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Power Factor and Energy Loss Cost Evaluation of Radial Distribution Systems

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ABSTRACT: In the power system network, radial distribution system plays main role to distribute power for the consumers. When the power is supplied to the consumers due to resistance nature of distribution system power losses occurs and due to inductive nature reactive power loss occur which in turn causes the voltage level decrement in the system. The power consumption depends mainly on power factor. The consumer has to pay for this power loss.
This paper presents the analysis of energy loss cost and power factor evaluation for balanced radial distribution systems. The power factor is calculated by using given load data directly by using a simple equation. Energy loss cost depends on power loss of radial distribution. In this paper radial distribution systems without laterals (only main feeder) are considered. 10-bus and 12-bus radial distribution systems are used to evaluate (i) Power factor and (ii) Energy loss cost.

I. INTRODUCTION

When the power quality is not within limits the consumer suffers from severe problems as low voltage, voltage drops, machine damage, and high bill payment. Hence there is a need for to analyze a distribution system performance in order to overcome these problems. The performance of radial distribution system is evaluated by using some parameters. In this paper power factor and energy loss cost are considered. To find these quantities load flow solutions are compulsory. Due to high resistance to reactance ratio the distribution system losses are more hence traditional methods are not used for load flows. In order to overcome this problem in literature number of authors proposed new methods for load flow analysis.

Baran and Wu [1] has implemented a load flow solution, based on real power, reactive power and voltage calculation in iterative process. Shirmohammadi [2] had given a new solution methodology by using simple KCL and KVL equations. This method is useful only for weakly meshed systems but not used for radial systems. Kersting [3] had given a load flow solution where convergence problem comes due to pure ladder network. Renato [4] had given a solution which gives an electrical model for every node by summing all the power beyond that node. A single line equivalent distribution system is implemented by Jasmon and Lee [5]. Direct solution methodology had executed by Goswami and Basu [6]. This method is not used for the system which has a node more than three branches. Das [7] had mentioned a load flow method based on total active and reactive power fed through any node. Sivanagaraju [8] had given an optimization based problem to minimize energy loss cost. Ponnavaikko [9] had given a model to find feeder cost, energy loss cost by using conductor cross section.
This paper gives the load flow analysis using backward and forward sweep method. After load flow evaluation the energy loss cost is evaluated. The power factor of the systems is calculated by using load data.

II. PROBLEM FORMULATION

1. The power factor of the system is calculated by using

$$PFT = \frac{PD}{\sqrt{PD^2 + QD^2}}$$

Where
PFT is Total power factor of the system.
PD is total load real power.
QD is total load reactive power.

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2. The energy loss cost is calculated by using
$ELC = PTL * anual\ power\ loss\ cost\ in\ \$.$
Where
ELC is Energy Loss Cost.
PTL is Total Power Loss.

III. LOAD FLOW TECHNIQUE

Consider a branch whose impedance is Z_i.

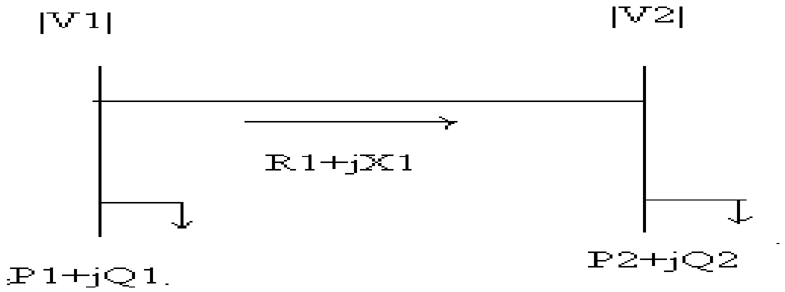

Figure 1: Single branch diagram
Where
V1 and V2 are voltages of bus-1 and bus-2.
P1 and Q1 are load real and reactive powers at bus-1.
P2 and Q2 are load real and reactive powers at bus-2.
R1 and X1 are resistance and reactance of branch-1.
1. Calculation of bus currents: $Load\ current_i = conj\left(\frac{Apparant\ power_i}{Bus\ voltage_i}\right)$
Where
i is from 1 to number of total buses.
2. Calculation of branch currents:
$$branch\ current(i) = branch\ current(i+1) + Load\ current(i+1)$$
Where
i is from 1 to number of branches
3. Bus voltage: $v(i+1) = v(i) - branch\ current\ (i) * R(i)$
Where
i is from 1 to number of buses.
4. Total real power loss: $\sum branch\ current(i)^2 * R(i)$
5. Total reactive power loss: $\sum branch\ current(i)^2 * X(i)$
Where
i is from 1 to number of branches.

IV. RESULTS AND DISCUSSIONS

Here power factor and energy loss cost are evaluated by considering two test systems which have radial nature without laterals and sub laterals. 10-bus and 12-bus radial distribution systems are considered.
Assume annual cost of power loss as 168 $\$/(kW - year)$.

Test system-1: 10-bus RDS (Radial Distribution System)
The 10-bus radial distribution system BASEKVA is 100 and BASEKV is 23 [10].

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The power loss results:

Table-1: The branch power loss results of 10-bus radial distribution system.

Branch number	Branch real power loss (p.u.)
1	0.0005
2	0.0000
3	0.0018
4	0.0011
5	0.0019
6	0.0005
7	0.0008
8	0.0009
9	0.0004

Table-1 describes the power loss of each branch. It is observed that the total real power loss is 988.4983 kW. The minimum branch power loss occurred at branch-2. The maximum power loss occurred at branch-5.

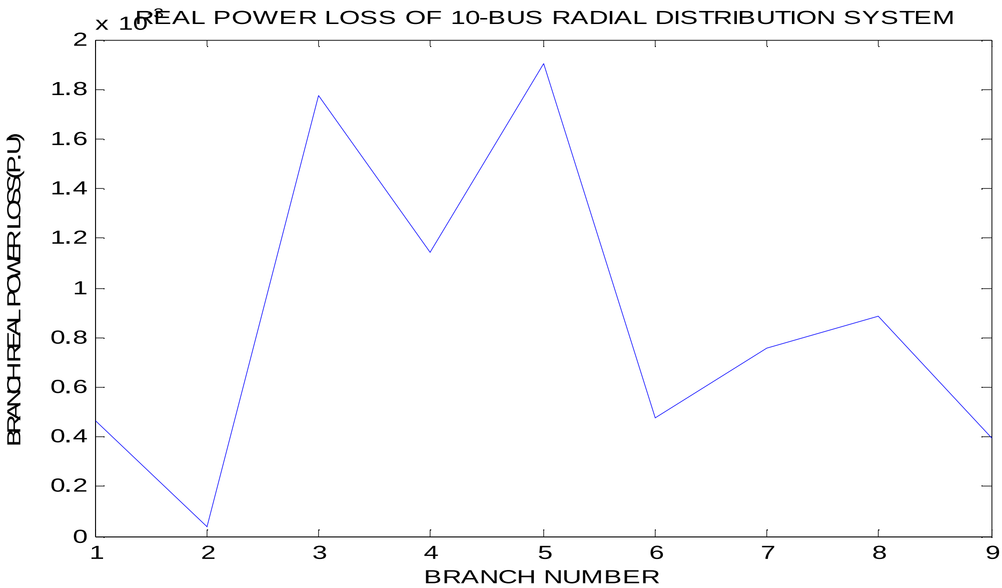

Figure 2: The branch real power loss of 10-bus RDS

Figure 2 gives the details of branch power losses in 10-bus radial distribution system. The maximum branch power losses are at branch-5. The minimum branch losses are at bus-2.

Power factor of 10-bus radial distribution system is 0.9472.
The total energy loss cost of 10-bus radial distribution system is 166067.7225 $\$/(kW - year)$.

Test system-2: 12-bus RDS
The BASEMVA and BASEKV of 12-bus radial distribution system are 10 and 11 [7].

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The power loss results:

Table-2: The branch real power loss results of 12-bus radial distribution system.

Branch number	Branch real power loss (p.u.)*10^-3
1	0.3417
2	0.2747
3	0.3980
4	0.4220
5	0.1148
6	0.0906
7	0.2277
8	0.1573
9	0.0368
10	0.0071
11	0.0005

Table-2 gives the details of branch power losses at each branch. The branch-4 is having the more power loss and the branch-11 contains minimum power loss. The total real power loss is 20.7120 kW.

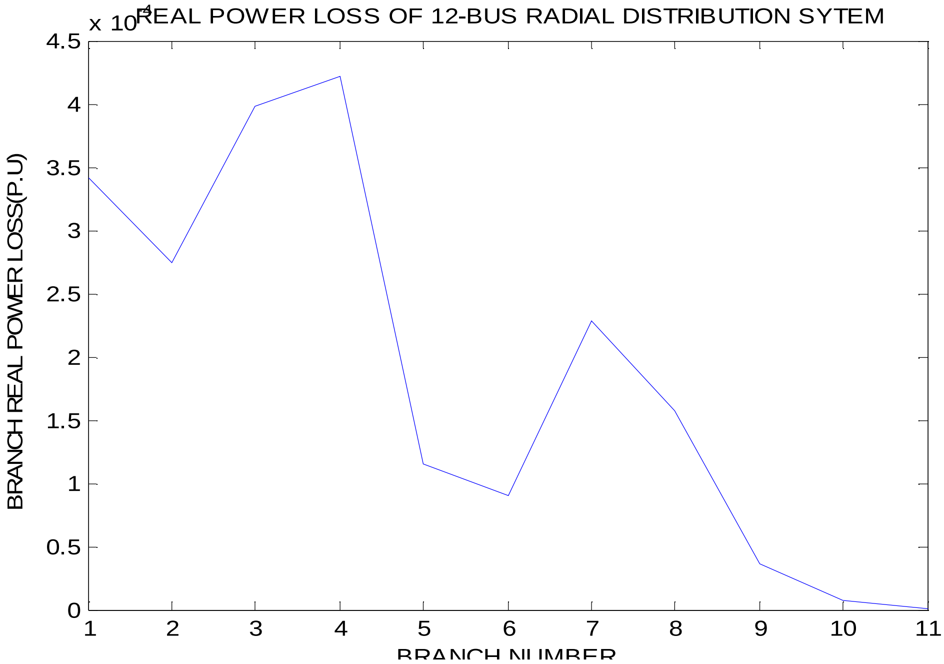

Figure 3: The branch real power loss of 12-bus RDS

Figure 3 analyses the branch power loss at each branch of 12-bus radial distribution system. From the figure 3 it is clear that the maximum power loss occurred at branch-4 and minimum power loss occurred at branch -11.

Power factor of 12-bus radial distribution system is 0.7318.
The total energy loss cost is 3479.6184 $\$/(kW - year)$.

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V. CONCLUSION

The distribution system loss depends on load power factor and resistance of the line. In this paper the energy loss cost is calculated and the power factor of the radial distribution system is evaluated. In order to calculate power loss backward and forward sweep method is considered. With this knowledge of power factor and power loss, one can analyze the power quality of a radial distribution system. In order to improve power quality, compensating techniques can be used.

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BIOGRAPHY

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