OPTIMAL RECONFIGURATION OF EDS FOR MINIMIZING I^2R LOSSES

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ABSTRACT

Electricity plays a crucial role in our day to day life and also contributes to a nation's GDP. Power losses prevail at each and every stage in a power system which is indeed a burning issue. The work aims to recognize beneficial load transfers and minimum loss topologies through network reconfiguration. It is a multi-objective approach to increase the reliability and economic benefits of both distribution companies and consumers. The in-hand calculations are difficult and time-consuming so we need to develop a new efficient and simple MATLAB program for network reconfiguration using Mesh elimination. To illustrate the validity of the proposed algorithm, it is tested on 33 and 119-bus systems.

Keywords— *GDP; Power losses; network reconfiguration; mesh elimination.*

I. INTRODUCTION

Distribution systems which are highly radial in nature play a prominent part in the entire power system that is to carry electricity from a substation transformer till the customer terminal. Although they are developed as meshed structures, they function as radial structures so as to have better synchronism among the protection equipments and also help in managing different configurations manually or through automation. The major concern of a distribution system is, it has large set of interconnections of domestic, commercial and industrial loads the load variations are continuous and quite unpredictable. This leads to huge losses in the system. The dominant cause for these enormous power losses is low network voltages that result in huge currents and resistive loss. In the recent times most of the power utilities over the globe opted for a deregulated environment, extinction of coal or resources used for generation is resulting in increased competition among electricity suppliers which led to more and more research on the factors that can improve the overall system efficiency for increasing the life span, reliability and also give some economic benefits. Out of those researches power engineers concluded that reducing the losses can do the work though it is like a toughest challenge to them. So more and more techniques were tried on, of all feeder reconfiguration seemed to be simple and low cost technique.

Distribution system reconfiguration for loss reduction was first proposed by Merlin *et al* [1]. They employed a blend of optimization and heuristics to determine the minimal-loss operating configuration for the distribution system represented by a spanning tree structure at a specific load condition. A branch and bound type heuristic algorithm was suggested by Civanlar *et al.* [2], where a simple formula was developed for determination of change in power loss due to a branch exchange. In [3]–[5], the authors suggested to employ a power flow method-based heuristic algorithm (PFBHA) for determining the minimum loss configuration of radial distribution networks. In [6]–[8], the authors proposed a solution procedure employing simulated annealing (SA) to search an acceptable non-inferior solution. D. Zhang *et al.* [9] presented an improvised TS algorithm to look for the minimum loss configuration in IEEE 119 bus sytem. Das [10] presents an algorithm based on the heuristic rules and fuzzy multi objective approach for optimizing network configuration. In this paper, a new algorithm called mesh elimination technique is proposed for the minimization of power losses in the distribution system. The loop elimination method algorithm is a novel heuristic approach, proposed by P.Ravi babu [11]. It is inspired by the intelligent foraging behavior of honey bee swarm. The proposed method is tested on 33 and 119 bus systems and results obtained are effective and encouraging.

II. FEEDER RECONFIGURATION

An A.C distribution system is categorized into primary and secondary distribution systems. Primary distribution systems deals with a much higher voltage levels say 11kV in case of 33 and 119 bus systems. Generally two kinds of switches namely sectionalizing switches (typically closed) and tie switches (typically open) are constituted by a Primary distribution system. The feeder paths are very often reconfigured during the ordinary operating conditions by altering by switching ON/OFF the existing path to minimize the line losses or to elude the overloading of branches in network. Since so many candidate-switching patterns are possible in a distribution system realizing the optimal configuration becomes an intricate procedure and it also involves many non linear algebraic equations which are confined for differentiations. So, it is a combinatorial optimization problem as some feeders are heavily loaded at some point of time and lightly at the other. The main aim of this feeder reconfiguration is reduction of both real and reactive power loss and improvement of voltage magnitudes at each and every bus by conducting backward sweep power flow analysis. We must also see that it takes less time to carry out these calculations. When we get the optimal configuration we see that the route of power flows varies from source to load while minimizing the system losses and it satisfies all the constraints. A crucial tool for optimization in automation systems of distribution network is Network reconfiguration. We are going to eliminate all the meshes while changing the path. hence, it is called mesh elimination method.

III. PROBLEM FORMULATION

The work desires to reduce the real and reactive power losses in the system, put through several constraints while in operation with a definite patter of load. So the objective function can be mathematically given as (1) and (2)

$$\min f = \min (P_{T,LOSS}) \qquad (1)$$

Similarly, $$\min f = \min (Q_{T,LOSS}) \qquad (2)$$

Where, $P_{T,LOSS}$ and $Q_{T,LOSS}$ are the net system real power and reactive power losses. At each bus in the system the magnitude of voltage should be made to be limits. The branch current capacity should be satisfied at each one of it. These constraints can be represented as follows as in (3) and (4)

$$V_{min} < |V_i| < V_{max} \qquad (3)$$

$$|I_i| \leq I_{i,max} \qquad (4)$$

Where,

$|Vi|$ is the magnitude of voltage of branch i;

V_{min} and V_{max} are limits for minimum and maximum bus voltages;

$|I_i|$ is the magnitude of current and $I_{i,max}$ is the branch-i's maximum current limit.

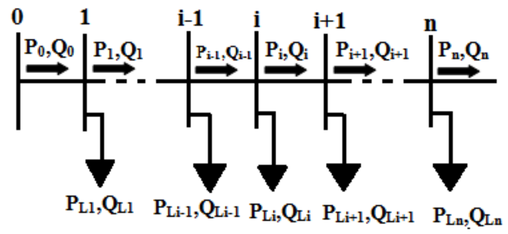


Fig 1: One line diagram of an n-bus system

Let us consider a one line diagram of main feeder where n-feeders are emerging out of source. It can be seen in Fig. 1, the group of repetitive equations to be used to calculate power losses and voltage magnitudes are given below as in (5), (6) and (7)

$$P_{i+1} = P_i - P_{Li+1} - R_{i,i+1} * \frac{(P_i^2 + Q_i^2)}{|V_i^2|} \qquad (5)$$

$$Q_{i+1} = Q_i - Q_{Li+1} - X_{i,i+1} * \frac{(P_i^2 + Q_i^2)}{|V_i^2|} \qquad (6)$$

$$|V_{i+1}|^2 = V_i^2 - 2(R_{i,i+1} P_i + X_{i,i+1} Q_i) + (R^2_{i,i+1} + X^2_{i,i+1}) * \frac{(P_i^2 + Q_i^2)}{|V_i^2|} \quad (7)$$

Where, P_i and Q_i are the outgoing real and reactive powers from i^{th} bus, P_{Li} and Q_{Li} are the i^{th} bus real and reactive load powers. $X_{i,i+1}$ and $R_{i,i+1}$ are the reactance and resistance connecting i^{th} and $i+1^{th}$ buses respectively.

The power losses for the line segment joining i^{th} and $i+1^{th}$ buses and is given as in (8) and (9)

$$P_{LOSS(i,i+1)} = R_{i,i+1} * \frac{(P_i^2+Q_i^2)}{|V_i^2|} \quad (8)$$

$$Q_{LOSS(i,i+1)} = X_{i,i+1} * \frac{(P_i^2+Q_i^2)}{|V_i^2|} \quad (9)$$

The power losses of the whole main feeder $P_{F,LOSS}$ and $Q_{F,LOSS}$ with several sub line sections can be calculated by adding up losses of every single line section constituted by the feeder which can be given as in (10) and (11)

$$P_{F,LOSS} = \sum_{i=0}^{n-1} P_{LOSS(i,i+1)} \quad (10)$$

$$Q_{F,LOSS} = \sum_{i=0}^{n-1} Q_{LOSS(i,i+1)} \quad (11)$$

The total real and reactive power loss in the system denoted by $P_{T,LOSS}$ and $Q_{T,LOSS}$ respectively is the sum of power losses of all feeders in the system.

IV. MESH ELIMINATION METHOD ALGORITHM

Step 1: The data for IEEE 33 and 119 bus system should be read.

Step 2: The voltage of the all the buses should be initialized to V(i) =1.

Step 3: A loop incidence matrix Z_{loop} should be calculated as in (12)

Size of Z_{loop} = (No. of links * No. of links) (12)

Step 4: Now the load current values are to be calculated using equation as in (13)

$$IL(i) = \frac{(PL(i) + QL(i))^*}{V(i)}$$

Where i=1,2,3,…… **(13)**

Now, starting from the last node to source node all the line segment currents are added up using a backward sweep method using equation as in (14)

IL(se(K)) = IL(re(K)) + IL (se(K) (14)

And from this branch current should be calculated using equation as in (15)

IBR(K) = IL(re(K)) (15)

Where K=Nb, Nb-1,Nb-2……….

Step 5: For the radial branches constituted in each loop the voltage drops should be calculated using equation as in (16)

$$VD_{loop}(i) = VD_{loop}(i)+c(i,j)*Z_{PU}(j) * IBR(j) \quad (16)$$

Where i=1,2,3….. and j=Nb,Nb-1,Nb-2….

C(i,j) is the basic loop incidence matrix and

$$Z_{P.U} = \frac{Z \text{ (in ohms)}}{Z_{base}} \quad (16.a)$$

$$Z_{base} = \frac{V_{base}^2}{S_{base}} \quad (16.b)$$

Step 6: In each loop the current values are to be calculated using the formula as in (17)

$$I_{loop} = (Z_{loop}^{-1}) * (-VD_{loop}) \quad (17)$$

Step 7: After obtaining the I_{loop} value the branch current values can be modified by (18)

$$IBR(i) = IBR(i) + c(i,j) * I_{loop}(j) \quad (18)$$

For i= nb and j=1:Lk

Step 8: The voltages at the receiving end node k can be calculated using (19)

$$V(re(K))=V(se(K))-Z_{PU}(K)*IBR(K) \quad (19)$$

For k =1: nb

Step 9: By subtracting the voltages of present iteration and previous iteration we can get the value of voltage deviation using (20)

del V= V-v (20)

The switches with maximum voltage deviations such as more than 0.0001 should be opened and the adjacent switch is to be closed in order to obtain the optimal configuration.

Criteria for convergence is which is mathematically represented as in (20.a)

$$\textbf{del } V_{max} = (\max(\text{del } V)) \qquad \textbf{(20.a)}$$

The newly obtained voltage values should be updated as in (20.b)

$$V=v \qquad \textbf{(20.b)}$$

Step 10: After all these steps finally the real and reactive power losses at each and every branch should be computed using the formula given as in (21) and (22).

$$P_{LOSS}(K)=IBR^2(K)*R_{PU}(K) \quad \text{for } K=1,2,...E \qquad \textbf{(21)}$$

$$Q_{LOSS}(K)=IBR^2(K)*X_{PU}(K) \quad \text{for } K=1,2,...E \qquad \textbf{(22)}$$

Step 11: stop.

V. RESULTS AND EXPLAINATION

A MATLAB program is developed with all the above mentioned formulae and program based on mesh elimination method is run in MATLAB 2013a version and results are obtained.

Case (i.) IEEE 33 bus system

3715 kW and **2300 kVAR** are the total active and reactive power capacities of installations respectively, S_{base}=100 MVA, V_{base}=12.66 kV. **201.89kW** and **134.64 kVAR** are the total real and reactive power losses obtained for initial configuration. **s33, s34, s35, s36** and **s37** switches are opened or which are tie switches as in fig 2. **128.41 kW** and **87.58 kVAR** are the total real and reactive power losses obtained for optimal configuration. **s33, s9, s35, s36 and s25** are the switches opened for the least loss configuration as in fig 3.

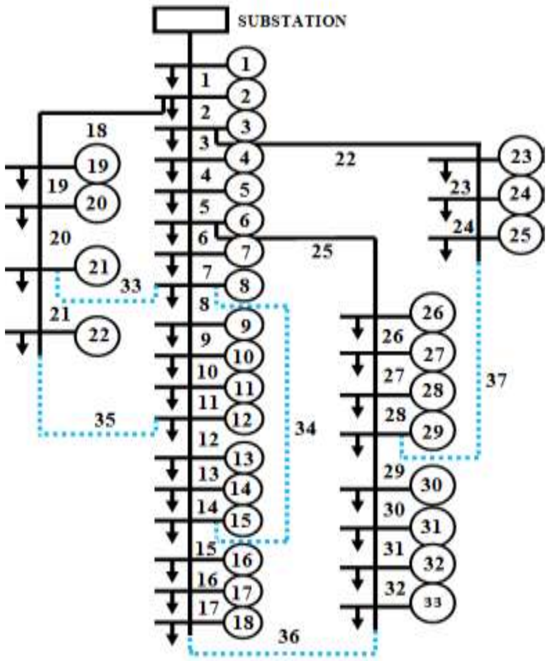


Fig 2: IEEE 33 bus system initial configuration

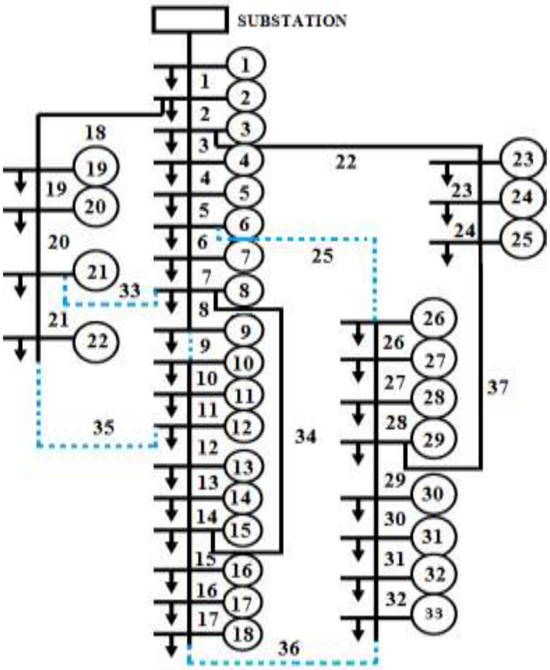


Fig 3: IEEE 33 bus system final configuration

TABLE 1: Simulated results for IEEE 33 bus system

	REAL	REACTIVE
LOSSES IN THE INITIAL CONFIGURATION	201.89 kW	134.64 kVAR
LOSSES IN THE FINAL CONFIGURATION	128.41 kW	87.58 kVAR
REDUCTION IN LOSSES	73.48 kW	47.06 kVAR
LOSS REDUCTION [%]	36.39%	34.95%
VOLTAGE IN THE INITIAL CONFIGURATION	0.9134 PU	
VOLTAGE IN THE FINAL CONFIGURATION	0.9591 PU	
TIE SWITCHES FOR THE OPTIMAL CONFIGURATION	S33, S9, S35, S36 And S25	

Case (ii) IEEE 119 bus system

22709.72 kW and **17041.068 kVAR** are the total active and reactive power capacities of installations respectively, S_{base}=275 MVA, V_{base}=11 kV. **1296.5 kW** and **664.2647 kVAR** are the total real and reactive power losses obtained for initial configuration. **S1-S119** switches are opened or which are tie switches as in fig 4. **363.6192 kW** and **176.1523 kVAR** are the total real and reactive power losses obtained for optimal configuration. **S41-42, S11-18, S121, S36-49, S123, S38-65, S125, S95-100, S127, S128, S70-71, S130, S131, S114-115**and **s133** are the switches opened for the least loss configuration as in fig 5.

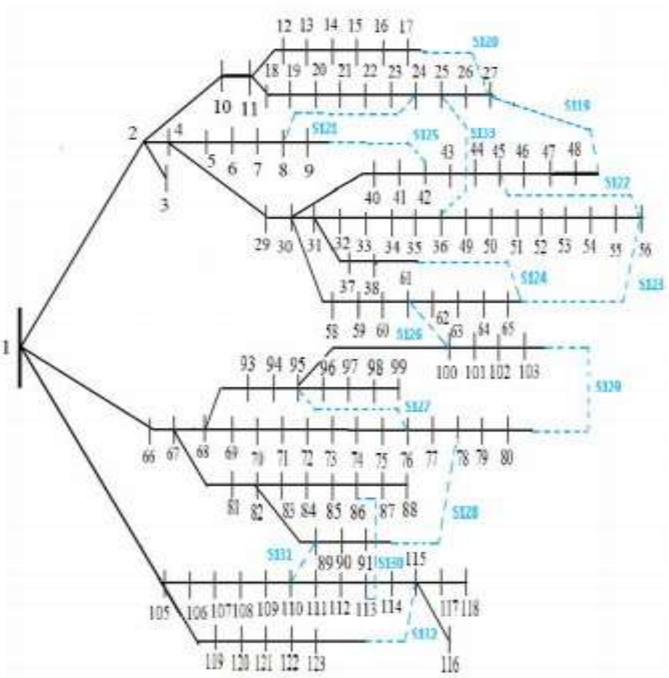


Fig 4: IEEE 119 bus system initial configuration

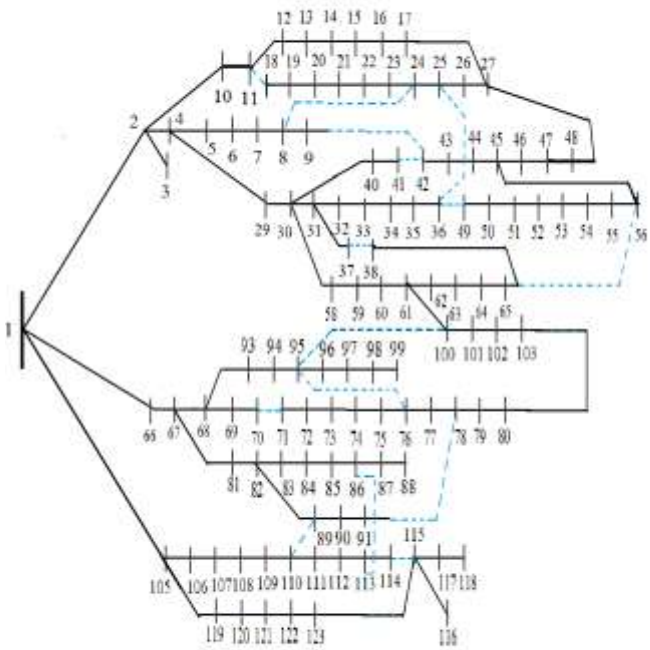


Fig 5: IEEE 119 bus system final configuration

TABLE 2: Simulated results for IEEE 119 bus system

	REAL	REACTIVE
LOSSES IN THE INITIAL CONFIGURATION	1296.5 kW	664.26 kVAR
LOSSES IN THE FINAL CONFIGURATION	363.61 kW	176.15 kVAR
REDUCTION IN LOSSES	932.89 kW	488.11 kVAR
LOSS REDUCTION [%]	71.95 %	73.48 %
VOLTAGE IN THE INITIAL CONFIGURATION	0.6036 PU	
VOLTAGE IN THE FINAL CONFIGURATION	0.9799 PU	
TIE SWITCHES FOR THE OPTIMAL CONFIGURATION	S41-42, S11-18, S121, S36-49, S123, S38-65, S125, S95-100, S127, S128, S70-71, S130, S131, S114-115and s133	

By comparing our obtained results with various references we can justify our results to be the best of what is obtained so far and is tabulated as in table 3.

TABLE 3: VALIDATION OF RESULTS

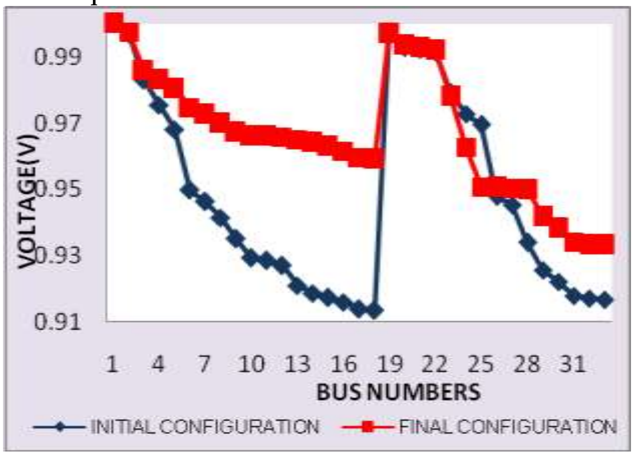
S.No	Real power losses		Voltage PU	
	33-bus	119-bus	33-bus	119-bus
Original Configuration	201.89kW	1292.83kW	0.9134	0.6036
Optimal Losses in various references	131.02kW [11]	884 kW [9]	-	0.9321 [9]
Proposed method losses	128.41kW	363.61kW	0.9591	0.9799

CONCLUSION

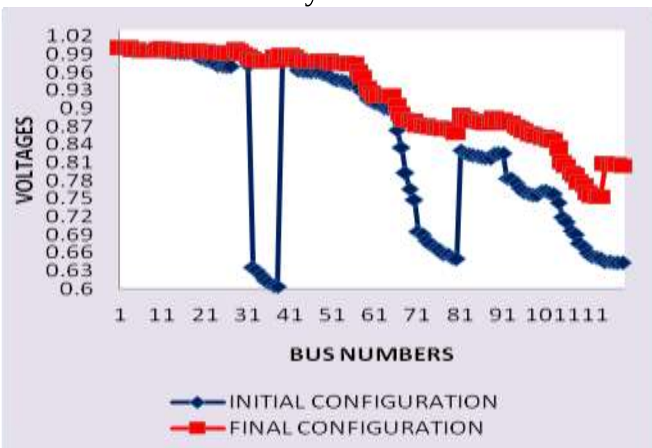
From the above validation of results we can prove how efficient the proposed algorithm is. This mesh elimination technique based algorithm is relatively very less time consuming. Network reconfiguration is the best and simplest possible solution that is used to minimize system real power losses and reactive power losses along with improving the voltage profiles at each and every bus constituted in the system.

ADDENDUM

The voltage profiles of the IEEE 33 and 119 bus systems before and after reconfiguration are seen in the graph 1 and 2 respectively. It's detected that a giant improvement at intervals the node voltages has appeared once reconfiguration with the M-E technique.



Graph 1: Improved voltage profile of IEEE 33 bus system



Graph 2: Improved voltage profile of IEEE 119 bus system

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REFERENCES

[1] ***A. Merlin, H. Back,*** *"Search for a minimal-loss operating spanning tree configuration in an urban power distribution system" Proceedings of 5th Power System Computation Conference (PSCC), Cambridge, UK, 1975, pp. 1-18.*

[2] ***S. Civanlar, J. Grainger, H. Yin, and S. Lee****, "Distribution feeder reconfiguration for loss reduction," IEEE Trans. Power Del., vol. 3, no. 3, pp. 1217–1223, Jul. 1988.*

[3] ***D. Shirmohammadi and H.W. Hong****, "Reconfiguration of electric distribution networks for resistive line losses reduction," IEEE Trans. Power Del., vol. 4, no. 2, pp. 1492–1498, Apr. 1989.*

[4] ***T. P. Wagner, A. Y. Chikhani, and R. Hackam****, "Feeder reconfiguration for loss reduction: an application of distribution automation," IEEE Trans. Power Del., vol. 6, no. 4, pp. 1922–1931, Oct. 1991.*

[5] ***S. Goswami and S. Basu,*** *"A new for the reconfiguration of distribution feeders for loss minimization," IEEE Trans. Power Del., vol. 7, no. 3, pp. 1484–1491, Jul. 1992.*

[6] ***H. C. Cheng and C. C. Kou****, "Network reconfiguration in distribution systems using simulated annealing," Elect. Power Syst. Res., vol. 29, pp. 227–238, May 1994.*

[7] ***H. D. Chiang and J. J. Rene****, "Optimal network reconfiguration in distribution systems: part 1: a new formulation and a solution methodology," IEEE Trans. Power Del., vol. 5, no. 4, pp. 1902–1908, Oct. 1990.*

[8] ***H. D. Chiang and J. J. Rene****, "Optimal network reconfiguration in distribution systems: part 2: solution algorithms and numerical results," IEEE Trans. Power Del., vol. 5, no. 3, pp. 1568–1574, Jul. 1992.*

[9] ***D. Zhang, Z. Fu, L. Zhang****, "An improved TS algorithm for loss minimum reconfiguration in large-scale distribution systems", Electric Power Systems Research, Vol. 77, pp. 685–694, 2007.*

[10] ***D. Das****, "A fuzzy multi-objective approach for network reconfiguration of distribution systems," IEEE Trans. Power Del., vol. 21, no. 1, pp. 202–209, Jan. 2006.*

[11]. Dr. P. Ravi Babu, M.P.R. Vanamali, M.P.V.V.R. Kumar, V. Sai Hemachandra, *"Network reconfiguration in Distribution Systems Using M-E Method",a proceeding of 2010 Annual IEEE India Conference (INDICON).*

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