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Performance Analysis of Harer Distribution System with Ring Topology and Integration of Renewable Energy Source

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Abstract:- A radial distribution system, which is typical for the Ethiopian electric power distribution network, particularly a radial distribution system of Harer, having higher power loss and poor voltage profile during heavy load conditions. In this paper, a technique has been established by converting existing systems to Ring topology and integration with Distributed Generation (DG) in the Harer distribution system. A Metaheuristic Particle Swarm Optimization (PSO) based is deployed for optimal Distributed Generation (DG) so, significantly minimizes the power loss and enhances the voltage profile of the system. The proposed method is tested by using MATLABR2017a and ETAP16 software. The objective function is evaluated by considering constraints such as voltage profile. The simulation results of Harer distribution System show that 75.9 kW active powers can be saved by applying the proposed method and also the entire bus's voltage profile is minimum voltage 0.78973 and a maximum of 1.000 are maintained within the IEEE acceptable range except for minimum voltage (Ring with Dg). In the end, reliability improvement of Harar Distribution system (from Radial to Ring with Dg) of SAIFI (f/customer.yr), SAIDI (hr/customer.yr) and EEN (Mwhr/yr) are 17.0493, 414.3857& 1031.956 to 11.05617, 270.1666 & 565.619 respectively. The cost - effectiveness and payback period are also assessed and the results obtained demonstrate that 476,302.22 Birr can be saved each year after 5 years from when the DG unit is integrated into the system.

Keywords: - Distribution System, Distribution Generation, Radial System, Ring System, PSO, MATLABR2017a, ETAP16

1. INTRODUCTION

WE are in need of energy for our industrial, commercial, and day - to - day activities, and we use energy in different forms. Out of all the forms of energy, electric energy is the most important one as it can be generated (actually converted from other's forms of energy) efficiently transmitted easily, and utilized ultimately at a very reasonable cost. At present, in many electric utilities, acceptable levels of service continuity are determined by comparing the actual interruption frequency and duration indices with arbitrary targets. Historically, the attention to distribution reliability, planning was proportional to the operating voltage of utilities and the primary focus was on generation and transmission reliability studies [1]. Nowadays, electric energy is considered an essential good, so it is extremely important to guarantee service continuity and minimize all interruptions, the accidental as well as maintenance action [2]. It has, however, been reported in the technical literature that approximately 80% of the customer interruption occur due to the problem in the distribution system [3]. Detailed reliability evaluation of the distribution system has, therefore, become very important in the planning and operating stage of a power system. For economic reasons, minimization of the losses in the distribution system should also be considered in a distribution system reconfiguration process [4]. Changing the environment of power system design and operation has necessitated the need to consider an active distribution network by incorporating DG units [5]. Distribution Generation which is grid-connected or stand-alone is a small generating plant directly connected distribution network. The integration of DG in the distribution system would lead to improved voltage profile and reducing active power loss [6], [7]. Optimization is a mathematical tool to identify the location and size of DG with certain limits and constraints. There are different Optimizations approaches that have been deployed for seeking its solution. They are the Apart from Analytical and Numerical approach, there is also a Heuristic method that has been introduced particularly PSO [8]. A novel PSO algorithm for distribution network for minimization active power loss and improvement of voltage profile with respect to their loading capacity. This method avoids premature convergence as well as converging towards global optima [5]. Optimal Siting and Sizing of Renewable Energy Resource for Power Loss Reduction in Radial Distribution System Using Whale Optimization Algorithm [9]. The paper was presented to determine the suitable location, type, and size of the DG unit to minimize the power loss and to improve the voltage profile in the distribution network. In order to test and validate the performance IEEE-33- bus and IEEE-69 bus systems have been considered. Combined loss sensitivity is used to identify the optimal location and whale optimization is used for optimal siting of DG. Therefore, type -2 DG unit performance is better in terms of power loss minimization and overall system voltage profile. Power Loss Reduction Strategy of Distribution Network with DG Integration [10]. The paper proposed a strategy of power loss reduction of radial distribution network with (DG) integration based on a fuzzy multi-objective method in order to improve the distribution system efficiency. Multi-objective functions are considered for power loss reduction, minimization of bus voltage deviation and maintaining the load balancing among feeders of the distribution network.

The proposed approach is tested on a Harer Distribution system. Particle Swarm Optimization (PSO) the method is proposed in this paper. This method is identifying the best location and size of Distribution Generation (DG). In this paper, the ETAP16 tool is used for evaluating the voltage Profile and total power loss of the system.

2.1. MATERIAL AND METHODS

2.2. Description of Study Areas

Ethiopia is a country in the horn of Africa and the total area is covered by 1.13 million square KM. Ethiopia is a highland country with 65 % of its total area having an elevation of more than 1400 meters above sea level and- a substantial area lying well over 3000M. The current population of the country is 114,742,892 million and the growth rate will be 2.57 per year [11]. Average annual GDP growth rate approximately 10.7% for last the 10 years [12]. Harer is a walled city in eastern Ethiopia. It is the capital of East Hararghe and the capital of the Harer Region of Ethiopia. The city is located on a hilltop in the eastern extension of the Oromia, about five hundred kilometers from the national capital Addis Ababa at an elevation of 1,885 meters and location coordinates: $9^0 19'$N$42^0 7'$E.

2.3. Particle Swarm Optimization (PSO)

Particle Swarm Optimization is one of the most popular nature-inspired metaheuristic optimization algorithm developed by James Kennedy and Russel Elberhart in 1995 [13], [14]. It's inspired by the social behavior of bird flocking or fish schooling. By definition Particle, A swarm is an approach to problems whose solution can be represented as a point in an n-dimensional solution space [15]. During every iteration, the particle observe the ''fitness'' of themselves and their neighbors and ''emulate'' successful neighbors (those whose current position represents a better solution to the problem than theirs) [16]. Particle velocities on each dimension are limited to a maximum velocity Vmax. If the sum of the velocity of all the particles exceeded Vmax, then their velocities are limited to Vmax [16].

There are many ways to define a ''Neighbored'' [13], [14] but we can distinguish them into two classes: (i)'' Physical'' Neighbored, which takes distance into account. (ii) ''Social'' Neighbored, which just take the relationship into account.

The difference steps of PSO are as follows [17]:-

1) Set parameters ω_{min},ω_{max},c_1 and c_2 of PSO.
2) Initialize population of particle having position X and V.
3) Set iteration k=1.
4) Calculate fitness of particle F_i^k=$f(X_i^k)$, $\forall_i$ and find the index of best particle i.
5) Select $pbest_i^k$=X, $\forall_i$ and $Gbest^k$=X_b^k
6) ω=ω_{max} - $\frac{Kx(\omega_{min}-\omega_{max})}{maxite}$
7) Update velocity and position particle
   $v_{i,j}^{k+1} = \omega x\ V_{i,j}^k + c_1$ x rand ()x$\left(pbest_{i,j}^k - X_{i,j}^k\right)$+$c_2$x rand() x $\left(Gbest_j^k - X_{i,j}^k\right)$; $\forall_j$ and $\forall_i$
   $X_{i,j}^{k+1} = X_{i,k}^k + V_{i,j}^{k+1}$; $\forall_j$ and $\forall_i$
8) Evaluate fitness F_i^{k+1} = $f(X_i^{k+1})$, $\forall_i$ and the index of the best particle b_1
9) Update $pbest$ of population $\forall_i$
   If F_i^{k+1} < F_i^k then $pbest_i^{k+1} = X_i^{k+1}$ else $pbest_i^{k+1}$ = $pbest_i^{k+1}$
10) Update $Gbest$ of population if Fb_1^{k+1} < F_b^k then $Gbest^{k+1}$ = $pbest_{b1}^{k+1}$ and set $b = b_1$ else $Gbest^{k+1}$ = $Gbest^k$
11) If $k < maxite$ then $k = k + 1$ and go to step 6 else go to step 12.
12) Print optimal solution $Gbest^k$

The most common used parameter of PSO algorithm are considered as follows: (Mohamad Nabab Alam, 2016)

- Inertia weight (ω): 0.9 to 0.4
- Acceleration factors (c_1 and c_2) : 2 to 2.05
- Population size : 10 to 100
- Maximum iteration (maxite) : 500 to 10000
- Initial velocity : 10% of position

Detail flow of PSO considering the above steps

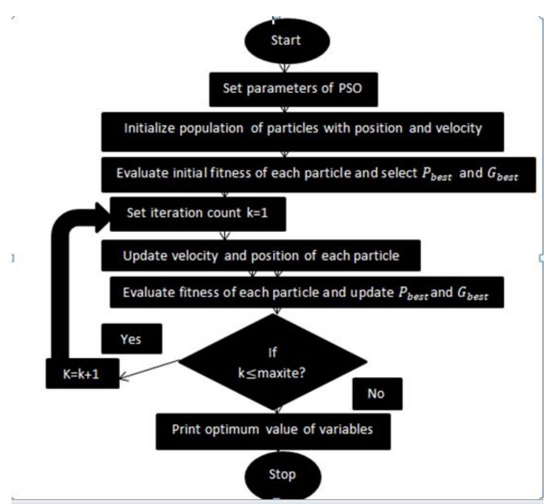

Fig.1. Flow chart of PSO

2.4. Objective function

As the main, the objective of this work is to determine the performance of Harer Distribution system by converting existing to ring with Dg and to find optimal location and sizing of the distributed generation in the distribution system to minimize the losses (active power loss), the following objective function is selected as:

$$F = Ploss_{minimization} = \sum_{k=1}^{n+1} |I_k|^2 \ R_k \qquad (1)$$

Where

F : is the objective function to minimize power losses

$P_{loss:}$: is the active power loss

n^{th} : is the number of line in the distribution system.

Subject to constraint

$$V_i^{min} \leq V_i \leq V_i^{max}$$

Where

V_i : is voltage magnitude

Problem formulation

The problem formulation for the optimal location and sizing of the distributed generation in the distribution system to minimize active power loss. The distribution generation is considered as active power generation at a particular voltage, which is at a unity factor. The wells know basic load flow equations are [13] [7]

$$S_i = P_i + jQ_i = V_i I_i^* \qquad (2)$$

$$= V_i \sum_{k=1}^{n} Y_{ik}^* = \sum_{k=1}^{n} |V_i| |V_k||Y_{ik}| < (\delta_i - \delta_k + \theta_{ik}) \qquad (3)$$

Resolving into real and imaginary parts, them the load flow equation without DG are given as

$$P_i = \sum_{k=1}^{n} |V_i| |V_k| |Y_{ik}| \cos(\delta_i - \delta_k + \theta_{ik}) = PG_i + PD_i \qquad (4)$$

$$Q_i = \sum_{k=1}^{n} |V_i||V_k| |Y_{ik}| \sin(\delta_i - \delta_k + \theta_{ik}) = QG_i + QD_i \qquad (5)$$

The basic power balance equation

$$PG_i = PD_i + P_L \qquad (6)$$

$$QG_i = QD_i + Q_L \qquad (7)$$

The power flow equation considering losses with DG for practical distribution system and the DG is an active source of the unity power factor (PV generator). Then, power flow is given as:

$$P_i + PDG_i = PD_i + P_L \qquad (8)$$

$$Q_i + QDG_i = QD_i + Q_L \qquad (9)$$

The DG is active source only at unity power factor so $QDG_i = 0$, then we have

$$P_i + PDG_i = PD_i + P_L \qquad (10)$$

$$Q_i = QD_i + Q_L \qquad (11)$$

The final power flow equation for distribution system is:-

$$\sum_{k=1}^{n} |V_i| |V_k||Y_{ik}| \cos(\delta_i - \delta_k + \theta_{ik}) + PDG_i = PD_i + P_L \qquad (12)$$

$$\sum_{k=1}^{n} |V_i| |V_k||Y_{ik}| \sin(\delta_i - \delta_k + \theta_{ik}) = QD_i + Q_L \qquad (13)$$

$$\sum_{k=1}^{n} |V_i| |V_k||Y_{ik}| \cos(\delta_i - \delta_k + \theta_{ik}) + PDG_i - PD_i - P_L = 0 \qquad (14)$$

$$\sum_{k=1}^{n} |V_i| |V_k| |Y_{ik}| \sin(\delta_i - \delta_k + \theta_{ik}) - QD_i - Q_L = 0 \qquad (15)$$

$$Pi^{min} \leq P_i \leq Pi^{max} \qquad (16)$$

$$Qi^{min} \leq Q_i \leq Qi^{max} \qquad (17)$$

$$Vi^{min} \leq V_i \leq Vi^{max} \qquad (18)$$

$$PDG^{min} \leq PDG \leq PDG^{min} \qquad (19)$$

Where,

$P_{i,} Q_i$: Real and reactive power flow at bus i

PD_i, QD_i : Real and reactive load at bus i

V_i, V_k : Voltage magnitude at bus i and k.

PDG_i: Real power of DG at bus i

N: Total number of bus

δ_i, δ_k : Voltage angle of bus i and k

.Y_{ik} : Magnitude of the ik^{th} element in bus admittance matrix

Q_{ik}: Angle of the ik^{th} element in bus admittance matrix

2.5. ETAP Implementation of Test of System

In this work, we have presented the load flow and reliability simulation results of the 12-bus distribution system using ETAP (Electrical Transient Analyzes Program) [16].

2.6. Introduction to ETAP (Electrical Transient Analyzes Program)

Modeling and simulation software hold great value for the power system designer. Engineers have to use this software all the time to analyze and test what they are designs before actual implementation. Software is used for various analyses example, Cost benefits analysis, feasibility analysis, and protection coordination, etc before deploying the system. ETAP is full - spectrum analytical engineering software developed by Operational Technology Inc. (OTI) the software specializing in the analysis, simulation, monitoring, control, optimization, and automation of electrical power systems. ETAP software offers the most comprehensive and integrated suite of power system enterprise solutions that spans from modeling to operation. ETAP software provides a good interface for performing rigorous analysis on the electrical power system and is one of the best in Electrical Transient Analysis Software. ETAP software provides a good interface for performing rigorous analysis on the electrical power systems and is one of the best in Electrical Transient Analysis Software.

2.7. Harer 12 Bus Radial Distribution System

The distribution system of Harer was simulated with the help of ETAP 16 software and its diagram is presented in fig.2. A load flow analysis was performed without connecting any DG in order to calculate voltage profile at each bus, real and reactive power losses in each line by using busload and line data in table 1.

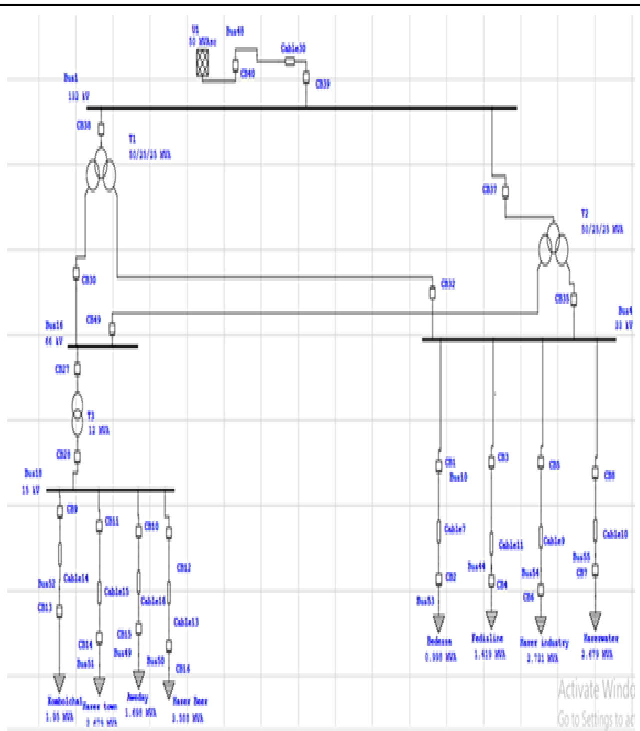

Fig.2. Radial system of Harar Distribution.

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TABLE 1
RADIAL HARER DISTRIBUTION SYSTEM BUS LOADING AND LINE DATA

No	PLoad(KW)	QLoad(KW)	No	Sending Bus	Receiving Bus	R(ohm)	X(ohm)
1	2562	684	1	1	2	5.34	69.38
2	2108	1256	2	2	3	0.09	0.04
3	668	604	3	3	4	0.03	-0.02
4	455	29.9	4	4	5	1209.12	266.12
5	75.8	3.1	5	5	6	314.99	122.44
6	49.3	1.8	6	6	7	3606.21	130.3
7	95.8	3.3	7	7	8	11636.05	420.6
8	176	14.4	8	8	9	9661.13	1273.
9	272	18	9	9	9	1477.20	247.8
10	246	11	10	10	11	4347.51	573.0
11	544	12.7	11	11	12	7.54	14.69
12	776	52.8	12	12	12	805.76	474.4

The 12 Bus Radial Distribution the System of Harer is shown in fig.2. It consists of 12 buses, 12 lines (branches), 8 loads and 1 power grid. All buses have a voltage level of 132KV, 66KV, 33KV, and 15KV respectively. The network is fed from the main substation through an overhead distribution line while it is loaded from 2.567MW and 0.179MVAR.

3. RESULT AND DISCUSSION

3.1. Radial or Existing System

TABLE 2
VOLTAGE PROFILE

No. of Bus	Voltage (pu.)
1	1.0000
2	0.5758
3	0.5759
4	0.5760
5	0.7833
6	0.8443
7	1.7407
8	2.0011
9	3.8748
10	4.1147
11	4.6982
12	4.6989

For the radial system, we can determine power loss, voltage profile, and system index by using bus data and line data as input from table 1. By apply load flow using ETAP we can determine voltage profile and power loss by feeding the bus data and line data.

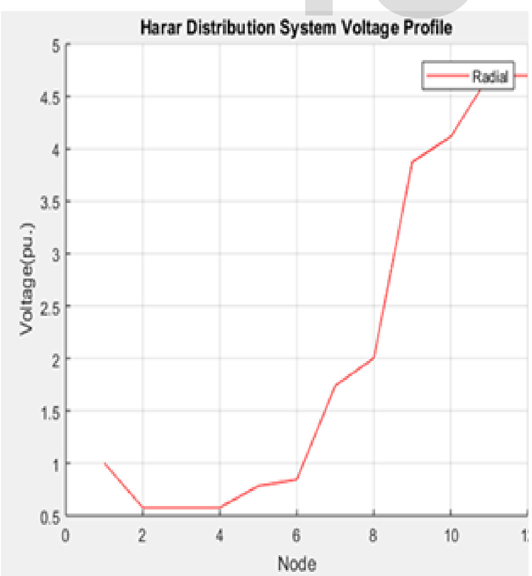

Fig.3. Voltage Profile

Fig.3. voltage profile for radial Harar distribution system. As it can be observed the radial voltage profile of all buses except bus 1 are below the minimum threshold value (0.95pu) and Bus 6,7,8,9,10,11,12 are above a maximum

TABLE 3
POWER LOSS

No. of Lines	Ploss(Active Power in KW)	Qloss(Reactive Power inK
1	5.0	9.7
2	9.7	2.1
3	201.3	7.3
4	56.7	33.4
5	141.6	-2933.0
6	0.1	1.4
7	3.2	0.1
8	50.2	6.6
9	1.4	0.2
10	2.7	0.4
11	0.00	0.06
12	0.00	0.00
Total	332.3	62.0

threshold value (1.05pu). Bus 2 presents the lowest voltage

TABLE 4
SYSTEM INDEX

System Index	Values
SAIFI (f/cust.yr)	17.0493
SAIDI (hr/cust.yr)	414.3857
EENS(MW.hr/yr)	1031.956
AENS (MWhr/customer.yr)	128.9945

profile among other buses

3.2. Ring Distribution System

For Harer distribution system 12 bus radial network, six additional lines have been connected. Line 29 between bus 29 and 36, line 30 between bus 36 and 37, line 31 between bus 37 and 38, line 32 between bus 39 and 40, line 33 between bus 40 and 41, line 34 between bus 41 and 5 to form a loop. Both the lines are 50m and follow ICEA rubber line configurations as shown. The rating of buses such as 29, 36, 37, and 38 are 15KV and the rest of the buses are rated 33KV. To synchronize the voltage rating of every bus, a transformer is used between bus 38 and 39 to step up the bus voltage from 15KV to 33KV.

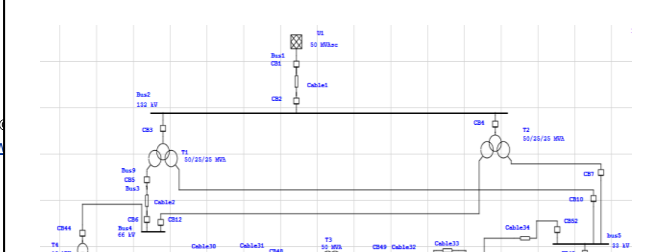

TABLE 5

RING SYSTEM HARER DISTRIBUTION SYSTEM BUS LOADING AND LINE DATA

Bus	Pload (KW)	Qload (KVAR)	Line	Sending Bus	Receiving	R (ohm)	X (ohm)
Bus 2	1791	370	T3	Bus 20	Bus22	1.28	16.65
Bus 4	192	111	T4	Bus 4	Bus 29	5.34	69.38
Bus 6	1917	459	T1	Bus 2	Bus 9	0.09	0.04
Bus 9	126	111	T2	Bus 2	Bus 4	0.03	-0.02
Bus 12	61	2.7	Cable1	Bus 1	Bus 2	340.82	6.76
Bus 14	94.4	3.3	Cable 2	Bus 9	Bus 4	1.00	0.04
Bus 19	121	4.2	Cable 6	Bus 29	Bus 12	1939.341	701.13
Bus 25	207	5.3	Cable 7	Bus 29	Bus 13	5818.02	2103.4
Bus 26	352	8.1	Cable 8	Bus 13	Bus 14	5818.02	2103.4
Bus 27	406	10.4	Cable 9	Bus 13	Bus 16	4006.90	1893.0
Bus 28	269	8.8.	Cable 11	Bus 18	Bus 16	2804.83	1014.0
Bus 29	72.5	20.5	Cable 12	Bus 18	Bus 19	1001.73	473.2
Bus 36	107	17.4	Cable 13	Bus 18	Bus 20	2404.14	869.2
Bus 37	107	13.9	Cable 14	Bus 22	Bus 25	4.93	0.33
Bus 38	239	13.9	Cable 15	Bus 22	Bus 23	4.93	0.33
Bus 39	471	9.2	Cable 16	Bus 23	Bus 26	4.93	0.33
Bus 40	875	9.9	Cable 17	Bus 18	Bus 20	1.00	0.04
Bus 41	1309	13.6	T3	Bus 20	Bus 20	1.28	16.65

The 19-bus Ring the Distribution System of Harar is consists of 19 buses, 19 lines (branches), 8 loads and 1 power grid. All buses have a voltage level of 132KV, 66KV, 33 KV, and15KV respectively. Then, network is fed from the main substation through an overhead distribution line while it is loaded from 1.766 MW and 0.0479MVAR.

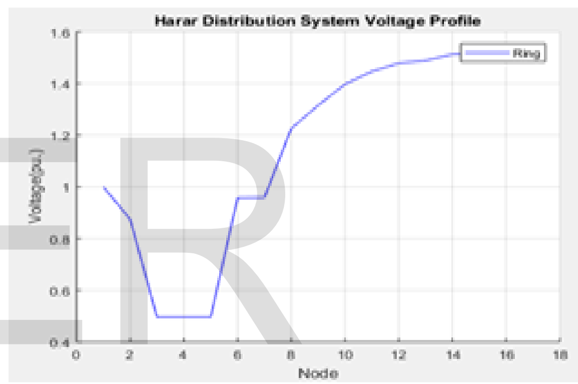

Fig.5. Voltage Profile

TABLE 6

VOLTAGE PROFILE

No. of Bus	Voltage (pu.)
1	1.000
2	0.8747
3	0.4963
4	0.4963
5	0.4963
6	0.9568
7	0.9584
8	1.2261
9	1.3156
10	1.3971
11	1.4460
12	1.4790
13	1.4892
14	1.5134
15	1.5185
16	1.5232
17	1.5270

No of Bus	Ploss (Active Power in KW)	Qloss (Reactive Power in KVAR)
1	106.4	2.1
2	0.0	0.0
3	0.0	0.0
4	23.3	0.8
5	0.0	-2.5
6	11.6	0.4
7	24.4	1.2
8	51.7	1.9
9	20.6	1.0
10	0.0	0.00
11	0.00	0.00
12	0.0	0.00
13	0.0	0.1
14	0.0	-0.2
15	0.0	-0.2
16	0.0	0.0
Total	256.4	5.2

TABLE 8

SYSTEM INDEX

System Index	Values
SAIFI (f/cust.yr)	15.9380
SAIDI (hr/cust.yr)	385.1297
EENS(MW.hr/yr)	784.376
AENS (MWhr/customer.yr)	112.0537

As it can be observed the ring voltage profile of buses 2,3,4,5 are below the minimum threshold value (0.95pu) and Bus 8,9,10,11,12,13,14,15 are above maximum threshold value (1.05pu). Bus 3, 4, 5 presents the lowest voltage profile among other buses. But its show that remarkable improvement to achieve the target.

TABLE 10

VOLTAGE PROFILE

Bus	Voltage (p.u.)
1(Bus 1)	1.0000
2(Bus 2)	0.93976
3(Bus 4)	0.93976
4(Bus 6)	0.93976
5(Bus 9)	0.93975
6(Bus 12)	0.78973
7(Bus 14)	0.87692
8(Bus 19)	0.85782
9 (Bus 20)	0.84072
10(Bus 25)	0.81919
11(Bus 26)	0.89421
12(Bus 27)	0.86489
13(Bus 28)	0.93968

By using the PSO code we can determine the size and location of DG respectively.

3.3. Dg connected with the Ring system

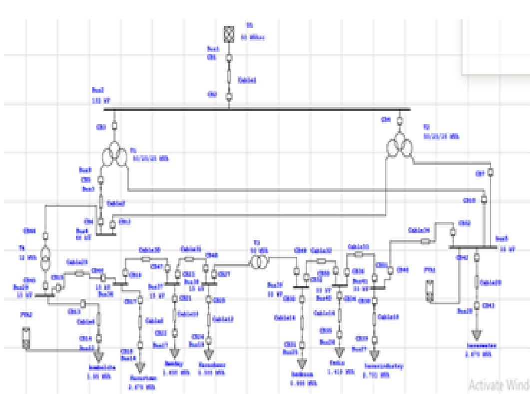

Fig.6. Voltage Profile

After optimal placement and size the voltage profile and power loss as follows:

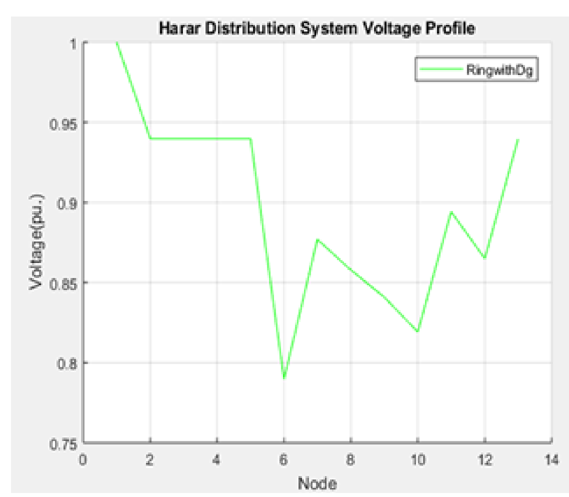

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TABLE 11

POWER LOSS

No. of Lines	Ploss (Active Power in KW)	Qloss(Reactive Power in KVAR)
1	106.4	2.1
2	0.0	0.0
3	0.0	0.0
4	23.3	0.8
5	0.0	-2.5
6	11.6	0.4
7	6.8	0.2
8	11.5	0.4
9	24.4	1.2
10	51.7	1.9
11	20.6	1.0
12	0.00	0.00
13	0.00	0.00
14	0.00	0.00
15	0.00	0.1
16	0.00	-0.2
17	0.00	-0.2
Total	245.6	1.2

TABLE 12

SYSTEM INDEX

System Index	Values
SAIFI (f/cust.yr)	11.05617
SAIDI (hr/cust.yr)	270.1666
EENS(MW.hr/yr)	565.619
AENS (MWhr/customer.yr)	80.8027

As it can be observed the ring voltage profile of all buses except bus 1 is below the minimum threshold value (0.95pu). Bus 6 presents the lowest voltage profile among other buses. But it shows that remarkable improvement to achieve the target.

TABLE 13

SYSTEM INDEX

System Index	Radial	Ring	Ring with DG
SAIFI (f/cust.yr)	17.049	15.9380	11.05617
SAIDI (hr/cust.yr)	414.3857	385.1297	270.1666
EENS(MW.hr/yr)	10131.956	784.376	565.619
AENS (MWhr/customer.yr)	128.9945	112.0537	80.8027

3.4. Summary result of Harar Distribution system

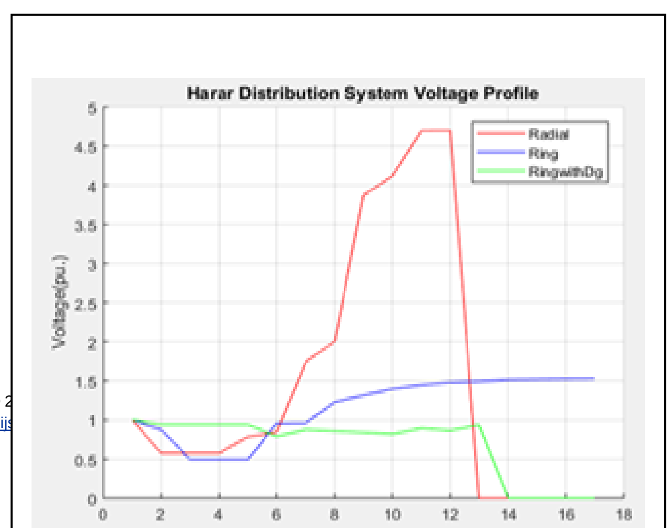

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TABLE 14

HARER DISTRIBUTION SYSTEM SUMMARY IN ALL CASES

Scenarios	Performance analysis in all Scenarios	
Radial (Scenario 1)	Active Power loss (KW)	332.3
	Reactive Power loss (KVAR)	62.0
	Minimum voltage (pu.)	0.5758 (Bus 2)
	Maximum voltage (pu.)	4.6989 (Bus 12)
	SAIFI (f/cust.yr)	17.0493
	SAIDI (hr/cust.yr)	414.3857
	EENS(MW.hr/yr)	10131.956
	AENS (MWhr/customer.yr)	128.9945
Ring (Scenario 2)	Active Power loss (KW)	256.4
	Reactive Power loss (KVAR)	5.2
	Minimum voltage (pu.)	0.4963 (Bus 3,4, and 5)
	Maximum voltage (pu.)	1.5270 (Bus 17)
	SAIFI (f/cust.yr)	15.9380
	SAIDI (hr/cust.yr)	385.1297
	EENS(MW.hr/yr)	784.376
	AENS (MWhr/customer.yr)	112.0537
Ring with DG (Scenario 3)	Dg size in (KW)	57.36 and 83.06
	Dg location	5 and 12
	Active power loss (KW)	245.6
	Reactive power loss(kvar)	1.2
	Minimum voltage (pu)	0.78973 (Bus 6)
	Maximum voltage (pu)	1.0000 (Bus 1)
	SAIFI f/customer.yr)	11.05617
	SAIDI (hr/customer.yr)	270.1666
	EENS (MWhr/yr)	565.619
	AENS (Mw hr/customer.yr)	80.8027

The simulation results reveal that the voltage profile of the system is significantly improved after the ring with DG is connected as shown in fig.8. above. The minimum voltage before the system connected with DG was 0.5758pu, and it is improved to 0.78973pu after the system is connected to the ring with DG by using PSO optimization. The ring with DG diagram is presented in figure 6 the voltage profile of all buses is improved.

TABLE 15

INITIAL CAPITAL COST OF SOLAR PLANT ACCORDING CURRENT MARKET ASSESSMENT

Type of Equipment	Price in ETB for 1MW	Price in ETB for 125K
Solar panel	10.0711 million	1.25888 million
Inverter	3.486 million	0.43575 million
Batteries	2.124 million	0.2655 million
Mounting structure and	2.425 million	0.303125 million
Fencing material cost with Accessories		
Installation and maintains cost (10% of total cost)	1.8106 million	0.22635 million

3.5. Cost of Energy loss on Harar distribution system

Based on Ethiopia electric bill tariff cost of energy loss of distribution system is calculation using:-

$$\text{Cost Energy Loss} = \$((\text{Total real powr loss in kw}) * (Ec * T)) \quad (20)$$

Where Ec, Ethiopian electric billing tariff.

T:- time in hour

- Radial system
  - Energy loss=332.3 KWhr/yr and the tariff based on range is 0.5880 Birr/KWhr
  - Cost of energy loss per year for radial =1,711,637.42 ETB/yr
- Ring with DG
  - Energy loss per year=256.4KWhr/yr and the tariff based on range is 0.5500birr/KWhr.
  - Cost of energy loss per year for Ring with DG =1,235,335.2 ETB/yr.

  - By using payback equation 21, since saving cost and energy are 476,302.22 ETB/yr and 75.9 KWhr/yr respectively.

- The capital cost and connected PV is close to 1MW/125 KW.
- The capital cost from table 12, according to market assessment price including PV accessories and installation cost for 1Mw/125KW is 19.9167 /2.491355million birr.

$$\text{Payback period} = \frac{\text{Captial Cost (ETB)}}{\text{Saving Cost (Birr/yr)}} \quad (21)$$

- $\text{Payback period} = \frac{2.491355 \text{ million ETB}}{476{,}302.22 \text{ ETB/yr}} =$ 5.23 yr.

So that, the cost of DG can be paid from the 5.23 yearly revenue losses from distribution system.

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

In this research work, an efficient method has been implemented during DG integration and installs DG units simultaneously in distribution systems. In addition, different loss reduction methods (Radial, Ring, and Ring with DG) are also simulated to establish the superiority of the proposed method. A Metaheuristic PSO is used in the optimization process for DG integration. The proposed method is tested on Harar Distribution System. The results show that 75.9 kW active power and 476,302.22 Birr/year can be saved by applying the proposed method and also the entire buses voltage profile are minimum voltage 0.78973 and a maximum of 1.000 are maintained within the IEEE acceptable range except for minimum voltage (Ring with DG). The minimum voltage profile is 0.78973 which confirms DG installation method is more effective in reducing power losses and improving the voltage profile compared to other methods. In the end, reliability improvement of Harar Distribution system (from Radial to Ring with DG) of SAIFI (f/customer.yr), SAIDI (hr/customer.yr) and EEN (Mwhr/yr) are 17.0493, 414.3857& 1031.956 to 11.05617, 270.1666 & 565.619 respectively.

The cost effectiveness and payback period are also assessed and the results obtained demonstrate that 476,302.22 Birr can be saved each year after 5 years from when the DG unit is integrated into the system.

4.2. Recommendation

First of all, I strongly recommend that further researches shall be done on the protection and controlling of the upstream and downstream side of the system when DG is connected and installed. However, DG integration to the existing system can bring have an impact on the system such as poor system instability; reverse current flow, higher fault current harmonics, and the complexity of the network.

Finally, I highly recommend to Ethiopian Electric Utility (EEU) to apply Dg integrated system for Harar Distribution System in order to improve the existing system (Voltage profile, power loss and reliability) data recording method and existing data should be documented in an advanced manner.

5. ABBREVIATIONS

DG = Distribution Generation

ETB = Ethiopian Birr

E-TAP = Electrical Transient Analysis Program

IEEE = International Electrical and Electronics Engineering.

PSO= Particle Swarm Optimization

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REFERENCES

[1] Valter Santos, Adelino J.C. Pereira, C.M. Machado Ferrira, "Effective and Simple Measure to Improve the Electric Power Distribution System Service Conitutity," *IEEE*, 2014.

[2] R.C.Dugan,M.F.McGranaghan, S.Santos and H.W. Beaty, *Electrical Power Quality.*: Mc Graw- Hill,

2012.

[3] Ali A. Chowdhury and Don O. Koval, *Power Distirbution System Reliability: Practical Methods and Application*.: IEEE Press Series in Power Engineering, 2009.

[4] B. Amanulla, S Chakrabarti, SN. Singh, "Reconfiguration of Power Distribution System Considering Reliability and Power Loss," *IEEE Transaction on Power Delivery*, pp. 918-26, 2012.

[5] J.Z. Zhu, "Optimal reconfiguration of electrical distribution network using refined genetic algorithim," *Elsevier*, vol. 62, pp. 37-42, 2002.

[6] Paulos S. Georgilakis and Nikos D. Hatziargyriiou, "Optimal Distribution Generation Placement in Power Distribution Networks: Model, Methods and Future Research," *Transtion on Power System*, vol. 28, Aughust 2013.

[7] C.L.Wadhwa, *Electric Power System*, 6th ed.: New age International Publication , 2010.

[8] James Kenndy and Russell C.Eberhart, *Swarm Intilligence*, Yuhi Shi, Ed.: Morgan kaufmann, 2001.

[9] Sabarinath.G, T.Gowri Manoha, "Optimal Sitting and Sizing of Renewable Energy Resource for Power Loss Reduction in Radial Distribution System using Whale Optimization Algorithim," *IEEE*, 2018.

[10] Soedibiye, Mochamed Ashari, Ramadami Syahputta, "Power Loss Reduction Strategy of Distribution Network with DG Integration," *ICITACEE*, 2014.

[11] United Nation, "Live population estimate.," UN, USA, 2020.

[12] Mekuriya Lema, "Ethiopia Electric Power Strategy and Investment ," HeadPower Africa Geothermal Road Show, Addis Ababa , 2014.

[13] J. Kennedy, R.Elberhart, "Particle Swarm Optimization," *IEEE International Confernce on Neutral Network*, vol. 4, pp. 1942-1948, 1995.

[14] R. Elberhart, J.Kennedy, "Anew Optimizet using Particle Swarm Theory ," *IEEE procedding of the six international symposium on micro machine and human science*, pp. 39-43, 1995.

[15] Jamdi S, Rezaei L, and Gudakahriz S., "An Energy-efficient Routing protocol for MANETS: a Particle Swarm Optimizaton Approach ," *Journal of Applied Research and Technology*, vol. 11(6), pp. 803-812, 2013.

[16] Srivatsa Sarat Kumar Sarvelpalli, *Particle Swarm Optimization.* Liverpool Hope University, 2019.

[17] Mnemstudio.org, "Introduction to Particle Swarm Optimization," [online] Avaliable at: http://Mnemstudion.org/Particle Swarm Introudciton.html, 2015.

[18] Hadi Sadat, *Power System analysis*.: TMH Publication , 2002.