International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 14 (2017) pp. 4651-4657
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Distributed vs Bulk Power in Distribution Systems Considering Distributed Generation

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Abstract

The increasing demand of electrical energy led to power grid expansion. Increased transmitted power caused power losses to increase and voltage levels to deviate. This represented a problem that utilities always try to deal with. Various devices as well as techniques are tried and developed to reduce system losses and maintain voltage profile while transmitting large MW's. One of these methods is to use small energy sources (called distributed generation DG) which include renewable energy sources and others in distribution systems closer to the loads. This paper aims at finding the best capacities and locations of DG's as bulk and distributed power in typical distribution systems . It will be applied to the IEEE 33-bus radial distribution system to achieve the lowest loss and improved bus-voltages. Particle Swarm Optimization(PSO) is implemented based on the Power Flow(backward / forward sweep) to determine the optimum capacities and location of distributed generators . Both active and reactive power will be considered capacity determination .

Keywords: Distributed generation , Optimal capacity of DG , Optimal location of DG , Power losses , Voltage drop . (key words)

INTRODUCTION

The discovery of electricity is one of the most important discoveries in human history because electricity is man's daily lifeblood. Since Thomas Edison invented the first electric system in New York in 1882, reliance on electricity has been increasing day after day . Recently, urban areas expanded. This expansion coincided with an increase in electrical loads which resulted in the growth of electrical networks significantly. This in turn , led to some new phenomena that give rise to problems which were not considered as an obstacle in the networks before . There are sectors : power losses and voltage drop. They represent the most important phenomena that reduce the electrical efficiency of the grid. Power losses occur in each part of the electrical system, for example, step-up transformers, transmission lines (T.L), step-down transformer and distribution systems. Losses are divided into two types: no load (core) losses which are in the transformer (25 to 30% from the total distribution losses) and resistive (copper) losses which change with changing the loads[1]. In step-up transformers (connected directly to generators), an increase in the losses occurs when generation has been "uprated". It also occurs in the substation distribution transformers due to no-load losses (light loads) and resistive losses (heavy loads)[1]. In the transmission line, although the conductors have low resistance, the length and cross section area of T.L affect the value of losses [1].

Voltage drop or voltage deviation (VD) is a physical phenomenon that arises from length and impedance of the feeder as well as increased transmission current . Voltage drop will cause induction motor current to increase which may affect equipment performance [2]. The permissible voltage drop varies from country to another and also from one system to another (transmission or distribution) [3] .

Engineers found some ways to reduce the losses and voltage drop in the power system. One of these is distributed generation (DG). It is a generator that has a capacity from 1KW to 50 MW and is close to the loads. Renewable energy as well as conventional generators (with small capacities) can be considered distributed generation which means that they can generate electricity while preserving the environment. The technical benefits of DG implementation include power loss reduction, supporting the voltage and improving the reliability of electric system.

METHODOLOGY

a. Objective Function

This work aims at finding best location and sizing of distributed generators to achieve lowest power losses (eq.1) , voltage deviation(eq.2) and both (eq.3)[4].

$$PL = \sum_{J=1}^{nob} Rj\, I^2 \qquad (1)$$

$$VD = \sum_{i=2}^{n} |Vi - 1| \qquad (2)$$

$$OF = PL + \mu \times VD \qquad (3)$$

Where :

PL : Total Active power losses.

nob:Total Number of Branch.

n : Total Number of Buses.

Rj : Resistance of branch j.

Ij : Current of branch j.

VD : Voltage deviation.

Vi : voltage of bus i .

OF : Objective Function.

μ: proportionality coefficient (500kW/pu).

b. *Backward / Forward Sweep(BFS)*

Some techniques of power flow such as Newton-Raphson and Gauss-Seidel are might not be the best tool for load flow in distribution system because the distribution system has special characteristics like unbalanced load and high R/X ratio [5] . Backward / Forward Sweep is suitable technique for distribution system .The following flow chart(fig.1),Fig.2 and the equations3 to 6 describe the steps of BFS and the explaining of BFS is represented in [6].

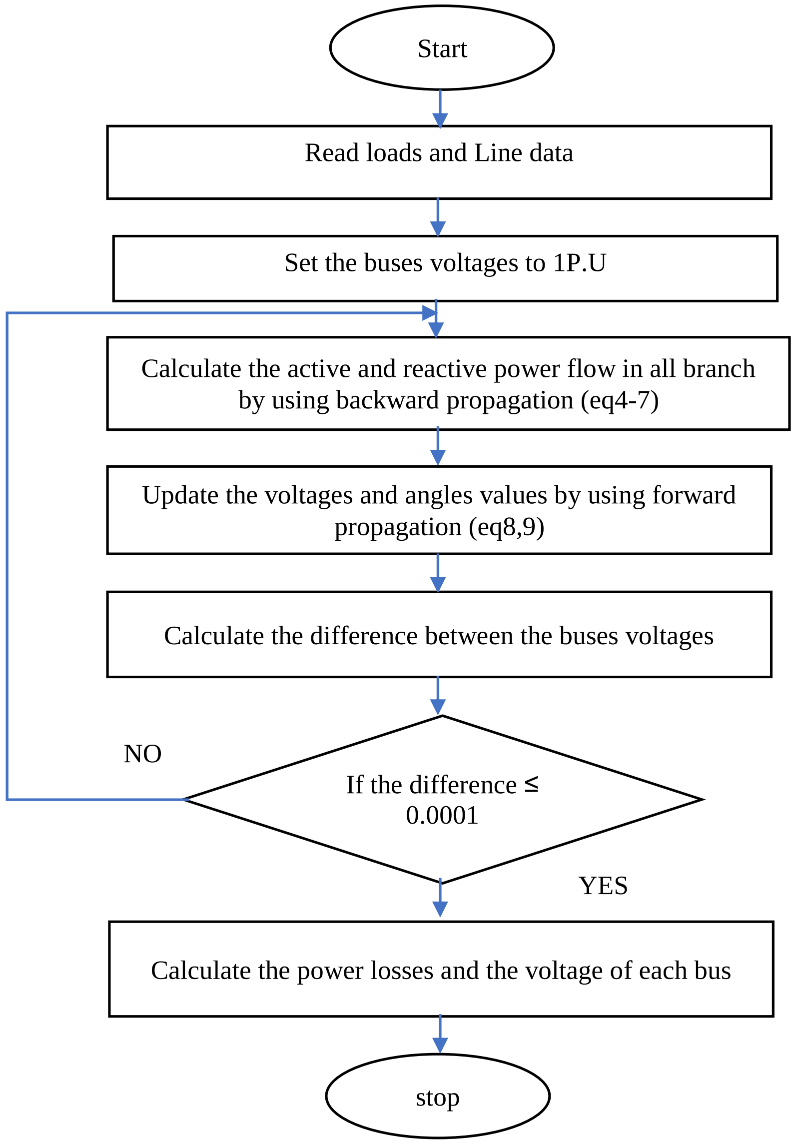

Figure 1: BFS flowchart

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 14 (2017) pp. 4651-4657
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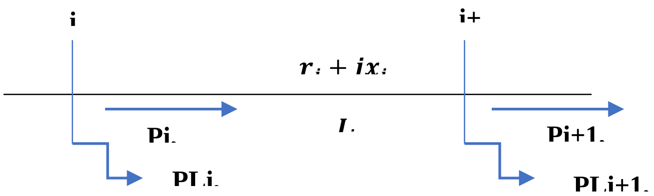

Figure 2: Explaining the power flow in distribution system

$$Pi = P'_{i+1} + rj\frac{(P'^2_{i+1} + Q'^2_{i+1})}{V^2_{i+1}} \tag{4}$$

$$P'_{i+1} = P_{i+1} + P_{Li+1} \tag{5}$$

$$Qi = Q'_{i+1} + xj\frac{(P'^2_{i+1} + Q'^2_{i+1})}{V^2_{i+1}} \tag{6}$$

$$Q'_{i+1} = Q_{i+1} + Q_{Li+1} \tag{7}$$

$$V_{i+1} = \left[V_i^2 - 2(P_i r_j + Q_i x_j) + (r_j^2 + x_j^2)\frac{(P_i^2 + Q_i^2)}{V_i^2}\right]^{1/2} \tag{8}$$

$$\delta_{i+1} = \delta_i + \tan^{-1}\frac{(Q_i r_j - P_i x_j)}{V_i^2 - (P_i r_j + Q_i x_j)} \tag{9}$$

Where

Pi and Qi : active and reactive power which flow from i to i+1

$P_{i+1}$and Q_{i+1}: active and reactive power which flow from i+1

$P_{Li+1}$and Q_{Li+1}: active and reactive loads which connected to bus i+1

c. The Particle swarm optimization technique

Particle swarm optimization (PSO) was developed in 1995 by J. Kennedy and R.Eberhart. The idea behind PSO comes from birds or fish when a bird or fish does not know where the food is but knows which fish or bird is the nearest to the food and the searching will be near this area. PSO will be used in this paper because the algorithms and equations are free of derivation, unlike the other methods. In addition, it has the flexibility to integrate with other technologies and not be affected by the nature of the objective function. It also has a few elements which need to be adjusted. Easy implementation and programming with mathematical operations. Does not require a good initial values began in the solution process[7]. The flow chart(fig.3) and eq.10 and 11 represent PSO[8].

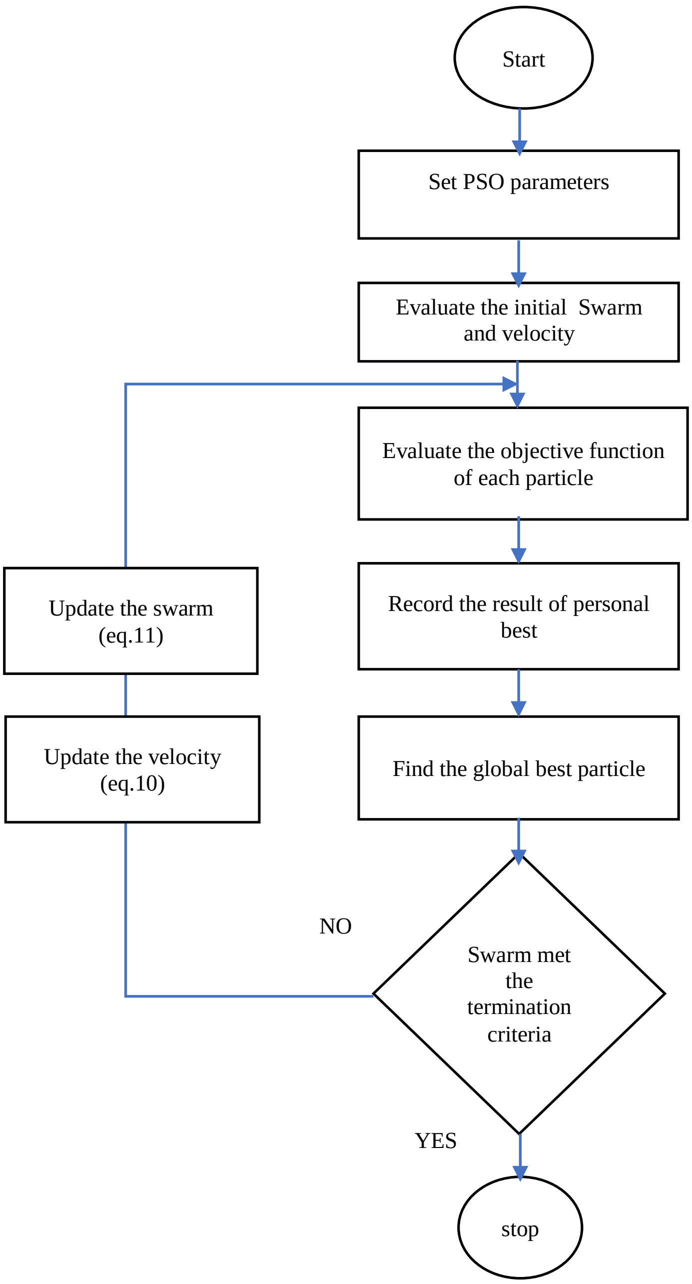

Figure 3: PSO flowchart

$$V_{d+1} = K \times (W \times V_d + \phi_1.rand(\ ) \times (P_{best} - X_d) + \phi_2.rand(\ ) \times (G_{best} - X_d) \tag{10}$$

$$X_{d+1} = X_d + V_{d+1} \tag{11}$$

Where :

w : inertia factor,

1 ϕ and 2 ϕ : acceleration factors,

rand () : random number between 0 and 1.

k is the constriction factor.

d. *Constraints*

The optimization method has some constraints. These constrains depend on the objective function . The type of constraints are equality constraints and inequality constraints . Equation 12 presents the equality constraints [5] .

$$SS.S + SDGs = Sloads + Slosses \tag{12}$$

Where

SS.S : apparent power from substation.

SDGs :apparent power by DG.

Sloads apparent power of loads.

Slosses apparent power losses from system.

Inequality constraints are those given in table 1 :

Table 1: Inequality constraints

Constraints	Minimum	Maximum
DG location	DG location ≥ 2nd bus	DG location ≤ NO. of bus
DG capacity	DG capacity ≥ minimum limit of DG	DG capacity ≤ maximum limit of DG
Voltage bus limit	Voltage bus ≥ minimum limit of voltage	Voltage bus ≤ maximum limit of voltage

In this paper the selected DG capacities are 0 to 10MW for active power and 0 to 10MVAR for reactive power . The voltage limit is between 0.95 to 1.05 P.U .

RESULTS AND DISCUSSIONS

A. Bulk generation

The previous methodology is applied on IEEE-33 distribution system. IEEE-33 distribution system has voltage base which is 12.66KV. The total load is 3715KW and 2300KVAR and the data are presented in [4] . Before adding DG, the total power losses and voltage deviation are calculated by using backward/ forward sweep. The power losses is 210.998KW and the voltage deviation is 1.805 P.U . The lowest bus voltage was 0.9038P.U on bus 18. To find the optimal locations and capacities, the PSO should be used. PSO will be applied on three case. . Each case has one and more DG

1) Case I

In this case the objective function is the total active power losses . After applying the PSO With constrains Observed the decreasing in the total active power losses after adding the first DG on bus 6 where the power losses is 67.950KW . The best value of PL is 18.210KW when adding three DG on buses 3 , 14,and 30 . The effect of the DG adding is shown in figure 4 and table 2 .

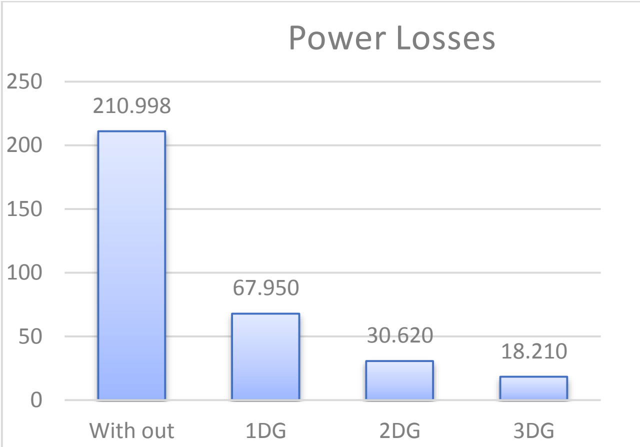

Figure 4: The total power losses with and with out DG's

Table 2: Locations, active, reactive power of DG's and the power losses

	Total Active Power Losses			
NO.of DG	PL (KW)	Location	P of DG	Q of DG
With out	210.998	-	-	-
1	67.950	6	2582.736	1835.726
2	30.620	13	845.428	604.114
		30	1140.687	1058.896
3	18.210	3	1633.301	800.153
		14	741.366	346.898
		30	987.416	990.388

1) Case II

The voltage deviation is the objective function achieved using equation 2 .VD improved to 0.258P.U after adding the first DG and 0.115P.U with Two DGs (where the best location was bus 7 with One DG and buses 13 & 28 with Two DG s) . The best location was when adding three DGs on buses 13 , 24 and 29 where the VD is 0.058P.U . Table3 and Figure 5 show the best locations and capacities with each DG .

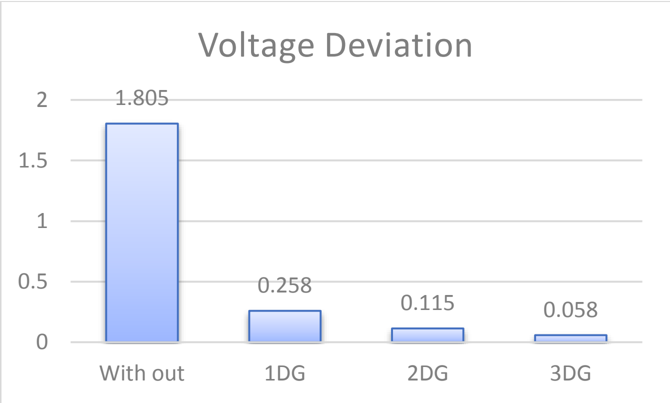

Figure 5: The Voltage Deviation with and with out DG's

Table 3: locations, active, reactive power of DG's and the voltage deviation

	Voltage Deviation(P.U)			
NO.of DG	VD (P.U)	Location	P of DG	Q of DG
With out	1.805	-	-	-
01DG	0.258	7	3702.703	2396.076
2DG	0.115	13	597.408	570.459
		28	2667.084	0.101
3DG	0.058	29	2140.939	0.352
		13	194.718	1187.591
		24	1378.059	278.326

2) Case III

This case depends on both the total active power losses and voltage deviation . Table4 and Figure 6 show the best locations and capacities with each number of DG . Buses 4,13 and 30 are the best location after adding 3 DG on it where the O.F decreases to 59.910KW .

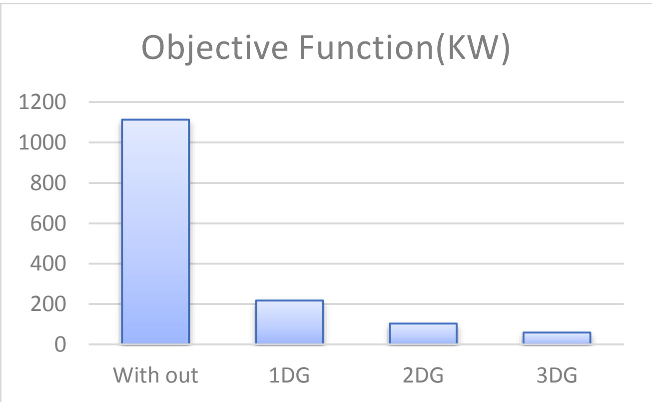

Figure 6: The Objective Function with and with out DG's

Table 4: Locations, active, reactive power of DG's and the objective function

	Objective Function			
NO.of DG	OF (KW)	location	P of DG	Q of DG
With out	1113.498	-	-	-
1DG	218.430	7	3291.587	2320.605
2DG	103.782	28	2030.300	1185.577
		13	637.381	449.328
3DG	59.910	30	947.501	949.733
		13	740.849	405.088
		4	1709.200	801.351

B. Distributed generation

In the previous section, bulk generation has been studied and in this section will be studing at distributed generation case . Distributed generation means more than one DG's in various location and capacities . in this paper , The study was based on the choice sites and capacities of five distributed generators using equations 1,2 and 3 and Comparison it to the bulk generation (one DG) . There are two case in this part . first is generation in different capacities and the other part is generation in identical capacities.

I) Generation by different capacities

Table 5 shows the decrease in the power losses which achieve from 67.950K.W to 6.953K.W after adding the DG's on the buses 32 ,25 ,7, 14 and 30 .VD improved to 0.033P.U after adding the 5 DG's where the best location was 26,21,24,31 and 13. Table 6 show the best locations and capacities with each DG . Also Table 6 show the best locations and capacities with each DG nepend on eq.3 . Also the O.F improve where the best location was 6,31,16,24 and 9 from 218.4295K.W to 26.933 K.W.

Table 5: Locations, active , reactive power of DG's and the power losses of distributed generation case

	Total Active Power Losses			
NO.of DG	PL (KW)	Location	P of DG	Q of DG
1	67.950	6	2582.736	1835.726
5	6.953	32	383.835	293.179
		25	782.431	377.574
		7	785.944	376.660
		14	632.330	294.604
		30	404.310	801.405
Total generation of 5 DG's			2988.851	2143.423

Table 6: Locations, active , reactive power of DG's and the voltage deviation of distributed generation case

	Voltage Deviation(P.U)			
NO.of DG	VD (P.U)	Location	P of DG	Q of DG
1	0.258	7	3702.703	2396.076
5	0.033	26	1135.993	0.009
		21	236.675	183.382
		24	1288.011	273.886
		31	433.717	945.434
		13	620.575	537.077
Total generation of 5 DG's			3714.971	1939.788

Table 7: Locations, active , reactive power of DG's and the Objective Function of distributed generation case

	Objective Function			
NO.of DG	OF (KW)	location	P of DG	Q of DG
1	218.430	7	3291.587	2320.605
5	26.933	6	653.014	499.196
		31	705.803	653.949
		16	461.060	153.208
		24	1041.833	504.575
		9	402.581	245.221
Total generation of 5 DG's			3264.291	2056.148

After review the results and comparing them with the bulk generation, there is a noticeable improvement in the objectives but with a significant increase in the generation. Therefore, this study was repeated but with the total distributed generation being less than or equal to the bulk generation .

II) Generation by identical capacities

Tables 8,9 and 10 show that there are some improvement in the objective when comparison with bulk distribution generation . When comparing the results of the objectives in the cases of distributed generation, there is a slight difference between the results in the goals, but there is a difference in the amount of distribution capacities of generators as figure no.7.

Table 8: Locations, active , reactive power of DG's and the power losses of distributed generation case

	Total Active Power Losses			
NO.of DG	PL (KW)	Location	P of DG	Q of DG
1	67.950	6	2582.736	1835.726
5	9.632	30	516.547	367.145
		14	516.547	265.005
		32	451.626	367.145
		8	516.547	367.145
		25	516.547	367.145
Total generation of 5 DG's			2517.814	1733.586

Table 9: Locations, active , reactive power of DG's and the voltage deviation of distributed generation case

	Voltage Deviation(P.U)			
NO.of DG	VD (P.U)	Location	P of DG	Q of DG
1	0.258	7	3702.702	2396.076
5	0.0538	25	545.260	479.215
		27	740.541	479.215
		13	740.541	395.916
		3	740.541	235.758
		33	716.466	479.215
Total generation of 5 DG's			3483.348	2069.320

Table 10: Locations, active , reactive power of DG's and the Objective Function of distributed generation case

	Objective Function			
NO.of DG	OF (KW)	location	P of DG	Q of DG
1	218.429	7	3291.587	2320.605
5	33.0291	13	658.317	380.200
		7	658.317	435.442
		29	545.807	464.121
		25	658.317	464.121
		33	377.415	318.665
Total generation of 5 DG's			2898.174	2062.550

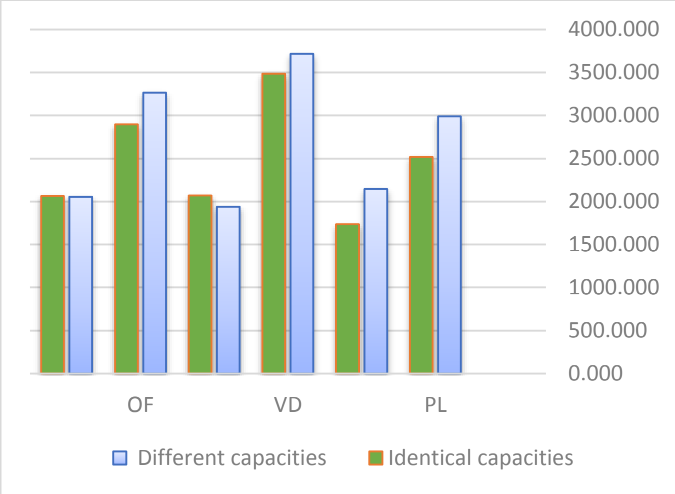

Figure 7: comparison between the total generations on distributed generation case

CONCLUSION

The aim of this paper is finding the optimal locations and sizes of DGs for reduce the active power losses, reduce the voltage deviation or both. PSO based backward forward sweep is proposed to find the optimal location and sizes of DG. This algorathim include some constrains. This methodology is applied on the IEEE 33-bus radial distribution system. This method is applied in three stages(PL ,VD and OF), in each stage one or more generators used. Active power losses and voltage deviation are improved . The maximum power losses reduction was when using distributed generation case(5 DG's) and that happened with VD and OF .

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