DG Types Effect on the Optimal Location for Voltage Sag Mitigation

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Abstract

Voltage sag is considered to be the most serious hazard of power quality and can produce a harmful effect in electrical power system stability. Distributed Generation which used in this paper is playing an important role in power system to improve the grid performance. Grid performance and avoiding degradation the power system networks depend probably on the locations of DGs, hence, optimizing the DGs locations are necessary. In this paper Genetic algorithm is used for DGs locations optimization. The type of DG will directly influence the penetration level “size” and the locations of DGs. Three different DGs “synchronous generator, wind turbine and photo voltaic” will be penetrated individually to find their optimum location and compare their performances on the power system grid and investigate their impact in mitigation voltage sag. This approach will be applied on IEEE 13 bus system which is simulated using PSCAD software. Genetic Algorithm is used to find the optimum solution of multi-objective function; the objective function combines the overall number of buses experience voltage sag, the number of buses experience voltage drop, the number of buses experience voltage less than 10% and the overall number of buses experience voltage swell which Matlab software is used for simulation. Finally, Results are analyzed and discussed which show that the optimum locations of each DG will vary according to the type of DG but all of them will be around the load center.

Keywords—Voltage Sag Mitigation, Power Quality, Optimal DG Locations, Genetic Algorithm.

I. INTRODUCTION

Voltage sag is a momentary drop in voltage magnitude and is considered the most serious problem in power system and could produce a harmful effect [1, 2]. As the voltage sag and short duration power outage are accounted 92% of the power quality problems reported by industrial consumers [1], and this is due to spreading the sensitive devices in industry and commercial loads then this phenomenon will be highly considered to find the best solution to mitigate the voltage sag. This phenomenon is produced due to starting large motors or due to short circuit balanced or unbalanced and can lead to malfunction and stacking or freezing sensitive devices specially electronics and power electronics equipments such as PCs, PLCs and variable speed drives. To improve the power system network performance and reduce the effect of the voltage sag phenomenon, distributed generations are proposed to provide a lot of benefits to the electrical network. Also, sag mitigation is implemented using VSC (Voltage Source Converter) [2] but to mitigate the voltage sag at a specific location which the authors focus on the controlling the power electronic converter to compensate the voltage at this location. Improving the voltage profile and reducing the power loss without considering the voltage sag improvement are widely considered in [5-9] using DGs. Improving the reliability and stability of power system without finding the optimal location of DG are considered in[4, 14, 15]. DGs are used also to mitigate the voltage sag phenomenon and to reduces the effect of this phenomena as much as possible [1, 2, 3, 4, 12, 16] but with many limitations and without optimizing their locations except in [1]. The researcher in [1] applied only 3ph fault to ground, which used general type of single phase DG with high power at medium voltage which is not realistic. While in [2, 3, 16] concentrated on the power electronic technology to optimize the control scheme, series or shunt DVR (Dynamic Voltage Restorer). Different types of distributed generation are widely inserted through the power system network while the renewable energy types are the most commonly used due to their environmentally friendly features and protect the earth from the emission of worm gasses [12, 15, 16]. In this paper Generation from photo voltaic, wind turbine and diesel generator are used to improve the performance of unbalanced radial system used for medium voltage distribution. IEEE 13 bus approach is used to represent the unbalanced redial network.

The proposed solution is to insert three individuals DGs resources, these resources are photovoltaic, wind turbine and diesel generator. The optimum location will be defined using genetic algorithm, the genetic algorithm, will be implemented by constructing an objective function, this function will combine four factors. The first factor is the overall number of 1ph buses experience voltage sag all over the whole process, the sag will be produced by executing short circuit (1ph and 3ph) at all the buses for a specific period of time 0.3-0.5 sec for each DG location. 2nd factor is the overall number of 1ph buses experience voltage drop 0.9 over the whole process. The 3rd factor is the overall number of 1ph buses experiences zero voltage. The 4th one is the overall number of 1ph buses experience voltage swell 1.1. To minimize the search space some assumptions are considered such as, the inserted DGs are two identical types and size each three-phase 500 KW. An important assumption is that the load is considered fixed with time to avoid the necessity of increasing or decreasing the DG sizes. This paper is organized as follows, section II describes DG features for used three types and a brief description about GA technique, in section III the problem formulation and optimization technique are introduced. Analysis, simulation results and discussion are presented in section IV. Finally, conclusion is presented in section V.

II. DISTRIBUTED GENERATION AND GENETIC ALGORITHM (GA)

Distributed Generation is a power source ranges from tens of KW up to tens of MW and normally provided in medium voltage and sub-transmission. DGs are inserted in the electrical network grid to improve the grid performance. Different types of DGs are considered to play an important role due to the great development in the electronic and power electronics technology to control most of the new types of DGs such as photovoltaic which needs sun tracking system and needs for DC to DC converters for MPPT (maximum power point tracking) in-addition to frequency converter to change to AC, the photovoltaic actually relies on two parameters which will be considered as constant in this work , they are the temperature and the irradiance and will be taken 70 oC and 650 W/M2 respectively. Another type of used DGs in this work is wind turbine, it can be connected directly to the grid or it can include converter and inverter to control the turbine to avoid the frequency disturbance due to the variation of the wind speed which changes frequently. The wind turbine also needs control scheme to control the pitch angle of the tail according to the direction of wind. The last type of used DGs in this paper is the synchronous generator and will be connected directly to the grid network. Other types of DGs are used also but not included in our scope are Concentrated Solar Power, Tidal Wave Power and Biomass Electricity Generation and some DGs use CHP (Combined Heat and Power). Genetic Algorithms are family of computational model that rely on the concept of the revolutionary process [1]. It is well known in the law of natural in the course of several generations that the individuals that better adapted to the environment will manage to survive and pass their gens to the succeeding generation.

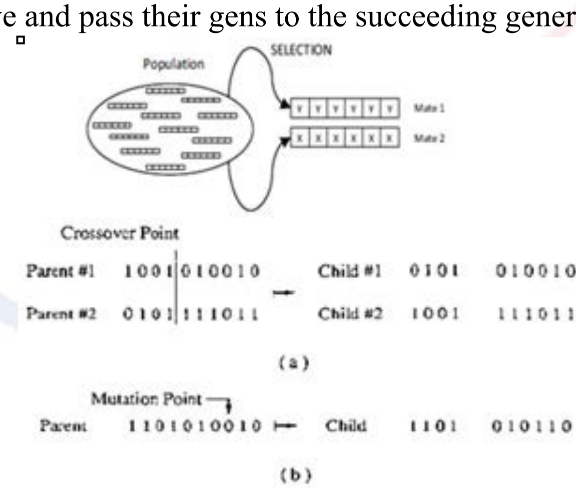

Fig. 1 Selection, Crossover and Mutation of GA

The encoding of the system to a string or a vector of binary (1 or 0), the encoding can be also numbers or letters, the length of the string depends on the number of nodes in the grid. Suppose that we have 7 nodes grid network and 2 DGs with same size, then number of possible solutions are 27 = 128 because if there is a DG the status will be 1 while no DG the status will be 0 but if we assume two different DGs, so we will have 3 status (DG1=1, DG2=2 and noDG=0) then the number of possible iterations or solutions will be 37 = 2187, this assumption will be considered in this work. Cross over and mutation are used here with the genetic algorithm, the cross over will be used up to 80% while the mutation will be around 1-5%. Fig.1 shows the three Genetic Algorithm operators, selection, crossover and mutation to generate the new generation. The flow chart in Fig. 4 shows all the optimization procedures.

III. PROBLEM FORMULATION AND OPTIMIZING TECHNIQUE

The main target in this paper is to find the optimum location of each DG type individually to mitigate the sag. Procedures which proposed to obtain this target are as following:-

Firstly, Make Simulation without penetrating any DG type and coding the IEEE 13 bus using Matlab Software as a start of GA technique so that the bus with DG is 1 while the bus without DG is 0.

Secondly, The IEEE13 bus system which shown in Fig. 2 is simulated using PSCAD software. Power System Computer Aided Design is software which used to process electrical network in transient and steady state condition in-addition to many control processes and mathematical operations.

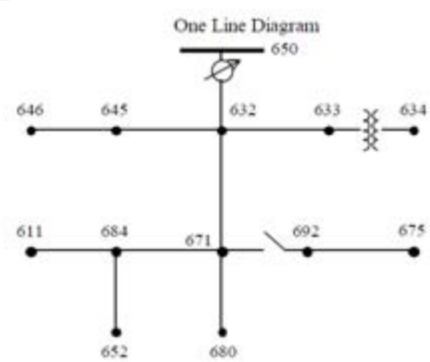

Fig. 2 Single line diagram of IEEE 13 bus system, the buses 611, 684,652, 645 and 646 are 1ph

Thirdly, Simulating GA for each DG type individually by selecting a random solution (two identical DG types as initial solution), each DG model will be inserted to the 13 bus system then 1ph short circuit which is 80% probably occurs and 3ph short circuit which is the most severe fault will be applied at all possible locations in the grid which all voltage measurements are considered. Fig. 3 shows the PSCAD simulated grid for IEEE 13 bus grid which includes main generator 5MVA 115KV, transformer 5MVA 115/4.16 KV, all the DG types synchronous, wind and PV in-addition to all the measuring meters at all buses and the fault modules for 1ph and 3ph. The synchronous generator is connected to the grid while both wind turbine and PV sources are ready to be connected.

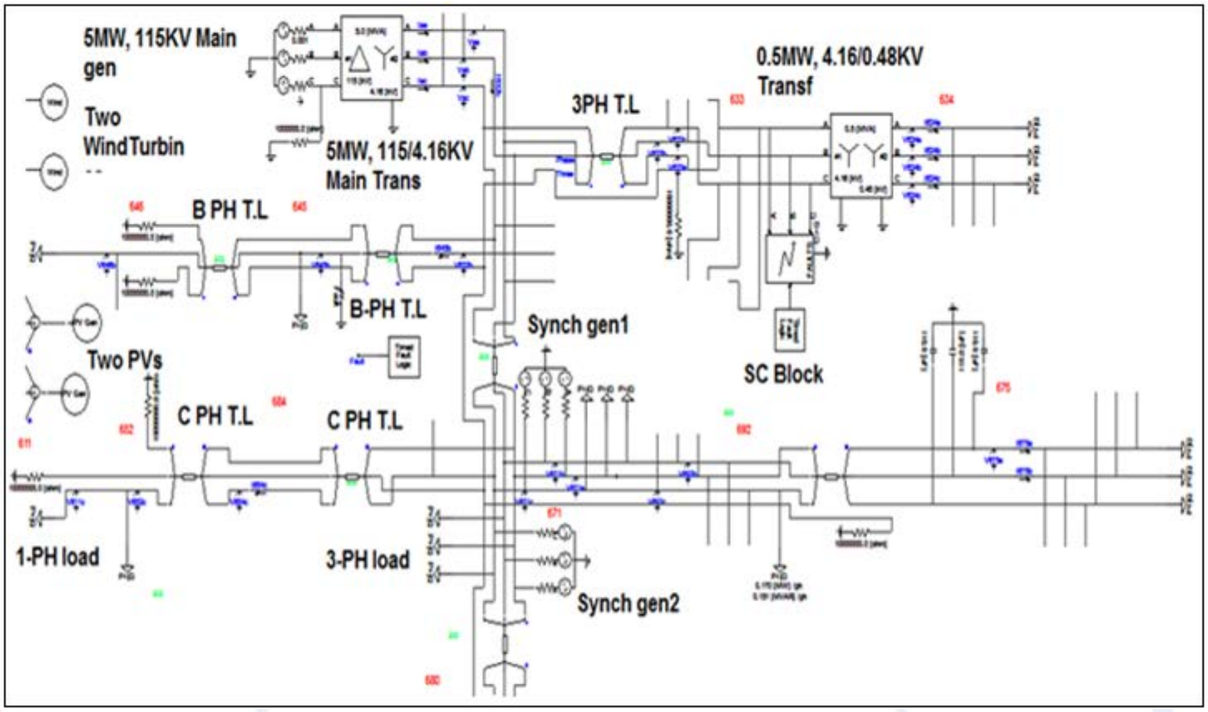

Fig. 3 PSCAD simulated grid for IEEE 13 bus grid

Fourthly, Objective function is applied to specify if the solution is fit or not using Matlab Software. The objective function combines four variables, the overall number of buses experience sag, the overall number of buses experience voltage drop, the overall number of buses experience zero voltage(less than 10%) and the number of buses experience swell voltage. All these variables are calculated over the whole short circuit process. The measured buses in this work are considered as single phase buses because the applied short circuit is 1ph an 3ph so it is suitable to deal with single phase bus than three phase bus and the SC is approximately occurs 80% while the 3ph SC is 10%. These variables are denoted as Nsag, Ndrop, Nzero and Nswell. The objective function is defined as, Fobj =a* Nsag + b*Ndrop+c*Nzero+d*Nswell Where a =0.7, b =0.1, c=0.1 and d=0.1 are factors can be changed according to importance of the 4 variables and the paper target.

Fifthly, The selection, crossover and mutation are applied to reproduce the next generation, each solution will violates the constrains are ignored, the constrains are that the DGs penetration will be 25% and the DGs will be three phase. This means that the solutions which include 1ph bus locations will be ignored.

Finally, The new solution will be added to the to network as a new location until reaching to the optimum location, after that all these steps are repeated to all different DG types to obtain the optimization locations for all types. Flow chart that indicates Optimization procedure technique is shown in Fig.4.

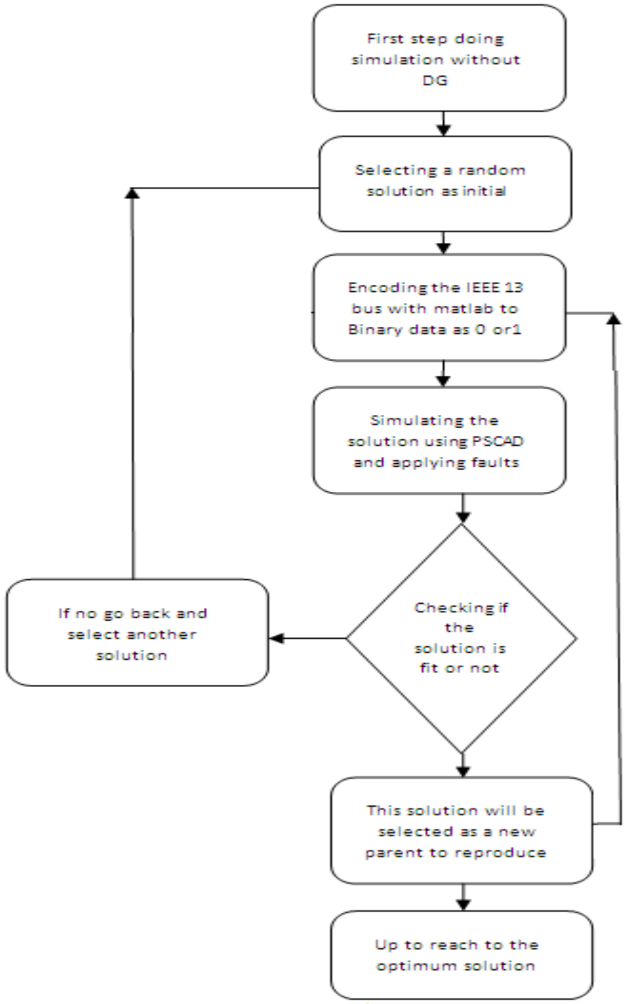

Fig. 4 Optimization procedure technique of GA

IV. ANALYSIS, SIMULATION RESULTS AND DISCUSSION

A. Synchronous Generator as a DG Type

In general, DGs penetration provides boosting to the bus voltage. Hence, Simulation is done for IEEE 13 bus grid without and with DG penetration at the buses 633 and 692 which results is shown in Figure 5. It is clear when looking to Fig. 5 below, the voltage sag “in another buses” in case of no-DG (Fig.5 a) is deeper than the case while the DGs penetrated (Fig.5b). This means that it is not only important to insert DG to the grid but the important is to find the optimum location to have better performance.

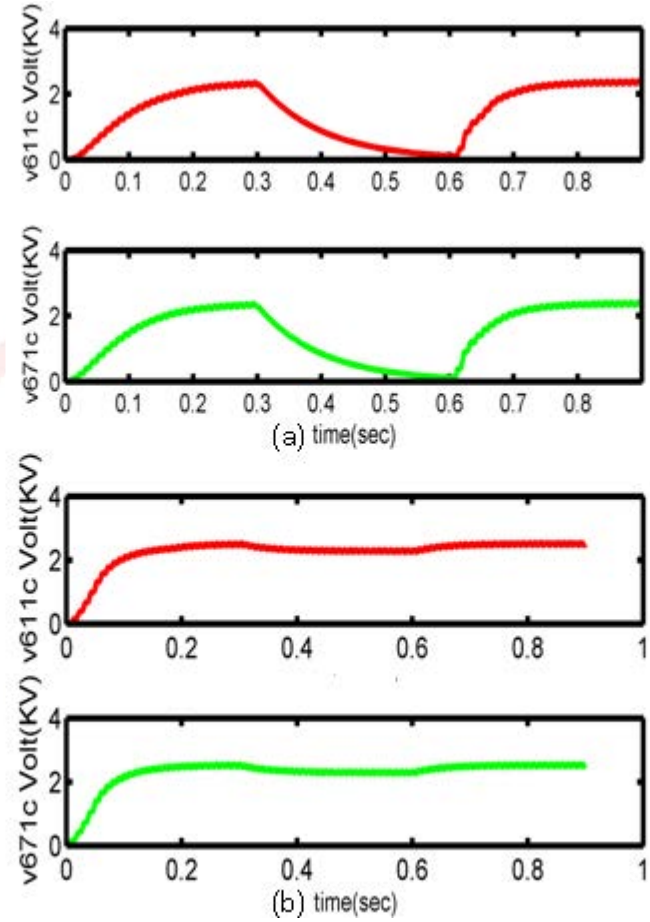

Fig.5 the buses voltages without (a) and with (b) DGs of IEEE13 bus

The simulation results shown in Table I prove that not all the synchronous generator locations as a DG produce an improvement on the grid better than no DG case. The location like 632-671produces Fobj value 225.6 which is higher than 117.8 for no DG but the location 633-692 is 54.8 which more is better than no-DG and this location produces the minimum objective function value. Then, optimization of DG penetration is highly important. Fig. 6 shows that the locations 671-675 are local optima and the most optima are 633-692.

TABLE I
DG SYNCH GENERATOR LOCATIONS AND PERFORMANCES

DG locations	N_{sag}	N_{drop}	N_{zero}	N_{swell}	F_{obj} Objective Function
No-DG	310	40	31	77	231.8
DG633-675	69	38	43	292	85.6
DG633-680	73	21	34	278	84.4
DG633-692	51	20	12	159	54.8
DG633-671	52	20	12	158	55.4
DG632-671	313	47	8	10	225.6
DG632-692	305	47	14	12	220.8
DG632-645b	360	8	35	0	256.3
DG671-675	77	30	5	128	70.2
DG671-675	77	32	5	140	71.6

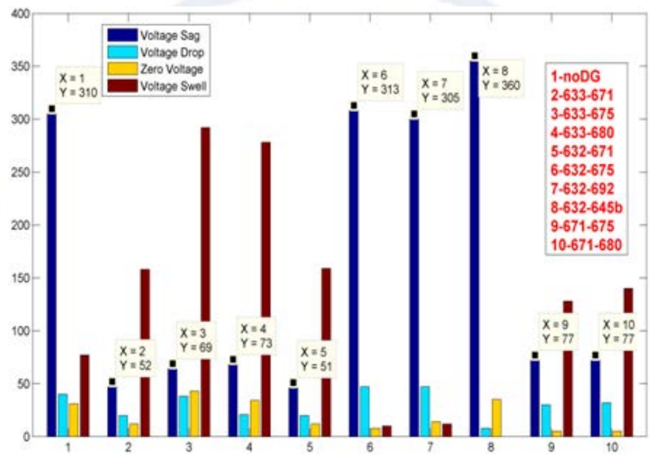

Fig.6. Nsag, Ndrop, Nzero and Nswell for synch generator as a DG

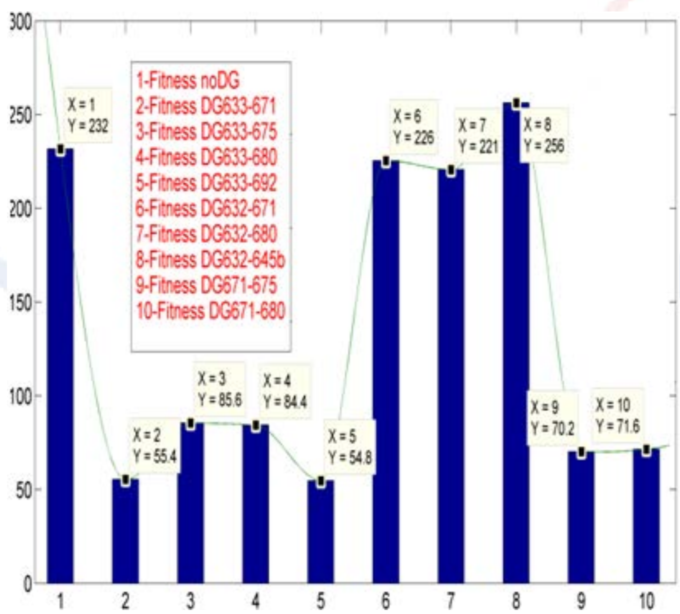

Fig.7 Fitness values for synchronous generator as a DG

Figure 7 shows the DG location which produces minimum objective function value (fitness value) is at the location 633-692.The results shown in figures 5,6,7 and Table I provides the improvements in the grid performance by mitigating the voltage sag and reducing the overall number of buses experience sag in-addition to the overall number of buses experience voltage drop, the overall number of buses with zero voltage and finally the overall number of buses experience voltage swell but attention should be taken because not all the location improve the grid performance, some of them could lead to degradation of the performance as shown in the locations DG632-671 and DG632-680 in figure6. Finally the best location provides the better performance is at the buses 633-692 and produce the lower objective function value as found in figure 7 and Table I in which is 54.8.

B. Wind Turbine as a DG Type

In this case, all variables, Nsag, Ndrop, Nzero and Nswell shown in Table II clarify how the presence of DG produces better performance than the case without DG except roughly the location 633-692 while the best location was 632-671. In this best location Nsag is minimum, Nzero and Nswell are low too except Ndrop but this do not affect the objective function value (fitness value) in which is 225.2. If this produced value is compared with the produced value in synchronous DG type which is 54.8 at the solution (location) 633-692, we can find that the synchronous generator mitigates the voltage sag better than the wind turbine and in a different location too. So, this is a proof that each DG type provides different effect on the grid.

TABLE II
DG WIND TURBINE LOCATIONS AND PERFORMANCES

DG locations	N_{sag}	N_{drop}	N_{zero}	N_{swell}	F_{obj} Objective Function
No-DG	310	40	31	77	231.8
DG633-671	305	16	29	83	226.3
DG633-675	302	8	32	131	228.5
DG633-680	308	3	35	91	228.5
DG633-692	302	6	34	161	231.5
DG632-671	300	60	29	63	225.2
DG632-692	309	3	32	92	229
DG632-675	309	3	32	92	229
DG-671	21	1	81	242	331

C. Photo Voltaic as a DG Type

Table III shows Nsag, Ndrop, Nzero, Nswell and the objective function (fitness) values for PV source as a DG. It shows also that all the DG solutions (locations) produce a worse performance than the case without DG where all PV locations fitness ranges from 241.5 up to 251.6 while the case without PV is 231.8 but anyway PV is considered an important DG and the penetration of it to avoid severe degradation and to better compensate the voltage in case of SC or starting of large motors. So, it is recommended to select the location that provides better performance on the grid than the others and this location is can be 633-692 or 632-633.

TABLE III
DG PHOTOVOLTAIC LOCATIONS AND PERFORMANCES

DG locations	N_{sag}	N_{drop}	N_{zero}	N_{swell}	F_{obj} Objective Function
No-DG	310	40	31	77	231.8
DG633_675	339	18	3	122	251.6
DG633_680	336	12	2	81	244.7
DG633_692	331	12	2	84	241.5
DG633_671	336	12	2	84	245
DG632_671	336	12	2	79	244.5
DG632_692	336	12	2	79	244.5
DG632_675	336	12	2	79	244.5
DG632-633	330	23	2	80	241.5
DG633	341	32	3	77	249.9

TABLE IV
THE OPTIMAL LOCATIONS OF THREE DG TYPES

DG Type	Synchronous Generator	Wind Turbine	PV Source
Location	DG633-692	DG632-671	DG632-633 or DG633-692
Min $F_{obj.}$ (Fitness)	54.8	225.2	241.5

Table IV shows the comparing results of PV with the both synchronous and wind turbine, it is found that the synchronous has better performance than wind and PV while wind is better than PV.

V. CONCLUSION

In This paper Genetic Algorithm is used to optimize the location of three types of DG with a modified reference to the random solution and the next generations and the target is to minimize the objective function, which evaluates each DG location individually. Each model of DG type is inserted separately to investigate its behaviors on the grid precisely, which results shows that each type provide different features and behaviors on the IEEE 13 bus. In the mean time, results prove that the optimum locations differs by each DG type in which, synchronous generator mitigates the sag better than wind turbine and photovoltaic while wind turbine is better than photovoltaic.

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