Load flow solutions of radial distribution system using backward forward sweep method

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ABSTRACT

The concept of load flow for radial distribution network (RDN) is presented in this paper. It is very essential for power system that the investigator or system planner have full idea of system before going to any restructure or expansion planning. For this the load flow solution is mandatory. Actually, load flow solution presents the real time picture of existing system. In load flow four quantities these are voltage, phasor angle of voltage, real power and reactive power at any particular bus is specified out of these four quantities two are given and remaining two can be calculated for any bus with the help of load flow equations. In this research article load flow of RDN is being solved by backward forward sweep (BFS) method is applied. As there are two established methods for load flow solutions these are Gauss-Seidel, Newton-Raphson but these methods are not suitable for RDN because the R/X ratio of RDN is more than that transmission system. Therefore, Gauss-Seidel Newton-Raphson based methods are not generally applied in order to solve the load flow solutions of RDN because these methods are not converge properly. In order to obtain load flow solutions the program for solution is developed in MATLAB environment.

Key words: Radial distribution network; load flow; backward forward sweep method; active power loss; reactive power loss.

INTRODUCTION:

In load flow solution the non-linear equations are being solved by developing the program in MATLAB environment. The advancement and reinforcement is continuous process because load demand is increasing exponentially. Therefore, to meet this increasing demand it is essential to determine solution of load flow and other reinforcement. The cutting edge distribution system is always being looked with a regularly developing burden. This expanding burden is coming about into expanded weight and decreased voltage [1], [2], [3], [4]. The dissemination arranges likewise has a run of the mill include that the voltage at (nodes) decreases whenever moved far from substation. The advanced power system is always being subjected to a consistently developing burden request. This expanding burden is coming about into expanded power demand and low voltage. This reduction in voltage is primarily because of deficient measure of reactive power. Indeed, even in certain industry, it might prompt voltage collapse due to critical loading. In this way to improve the voltage profile and to stay away from voltage breakdown responsive pay is required [1], [2], [5], [7]. The low X/R ratio leads to higher power loss and voltage sag when compared with transmission lines [2], [3] [5], [7], [8], [9]. Such non-unimportant misfortunes directly affect the monetary issues and generally performance of distribution system. The importance of enhancing the performance has constrained the power utilities to lessen the losses at distribution level. Numerous courses of action can be applied to diminish these misfortunes like system reconfiguration, shunt capacitor, distributed generation placement etc [3], [4], [6], [7]. The distributed generators supply some portion of dynamic power request, in this manner lessening the current and MVA in lines. Establishment of DGs on power system will contribute in lessening vitality misfortunes, top interest misfortunes and enhancement in the systems voltage profile, systems steadiness and influence factor of the systems [3], [4]. Distributed generation (DG) innovations under smart grid idea frames the foundation of our reality Electric appropriation systems [4], [6]. These DG advances are grouped into two classes: (I) sustainable power sources (RES) and (ii) petroleum derivative based sources. Sustainable power sources (RES) based DGs are biomass, wind turbines, photovoltaic, , geothermal, little hydro, and so on. Non-renewable energy source based DGs are the internal combustion engines (IC), combustion turbines and fuel cells [3] [5]. Nearness of distributed generation in dissemination systems is a pivotal test regarding specialized and well being issues [7-9]. In this way, it is basic to assess the specialized effects of DG in power systems. Hence, the generators are should have been associated in conveyed 10 frameworks in such a way, that it maintains a strategic distance from debasement of intensity quality and unwavering quality. Assessment of the specialized effects of DG in the power systems is basic and arduous. Deficient allotment of DG as far as its area and limit may prompt increment in shortcoming flows, causes voltage varieties, meddle in voltage-control forms, lessen or increment misfortunes, increment framework capital and working expenses, and so forth [8]. Also, introducing DG units isn't clear, and hence the arrangement and measuring of DG units ought to be painstakingly tended to [8], [9].

Examining this improvement issue is the significant inspiration of the present postulation look into. DG portion is fundamentally a typical combinatorial enhancement agenda which needs simultaneous improvement of numerous destinations [10], for example minimizations of active and reactive power losses, bus voltage deviation, carbon radiation, line stacking, and impede and augmentation of system unwavering quality and so forth. The objective is to decide the ideal location(s) and size(s) of DG units in distribution system. The enhancement is completed under the limitations of most extreme DG ratings, warm breaking point of system branches, and voltage farthest point of the nodes [9-10]. In [11], an explanatory way to deal with the ideal area of DG is exhibited. In the vast majority of the present works, populace based developmental calculations are utilized as arrangement techniques. This incorporates hereditary calculation (GA) and molecule swarm enhancement [6] [13], [14]. The benefits of populace based meta-heuristics calculations, for example, GA and PSO are that a lot of non-overwhelmed arrangements can be found in a solitary run due to their multi-point search limit. They are additionally less inclined to dimensionality issues; nonetheless, intermingling isn't constantly ensured.

The present research article presents the load flow solutions of non-linear equations for networks which have nature of opposite of transmission system means in this network the ratio of resistance to inductive reactance is higher. In present method there is no need to form Jacobian matrix and admittance matrix therefore the computational burden is reduced significantly. In this study the major steps which are discussed as follows

CURRENT INJECTION CRITERION:

In this criterion basically current is injected and it is bus injected branch current (BIBC). This phenomenon is based on equivalent current injection at bus in distribution networks. Basically, this model is more realistic and real time based in this concept the complex load model at k^{th} bus is expressed as follows

$$S_k = P_k + jQ_k \qquad \text{where,} \quad k = 1, 2, ...\text{N} \tag{1}$$

The equivalent current injected from k^{th} bus is expressed as follows

$$I_k = \left(\frac{S_k}{V_k}\right)^* = \left(\frac{P_k + jQ_k}{V_k}\right)^* \tag{2}$$

In this load flow BIBC and branch current and bus voltage (BCBV) matrix is required. Therefore, the procedure of formation of this matrix is given herewith.

- The injected power at different bus is transformed into equivalent current
- The relation of bus current branch current is obtained by Kirchhoff's current law (KCL) and by using BFS based method
- The branch current is represent in the function of IB1, IB2 and so on
- These branch current are further expressed in terms of bus injected current

In this section the matrix formation is presented. It is illustrated by taking a simple network comprising six buses and five branches. Further, load current at each node except root node is represented by IL1, IL2 and IL3 and so on and branch current in respective branch it is given by IB1, IB2 and so on. The distribution network which is considered is shown in Fig. 1

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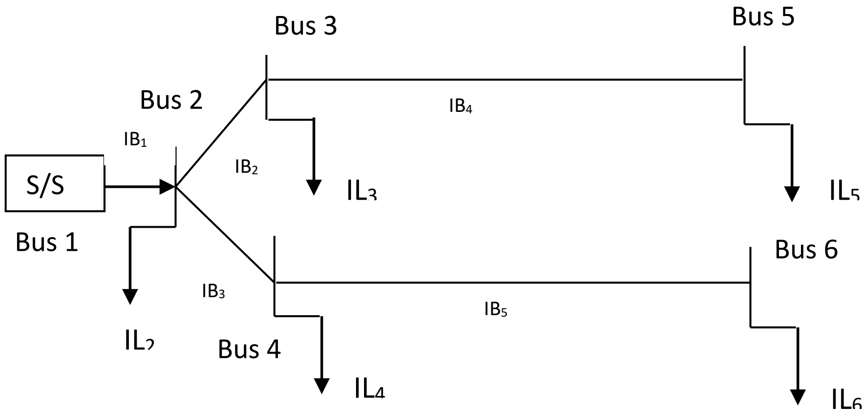

Figure 1 Distribution network

The various equations for branch current pertains to this network shown in Fig. 1 are expressed as follows

$$IB_4 = IL_5 \tag{3}$$

$$IB_5 = IL_6 \tag{4}$$

$$IB_3 = IL_4 + IL_6 \tag{5}$$

$$IB_2 = IL_3 + IL_5 \tag{6}$$

$$IB_1 = IL_2 + IL_3 + IL_4 + IL_5 + IL_6 \tag{7}$$

These equations from (3) – (7) can be represent in the form of matrix as follows

$$\begin{bmatrix} IB_1 \\ IB_2 \\ IB_3 \\ IB_4 \\ IB_5 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} IL_2 \\ IL_3 \\ IL_4 \\ IL_5 \\ IL_6 \end{bmatrix} \tag{8}$$

The matrix given in equation (8) is further expressed as in form of BIBC matrix, branch currents and load currents etc. as follows

$$[IB_k] = [BIBC][IL_{k+1}] \tag{9}$$

Where, BIBC is matrix given as 0 and 1 elements, [IB] and [IL] are also defined above equations. Moreover, the branch current bus voltage (BCBV) is defined as follows. The BCBV matrix is related to BIBC matrix which is given in above equations. These relationship are obtained with the help of Kirchhoff's voltage law (KVL) is applied in forward loop.

$$[BCBV] = [BIBC]^T [ZD] \quad \text{where, } ZD \text{ is branch impedance matrix} \tag{10}$$

ZD is one of the matrix is called branch impedance matrix having diagonal elements are 1 remaining all elements are 0 (zero)

MODELING OF LOAD DEMAND:

In this present paper load demand is considered as real time load model as constant power load (P), constant current load model (I), constant impedance load model (Z) and composite load model (ZIP). These combined load models are basically characterized by per phase complex power as line to neutral voltage. The complex power in the form of voltage is expressed as

$$S = P + jQ \ \text{ or } \ S = |S|\angle\theta \tag{11}$$

$$V = |V|\angle\delta \tag{12}$$

Further, load current for constant power for both type i.e. (real and reactive) is defined as

$$IL_{pq} = \left[\frac{|S|}{|V|}\right]\angle(\theta - \delta) \tag{13}$$

In this expression shown in equation (13) the bus voltage magnitude is not remain constant at time of iterations are executed in order to obtain convergence process.

Further, the next load demand profile i.e. constant impedance is expressed as

$$\text{Impedance } Z = \frac{|V|^2}{|S|}\angle\theta \tag{14}$$

Moreover, the load current is basically function of impedance is expressed as follows

$$IL_Z = \frac{|V|}{|Z|}\angle(\delta - \theta) \tag{15}$$

LOAD PROFILE AS FUNCTION OF CURRENT:

This is the load profile is constant current load profile hence the value of current is change according to following equation

$$IL_i = \left(\frac{S}{V}\right)^* = \left(\frac{|S|}{|V|}\right)\angle(\theta - \delta) \tag{16}$$

In equation (16) θ and δ are power factor angle and voltage angle respectively

ZIP TYPE OF LOAD MODEL:

It is the special category of load in which three quantities i.e. impedance (Z), current (I), and power (P) are all remains constant during operation and their value taken in some proportion to make the ZIP type load. In this load the total current which is entering in the load is sum of all current components in order to obtain ZIP load profile. In this study the coefficient of different load profile are taken as follows

COEFFICIENT OF ZIP:

The description of ZIP load model is given as follows

a) Z type load profile is considered as ZP, in this study its value is taken as 0.3
b) I type load profile is considered as IP, in this study its value is taken as 0.1
c) PQ type load profile is considered as SP, in this study its value is taken as 0.6

As the sum of all considered parameters is 1. Therefore, $ZP+IP+SP = 1$, further, load current is represent as follows

$$IL_{ZIP} = I_z + I_i + I_{pq} \text{ and } I_z = ZP \times IL_z,\ I_i = IP \times IL_i \text{ and } I_{pq} = SP \times IL_{pq} \quad (17)$$

LOAD FLOW ALGORITHM FOR DISTRIBUTION SYSTEM:

In this section algorithm adopted for evaluation of solution of load is discussed. There are several steps which are using are given as follows

- Step 1: Data of branch and load data are read
- Step 2: Calculate the branch current and injected current from bus using the different equations
- Step 3: Determine BIBC matrix
- Step 4: Determine the three matrices these are [BIBC] and [BCBV] and impedance matrix is [ZD]
- Step 5: Calculate [DLF] matrix by [DLF] = [BCBV]*[BIBC]
- Step 6: Estimate [IB] = [BIBC]*[IL] and [Δ V] = [DLF]*[IL]
- Step 7: Fix iteration counter K = 0
- Step 8: Update iteration counter K = K + 1
- Step 9: Determine voltage at each bus for different load models
  $\left[\Delta V^{K+1}\right] = \left[DLF\right] \times \left[IL^{K}\right]$
- Step 10: Calculate updated voltage $\left[V^{K+1}\right] = \left[V^{0}\right] + \left[\Delta V^{K+1}\right]$
- Step 11: check tolerance level is obtained i.e. $\left[\left|V(K+1)\right| - \left|V(K)\right|\right] > \text{tolerance}$, go to step 8
- Step 12: Estimate current of each branch and hence calculate system power loss
- Step 13: Estimate bus voltage magnitude and print the results
- Step 14: End

DESCRIPTION OF OBTAINED RESULTS:

In this research article load flow of solution is applied on 85-bus network. The single line representation of considered 85-bus network is shown in Fig. 2. Moreover, it is evident from Fig. 3 that the voltage profile at various for different load demand. From this figure it is observed that voltage at various buses is lowest in values for const power load while the voltage values are higher for constant impedance load demand and for constant current load model the voltage values are in between in constant power and constant impedance. Furthermore, Fig. 4 is representing the branch current profile for different load model. From this figure it is noticed that branch number 1 to 9 current required by different load model is different additionally, up to branch 1 to 9 the constant power load profile require more current as compare to other load profile such as constant impedance and constant current load model. Secondly, constant impedance load model required minimum value of current for branch number 1 to 9 and for constant current load model required less current as compare to constant power load model and more current required from constant impedance load model.

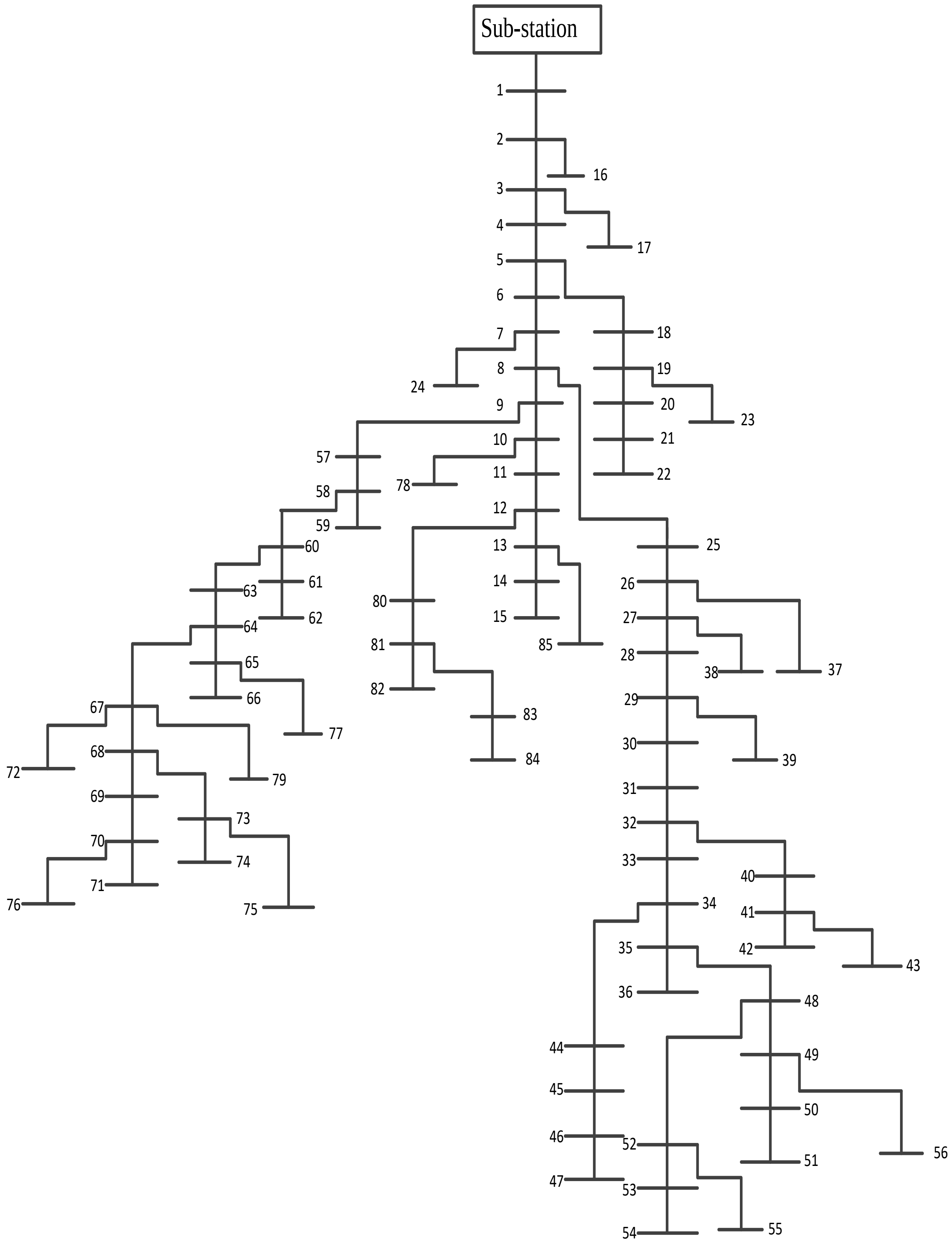

Figure 2: Representation of 85-bus network

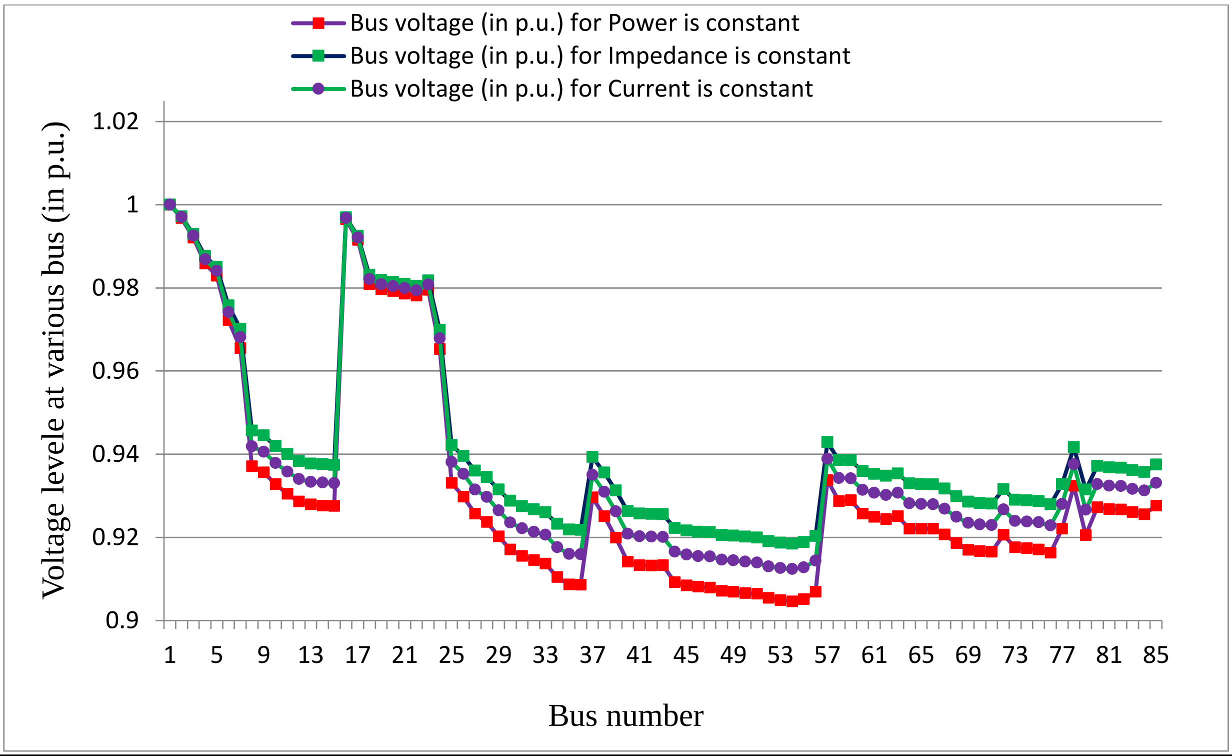

Figure 3: Bus voltage profile for different load demand

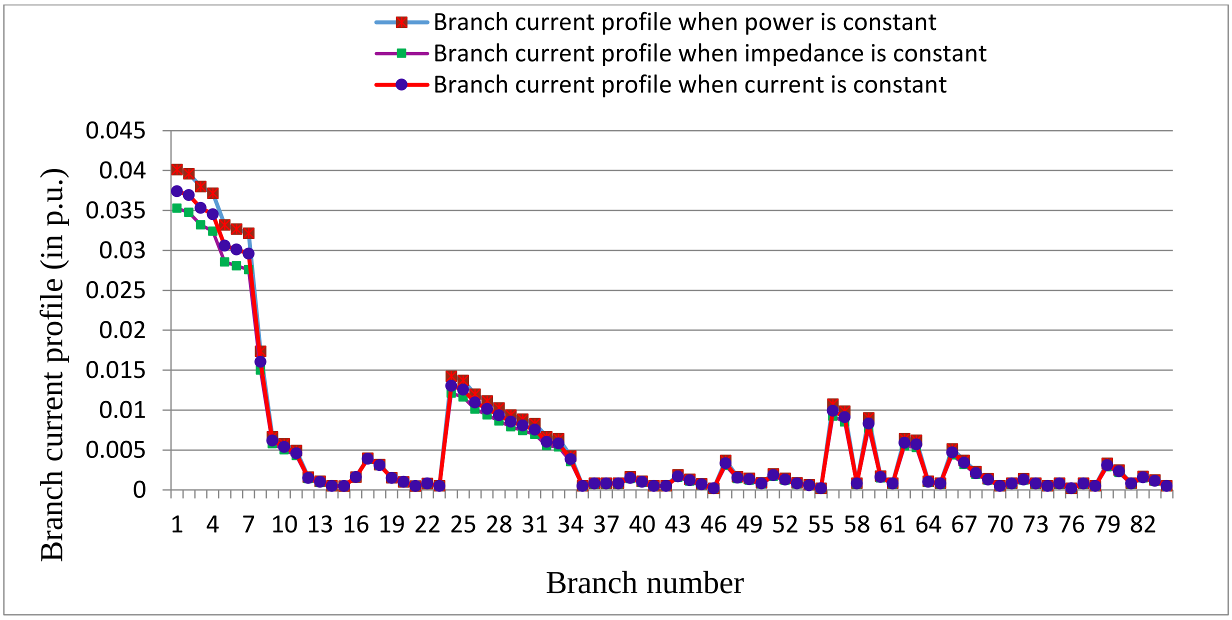

Figure 4: Profile of branch current for different load

Figure 3 shows the bus voltage profile of IEEE 85-bus distribution system at different buses for different load profile. These load profiles are constant impedance, constant current and constant power load demand. From this figure it is observed constant impedance load has maximum value of bus voltage and constant power load has lowest value of bus voltage at different buses and constant current load profile has medium value of bus voltage between constant impedance and constant power load profile. Figure 4 shows the current profile of different branches for different load profile as it is observed from this figure that constant power load has higher value of branch current profile while constant impedance has lower value of branch current profile.

CONCLUSIONS:

The present research article elaborate the load flow solutions of different load demand models these load models are constant impedance load demand, constant current load demand and constant power load models. The load flow solutions are performed by BFS based method in this method in this method BIBC and BCBV matrices are formed in order to obtained solutions of load flow in form of branch current, bus voltage and hence obtained the power flow in each branch which helps to estimate the system power losses for further helpful to restructure, reinforcement and expansion of existing distribution network. The program for solution of load flow equations is formed in MATLAB environment and obtained results it is found that voltage value in p.u. at various buses for various load model from this it is noticed that pattern of voltage is almost similar but constant power load model has lower value of voltage and this value is higher for constant current load model and constant impedance load model. Further, the branch profile for all considered load model is almost similar. These results are obtained by considering 85-bus network for validate the algorithm.

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