The Distribution Network Reconfiguration Improved Performance of Genetic Algorithm Considering Power Losses and Voltage Profile

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Abstract— **Power losses issues persevered over few decades in the high demand utilization of energy electricity in developing countries. Thus, the radial structure of distribution network configuration is extensively used in high populated areas to ensure continuity of power supply in the event of fault. This paper proposes heuristic Genetic Algorithm known as SIGA (Selection Improvement in Genetic Algorithm) in consideration of genetic operator probabilities likewise the progression of switch adjustment in Distribution Network Reconfiguration (DNR) while satisfying the parameters constraints. The SIGA algorithm was embodied throughout the process in IEEE 33-bus distribution system in selection of five tie switches. As a consequence, the power losses were ranked in accordance to the minimum values and voltage profile improvement obtainable by the proposed algorithm. The results show that the SIGA performs better than GA by giving the minimized value of power losses.**

Keyword - Power Losses, Genetic Algorithm (GA), Selection Improvement in Genetic Algorithm (SIGA), Distribution Network Reconfiguration (DNR).

I. INTRODUCTION

Power interruptions are the biggest obstacles to be tackled in the power distribution fields. They come in two types which are scheduled and unscheduled power interruption. Firstly, a scheduled power interruption that is normally conducted by the power utility company for maintenance purposes. Secondly, an occurrence of power failure namely as an unscheduled interruption that happens because of abrupt circumstances for example natural disaster like lightning strikes [1]. Besides natural disaster, there are thousands other causes of power interruptions like low voltage of distribution level, load variations, overload, damage of equipment, damage caused by third party, loose of connection and even work quality [2-6].

Indeed, numerous researches have been done with the aim of reducing power losses in distribution system while maintaining its quality and reliability of the system itself. Having this in mind, many techniques have been approached such as Distributed Automation System (DAS) and Distribution Network Reconfiguration (DNR) [7-9]. This research attempts to use DNR which is a usable operation in reducing distribution feeder as well as improving the system security.

DNR technique consists of traditional network reconfiguration and heuristic reconstruction method. In order to solve DNR, there are few categories of algorithm that can be applied which are switch exchange method, mathematical optimization theory, artificial intelligence algorithm and optimal flow pattern [3].Initially, the traditional network reconfiguration is implemented to reduce power losses, balance the load and stabilize voltage in normal operating conditions where it does not include the impact of network reconfiguration to the system reliability.

There are many ways to reconfigure the distribution network are introduced such as the developing of algorithms like Particle Swarm optimization (PSO), Simulated Annealing (SA), Tabu Search (TS) and Genetic Algorithm (GA). Particle swarm optimization (PSO) algorithm proposed in [2] used population-based approach. Modification was done by linearly decrease the inertia weight during simulation. It is capable of finding optimal or near-optimal solution to the test system and it operating time is acceptable for practical applications.

In this paper [4], the authors attempt to use IGA to find the optimal small size subset of features from the original large feature set. It proposed a new modified GA based on enhanced diversity, parents selection and

improved genetic operators. The DGA is done through a modified roulette wheel selection procedures to be able to introduce more diverse feature of GA members and to avoid the mating of exact members.

The study on this paper comprises of four parts which are the Test System in Part I, the Methodology of the SIGA algorithm in Part II, the Result Analysis and Conclusion in part III and IV respectively.

II. SYSTEM MODELLING

In order to successfully implement the SIGA algorithm, the 33 IEEE busses of distribution system is tested in MATLAB vr2013. The test system consists of 38 switches whereby 5 of them are tie switches and the remaining 33 are sectionalizing switches. Fig. 1 and 2 (a) (b) below show the condition of the 33-bus distribution system before and after it undergoes any changes from the proposed algorithm of this paper.
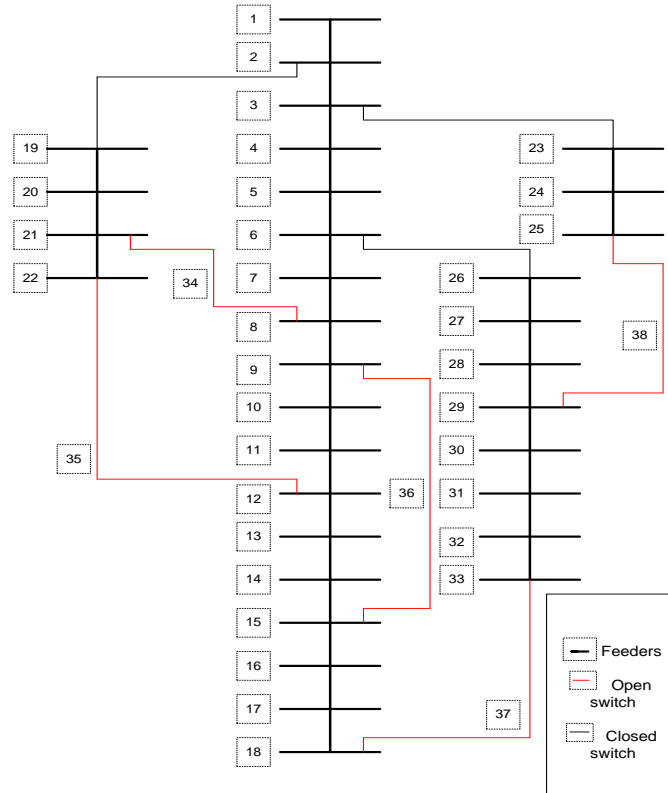

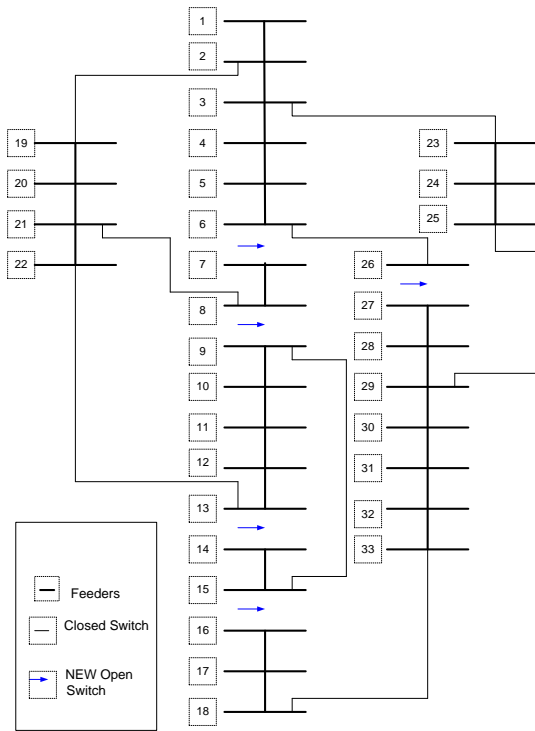Fig. 1. IEEE 33-bus distribution system (initial system)

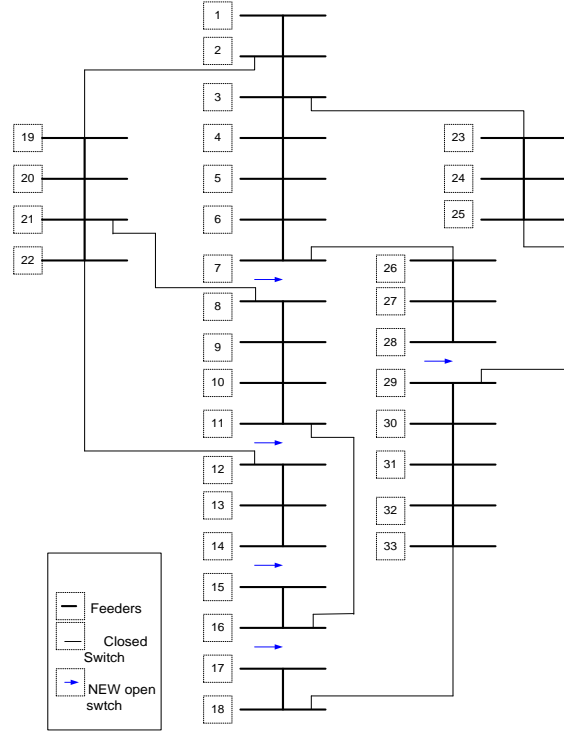Fig. 2(a). Best Case of Tie Switches for Regulated pm
(After Reconfiguration)

Fig. 2(b). Best Case of Tie Switches for Regulated pc
(After Reconfiguration)

III.IMPLEMENTATION OF PROPOSED ALGORITHM

A. Overview on GA Algorithm

The conventional technique of GA (Genetic Algorithm) does not operate on a single point but required the overall process involving the whole parameter code. The operation is based on probabilistic change rules than uncertain rules. Fig. 3 below depicts the working principle of a simple GA.

```
/*A Simple GA*/
Initialize population randomly
Calculate fitness function
Apply genetic operators
        Selection
        Crossover
        Mutation
Repeat until maximum  iterations reached
Stop
```

Fig. 3. Working Principle of a Simple GA [7]

In GA, the problem is simply described by the coding of variables where the common variable used is a binary string or a vector. However, this conventional GA has slow convergence rate, local optimum and it ignores cooperation between populations [8-14].

B. SIGA Algorithm

The GA (Genetic Algorithm) is predominantly improved in selection part named as SIGA algorithm. The SIGA algorithm is simply drawn into a flowchart as shown in Fig. 4 below and followed by the elaborations on each processes involved.
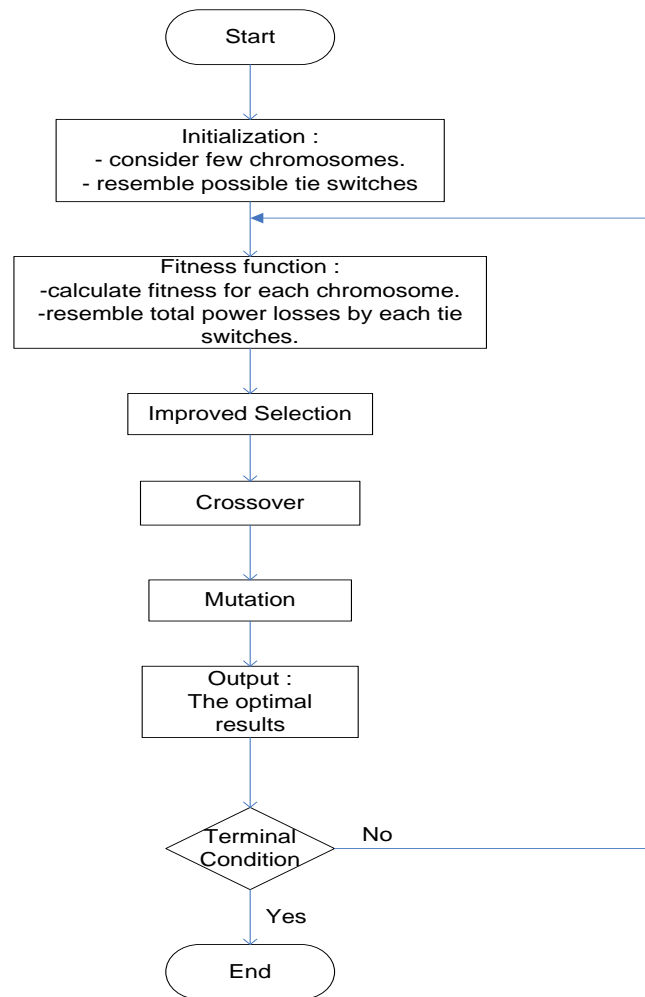
Fig. 4. Flowchart of SIGA algorithm

C. Problem Formulation

Step 1 : Initialization

The very first step in SIGA is initialization where an initial population is being generated. A binary string or sometimes called chromosome is generated randomly to each members of the population. The number of chromosomes resembles number of switches available in the test system. This research takes 33-bus distribution system with 5 open switches and 28 closed switches. Initially, crossover probabilities are set to be 0.5 and mutation probabilities are 0.4 where these values are the reference point for this research.

Step 2 : Fitness Fumction

The fitness resembles total power losses obtained by each switches being selected in the initialization. In this research, the method used to calculate power losses is Newton-Raphson Method due to its ability to converge where the iterations number is independent to the number of buses, N.

During this process for the research, five (5) switches are being randomly picked for calculation of their power losses.

At any given bus of i and j, Newton-Raphson Method equation are given as:

$$Pi = \sum_{j \neq 0}^{n} |Yi||Vj||Yij| \cos(\theta ij - \delta i + \delta j) \tag{1}$$

$$Q_i = \sum_{j \neq i}^{n} |Y_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \tag{2}$$

Where:

Vi, Vj   : voltage magnitude of bus i and j respectively

δi, δj   : voltage angle of bus I and j respectively

Step 3 : An Improve Selection Operator

Selection is related to fitness and the most common used method in selection is *roulette-wheel method*. This method attempts to choose from given string which depends on their fitness values. A higher fitness value strings contribute high chances in producing children in the next generations. Thus, the new offspring produce is to be same-like as its parents.

The process continues whereby the parent is reflected by the 38 available switches in test system and the child is being resembles by the possible five (5) combination of tie switches that has high probability in producing minimal total power losses are selected.

The following Fig. 5 illustrates the working principles of an improved selection operator where it denotes that output 1 is the scattered list of tie switches with their total power losses and after undergoing improved selection operator, they are listed accordingly in ascending order of their total power losses to become new output 1.
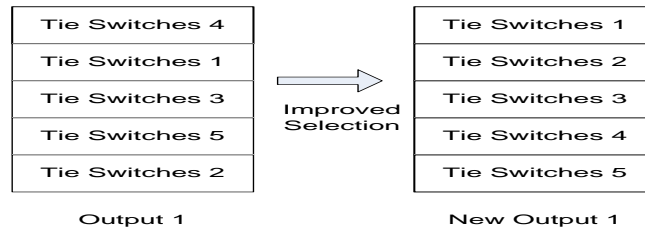

Fig. 5. Working Principle of SIGA

Step 4 : Crossover

At this step, crossover randomly mates the mating pool of the selected strings obtained from roulette-wheel method. This is simply drawn in Fig. 6 that crossover takes the output of selection (child 1) to recombine in order to produce new output that is better than the first one (child 2).
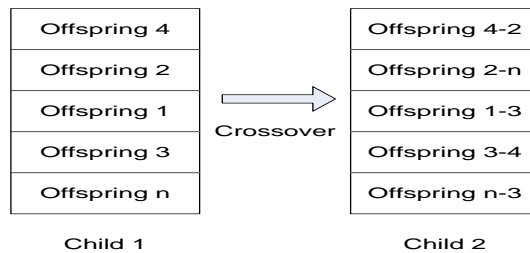
Fig. 6. Crossover Operator

Step 5 : Mutation

The last stage is mutation which is simpler than crossover. A mutation process is about random change of a new bit generated or sometimes referred as flipping the bit. However, to obtain good results in mutation GA, it may need about thousand bits of transfer and that is why mutation is treated as the secondary role in GA. Somehow in a binary string, mutation is about complement the chosen bits. Mutations also clearly copy the best combination in the next reproduction to produce new child and this process of mutation is being displayed in Fig. 7 below.

Fig. 7 Mutation Operator

IV.PARAMETER ALLEVIATION

In considering the proposed SIGA algorithm of this paper, few parameters have to be controlled to optimize the results efficiently. The control parameters are probability of crossover occurrence, 'pc' and probability of mutation occurrence, 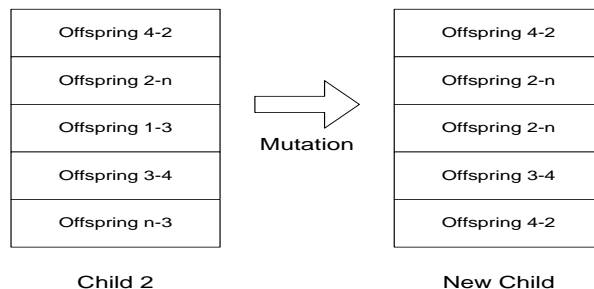'pm' are adjusted according to the following conditions and considering minimum and maximum bounds, B_{min} and B_{max} as shown in (3) and (4) below. Both 'pc' and 'pm' are important in determining the performance of SIGA algorithm. Probability of crossover occurrence, 'pc' determines how often the crossover operator is applied for switching in DNR and it should never be too small so that it can cater extra high voltage of test distribution system. Meanwhile, probability of mutation occurrence, 'pm' should not be necessarily large since it helps to maintain population diversity effectively.

$$p_c = \begin{cases} pc_{min}, \text{ if } G_{div} < B_{min} \\ pc_{max}, \text{ if } G_{div} > B_{max} \end{cases} \tag{3}$$

$$p_m = \begin{cases} pm_{min}, \text{ if } G_{div} < B_{min} \\ pm_{max}, \text{ if } G_{div} > B_{max} \end{cases} \tag{4}$$

Where:

G_{div} = genetic diversity

V. RESULT ANALYSIS

This research is conducted in MATLAB vr2013 in order to analyse the effectiveness of the proposed algorithm, SIGA. The proposed algorithm with improved selection operator is tested to the initial 33-bus distribution system with 28 closed switches and 5 open switches. The analysis involved the determination of power losses and voltage profile before and after DNR while maintaining the radially of the original network.

A. Simulation Results

There are three types of limitations to configure both GA and SIGA algorithm into MATLAB vr2013 in order to maintain the reliability of the results obtained. The limitations are as follows:

Number of possible tie switches: 5

Number of iterations: 10

Size of population: 30

Table 1 indicates the eight (8) numbers of cases to be imposed in both GA and SIGA algorithm. As being mentioned earlier, (pc) represents as probabilities of crossover occurrence, while (pm) is the probabilities of mutation occurrence. There are 8 cases considered during this research however they are separated into two parts for better analysis and understanding. Firstly, case 1 to case 4 involved constant pc values and regulated pm value. Meanwhile, case 5 to case 8 involved regulated pc value and constant pm values.

The parameter setting for Case 1, 2, 3 and 4 is constrained by constant value of crossover probability (pc) and regulated mutation probability (pm). The adjustment for pm is started with 0.2 followed by an increment of 0.2 till it reached the maximum value constraints of 0.8. For case 5, 6, 7 and 8, the performance of the test system is set to constant value of pm with varied value of pc from 0.2, 0.4, and 0.6 rights up to 0.8.

TABLE 1
Cases Consideration

No. of cases	Pc	Pm
1	0.5	0.2
2	0.5	0.4
3	0.5	0.6
4	0.5	0.8
5	0.2	0.4
6	0.4	0.4
7	0.6	0.4
8	0.8	0.4

Based upon the parameters above, power losses performance is being analysed individually in kW. The following formula is used to obtain the percentage of total power losses after reconfiguration.

$$TotalPowerLosses(\%) = \frac{newpowerlosses}{\sum powerlosses} \times 100\% \tag{5}$$

B. Minimization of Power Losses

The proposed algorithm shows great contribution towards the initial 33-bus test system where it has been proved that it is capable of minimizing the initial total power losses. Table 2 and 3 below displays the possible tie switches for all 8 cases including its total power losses for both GA and SIGA.

TABLE 2
Tie Switches and Total Power Losses for Case 1, 2, 3 and 4

		Tie Switches	Total Power Losses (kW) *best case*	Total Power Losses (kW) *worst case*	Total Power Losses (%)
Before Reconfiguration		34,35,36,37, 38	202.6	-	0.0
After Reconfiguration					
Case 1	GA	33,7,32,24,12	160.9	837.8	11.5
	SIGA	32,6,25,33,13	159.7	753.7	11.8
Case 2	GA	32,26,5,11,8	141.5	829.9	17.8
	SIGA	8,26,13,15,6	139.7	815.6	18.4
Case 3	GA	14,15,9,26,4	145.0	849.1	16.6
	SIGA	28,4,9,14,16	141.4	844.1	17.8
Case 4	GA	4,17,10,13,7	159.6	890.3	11.9
	SIGA	26,33,21,17,10	155.2	843.3	13.3

TABLE 3
Tie Switches and Total Power Losses for Case 5,6,7 and 8

		Tie Switches	Total Power Losses (kW) *best case*	Total Power Losses (kW) *worst case*	Total Power Losses (%)
Before Reconfiguration		34,35,36,37,38	202.6	-	0.0
Case 5	GA	26,5,32,12,21	154.2	847.3	13.6
	SIGA	28,5,8,14,10	149.5	909.3	15.1
Case 6	GA	27,30,33,14,9	129.9	926.9	21.9
	SIGA	14,28,11,7,16	125.1	766.4	23.7
Case 7	GA	13,27,15,6,11	137.4	890.2	19.2
	SIGA	7,15,21,12,28	135.6	966.4	19.8
Case 8	GA	9,4,31,7,13	153.7	871.3	13.7
	SIGA	16,33,26,11,7	145.6	971.8	16.4

From Table 2 with the adjustment of (pm), case 2 shows the highest percentage of total power losses generated by SIGA algorithm which is 18.4% after the reconfiguration of with possible tie switches of 8, 26, 13, 15 and 6. Then followed by case 3, 4 and 1 with 17.8%, 13.3% and 11.8% consecutively. As for GA, case 1 shows the least percentage of total power losses of 11.9% while case 2 with 17.8%, case 3 with 16.6% and case 4 with 11.9%.

Meanwhile, Table 3 depicts the analysis results for case 5, 6, 7 and 8 for GA and SIGA. It shows that the highest percentage of total power losses after implementation of SIGA which is 23.65% is produced by case 6 with possible tie switches of 14, 28, 11, 7 and 16. In case of GA, case 6 also possess the best power losses reduction compared to case 7, 8 and 5.

By imposing both GA and SIGA into reconfiguration, it clearly shows that both algorithm results in reduction of power losses but somehow the SIGA algorithm possess the best reduction for case 6 comparable with GA algorithm.

C. Improvement of Voltage Profile

Performance of voltage profile is done towards each number of buses to observe the improvement of voltage profile when implementing the proposed algorithm of this paper in comparison with GA. This is to ensure that the proposed algorithm improved the actual voltage profile of the initial 33-bus test system.

The following Table 4 and 5 below listed the value of voltages obtained at each bus for case 1 to case 4 and case 5 to case 8, respectively. In the meantime, Fig. 8 and 9 below show graphically the voltage profile for case 2 and 6 that produce the best improvement when GA and SIGA takes place.

As shown in Table 4, case 1 yields great improvement on voltage profile for bus number 3 onwards, until it reaches to maximum value at bus number 19. After that, it drops to 0.996 p.u and steadily maintain its improvement aside of the conventional GA. Referring to the same Table 4, case 3 and 4 have similar voltage profile improvement where the bus number 1 till bus number 10 acquire only a slight improvement of voltage profile. However, the maximum value of 0.9998 p.u is achieved at bus number.

For case 5 as represented in Table 5 where the voltage profile is being improved from the implementation of SIGA comparable with GA for all number of busses except those bus number 19 and 23 that has reached their maximum values of 0.9999 p.u. Bus number 1 until bus number 15 experience minimum values of voltage profile as indicates by case 7 and 8 which is implemented by SIGA algorithm compared to conventional GA and enable to escalate its value to almost 0.998 p.u at bus number 19.

TABLE 4
Voltages at each bus for Case 1, 2, 3 and 4

No of buses	After reconfiguration							
	case 1		case 2		case 3		case 4	
	SIGA	GA	SIGA	GA	SIGA	GA	SIGA	GA
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	0.9938	0.9904	0.9999	0.9939	0.9958	0.9999	0.9999	0.9896
4	0.9938	0.9904	0.9972	0.9939	0.9958	0.9999	0.9999	0.9896
5	0.9952	0.9904	0.9972	0.9952	0.9957	0.9998	0.9999	0.9896
6	0.9952	0.9967	0.9972	0.9952	0.9960	0.9990	0.9994	0.9897
7	0.9959	0.9968	0.9968	0.9961	0.9967	0.9978	0.9986	0.9896
8	0.9959	0.9968	0.9968	0.9958	0.9965	0.9981	0.9988	0.9957
9	0.9959	0.9945	0.9966	0.9957	0.9957	0.9934	0.9986	0.9951
10	0.9958	0.9949	0.9966	0.9957	0.9959	0.9951	0.9986	0.9951
11	0.9958	0.9949	0.9966	0.9970	0.9959	0.9951	0.9994	0.9969
12	0.9970	0.9947	0.9966	0.9970	0.9959	0.9951	0.9994	0.9969
13	0.9970	0.9947	0.9964	0.9954	0.9951	0.9944	0.9994	0.9969
14	0.9958	0.9946	0.9964	0.9954	0.9951	0.9937	0.9982	0.9939
15	0.9958	0.9937	0.9964	0.9955	0.9951	0.9934	0.9983	0.9940
16	0.9961	0.9943	0.9964	0.9955	0.9952	0.9940	0.9987	0.9946
17	0.9958	0.9926	0.9979	0.9954	0.9947	0.9926	0.9978	0.9926
18	0.9958	0.9923	0.9980	0.9941	0.9946	0.9924	0.9978	0.9922
19	0.9998	0.9997	1.0000	0.9998	0.9998	1.0000	0.9999	0.9997
20	0.9980	0.9979	0.9999	0.9979	0.9980	0.9999	0.9997	0.9979
21	0.9972	0.9971	0.9998	0.9972	0.9972	0.9970	0.9996	0.9971
22	0.9971	0.9958	0.9965	0.9971	0.9966	0.9959	0.9995	0.9970
23	0.9938	0.9905	0.9997	0.9939	0.9958	0.9999	0.9999	0.9896
24	0.9939	0.9905	0.9990	0.9939	0.9957	0.9911	0.9998	0.9901
25	0.9941	0.9908	0.9985	0.9941	0.9957	0.9913	0.9973	0.9902
26	0.9952	0.9967	0.9972	0.9952	0.9956	0.9990	0.9994	0.9897
27	0.9952	0.9967	0.9973	0.9952	0.9956	0.9990	0.9994	0.9898
28	0.9946	0.9909	0.9978	0.9952	0.9957	0.9914	0.9994	0.9901
29	0.9943	0.9909	0.9983	0.9943	0.9957	0.9914	0.9973	0.9903
30	0.9960	0.9910	0.9984	0.9944	0.9959	0.9914	0.9974	0.9904
31	0.9958	0.9914	0.9981	0.9942	0.9944	0.9917	0.9974	0.9910
32	0.9958	0.9917	0.9980	0.9941	0.9944	0.9919	0.9975	0.9913
33	0.9959	0.9922	0.9980	0.9941	0.9945	0.9923	0.9977	0.9920

TABLE 5
Voltages at each bus for Case 5, 6, 7 and 8

No of buses	After reconfiguration							
	case 5		case 6		case 7		case 8	
	GA	SIGA	GA	SIGA	GA	SIGA	GA	SIGA
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	1.0000	0.9999	0.9999	1.0000	0.9999	0.9999	0.9999	1.0000
4	0.9885	0.9999	0.9927	1.0000	0.9999	0.9999	0.9999	0.9966
5	0.9885	0.9999	0.9927	1.0001	0.9971	0.9998	0.9999	0.9966
6	0.9986	0.9992	0.9928	0.9997	0.9972	0.9992	0.9937	0.9967
7	0.9884	0.9981	0.9929	0.9995	0.9967	0.9985	0.9937	0.9971
8	0.9884	0.9984	0.9929	0.9995	0.9967	0.9985	0.9937	0.9969
9	0.9940	0.9961	0.9932	0.9962	0.9956	0.9982	0.9940	0.9966
10	0.9945	0.9963	0.9932	0.9962	0.9956	0.9982	0.9933	0.9966
11	0.9944	0.9962	0.9922	0.9974	0.9956	0.9982	0.9933	0.9966
12	0.9943	0.9961	0.9922	0.9974	0.9956	0.9975	0.9933	0.9975
13	0.9943	0.9961	0.9922	0.9969	0.9956	0.9976	0.9947	0.9975
14	0.9942	0.9960	0.9921	0.9965	0.9955	0.9977	0.9947	0.9974
15	0.9929	0.9958	0.9941	0.9963	0.9955	0.9977	0.9945	0.9962
16	0.9935	0.9962	0.9938	0.9964	0.9955	0.9978	0.9958	0.9963
17	0.9914	0.9953	0.9953	0.9959	0.9979	0.9974	0.9962	0.9957
18	0.9911	0.9952	0.9957	0.9958	0.9979	0.9973	1.0000	0.9956
19	0.9998	1.0000	0.9924	0.9999	1.0000	1.0000	0.9935	0.9998
20	0.9980	0.9975	0.9925	0.9990	0.9999	0.9984	0.9935	0.9984
21	0.9972	0.9976	0.9925	0.9987	0.9963	0.9984	0.9934	0.9978
22	0.9957	0.9967	0.9924	0.9981	0.9960	0.9975	0.9997	0.9976
23	1.0000	0.9999	0.9996	0.9991	0.9997	0.9999	0.9990	0.9999
24	0.9889	0.9997	0.9989	0.9991	0.9990	0.9998	0.9984	0.9998
25	0.9890	0.9946	0.9982	0.9992	0.9985	0.9997	0.9937	0.9967
26	0.9886	0.9992	0.9928	0.9997	0.9972	0.9992	0.9937	0.9967
27	0.9886	0.9992	0.9979	0.9998	0.9972	0.9992	0.9982	0.9968
28	0.9889	0.9946	0.9979	0.9995	0.9978	0.9998	0.9982	0.9968
29	0.9892	0.9947	0.9980	0.9994	0.9983	0.9998	0.9982	0.9968
30	0.9893	0.9947	0.9980	0.9995	0.9984	0.9999	0.9982	0.9969
31	0.9899	0.9948	0.9970	0.9956	0.9981	0.9999	0.9973	0.9954
32	0.9902	0.9949	0.9966	0.9956	0.9980	0.9972	0.9969	0.9954
33	0.9908	0.9951	0.9960	0.9957	0.9980	0.9973	0.9964	0.9956

For case 2 and 6, the voltage profile are shown in graph for better view of voltage profile performance represented by both SIGA and GA algorithm accordingly. As displayed in Fig. 8 below for case 2, conventional GA shows 0.9939 p.u at bus number 4 and 5 but SIGA algorithm successfully increases the previous bus number value to 0.9972 p.u. For the next bus number, SIGA algorithm demonstrates steady improvement of voltage profile and securely maintains this pattern until bus number 33 but somehow still gain maximum at bus number 19.

Meanwhile, Fig. 9 presented the voltage profile for case 6 that exhibits the ability of SIGA algorithm to surge the voltage profile of that conventional GA. This has been proved when looking at bus number 3 until bus number 18 where SIGA algorithm shows huge improvement of voltage profile comparable with GA. Then, the

voltage profile rises to maximum value at bus number 19 before both algorithm suffers rapid drop of voltage profile at bus number 32 and 33.
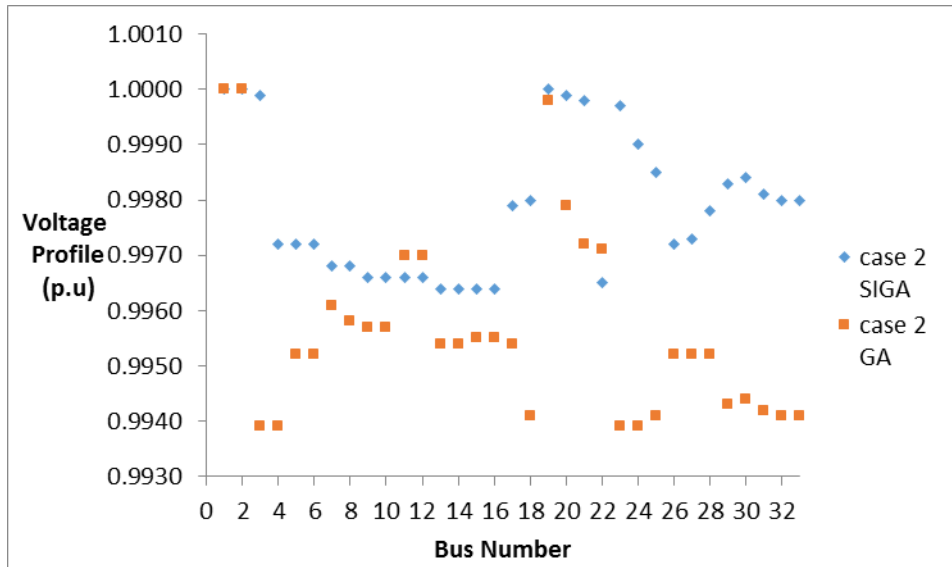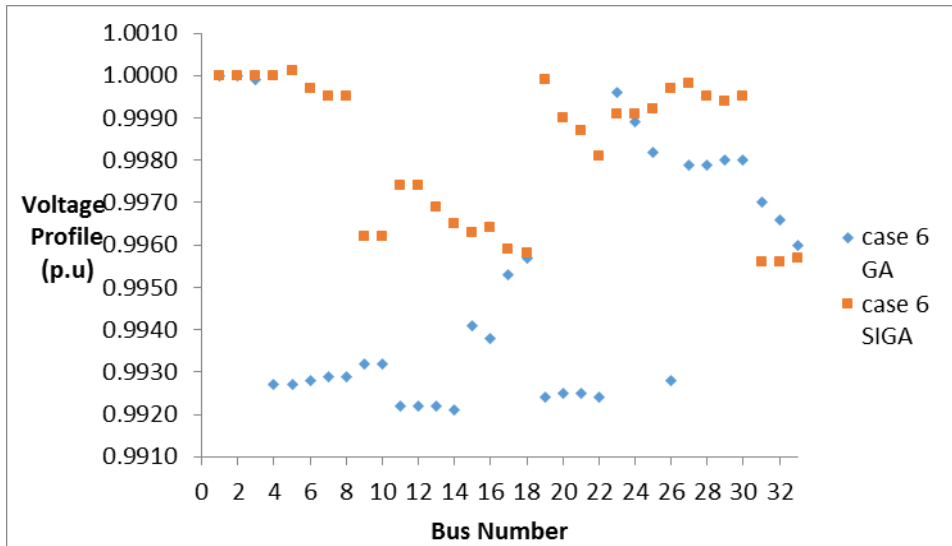

Fig. 8. Voltage Profile for Case 2

Fig. 9. Voltage Profile for Case 6

After analyzing all eight cases that involve both regulated value of (pc) and (pm), it shows that both GA and SIGA are able to produce voltage profile within allowable range which is 0.95 p.u until 1.0 p.u. However, SIGA algorithm illustrates a firm improvement of voltage profile while GA have unstable improvement for each number of buses. Thus, SIGA algorithm has the proficiency of improving the voltage profile of that conventional GA.

VI. CONCLUSION

The optimization of power losses and voltage profile improvement in IEEE-33 bus distribution system using SIGA algorithm for DNR has been successfully carried out in MATLAB vr2013. The validity of the proposed algorithm is performed by adjusting the parameters that influences the power losses and voltage profiles. The parameters regulated are genetic operator probabilities inclusive of crossover and mutation whereby the results show that both GA and SIGA results in reduction of power losses and improvement of voltage profile but somehow SIGA algorithm demonstrates higher reduction of power losses and better improvement of voltage profile compared than the GA algorithm.

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