfiguration may be formulated as[2]:

[1] Minimize Power loss in the network.

[2] Maximize Sag voltage in the network during fault or switching.

[3] Minimize Harmonic distortion of the node voltages.

[4] Minimize System unbalances

6. METHODOLOGY

6.1 Branch exchanges for loss minimization[2]: The minimum-power loss configuration is obtained by following the method proposed in, where an optimum flow pattern is established through a number of branch exchange operations. A normally open tie switch is closed to form a loop.

Optimum flow pattern is identified in the loop by solving the KCL and KVL equations of the loop, where the KVL is written as the summation of the resistive voltage drops in the loop to be equal to zero. Such a power flow pattern in the loop corresponds to the minimum loss power flow. To restore the radial configuration, the branch having the minimum current is opened. The process is repeated for all the tie lines, one after another, so long as a branch exchange operation results in a reduction of the loss.

6.2 Branch exchanges for minimization of voltage unbalances[2]: For the minimization of voltage unbalances we start with an initial radial configuration. Load flow of the network is performed and the voltage unbalances at the nodes. The node having the maximum voltage unbalance is identified and a tie branch is selected such that closing the tie switch a loop can be formed including the identified node.

The modified voltages of the nodes included in the loop are calculated and the flows through the loop branches are determined. Line having the minimum flow is then selected to be opened such that in the restored radial configuration node voltages are minimally disturbed. The calculation of the modified voltage and line flows of the branches of the loop are done following the methods in.

The above procedure reduces voltage unbalance as due to formation of the loop, the flow of currents are redistributed. Because of the availability of the alternative paths, maximum branch flows are reduced, resulting in the reduction of the branch voltage drops. This helps in improving the node voltages and the unbalances. When the branch having the minimum flow is opened, the flow pattern of the loop is least disturbed and resulting radial network gets modified to an improved one.

6.3 Branch exchanges for compounded problem[2]: The compounded formulation of the reconfiguration problem attempts to satisfy all the objectives simultaneously, thus minimization of any single objective is avoided. However, priority is assigned to the objectives depending upon their importance and their values in the prevailing configuration of the network. Since power loss is a major issue, as loss involves continuous wastage of money, it is given the highest priority. The effort therefore is to attempt for the reduction of the system losses if there is no violation of the indices related to power quality. In case of violation of the power quality indices, attempt is made for the reduction of the most severe one of the violations. Starting from a radial configuration, load flow, harmonic flows are solved and the system losses, harmonic distortion and voltage unbalances are determined.

Voltage sag analysis is then performed. The power quality indices are then evaluated and compared with their limiting values. In case of any violation, the most severe one is identified and tie branch is such selected that a loop can be formed to include the problematic node in the loop following the method as discussed in the earlier sections. The modified quantities of the loop formed are determined and a branch is selected to open following the method discussed in the earlier sections.

Solution of the problem:

Solutions of the above problems require the solutions of the power flow problem, harmonic flow problem and the voltage sag analysis problem. An optimization technique is necessary to search for the best network configuration, while the operation of the generated configuration is determined.

For the object of generation of the new configurations and the determination of the excellent solution, the branch exchange technique is applied. The branch exchanges, however, are decided based upon the newly proposed indices depending upon the objectives to be optimized. The analysis techniques are discussed very briefly in the following[2].

7. SYSTEM SUMMARY

Table 2. System summary

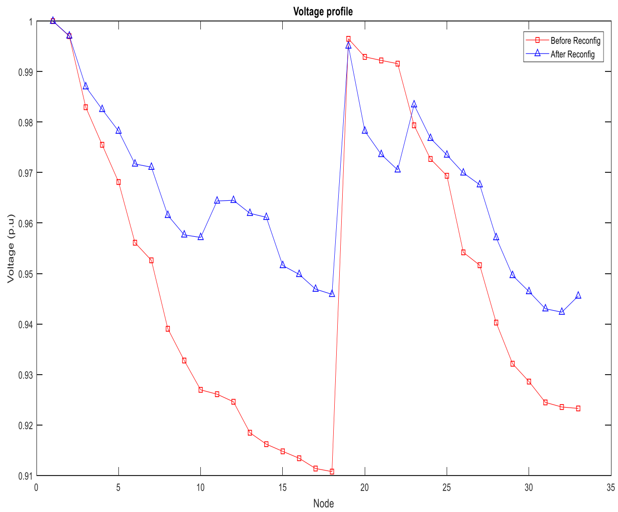
How many		How much	P(MW)	Q(MVAr)
Buses	33	Total Gens Capacity	0.0	0.0 to 0.0
Generator	1	Online Capacity	0.0	0.0 to 0.0
Committed Gens	1	Generation (actual)	3.9	2.4
Loads	32	Load	3.7	2.3
Fixed	32	Fixed	3.7	2.3
Dispatch able	0	Dispatch able	-0.0 of 0.0	-0.0
Shunts	0	Shunt(inj)	-0.0	0.0
Branches	37	Losses(I^2*Z)	0.17	0.14
Transformer	0	Branch charging	-	0.0
Inter-ties	0	Total inter-tie flow	0.0	0.0
Area	1			

	Minimum	Maximum
Voltage magnitude	0.901 p.u. @ bus 32	1.00p.u. @bus 1
Voltage angle	-1.85 deg @ bus 32	0.87 deg @ bus 30
P losses	-	0.03 MW @ line 19-20
Q losses	-	0.03 MVAr @ line 19-20

Table. 3. Simulation Results of 33-Bus Distribution Network

	BEFORE RECONFIGURATION	AFTER RECONFIGURATION
Tie switches	33 34 35 36 37	7 10 14 32 37
Power loss	208.4592 kW	139.6552 kW
Power loss reduction	-	33.006 %
Minimum voltage	-	0.94234 pu

Waveform :



8. COMPARISON AND DISSCUSION

In network reconfiguration problem has been solved for loss minimization, node voltage improvement, voltage unbalance reduction and minimization of total harmonic distortion of the node voltages. A fuzzy-Genetic algorithm (GA) approach has been used where the fitness function for optimization through GA has been formed using fuzzy membership functions for the cost, bus voltage, harmonic voltage distortion and voltage unbalance factor. Results are produced for the IEEE 33-bus test system with 5 tie switches[2].

The formulation in the present paper is very close to that in, with the only difference in the objective function is that, voltage sag maximization has been considered instead of node voltage improvement. The solution algorithm however is totally different from that in[2]. The network configuration obtained also is somewhat different from. The network, load and harmonics data used for the study are as given in[2] . The three cases mentioned in the table are those defined in. It may be observed that, the network configuration obtained by the proposed algorithm results in a lower power loss than that obtained by the method in. Voltage sag, voltage distortion and voltage unbalances are all well within the permissible limits, though these values are somewhat on the superior side in the configuration of. This is due to the fact that in the proposed branch exchange algorithm, the loss reduction objective is given much higher priority when the power quality factors are not violated [2].

9. CONCLUSION

There are several operational schemes in power distribution systems and one of these is network reconfiguration. Feeder reconfiguration for loss reduction is a very important function of automated distribution system to reduce distribution feeder losses and improve power quality of the system. A new algorithm has been proposed in this work for network reconfiguration. In some existing algorithms, the solution is largely dependent upon selection of tie branches and if the tie branches are not at appropriate locations, the results could be far away from optimal solution. The new algorithm proposed in this work is independent of specifying the tie branches in the data. The proposed algorithm has been applied to standard a 33- bus system which has been considered as a benchmark problem in many IEEE papers. It is interesting to note that there is a reduction of 31.11% of technical losses in the reconfigured network.

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