Power Loss Reduction using Instantaneous Network Reconfiguration and DG placement with Cuckoo Search Algorithm in Distribution System

Damershetty Jithender, Jami Sridevi

Abstract*: The aim of reducing power loss, enhancing profile of voltage in a radial distribution system at which consumers are connected and also determining the ratings of power, optimal placement of Distributed generator. In this paper to resolve the drop in voltage profile by using network reconfiguration that gives possible switching possibilities with an efficient Cuckoo Search Algorithm (CSA) is discussed and Sensitivity analysis are carried out simultaneously for finding sizing and possible location of distributed generation. To confirm the usefulness of the discussed method it was conducted on radial distribution system of 33 bus connected by various load levels, the result shows that the discussed method is fast and efficient. However to meet power requirement and lack of transmission capabilities importance for DG is rapidly evolving in electrical systems. For reliability and stability for the power system best possible location of Distributed Generator is needed in distribution system. To overcome the shortcomings of mathematical optimization practices, soft computing algorithms have been actively introduced during the last decade.

Keywords: Cuckoo Search Algorithm (CSA), network reconfiguration Distributed Generation, Sensitivity Analysis, Power loss.

I. INTRODUCTION

As distribution system is a complex network in which more number of consumer loads are connected to it resulting huge amount of reduced voltage profile and power losses. Distribution systems can be classified into sub-systems of radial feeders, consisting of normally closed and open switches. Based on the uncertainty of load on the various feeders, problem of losses in an open loop radial distribution system becoming one of the complex issues for Optimization. By performing manual switching operation all loads are supplied with electric power but resulting in power loss,

which effects system security and reduce power quality. Voltages are not corrected to the desired level by implementing network configuration under normal and abnormal operating conditions. by opening and closing the tie switch without a proper control strategy. The problem of possible DG placement is very exciting in smart grid systems, where renewable energy usage is estimated to increase. To meet energy demand Distributed generation equipment is intentionally connected for strengthening power grid, minimizing energy losses, reducing maximum running costs. DG technologies include small wind turbines; fuel cells and photovoltaic systems connected directly to distribution system and the range in DG size installed from KW to MW are in fact substituting most costly grid power. Based on how many DGs are to be placed, describes the classification of DG as a single DG or compound DG installation. Improper DG position involves increasing in network capital and operating costs. It is appealing to study reconfiguration of networks with immediate position of DGs, which are mutually dependent. Such corresponding scheduling can provide most advantage for the network owner and user. There is a requirement of network reconfiguration and possible placements of distributed generators such that instantaneous changes in distribution network takes place based on minimum voltage deviation and maximum power loss sensitivity factor. The most advantageous Cuckoo Search Algorithm (CSA), presented to work out reconfiguration of the network problem and generate real switching probability in the network such that actual power loss can be minimized [1]. The discussed algorithm quickly converts to the best possible solution with high accuracy. Total number of switches considered in the system describes range of the solution vector and computation time is advantageous compared to other methods.

II. POWER FLOW EQUATIONS OF OPTIMIZATION PROBLEM

A. Power equations at kth bus

By applying well-organized method [2], The power flow equations are derived from the below fig.1 used for load flow solutions in a distribution system repeated for finite number of iterations to make solution convergent.

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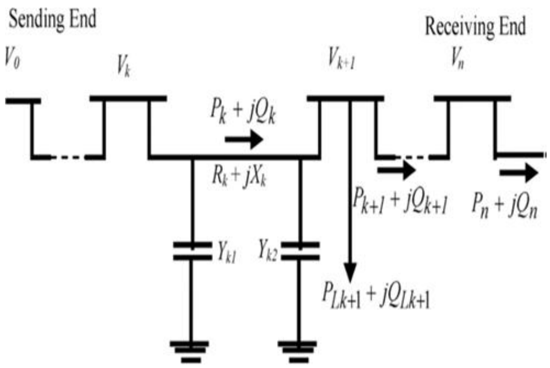

Fig.1 Power flow in a main feeder

$$P_{k+1} = P_k - P_{Loss,k} - P_{Lk+1}$$
$$= P_k - \frac{R_k}{|V_k|^2}\{P_k^2 + (Q_k + Y_k|V_k|^2)^2\} - P_{Lk+1} \quad (1)$$
$$Q_{k+1} = Q_k - Q_{Loss,k} - Q_{Lk+1}$$
$$= Q_k - \frac{X_k}{|V_k|^2}\{P_k^2 + (Q_k + Y_{k1}|V_k|^2)^2\} - Y_{k1}|V_k|^2 - Y_{k2}|V_{k+1}|^2 - Q_{Lk+1} \quad (2)$$
$$|V_{k+1}|^2 = |V_k|^2 + \frac{R_k^2 + X_k^2}{|V_k|^2}(P_k^2 + (Q_k + Y_k|V_k|^2)^2) - 2(R_kP_k + X_k(Q_k + Y_k|V_k|^2)). \quad (3)$$

By considering a line linking bus k and bus k+1 whose power loss is given as,

$$P_{Loss}(k, k+1) = R_k \cdot \frac{(P_k^2 + Q_k^2)}{|V_k|^2}. \quad (4)$$

Total power loss is obtained by accumulation of all losses in every line section is given by,

$$P_{T,Loss} = \sum_{k=1}^{n} P_{Loss}(k, k+1). \quad (5)$$

B. Calculation of power loss with network reconfiguration

Particularly reducing network power loss and to continue current carrying feeder capacity, working limits of voltage in distribution network, reconfiguration plays an important role. After changing the system configuration, line linking bus k, bus k + 1 whose losses are given by

$$P'_{Loss}(k, k+1) = R_k \cdot \frac{(P_k'^2 + Q_k'^2)}{|V_k'|^2}. \quad (6)$$

Accumulation of every line losses of feeder is represented as,

$$P'_{T,Loss} = \sum_{k=1}^{n} P'_{Loss}(k, k+1). \quad (7)$$

C. Minimum ΔP Loss with reconfiguration of network

ΔP_{Loss}^{R} is determined for before and after reconfiguration, is found by equation (5) and (7) is represented as

$$\Delta P_{Loss}^{R} = \sum_{k=1}^{n} P_{T,Loss}(k, k+1) - \sum_{k=1}^{n} P'_{T,Loss}(k, k+1). \quad (8)$$

D. Minimum power loss with DG installation

Installation of DG's in possible location of a distribution system results in various advantages.

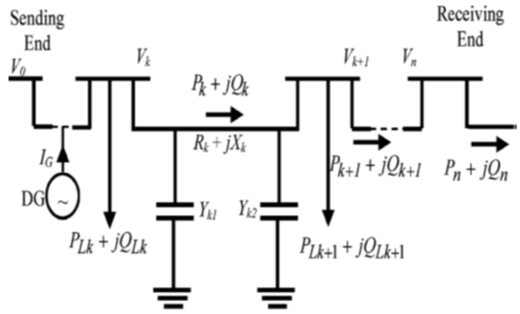

Fig.2. Installation of DG in Distribution System

These include reducing power costs, reducing ecological discharge, large amount of reliability, quality of power supply in transmission, distribution lines. Money through enhanced load capacity is the main application of DG. In addition to these enhancements, in a degenerated environment it is considered as secondary services. Power loss is specified while installing a DG

$$P_{DG,Loss} = \frac{R_k}{V_k^2} + \frac{R_k}{V_k^2}(P_G^2 + Q_G^2 - 2P_kP_G - 2Q_kQ_G)\left(\frac{G}{L}\right). \quad (9)$$

ΔP_{Loss}^{DG} is obtained by subtracting equations (16) from equation (9) is given by,

Reduction in power loss is observed from the positive sign of ΔP_{Loss}^{DG} with placement of DG. While negative sign of ΔP_{Loss}^{DG} shows more power loss.

$$\Delta P_{Loss}^{DG} = P_{DG,Loss} - P_{lineloss}$$
$$\Delta P_{Loss}^{DG} = \frac{R_k}{V_k^2}(P_G^2 + Q_G^2 - 2P_kP_G - 2Q_kQ_G)\left(\frac{G}{L}\right). \quad (10)$$

Reduction in power loss is observed from the positive sign of ΔP_{Loss}^{DG} with placement of DG. While negative sign of ΔP_{Loss}^{DG} shows more power loss.

E. Maximize decrease in power loss

For maximize decrease in power loss which is subjected to power balance constraints, voltage constraints, and current capability constraints whose objective function is expressed as

$$f = \max\cdot(\Delta P_{Loss}^{R} + \Delta P_{Loss}^{DG}) \quad (11)$$

The bus voltage magnitudes are maintained within specified limits during the optimization process, such that voltage constraints should be satisfied, as given below.

$$V_{min} \le V_k \le V_{max}$$

Constraints of feeder capability limits should be satisfied.

$$|I_{k,k+1}| \le |I_{k,k+1,max}| \quad (12)$$

Constraints of Power generating also should be satisfied.

$$\sum_{k=1}^{n} P_{Gk} \le \sum_{k=1}^{n}(P_k + P_{Loss,k})$$

V_{min} And V_{max} are the lower and upper limit voltages in radial distribution system

Condition for radial and non radial system is given as below

$$\det(A) = 1 \; or - 1 \; (radialsystem)$$
$$\det(A) = 0(\; notradial)\} \quad (13)$$

III. SENSITIVITY METHOD FOR DG INSTALLATION

It is discussed with the major advantage in transforming given nonlinear equation to linear equation about the initial working point, which helps to decrease the consequence break points. To resolve the DG placement problem loss sensitivity factor is to be determined [3]. Loss sensitivity factors [4] are calculated at every bus to start DG units, firstly by the use of values calculated from the base case power flow. Fig.3 shows a line impedance of $R_K + jX_K$ connecting bus k-1 and bus k and load$P_{LK,eff} + jQ_{LK,eff}$. The active power loss in kth line as shown in equation (14).

$$P_{Loss} = [I_k^2] \times R_k (14)$$

Where R is the resistance and I_k is the current of line

$$I_k = \left[\frac{P_{Lk,eff} + jQ_{Lk,eff}}{V_{Lk,eff}}\right]^* \quad (15)$$

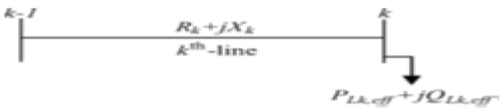

Fig.3: connected line between bus k-1 and k

By substituting equation (15) in (14) $P_{line\,loss}$ is calculated for the branch linking bus k-1, bus k is given as

$$P_{line\,loss} = \frac{(P_{Lk,eff}^2 + Q_{Lk,eff}^2)R_k}{V_k^2} (16)$$

From above V and P, Q are voltage, and power values on the load side.

Equation (17) which is obtained below is known as loss sensitivity factor that is calculated to find out which bus is having maximum sensitivity to power loss such that possible placement of DG is connected.

$$\frac{\partial P_{lineloss}}{\partial P_{LK,eff}} = \frac{2 * P_{LK,eff} * R_K}{V_K^2}. \qquad (17)$$

From the above equation (17), load flow is conducted that is required to determine Loss sensitivity factors such that they are ranked from highest values to the lowest values of their sensitivity factors to produce an initial record. The buses with top ranked loss sensitivity factors in the initial record are the most selective for DG placement in order to decrease losses.

IV. DISCUSSION OF PROPOSED ALGORITHM

The proposed cuckoo search algorithm (CSA) is motivated based on its ability to hatch their own eggs by choosing another nest, and also those are replica in its appearance. This algorithm is put forward by Yang and Deb in 2009 [5], useful in the engineering optimization issues and showed its capable efficiency. It has gained improved indistinctive solutions compared to other methods which are proposed earlier [6].When a bird from its own nest finds strange ones presented within it, then it give up its place of existence and finds a latest place of existence in a different place otherwise it clears all the strange ones within it. A latest solution, starting solution are indicated by cuckoo egg, and every egg of the bird which is present in its own place of existence. The motive is to eliminate undesirable results in the nests by the latest probable desirable results. For simplicity CS can be considered in the following key points [6].

• In each step of laying eggs of strange bird should be only one egg that is inserted in the chosen place of existence.

• This method will transmits improved superiority ones or solutions for the coming generation;

• Number of obtainable host places of existence is fine-tuned and the probability of finding a strange eggs within by the bird of its own place of existence is pa = [0, 1]. When producing latest results $x_i^{(t+1)}$ for every strange bird a random movement is performed for every step.

$$x_i^{(t+1)} = x_i^{(t)} + \alpha \oplus \text{Levy}(\lambda) \; (18)$$

From above equation α > 0 represents size of each random movement that leads to favourable units, but generally we equate it to value 1. Eq. (18) is mainly the stochastic equation for arbitrary walk. From above equation product ⊕ represent the starting multiplication. However the sequence of step position is lengthy as time increases, so it is more efficient to explore finding positions, arbitrary movements described by flights conducted by Levy. [6] The arbitrary step position declared by Levy flight introduces an arbitrary movement that is obtained by probability distribution characteristics with variance and mean at infinite.

$$LEVY \sim u = t^{-\lambda} \; (19)$$

In order jumps of a cuckoo primarily create an arbitrary walk course with an effectiveness contributions to step position is more distant [6]. Many latest results developed with Levy movement close to better results, Therefore this method tends to accelerate through an unfamiliar area. During distant area analysis without proper order of possible locations that are taken into account so, it is not confined to travel an unfamiliar area in order to learn about it [5].

A. Optimal selection of tie line switches using CS algorithm

The operation of CS is used for optimal selection of tie line switches in Fig. 4. In this study the setting of CS parameters involves step length α=1, total number of nests n=20, estimation of finding strange eggs will be Pa=0.6 are considered. Based on less computation time, low memory requirement, and fast convergence property forward/backward sweep analysis is used for calculating objective function [7].

1) Step 1: Initial population consideration

Starting population has to be calculated with aim of solving the power loss problem which is an important significance in CS. If the primary range is not mentioned it will consider starting population as default value, so it is better to assign number of population and primary range of other nest in beginning of the process.

2) Step 2: Generation of latest solution

A latest solution is produced arbitrarily by Levy flight. To determine the superiority of the solution a latest solution has to be calculated with load flow and aim of the problem.

3) Step 3: Substitution

If the standards of the obtained latest solution for the arbitrarily identified nest among n available nests are superior than previous solution then update the solution with latest solution.

4) Step 4: Removal of undesirable nests

The nests which are having least fitness in holding the solutions are discarded depending upon probability (pa) such that latest nests are constructed.

5) Step 5: Stopping criteria

Iterations gets stopped if Tolerance value 1e-6 and maximum number iterations 100 are satisfied then results of CS will be displayed.

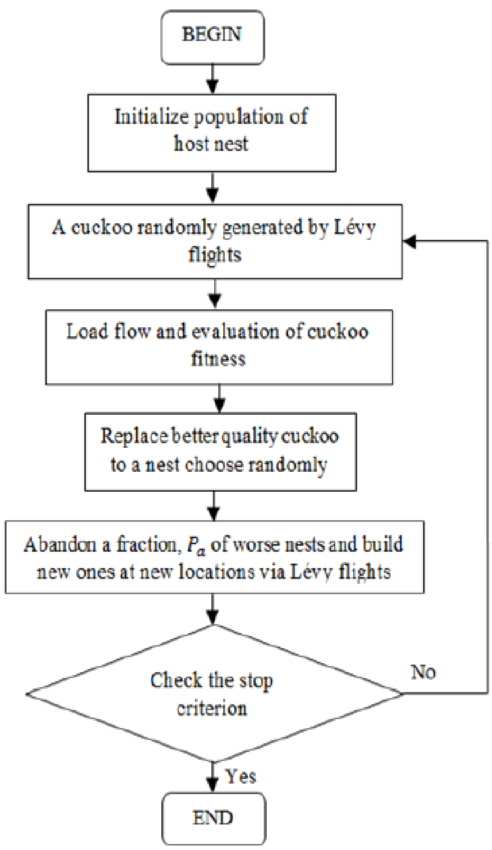

Figure 4: The CS method for optimal selection of tie line switches

V. SIMULATION RESULTS

The above discussed approach is implemented on radial distribution of 33 bus system.

Fig. 5 represents Network reconfiguration & allocation of DG in 33 bus distribution system with optimal location of 3 DG's at bus33, bus18, bus32 and their ratings are found to be 850kw, 950kw, 890kw respectively.

Fig.6 shows load demand variation with respect to time for a 33 bus distribution system at various load types during 24 hrs.

Fig.7 shows variation of Voltage waveforms at each bus of distribution system considering before and after reconfiguration.

Fig.8 Represents amplitude of voltage is enhanced from 0.9508 p.u. to about 0.9700 p.u for the cases of network reconfiguration without DG, and network reconfiguration with DG.

From Fig.9 Total active Power loss before reconfiguration is 202.07 kw is reduced to 66.86 kw after reconfiguration with DGs.

From Fig.10 Total reactive power loss before reconfiguration is 135.14 kvar is reduced to 60.06 kvar after reconfiguration with DGs.

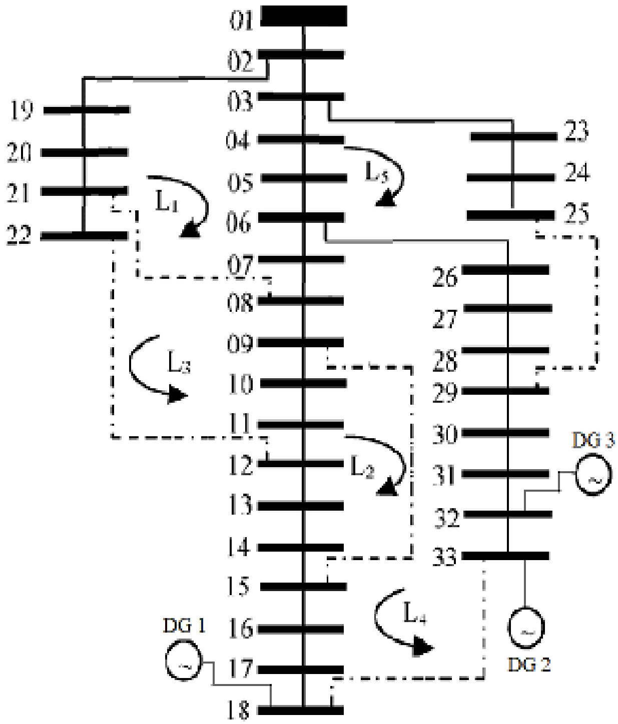

Fig. 5 Network reconfiguration & allocation of DG in 33 bus distribution system

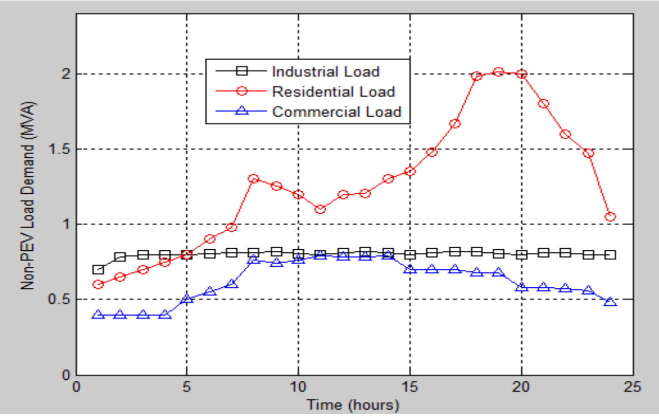

Fig. 6 load demand variation with respect to time for a 33 bus distribution system at various load types during 24 hrs.

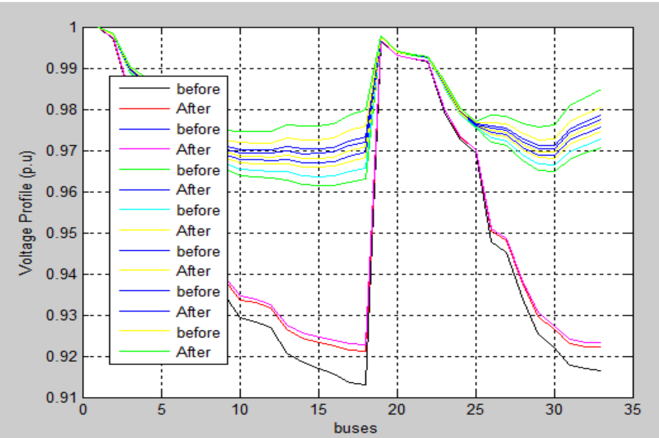

Fig. 7 Variation of Voltage waveforms at each bus of distribution system considering before and after reconfiguration.

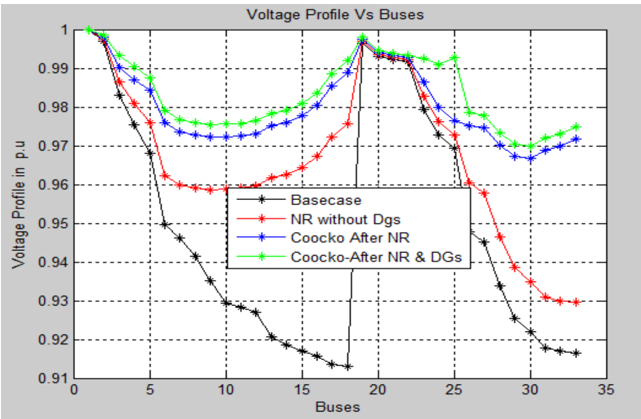

Fig. 8. Variation of Voltage waveforms at each bus of distribution system For Base case, network reconfiguration without DG,With only DGs, network reconfiguration with DG

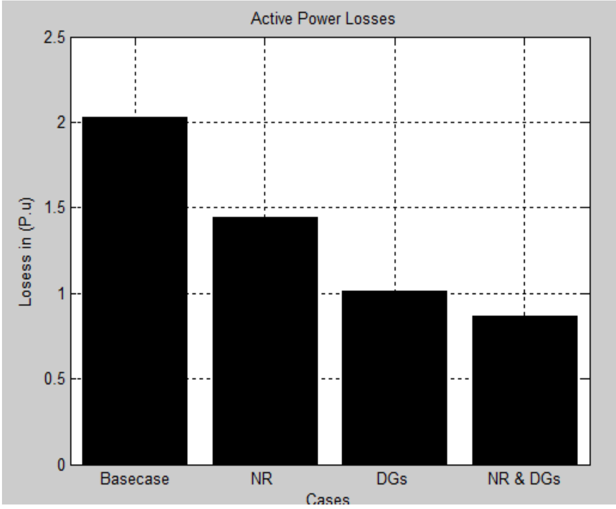

Fig9: Active power losses vs Number of buses

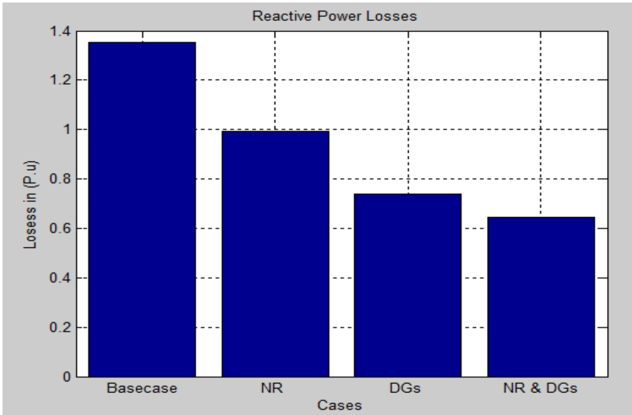

Fig10: Reactive Power Losses vs Number of buses

Table I: Indicates improvement of PL (kw), QL (kw), Vmin in Reconfiguration using CSA, Reconfiguration using CSA with DGs as compared to Base case

Table I: Voltages and Power values for different cases

Parameters	Normal	Reconfiguration using CSA	Reconfiguration & DGs using CSA
PL(Kw)	202.077	86.28	66.86
QL(Kvar)	135.14	64.46	60.06
Vmin	0.91309	0.95088	0.97

VI. VI. CONCLUSION

An algorithm is discussed to resolve voltage profile deviation and power loss problem in distribution system. Proper selection of tie line switches for network reconfiguration is achieved by Cuckoo search algorithm and sizing, proper placement of distributed generator is known by loss sensitivity factor. Therefore it is conducted on 33 bus distribution system at various types of loads.

The results show that we have found the possible location of Distributed generators at bus 33, bus 18, bus 32 and their ratings are found to be 850 kw, 950 kw, 890 kw, by sensitivity analysis, simultaneously Instantaneous network reconfiguration has improved minimum voltage from 0.9508 p.u. to about 0.9700 p.u and reducing active & reactive power losses 202.07 kw to 66.86 kw & 135.14 kvar to 60.06 kvar. Hence this approach is more efficient for improving voltage profile and reducing power losses compared to other methods. Instantaneous changes in distribution network takes place based on minimum voltage deviation and possible location of DG is found out depending on maximum power loss sensitivity factor.

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