Investigations of Load Flow on Radial Distribution Network using Backward Forward Sweep Method by Considering Different Load Profile

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Abstract

The types of load on power system are classified on the basis of operating hours such as domestic, commercial, industrial, agricultural loads etc. This paper is primarily focused on industrial load and commercial load. For commercial load, the electrical equipment such as fans, bulbs etc operates for 10 to 12 hours whereas in domestic load,the operating hours ranges between 4 to 5 hours and for industrial load the electrical equipment such as fans, machines and other equipments are used for complete 24 hours. This paper proposes the backward sweep and forward sweep technique to perform the power flow for IEEE 33-bus and IEEE 69-bus bus distribution system by applying the load profiles and voltage profiles of industrial and commercial load respectively. The distribution system has a very important position in power system as it acts as important point of link between bulk power andconsumer and the demand of various consumers such as domestic, commercial, industrial etc. are supplied by power system.

Keywords: Load flow, load profile, distribution system, BFS, radial distribution system

1. Introduction

The load on the power system are classified by the time duration for which the electrical equipments are to be operated.For domestic load the electrical equipments such fans, bulb, air conditioners etc are used for 4 to 5 hours this domestic load is for our house in which we use the electrical equipment for short duration and for commercial load the electrical loads such as fans ,bulbs , air conditioners etc are in the running condition for 8 to 10 hours this is because in our offices or buildings of school and college we use these electrical equipments such as fans ,bulb, air conditioners etc only for whole day not for night this is the basic difference between the domestic and whereas for industries these electrical equipments such fan bulbs and also big machines are in the running condition for complete 24 hours therefore the comes under the industrial load.

These industrial and commercial sectors cover the reasonable part of energy consumption which leads to more than 60% of the total energy used around the world [1].And demand response has also been improved widely for these sectors since 1970 but for now a day it has been observed that it is changing with the efficient technology and improved devices [2]. Andespecially wholesale energy and ancillary services markets can incentivize the participation of demand response in the markets [3]. Further progress of technology in equipment and devices and also in telecommunications enables faster and better management of demand response [4].

The power flow analysis is an important tool to determine the flow of power from the sending end to the load end or receiving end. There are various methods or technique that are used to determine the power flow of a transmission line and distribution system such as Newton Raphson method, Gauss Seidel method, Fast decoupled method and so on.The power flow analysis study of a distribution system is very advantageous for the preplanning of the transfer of load efficiently.

Due to the radial nature of distribution system they have very high ratio of R/X which leads to the complications of load flow evaluation and therefore the Newton Raphson and Fast decoupled method becomes difficult to evaluation or determination of flow of power for large distribution system.

Therefore, the new technique is proposed in this paper i.e., backward sweep and forward sweep method which is very easy to perform both in manual mathematical calculation and by using programming codes also. By using this technique, the voltage magnitude at each bus of the distribution system are evaluated.

This paper is primarily focused to give a brief view on the industrial load and commercial load. Further, this paper addresses how the load profiles of industrial load and commercial load is analyzed on IEEE 33-bus and IEEE 69-bus bus distribution system in MATLAB environment which are made in a manner to only follows the algorithm proposes in this paper. The output of total power loss on IEEE 33-bus and IEEE 69-bus on the applications of load profiles of the industrial load and commercial load using MATLAB codes will be discussed in the result section which will further leads to the conclusion of this paper.

2. Formulation of the Problem

For the power flow analysis the input data such as impedance , resistance , reactance, voltages at each bus can be either described or specified in actual values or it may be specified in per unit form it totally depends on the user but in most of the cases the user specifies the values in per unit or else convert the actual values in per unit by considering the base values because in per unit it become easy for the calculation rather by writing the unit of each of the values. And conversion of actual value into the per unit values is not a difficult task to perform as we all know the per unit is defined as the ratio of any arbitrary value of a particular dimension to the base value of the same dimension and due to the same dimension there is no unit for the per unit values.

The main objective of this paper is to evaluate the activepower and reactive power for IEEE33 and IEEE69 bus distribution system by applying the voltage profiles of commercial and industrial loads. And the reactive power is the useful power that is engaged in doing the useful work in the circuit and it is having a measured value in watts or in megawatts. And for the reactive power it is the power that is useless power which does nothing useful in the circuit but it keeps reflecting from the source end and the load end and also having the measured value in volt amperes Var

And the formula used for calculating these powers are as follows

$$activepower \quad = \left((I)\right)^2 * (Rpu)$$

$$reactivepower \; = \quad \left((I)\right)^2 * (Xpu)$$

3. Methodology Applied

The backward sweep and forward sweep is one of the most common techniques that is used to determine the power flow of a distribution system. Further this technique is simple, fast, easy convergence and occupies less memory for the processing with efficiencies and solution accuracy computational. A modified "ladder" network theory for linear system gives the robust and simple iteration technique for the power flow analysis of the distribution system [2]

3.1 Backward Sweep

First of all this method occurs at full load condition for the first iteration. In this method our main objective is to determine the current across each load or buss and it is assumed that the voltages at each bus are equal (for 1st iteration) i.e. Vs

And now we apply the Kirchhoff's current law at nodes5, 4, 3, 2 to determine the current at each node. Referring to the figure1 and applying KCL to node 5 we get that I45 is equal to I5 and further applying KCL at node 4 we get that I34 is equal to sum of I4 and I45 whereas I45 is equal to I5 therefore we get

$I45 = I5$ and

$I34 = I4 + I45$

$I34 = I4 + I5$ similarly we get

$I23 = I3 + I34$

$I23 = I3 + I4 + I5$

$I12 = I2 + I23$

$I12 = I2 + I3 + I4 + I5$

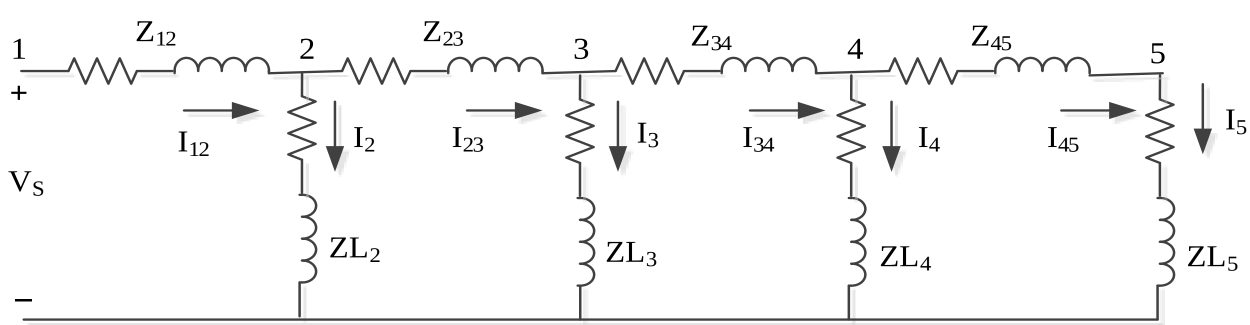

Fig.1 Backward sweep reference

3.2 FORWARD SWEEP

The forward sweep method is the technique that is used to determine the magnitude of voltage at each node of the circuit by using the Kirchhoff's voltage law (KVL). The determination of voltage starts from the sending end and then move towards the load end or source end and during the evaluation of voltages at each node the value of currents are taken from the backward sweep method

Considering the Figure 2 and applying the Kirchhoff's voltage law in the circuit shown below will give the voltages at each node and during the evaluation of voltages the current will be replaced from the backward sweep method as mentioned earlier in this paper.

$$V2 = Vs - Z12 * I12$$

$$V2 = Vs - Z12 * (I2 + I3 + I4 + I5)$$

$$V3 = V2 - Z23 * I23$$

$$V3 = V2 - Z23 * (I3 + I4 + I5)$$

$$V4 = V3 - Z34 * I34$$

$$V4 = V3 - Z34 * (I4 + I5)$$

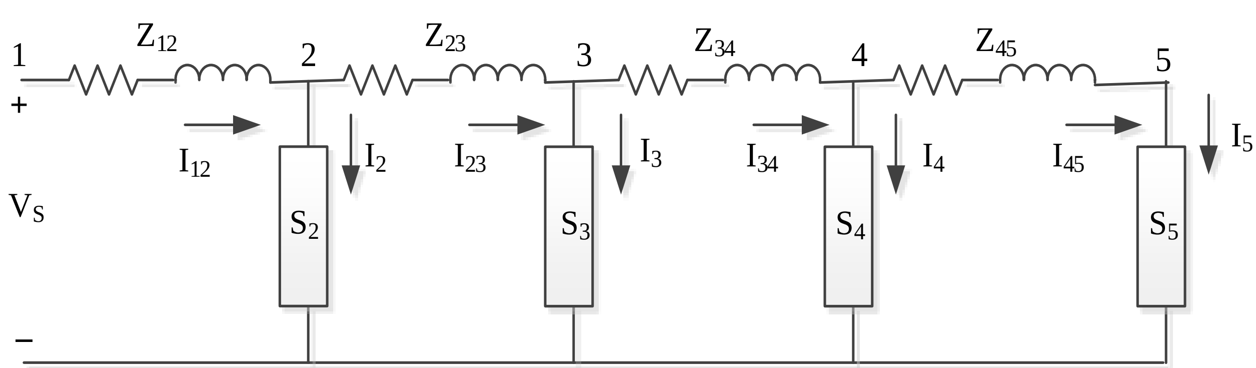

Fig. 2 Forward sweep reference

4. ALGORITHM

For the 0th iteration an initial flat voltage is supplied at each of the bus junction and each bus terminal in the power system and it is given in the step 1

STEP 1:

Initializing the voltages

$V^0 j = Vs\angle 0$ where, *j* goes from 2,3,4,5…………N

STEP 2:

Initializing the iteration count (I) as I=1

STEP 3:

Evaluation of load current by the reading the data on the buses and the voltages at each buses at 0th iteration

$I^I j = \left[\frac{Psj+Qsj}{V^{I-1}}\right]^*$ where, *j* goes from 2,3,4………..N

STEP 4:

Backward sweep

From the evaluation of the load current at each buses now we will do Backward sweep as described in the paper

$I^I mn = I^I m + \sum$ of all the current of the branches after the bus "*n*"

STEP 5:

Forward sweep

Now we apply the KVL between the two buses as described previously

$V^I q = V^I pq - Zpq * I^I pq$ where "q" goes from 2,3,4……….N

STEP 6:

Comparison of error (E)

In this we compare the voltages at each bus at Ith iteration and (I-1)th iteration

$E^I j = |V^I j - V^{I-1} j|$ where "j" goes from 2,3,4,5.........N

STEP 7:

Determination of maximum error

$E^I max = \max(E^I 2, E^I 3, E^I 4 \dots \dots E^I n)$

STEP 8: Setting the convergence criteria

$Emax = 0.00001\ or\ 0.0001, \quad \Delta Vmax = 0.00001\ or\ 0.0001$

STEP 9:

If the values of $E^I max$ is less than or equals to the tolerance then print the result otherwise update the iteration count I = I+1 and repeat the steps from step 3

5. OBSERVATION ON THE RESULTS OBTAINED

In this section bus voltage profile for IEEE 33-bus is described for commercial load and industrial load

5.1 Voltage profile for IEEE33 bus distribution system

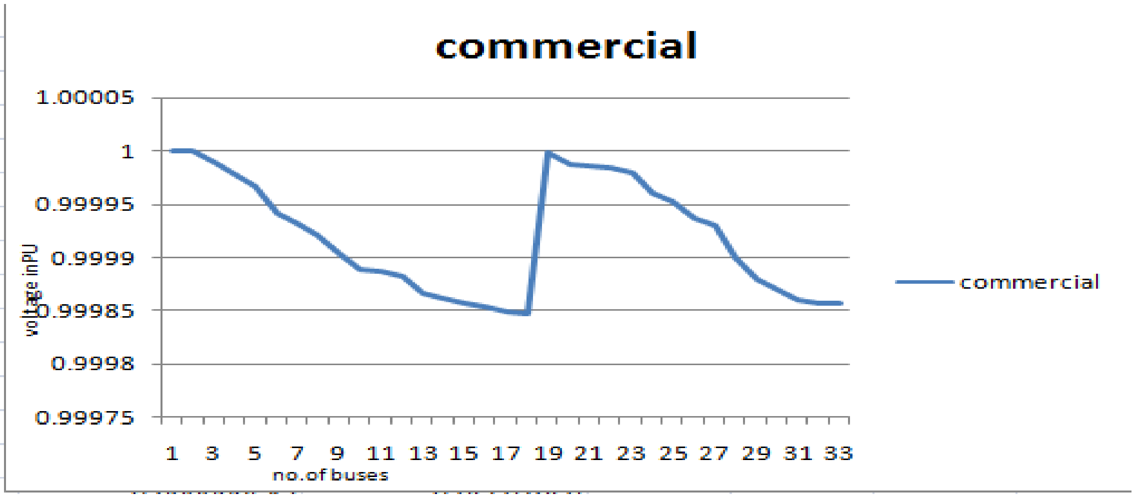

Fig. 3 Voltage profile of IEEE 33-bus for commercial load

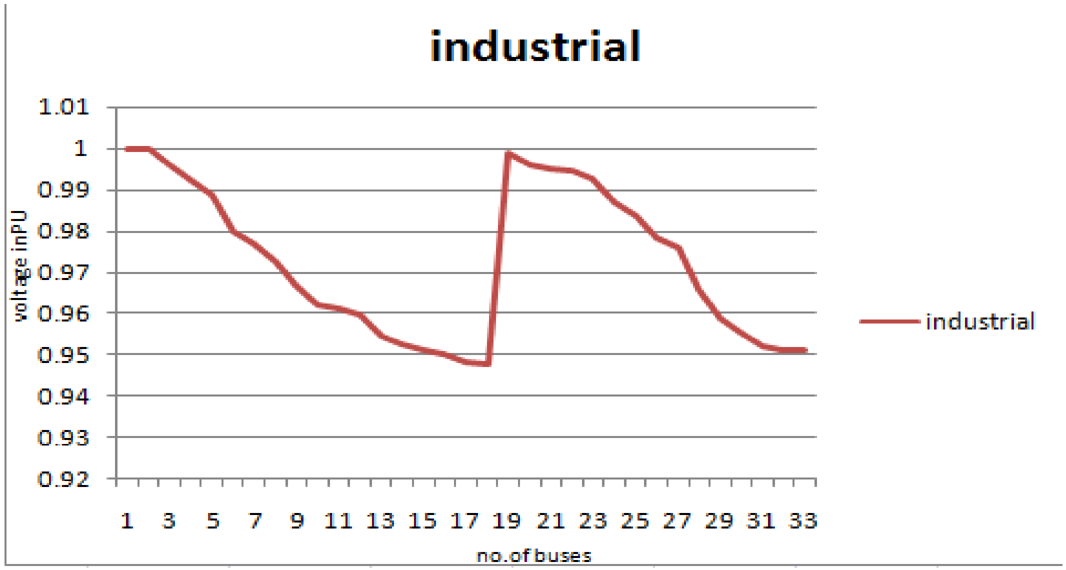

Fig. 4 Voltage profile of IEEE 33-bus for industrial load

The voltage profile for IEEE 33-bus distribution system for both commercial and industrial load is shown above in figure3.And it can be observed that there is almost identical shape is formed by both the type of load. Although there is a sudden increase in the voltage at bus number 19 this is because at bus number 18 the line terminates and bus 19 gets its supply from bus number 2

5.2 Voltage profile for IEEE 69-bus distribution system

Fig. 5 represents the voltage profile of IEEE 69-bus distribution system. From this figure it is observed that bus voltage almost remain constant except sum buses where the voltage profile is deviated.

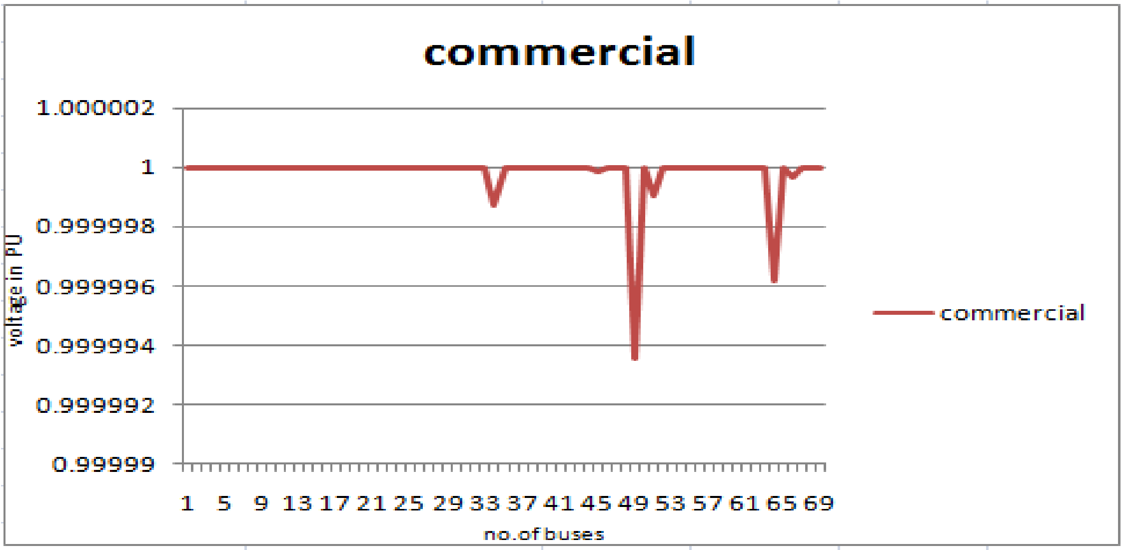

Fig. 5 Voltage profile of IEEE 69- bus for commercial load

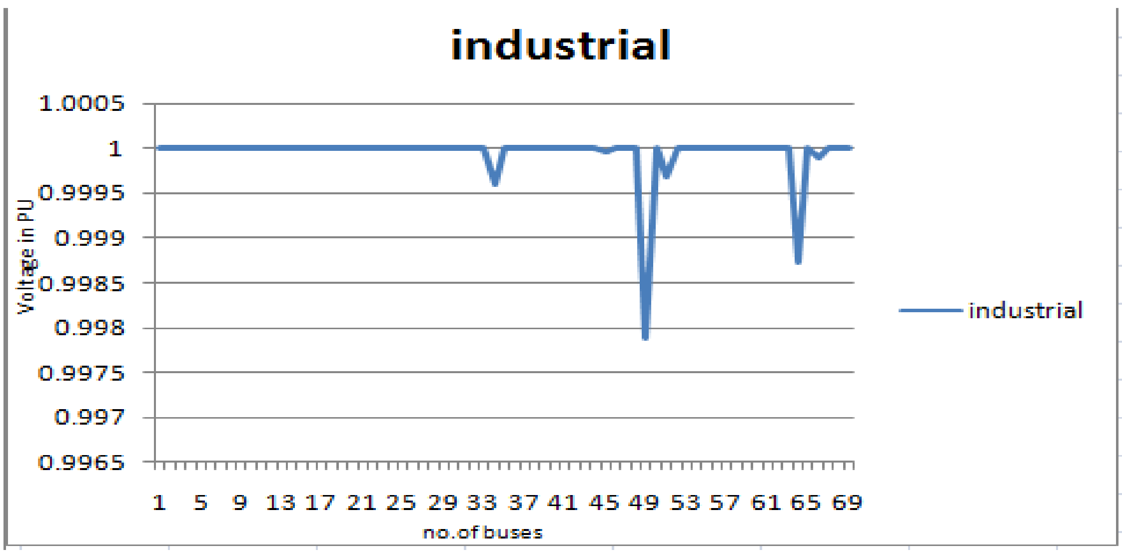

Fig. 6 Voltage profile of IEEE 69- bus radial distribution system for industrial load

The voltage profile for IEEE 69-bus system is shown for both industrial and commercial load the voltage profile as can be seen in identical irrespective of the voltage applied to the type of load the voltage across each bus is not actually at unity but it is less than or to say close to the unity

5.3 Current profile for IEEE 33-bus test radial distribution system

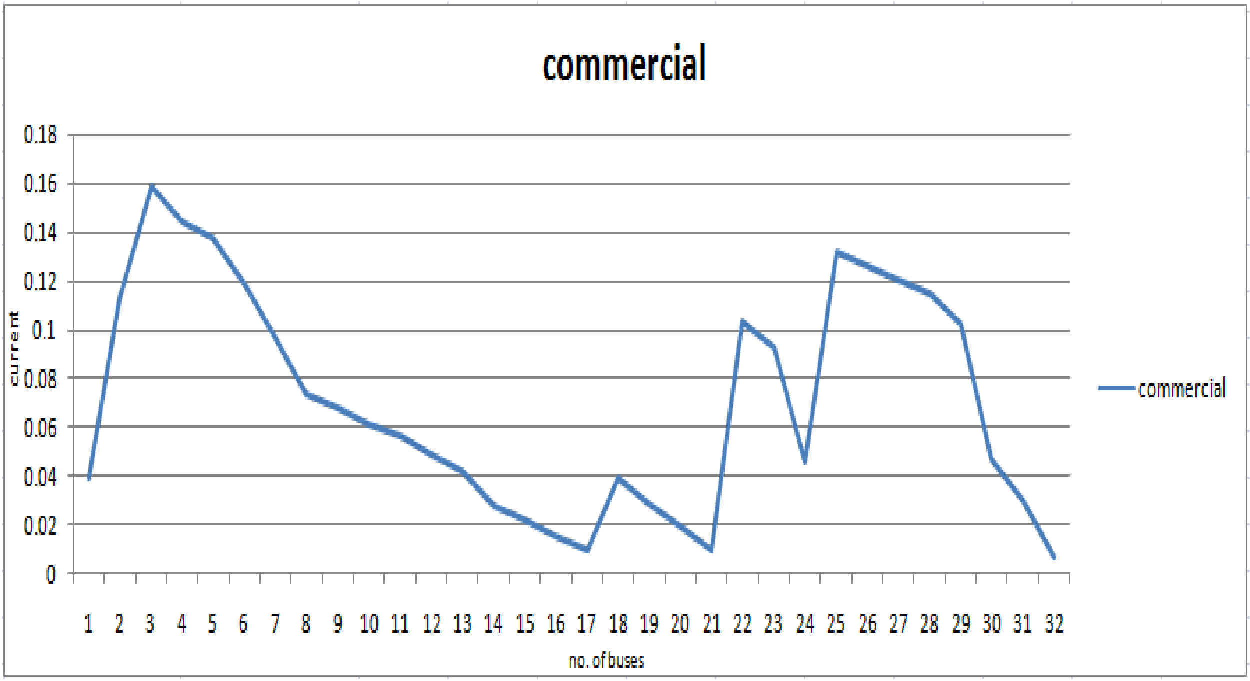

Fig. 7 Current Profile for IEEE 33-bus radial distribution system for commercial load

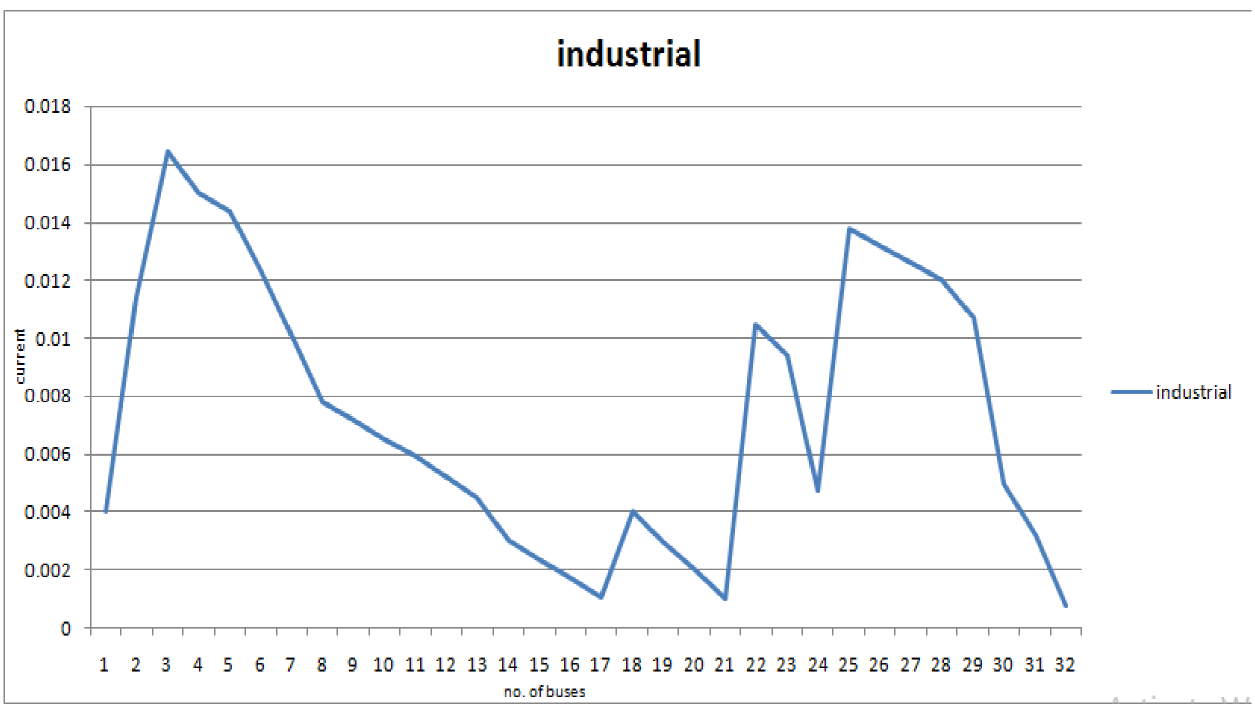

Fig. 8 Current Profile for IEEE 33-bus radial distribution system for commercial load

he current profile for IEEE33 bus system is shown in figure 4 and it has been observed that the current profile for both industrial and commercial load is identical and independent on the applied voltage to the distribution system and the sudden increment or decrement of current is nothing but the termination of bus and the line connected to the other bus.

5.4 Current profile for IEEE69 bus distribution system

Fig. 9 shows the magnitude of current profile (in p.u.) for commercial load profile of IEEE 69-bus test radial distribution network. Further, this magnitude of current is calculated on the basis of magnitude of branch current. This magnitude of current for commercial load can be further applied to other purpose as current magnitude is important constraint for designing the objective function.

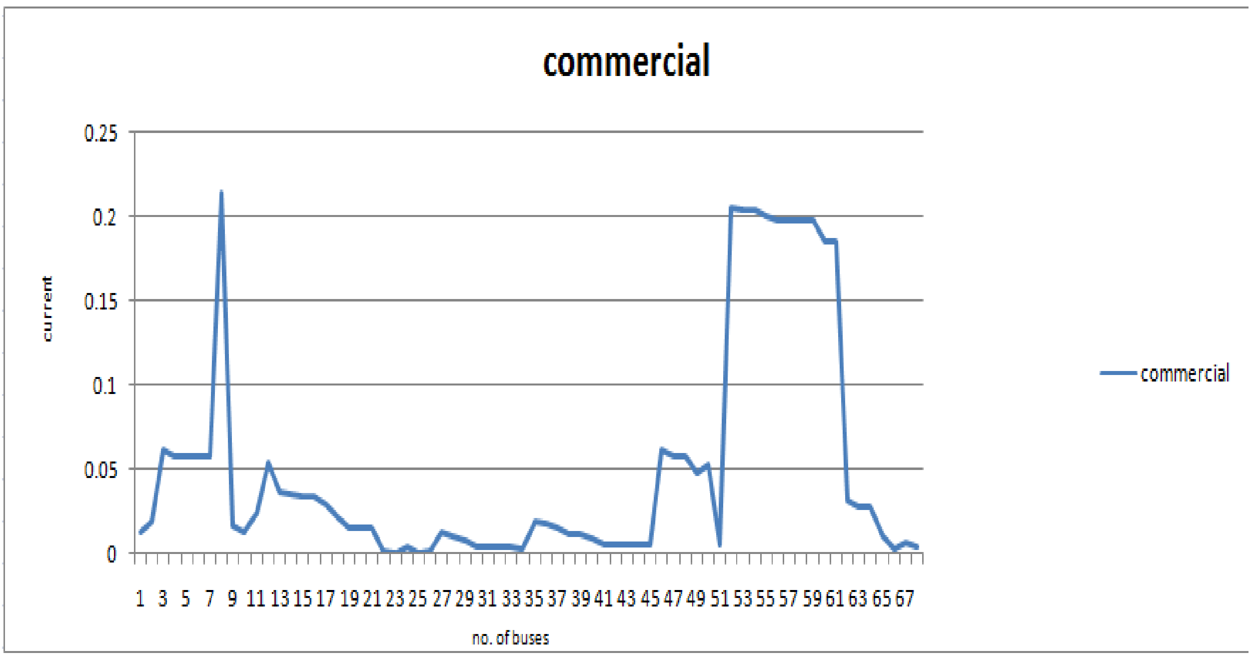

Fig. 9 Current Profile for IEEE 69-bus radial distribution system for commercial load

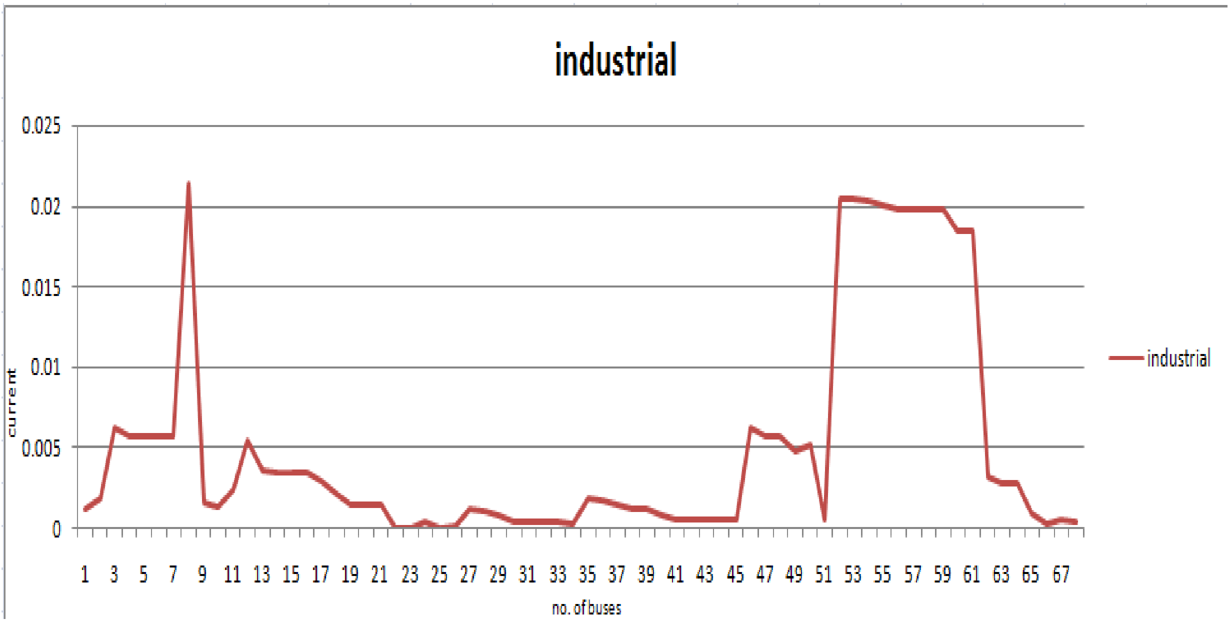

Fig. 10 Current Profile for IEEE 33-bus radial distribution system for industrial load

The current profile for IEEE 69-bus distribution system is shown in Fig. 10, the fluctuation of the current is again identical to Fig. 9 for commercial load in both cases that is for industrial and commercial load and shows that both are independent on the applied of voltage to the distribution system and again there is sudden increment or decrement of the magnitude of current this is nothing but it occur due to the termination of the line or bus and new connection with the bus

6. Final observation on the results

The proposed method as described in this paper takes the advantage as granted for the forward sweep and backward sweep and it is simple and it uses the basic laws of electrical engineering that are Kirchhoff's current law and Kirchhoff's voltage law.

The described methodology is programmed successfully using the MATLAB codes that are designed or coded in a manner that they completely obeys the algorithm as described in this paper. The result obtained using MATLAB codes prove the methodology applied that describes forward sweep and backward sweep shows a very good efficacy of the MATLAB codes.

The total power loss for IEEE 33-bus distribution system for both industrial and commercial load are 3.811 kW and 135.4152 kW respectively where as the total power loss for IEEE 69-bus distribution system for both industrial and commercial load are 4.7426 kW and 156.8449 kW respectively.

Conclusion

In this paper the effect of industrial load and commercial load on IEEE 33-bus and IEEE 69-bus distribution system is studied and the impact of electrical equipment or electrical load leads to the differentiation of the two types of loads. The advanced electrical equipment when used on either of the load shows the identical behavior as observed on the various current and voltage profile but as compared to the electrical equipment which when used previous 10 years before shows that the losses in flow of power from the sending end to the receiving end. Also the applied methodology further helps to obtain the results very easily. For future the advanced electrical equipment should be developed by keeping in mind in order to take the losses as low as possible

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