Power Loss Minimization of IEEE 33 Bus System with a Unified Approach of AC-DC Hybrid Limited Distribution Systems

Mokkala Chandrika1, Prof G.V.Marutheswar2
1Department of EEE, Student & Sri Venkateswara University College of Engineering,Tirupati,INDIA,
2Department of EEE ,Professor & Sri Venkateswara University College of Engineering,Tirupati,INDIA,

Abstract: A novel approach has been proposed in this paper to find out optimal position of DG units in radial distribution system. In order to find the optimal size, quantity and position of DG units for real power loss reduction and voltage profile enhancement .So a unified load flow (LF) model for AC-DC hybrid distribution systems (DSs) is proposed. The proposed model can be applied in hybrid DSs with mixed configurations for AC/DC buses and AC/DC lines. Such predictions underscore the need for the development of a unified AC-DC load flow (LF) model that can be used for the planning and operation of future hybrid DSs. A set of generic LF equations has been derived based on comprehensive analysis of the possible AC-DC hybrid system configurations. The new model has been tested IEEE 33 bus hybrid DSs that include different operational modes for the AC and DC distributed generators (DGs). As a means of evaluating the effectiveness, accuracy and voltage profile enhancement and power loss minimization in the proposed model, the LF solution was compared to the solution produced by MATLAB/SIMULINK.

Keywords: Load Flow Analysis, AC-DC Hybrid Distribution System, Voltage Source Converter (VSC), Distributed Generation.

I . INTRODUCTION

A wide various applications of micro-grids along with the many benefits, such as energy efficiency, improved Reliability and power quality, and with facilitated integration of renewable resources, So by considering this technology as a main constituent of future power systems. Most of the micro-grids are designed to be AC, similar to the traditional approach to develop and expand power systems. However, after the widespread usage of DC loads, such as data and communication centre's, electronic devices, and electric vehicles, on one hand, and development of DC distributed energy resources (DERs) [2], such as solar PV, fuel cell, and distributed energy storage (DES), on the other hand, DC micro-grids would potentially become more economical than AC.

There are many advantages associated with DC micro-grids [8] such as there is no need for synchronization of DERs, easier integration of DC components, and higher the system efficiency due to elimination of multiple AC-DC converters. Hybrid AC/DC micro-grids are more desirable when both AC and DC loads/DERs exist in the system. Hybrid micro-grids would take advantage of both AC and DC micro-grids by development of AC and DC DERs/loads. In hybrid micro-grids, there are two main bus types, i.e., AC and DC, in which AC components are connected to AC buses and DC components to DC buses. There is a need for bidirectional converters to connect AC and DC buses in the micro-grid .According to the level of generation and loads in different buses in AC and DC networks, power can go from AC to DC network (where the converter acts as a rectifier) or from DC to AC (where the converter acts as an inverter). The micro-grid can be connected to the utility grid from both AC and DC sides. By impressive feature of micro-grid that increases its reliability and resilience is the islanding capability which enables it to be disconnected from the utility grid in case of faults or disturbance in the upstream utility grid. The energy management in micro-grids is very important in both economically and energy wise. So it is more complex when there is a hybrid AC/DC micro-grid instead of individual AC or DC micro-grid

In this paper we introduces a unified LF model that can be applied to hybrid DSs with varied AC-DC configurations.
The proposed model is unique regards for formulation of the unified AC-DC LF equations. In this model, the AC and DC portions of the hybrid network are solved simultaneously by consider different operational modes of the system. The proposed model can be applied to radial or meshed; isolated or grid-connected; and to highly coupled hybrid DSs. The developed model employs three binary matrices to describe the AC-DC configuration of any hybrid DS. VSCs are used in the proposed model for AC-DC power conversions. Generic AC-DC power equations are constructed based on comprehensive analysis of the possible hybrid DS configurations. The new model has been used for solving the LF problem of grid-connected and isolated hybrid DSs. As a means of evaluating the effectiveness and accuracy of the proposed model, the LF results were compared to those obtained from PSCAD/EMTDC software

II. CONFIGURATION OF HYBRID AC/DC SYSTEM

The configuration of the hybrid AC-DC system [5] is shown in Figure 1 where various AC and DC sources and loads are connected to the corresponding AC and DC networks. The AC and DC links are linked together through with AC-DC VSC converters model

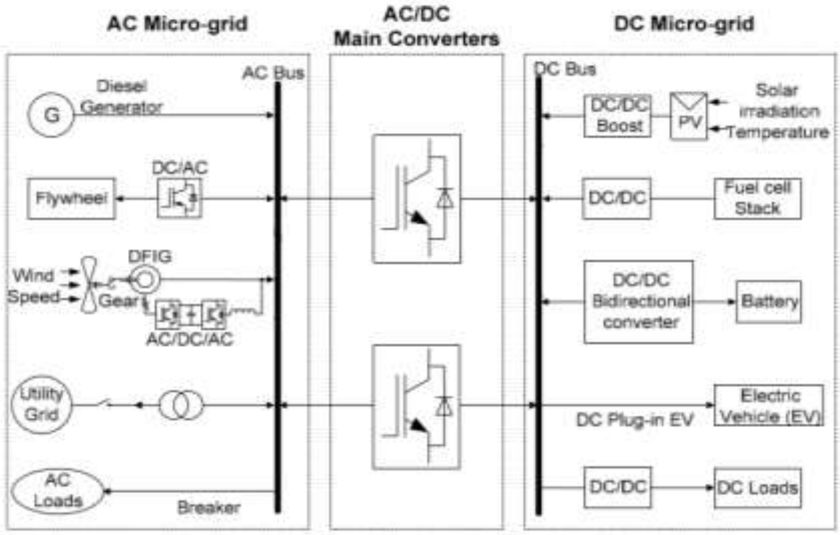

Figure 1. HYBRID AC/DC MICRO-GRID SYSTEM

(A) AC-DC Converter Model

In this study, VSCs are installed in the network lines for AC-DC power conversions. The DC side of the VSC is a unipolar circuit that has two DC lines, as shown in Fig. 2. The converter impedance Z_C shown in Fig. 2 includes the elements connected between the point of common coupling (PCC) and the AC bus of the VSC, such as power transformers, phase reactors, or low pass filters. Since Z_C is connected between two AC buses, it can be modelled.

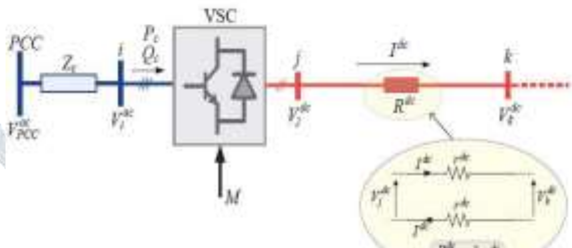

Fig. 2 Model of a voltage source converter

The steady-state model of the VSC can be represented by the following equations.

$$V^{ac}_{i,LL_{rms}} = K_{vsc} M V^{ac}_{base} = K_{vsc} V^{dc}_{base} \quad \ldots\ldots\ldots\ldots\text{..} (1)$$

Where M is the modulation index of the VSC. The value of the converter constant K_{vsc} is dependent on the type of the VSC as well as the type of the pulse width modulation (PWM) strategy [14]

The relation between the AC voltage base and the DC voltage base is given by

$$V^{ac}_{base} = K_{vsc} V^{dc}_{base} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Accordingly, a 1 p.u AC voltage is equivalent to a 1 p.u. DC voltage at a unity modulation index, as expressed

$$V^{ac}_{i.p.u.} = M V^{dc}_{j,p.u.} \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{..} (3)$$

The relation between the DC power and the AC active power [13] is a function of the efficiency η_c of the converter, as follows:

$$P_c = {P_c}^{dc} / \eta_c = (V^{dc}_j I^{dc}) / \eta_c \quad \ldots\ldots\ldots (4)$$

Where the I^{dc} DC current is given by

$$I^{dc} = G^{dc}(V^{dc}{}_j - V^{dc}{}_k) \ldots\ldots\ldots. (5)$$

Substituting (3) and (5) in (4) gives

$$P_c = \frac{G^{dc}{}_{p.u.}}{\eta_c}(M^{-2}(V^{ac}{}_{i.p.u.})^2 - M^{-1}V^{ac}{}_{i.p.u.}V^{Dc}{}_{K,p.u.} \ldots\ldots(6)$$

The reactive power Qc at the AC side of the VSC can be either controlled using a direct set point or calculated as follows:

$$Q_c = P_c \tan\varphi_C \ldots\ldots\ldots\ldots\ldots (7)$$

In order to equalize the loading of the AC and DC sub grids, the active power flow between the two sub grids can be determined using (8). The VSC in an isolated DS can also support the reactive power when the active power flows from the DC side to the AC side. The converter reactive power can then be controlled using the same reactive power droop of an AC DG unless the capacity limit of the VSC is reached .It should be noted that the upper and lower limits of the modulation index should be taken into consideration in order to avoid over modulation and excessive harmonics[15].

$$\widehat{\omega} = \widehat{V}^{dc} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

Where

$$\widehat{\omega} = \frac{\omega - 0.5\,(\omega^{max} + \omega^{min})}{0.5\,(\omega^{max} - \omega^{min})} \ldots\ldots\ldots\ldots\ldots.. (9)$$

$$\widehat{V}^{dc} = \frac{V^{dc} - 0.5\,(V^{dc,max} + V^{dc,min})}{0.5\,(V^{dc,max} - V^{dc,min})} \ldots\ldots\ldots\ldots (10)$$

B. Classification of AC-DC Hybrid Configurations

Here we present the classification of the possible cases of AC-DC connections. AC/DC buses can be interconnected via AC/DC lines and AC-DC converters according to one of the following cases:

1) Connection between Two AC Buses*:* A connection between two AC buses can be achieved using the method exemplified by either Case 1 or Case 2. In Case 1, two AC buses are connected via an AC line, as shown in Fig. 3(a). In this case, the active and reactive power equations[14] are given by

$$P^{(a)}{}_{nm} = V^2{}_n G_{nm} - V_n V_m (G_{nm}\cos\theta_{nm} + B_{nm}\sin\theta_{nm}) \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

$$Q^{(a)}{}_{nm} = -V^2{}_n B_{nm} - V_n V_m (G_{nm}\sin\theta_{nm} - B_{nm}\cos\theta_{nm}) \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

In Case 2, a DC line connects the two AC buses via two AC-DC converters, as shown in Fig. 3(b). The active and reactive power equations are expressed as equation (13) and (14), respectively. The values of a_1 and b_1, obtained from (15) and (16), respectively, are dependent on the direction of the power flow. If the power flows from bus n to bus m, the VSC at bus n functions as a rectifier, while the VSC at bus m functions as an inverter. In this case, the values of a_1 and b_1 become 1 and 0, respectively. In contrast, if the power flows from bus m to bus n, the values

$$P^{(b)}{}_{nm} = G^{dc}{}_{nm}(M^{-2}{}_n V^2{}_n - M^{-1}{}_{nm}V_n M^{-1}{}_{mn}V_m)\left(\frac{a_1}{\eta_{c-nm-r} + b_1\eta_{c-nm-i}}\right) \ldots.. (13)$$

$$Q^{(b)}{}_{nm} = P^{(b)}{}_{nm}\tan\varphi_{c-nm} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

$$a_1 = 0.5(1 + sign(M^{-1}{}_{nm}V_n - M^{-1}{}_{mn}V_m)) \ldots\ldots\ldots\ldots (15)$$

$$b_1 = 0.5(1 - sign(M^{-1}{}_{nm}V_n - M^{-1}{}_{mn}V_m)) \ldots\ldots\ldots\ldots (16)$$

$$sign(x) = \begin{cases} 1 & if \quad x > 0, \\ -1 & if \quad x < 0, \\ 0 & if \quad x = 0, \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

2) **Connection between AC and DC Busses***:* The active and reactive power equations for AC in (18) and (21) respectively .where as the DC power equation for DC is in (22) shown in fig3(a) and 3(b)

$$P^{(c)}{}_{nm} = G^{dc}{}_{nm}(M^{-2}{}_n V^2{}_n - M^{-1}{}_{nm}V_n V_m)\left(\frac{a_2}{\eta_{c-nm-r} + b_2\eta_{c-nm-i}}\right) \ldots.. (18)$$

$$a_2 = 0.5(1 + sign(M^{-1}{}_{nm}V_n - V_m)) \ldots\ldots\ldots\ldots (19)$$

$$b_1 = 0.5(1 - sign(M^{-1}{}_{nm}V_n - V_m)) \ldots\ldots\ldots\ldots (20)$$

$$Q^{(c)}{}_{c-nm} = P^{(c)}{}_{nm} \tan\varphi_{c-nm} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$

$$P^{(d)}{}_{nm} = G^{dc}{}_{nm}(V^2{}_n - V_n M^{-1}{}_{nm}V_m) \ldots\ldots\ldots (22)$$

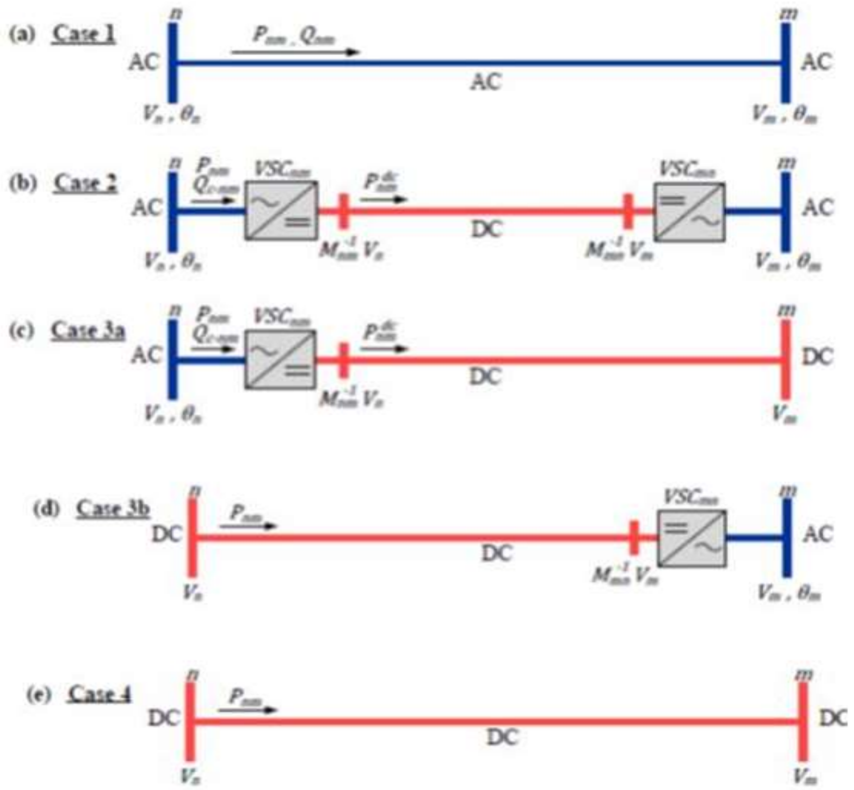

Fig .3: possible connection of AC-DC system

3) Connection between Two DC Buses:

A connection between two DC buses via a DC line, as depicted in Fig. 3€ In this case, the DC power equation is given by

$$P^{(e)}{}_{nm} = G^{dc}{}_{nm}(V^2{}_n - V_n V_m) \ldots\ldots\ldots\ldots\ldots\ldots (23)$$

C .SOLUTION PROCEDURE

The hybrid LF problem is defined by a system of equations that are solved simultaneously by decoupled method. In order to find the LF solution in this study, a generalized reduced gradient (GRG) method is used for solving the optimization problem described below

$$\text{Min } \|F(x)\|_2 \;,\; x \in \mathbb{R}^{n_v} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

Subjected to

$$F(x) = \begin{cases} P^{inj}{}_i - P^{cal}{}_i & ,\forall\, i \in N_b \\ Q^{inj}{}_i - Q^{cal}{}_i & ,\forall\, i \in N_b \\ P^{ac}{}_{Gi} - \frac{1}{\psi^{ac}{}_{p,i}}(\omega_0 - \omega) & ,\forall\, i \in N^{ac}{}_{G-dr} \\ Q^{ac}{}_{Gi} - \frac{1}{\psi^{ac}{}_{q,i}}(V^{ac}{}_{i,0} - V^{ac}{}_i) & ,\forall\, i \in N^{ac}{}_{G-dr} \\ P^{dc}{}_{Gi} - \frac{1}{\psi^{dc}{}_{p,i}}(V^{dc}{}_{i,0} - V^{dc}{}_i) & ,\forall\, i \in N^{dc}{}_{G-dr} \\ \hat{V}^{dc}{}_i - \hat{\omega} & ,\forall\, i \in N_{c-iso} \\ Q_{c-i} - \frac{1}{\psi^{ac}{}_{q,c-i}}(V^{ac}{}_{c-i,0} - V^{ac}{}_{c-i}), & ,\forall\, i \in N_{c-iso} \end{cases} \quad .. (25)$$

F(x) is the set of the system equations that include the power balance equations, the droop equations, and the VSC equations; ($N^{ac}{}_{G-dr}$ and $N^{dc}{}_{G-dr}$) are the number of the droop based AC and DC DGs, N_{c-iso}respectively; is the number of VSCs in an isolated DS;

The first step in the solution procedures is to define the type, the given parameters, and the unknown variables for each bus in the hybrid DS, In the second step, the configuration matrices as well as the AC admittance matrix Y and the DC conductance matrix $G^{dc}$are constructed.

In the third step, the system parameters are converted to per-unit values, and a flat start (V (0) = 1.0 p.u. and θ (0) = 0.0 ◦) is assumed for the unknown system voltages.

III.CASE STUUDIES

In this case study we use IEEE 33 test system with unlimited DG's with network data as shown in the table I and having efficiency for AC-DC converters and power factor of the VSC's installed in the network lines are 95%and bus 1 represents the slack bus. P-V buses are -5,24 and29.and remaining buses are load buses .where in case of isolated AC-DC hybrid (shaded area) represent in figure 4 has been islanded where two more DGS were added ,AC DG at bus 31 and DC DG at bus 16 and they operated as droop-controlled DGs .The active and reactive powers of the two converters (15-16) and (33-18) are controlled autonomously

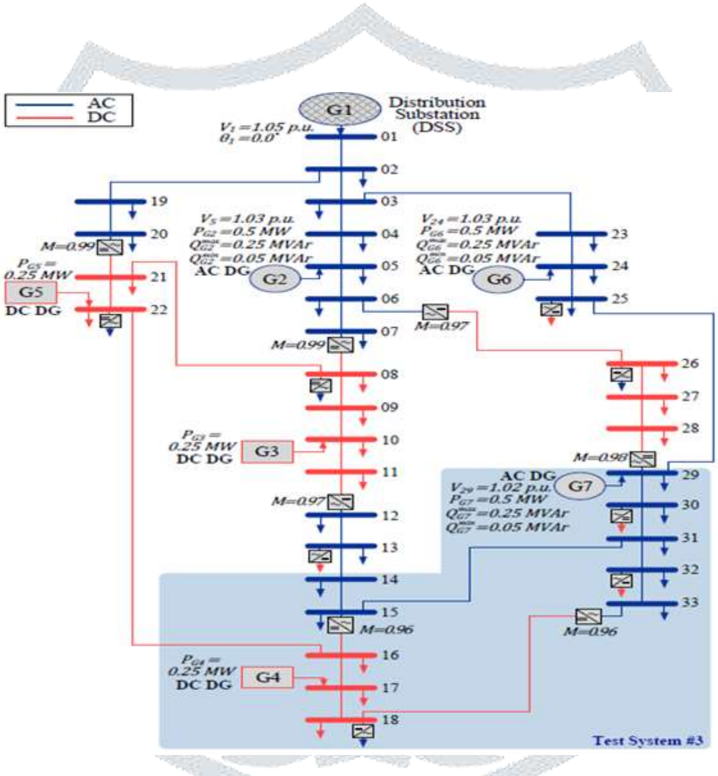

Figure 4:-33 –bus hybrid distribution system

Table 1

NETWORK DATA FOR 33 TEST HYBRID DISTRIBUTION SYSTEM

From Bus n	To bus m	Resistance	Reactance	Bus No	P_L^{ac}(KW)	Q_L^{ac}	P_L^{dc}	V_n(p.u)	$\emptyset_{n(degr.)}$
1	2	0.0922	0.0470	1	-	-	-	1.05000	0.00000
2	3	0.4930	0.2511	2	200	120	-	104709	0.00972
2	19	0.1640	0.1565	3	180	80	-	1.03776	0.02781
3	4	0.3660	0.1864	4	240	160	-	1.03360	0.03682
3	23	0.4512	0.3083	5	125	60	-	1.03000	0.05114
4	5	0.3811	0.1941	6	200	100	-	1.01912	0.27694
5	6	0.8190	0.7070	7	200	100	-	1.01869	0.29890
6	7	0.1872	0.6188	8	120	70	120	1.02923	-
6	26	0.4060*	-	9	-	-	120	1.0264	-
7	8	1.4228*	-	10	-	-	120	1.0249	-
8	9	2.0600*	-	11	-	-	300	1.02430	-
8	21	4.0000*	-	12	120	70	-	0.99317	0.62317
9	10	2.0880*	-	13	60	15	60	0.99215	0.66568

10	11	0.3932*	-	14	400	200	-	0.99225	0.66363
11	12	0.7488*	-	15	260	105	-	0.99449	0.62944
12	13	1.4860	1.11550	16	-	-	60	1.03692	-
13	14	0.5416	0.7129	17	-	-	60	1.03884	-
14	15	0.5910	0.5260	18	45	20	45	1.03930	-
15	16	1.4926*	-	19	180	80	-	1.04503	0.05930
15	31	2.0000	2.0000	20	180	80	-	1.02871	0.43950
16	17	2.5780*	-	21	-	-	300	1.03702	-
16	22	4.0000*	-	22	90	45	90	1.03715	-
17	18	1.4640*	-	23	180	100	-	1.03477	0.05338
18	33	1.0000*	-	24	115	60	-	1.03000	0.11852
19	20	1.5042	1.3554	25	300	100	300	1.02238	0.21870
20	21	0.8190*	-	26	60	35	60	1.04951	-
21	22	1.4178*	-	27	-	-	200	1.04808	-
23	24	0.8980	0.7091	28	-	-	120	1.04371	-
24	25	0.8960	0.7011	29	85	35	-	1.02000	0.22492
25	29	0.5000	0.5000	30	100	60	100	1.01404	0.24914
26	27	0.5684*	-	31	170	50	-	1.00228	0.50558
27	28	2.1180*	-	32	145	70	145	1.00006	0.57217
28	29	1.6084*	-	33	240	160	-	0.99823	0.63485
29	30	0.5075.	0.2585						
30	31	0.9744	0.9630						
31	32	0.3105	0.3619						
32	33	0.3410	0.5302						

IV.RESULTS AND DISCUSSIONS

The proposed methodology is implemented on a typical 33 distribution system network with limited DG's .the distribution network presented is used to demonstrate the accuracy and effectiveness of the proposed system. The proposed method is programmed in MATLAB. Here a modified IEEE 33 bus system with limited DG's was proposed by AGPSO [16] for power loss minimization in radial distribution system via DG and with out any load flow method is illustrated with the help of standard 33 test system are explained in this segment

For reconfiguration, closing tie-switched by simultaneously opening of sectionalizing switches keeping all possible radially structures are generated. .we observe the voltage profile over the 33 number of bus which is shown in the figure 5 and total losses of AC DERs in DC sub-system and DC DERs in AC sub-system are 2129.626 KW and 1451.030KW and with for unified it is1247.508KW

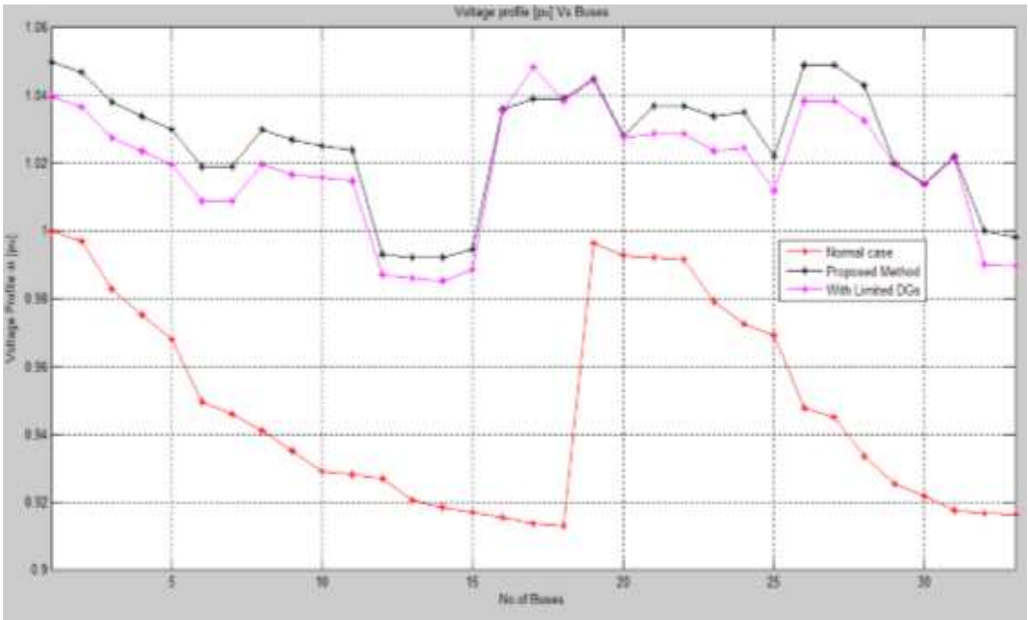

Figure 5: comparison of normal, proposed and with limited DG's of voltage profile Vs 33 buses

V.CONCLUSION

In this work the coordinated scheduling of both AC and DC sub-systems which results more economical solution when compared to the separate mode operation, however, coordinated scheduling may potentially results more efficiency and accuracy and to achieve the lowest power losses and to enhance the voltage profile can be achieved by limited DG's in hybrid micro grid.so the effectiveness of the proposed model was verified against the steady state solution produced PSCAD

REFERENCES

[1] European Photovoltaic Industry Association (EPIA). (2015, May). Global market outlook for photovoltaics 2014-2018.

[2]International Renewable Energy Agency (IRENA). (2015, May). Battery storage for renewables: market status and Technology outlook, 2015

[3] Energy Agency (IEA). (2015, April). Global EV outlook 2015.

[4] K. Chaudhary, J. M. Guerrero, and R. Teodorescu, "Enhancing the capacity of the AC distribution system using DC interlinks–A step toward future DC grid," IEEE Trans. Smart Grid, vol. 6, no. 4, pp.1722–1729, July 2015.

[5] K. Kurohane, T. Senjyu, A. Yona, N. Urasaki, T. Goya, and T. Funabashi, "A hybrid smart AC/DC power system, IEEE Trans. Smart Grid, vol. 1, no. 2, pp. 199–204, Sept 2010.

[6] M. Starke, L. M. Tolbert, and B. Ozpineci, "AC vs. DC distribution: A loss comparison," Transmission and Distribution Exposition Conference: IEEE PES Powering Toward the Future, PIMS, 2008.

[7] T. Kaipia, P. Salonen, J. Lassila, and J. Partanen, "Possibilities of the low voltage DC distribution systems," Nordac, Nordic Distribution and Asset Management Conference, pp. 1–10, 2006

[8] T. Kaipia, P. Salonen, J. Lassila, and J. Partanen, "Application of low voltage DC distribution system, a techno- economical study," 19th International Conference on Electricity Distribution, Vienna, no. 0464, 2007.

[9] M. S. ElNozahy and M. M. A. Salama, "Uncertainty-based design of a bilayer distribution system For improved integration of PHEVs and PV arrays," IEEE Trans. Sustain. Energy, vol. 6, no. 3, pp. 659–674, 2015.

[10] G. Byeon, T. Yoon, S. Member, and S. Oh, "Energy management strategy of the DC distribution system in buildings using the EV service model," IEEE Trans. Power Electron., vol. 28, no. 4, pp. 1544–1554,2013

[11] D. Salomonsson and A. Sannino, "Low-voltage DC distribution system for commercial power systems with sensitive electronic loads," IEEE Trans. Power Del., vol. 22, no. 3, pp. 1620–1627, 2007.

[12] A. Sannino, G. Postiglione, and M. H. J. Bollen, "Feasibility of a DC network for commercial facilities, " IEEE Trans. Ind. Appl., vol. 39, no. 5,pp. 1499–1507, 2003.

[13] L. G. L. Gengyin, Z. M. Z. Ming, H. J. H. Jie, L. G. L. Guangkai,and L. H. L. Haifeng, "Power flow calculation of power systems incorporating VSC-HVDC," 2004 International Conference on Power System Technology, vol. 2, pp.

[14] D. G. Holmes and T. A. Lipo, Pulse Width Modulation for Power Converters: Principles and Practice. John Wiley & Sons, 2003, vol. 18.

[15] J. Beerten, S. Cole, and R. Belmans, "Generalized steady-state VSC MTDC model for sequential AC/DC power flow algorithms," IEEE Trans. Power Syst., vol. 27, no. 2, pp. 821–829, 2012.

[16] G srinivan,,Dr.s.visalakshi, "Application of AGPSO for power loss minimization in radial distribution network via DG units, capacitor''