A Generalized Approach to The Load Flow Analysis of AC-DC Hybrid Distribution Systems

1"Mr.Nilesh S. Birari PG student,
2"Mr. S. M. Shembekar Asst. Prof.,
3"Dr. P. J. Shah Prof. and Head of Electrical Engg. Department SSBT COET Jalgaon, MS.

Abstract:

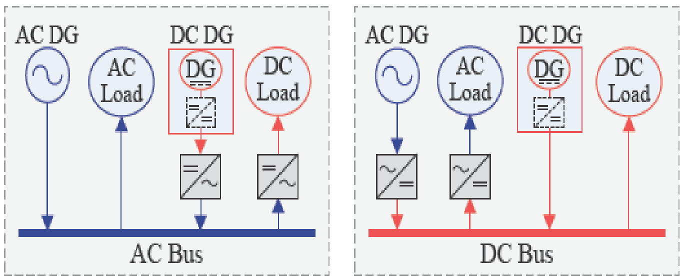
The power flow analysis is the important constraint in the electrical power system. It is necessary for planning, scheduling, and operation reliabilities with exchange of power between utilities and the contingency of transmission and distribution system. All types of power system studies are base on the load flow analysis of the distribution system. The loads flow analysis gives the principle information of power flow to knows the voltage magnitude and the phase angle of each bus and the transmission line. So the load flow analysis is the important work that consists of the numerical analysis and is applied on the hybrid distribution system. In this proposed work the iterative techniques are used on the basis of the known and the unknown parameters for the analytical methods. This paper gives the new and effective techniques for the load flow analysis of the AC-DC hybrid distribution system. The proposed work is done by the mathematical methods which are Newton Raphson and Gauss Seidel method and the test system is the 13 bus hybrid distribution system. A new classification of DS buses is also introduced for load flow analysis. A set of generic load flow equations has been derived as on comprehensive analysis of the possible AC-DC hybrid configurations. As a means of evaluating the effectiveness and accuracy of the proposed model the results are compared.

Introduction:

Now a days the manner in which the electric power is generated and utilized according to the electric power production from renewable distributed generators. Such as photovoltaic panels, wind mill and hydro power plants and other types of renewable energy sources. So it will increased the DC load demand connected on the DC distributed generators. both AC and DC hybrid configuration in which the AC-DC buses with AC and DC lines and AC-DC convertors are included. So this distribution system is necessary to develop with power convertor model. And this unified AC-DC load flow model can be used for the planning and operation of any complex hybrid distribution system. As we know the benefits of the DC power with respect to the AC power. The utilization of DC power in a distribution system improves the voltage profile and the power losses in the distribution system is also low at the DC power utilization. The other researches also have investigated and proven the advantages that have with the use of DC power in residential and commercial applications. The load flow analysis is the more implemented with the HVDC system also. The load flow analysis is to be solved independently with each iterations up to the AC-DC conversion is reached. So the generic load flow methods such as the Newton Raphson and the Gauss Seidel method that provides the iterative load flow solution for each voltage source convertors with every bus. In the other hand the sequential methods that have time consuming so these methods gives the advantages and solved the drawbacks of the sequential load flow methods. In this methods the main hybrid grid is divided into the several AC-DC sub grids which solved iteratively until the final converges is reached. So this paper introduce a unified load flow model that can be solves complex hybrid distribution system with AC-DC configurations.

I. Classification and analysis of AC-DC Hybrid Distribution System:

Hybrid distribution system consist of a variety of AC and DC components including loads, generating units, lines and buses. These components can be interconnected in different hybrid configurations. This section explains the classification of AC/DC buses and discusses the voltage source convertors. The classification of the AC-DC hybrid configurations that was used for deriving the unified AC-DC power equations.



(a) (b)

Figure no. 1 Connection of loads and DGs to (a) an AC Bus and (b) a DC Bus.

Hybrid distribution system includes DC loads and DC distributed generators alongside the conventional AC loads and AC generators. Examples of DC distributed generators include PV panels and fuel cells. Electric vehicles and modern elevators represent examples of DC loads. In the case of AC buses the AC-DC converters are necessary for connecting DC loads and DC distributed generator to an AC bus as shown in Fig.1(a). This arrangement is reversed in the case of DC buses, as shown in Fig.1(b).

In the voltage source convertor the AC side voltage is related to the DC side as follows

$$V_i^{ac} \rightarrow V_j^{dc} \quad (1)$$

$$v_{base}(ac) = k_{vsc}\, V_{base}(dc) \quad (2)$$

All the parameters are expressed in per unit value

$$V_i, pu = M\, V_j, pu\ (dc) \quad (3)$$

The efficiency of the function relates with the active reactive power is ɳc which is varies due to convertor losses.

$$Pc = \frac{P_J(dc)}{\eta} = \frac{V_{jdc}\, I_{jdc}}{\eta} \quad (4)$$

Where the I_{dc} is

$$I_{jdc} = G\left(V_{jdc} - V_{dc}\right) \quad (5)$$

Now substituting (3) and (5)

$$P_c = M\, V_{i,p.u} - M\,(V_{ac,p.u} \,.\, V_{dc,p.u}) \qquad (6)$$

Where the reactive power Qc at the AC side of voltage source convertor can be calculated as

$$Q_c = P_c \, tan\varphi c \qquad (7)$$

Now the power equations for the AC-DC hybrid configuration are as follows

the possible AC-DC connections are

A) Connection between the two AC buses:

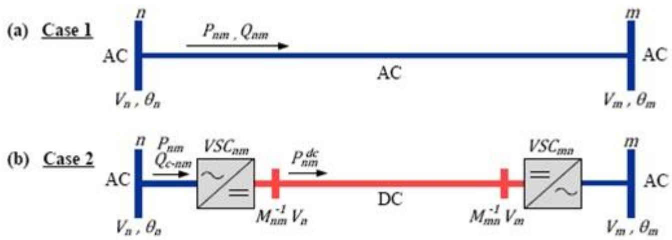


Fig.1 connection between the two AC buses

The two AC buses are connected via AC line as shown above the power equations for this AC possible case is as below:

$$P_{nm} = V_n^2 G_{nm} - V_n V_m (G_{nm} Cos\theta_{nm} + B_{nm}\, Sin\theta_{nm}) \qquad (8)$$

$$Q_{nm} = V_n^2 B_{nm} - V_n V_m (G_{nm} sin\theta_{nm} - B_{nm}\, Cos\theta_{nm}) \qquad (9)$$

For the power convertors used in the case of DC bus. For AC connections

$$Q_{c-nm} = P_{nm}\, tan\, \varphi c \qquad (10)$$

$$a_1 = 0.5(1 + \sin(M_{nm}^{-1} - V_n - M_{mn}^{-1}\, V_m)) \qquad (11)$$

$$b_{1=} 0.5(1 - \sin(M_{nm}^{-1}\, V_n - M_{mn}^{-1}\, V_m) \qquad (12)$$

$$Sin\,(x) \begin{cases} 1 & if\ x > 0 \\ -1 & if\ x < 0 \\ 0 & if\ x = 0 \end{cases} \qquad (13)$$

B) Connection between DC to DC buses:

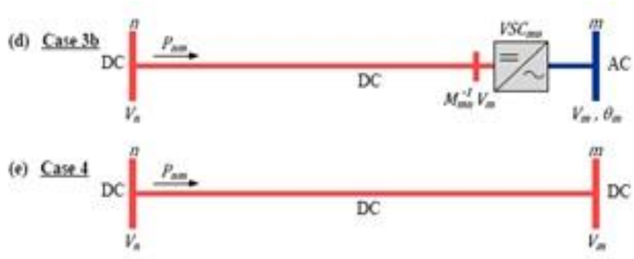


Figure 2. Connection between DC to DC buses

For this DC-AC possible cases the power flow equations are as follows:

$$a_1=0.5(1+\sin(M_{nm}^{-1}-V_n - M_{mn}^{-1}\,V_m)) \quad (14)$$

$$b_{1=}0.5(1-\sin(M_{nm}^{-1}\;V_n - M_{mn}^{-1}\,V_m)) \quad (15)$$

$$Q_{c-nm(dc)} = P_{nm(dc)}\,tan\,\varphi c \quad (16)$$

$$P_{nm}^{dc} = G_{nm}^{dc}(V_n^2 - V_n M_{mn}^{-1} V_m) \quad (17)$$

II. System development:

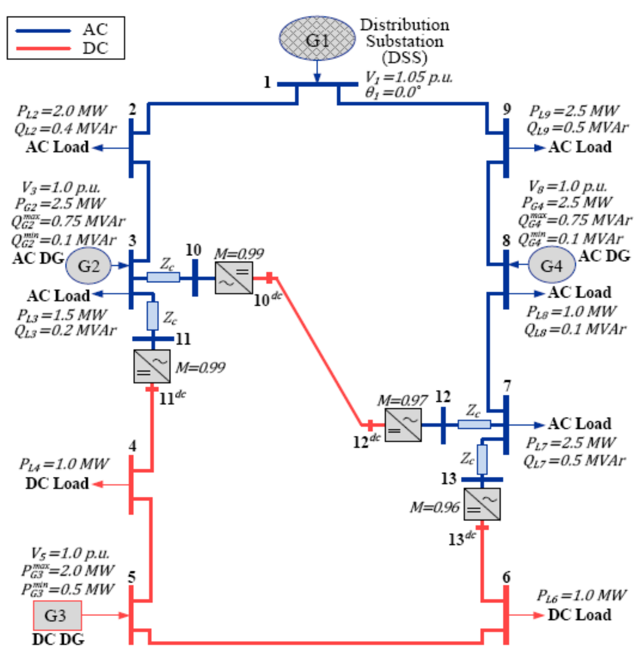


Figure 3. 13 bus test system

For the proposed work the 13 bus system is used and the system is consist of the 13 zones each including of different types of elements. The system is consisting of four distributed generator in which the G1 is the distributed substation. This distributed substation is connected to the buses from bus no.1 to 2 and from 1 to 9 the bus no. 2 has the AC load. And the bus no. 9 also has the AC load with different active reactive power. The bus no.2 to 3 has the DC distributed generator with the two impedances across the bus no.10 and bus no. 11 both the buses have the voltage convertors as the AC bus has DC load. The bus no.11 to 4 has DC load. The bus no.4 to 5 has the DC distributed generator at the bus no.5 the bus no. 5to 6 has the only DC generator to DC load. The bus no. 6 has the DC load. From this bus the bus no. 13 and bus no. 7 has the impedance with the voltage convertors. The bus no.12 and 10 are interconnected with AC to DC convertor. The bus no.7 to 8 both has the AC load with different active reactive power. The bus no. 8 has the AC distributed generator G4. The bus no. 8 to 9 has again AC load on the AC distributed generator.

A) Impedance of the 13-bus test system:

From Bus	To bus	Resistance	Reactance
1	2	0.2218	0.3630
1	9	0.2218	0.3630
2	3	0.8870	1.4520
3	10	0.0500	0.7540
3	11	0.0500	0.7540
4	5	0.2208	-
4	11	0.4415	-

From bus	To bus	Resistance	Reactance
5	6	0.2208	-
6	13	0.4415	-
7	8	0.4435	0.7260
7	12	0.0500	0.7540
7	13	0.0500	0.7540
8	9	0.4435	0.7260
10	12	0.8830	-

Bus 5 is a V_{dc} bus and the remaining buses are considered as load buses. The results obtained from the proposed LF model and the steady-state solution provided by the MATLAB software are listed in results. The LF model converged with a total power mismatch of the test system is equals to the equation given below

$$(\|P^{inj}n - P^{cal}\|2 + \|Q^{inj}n\|2)$$

To evaluate the accuracy of the proposed load flow model, the load flow solutions were calculated from the system variables by the Newton Raphson method and the Gauss Sidle method in the MATLAB software and the results are obtained with power losses and total time elapsed for the iterative calculation

III. Power equations for the system:

Active power at bus-***i*** can be written by P_{Gi} also, reactive power can be denoted by Q_{Gi}.

P and Q consumed at the ***i*** th bus can be denoted by $P_{li}$and.Q_{li}

So, the active power injected in bus-***i*** is l_i G_i

P_{inj}=Q_{Gi}−P_{li} (18)

P_{ical} is the calculated power by the load flow program. So, the different between the actual injected and computed values

ΔP_i= $Pi_{inj} - Pi_{cal}$ (19)

$= PG_i - P_{li}$– Pi_{cal} (20)

Also, the different between Q injected and calculated values

ΔQ_i= $Q_{inj} - Q_{cal}$ (21)

= Q_{Gi}– $Q_{li} - Q_{i\,cal}$ (22)

IV. Results

The results obtained from the Gauss-Seidel method

No. of Iteration	Total Power Losses		Max. Power Mismatch	Elapse Time
101	Gen. Side	Load Side	4.5687	2.458 Sec.
	0.329	-22.205		

The result obtained from the Newton Raphson method

No .of Iteration	The Total Power Losses		Max. Power Mismatch	Elapse Time
	Gen. Side	Load Side		
11	0.329	-22.205	4.5622	0.907 Sec.

The load flow solution formed by the Newton Raphson method is in eleven iterations with the maximum power mismatch is 4.5622 with the total time elapsed is 0.907 sec. Which is very time convenient than the Gauss Seidel method with higher accuracy. So the Newton Raphson method is effectively applicable for the analysis of any complex hybrid distribution system

IV. Conclusion:

The hybrid distribution system is analyzed by the general algebraic methods with the MATLAB software. The13 bus system is taking in the proposed work. And the load flow analysis is done by the methods of Newton Raphson and Gauss Seidel. These methods are implemented on the possible AC-DC hybrid configurations on the 13 bus system. Both the methods can solve the load flow analysis for the AC and DC power into one unified solution. Both the methods produced the result with higher accuracy and both methods are capable to solve the power equations for hybrid distribution system. And gives the load flow results for AC-DC hybrid configuration. But when the results are observed and compared with each other. The Newton Raphson method has the minimum iterations with less computational time. The load flow results are obtained by Newton Raphson method is more reliable and efficient as it gives the load flow result in minimum elapsed time and minimum iterations than the Gauss Seidel method. So the Newton Raphson method is very efficient and more convenient for solving the load flow analysis of any hybrid distribution system.

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