Energy Loss Reduction in Distribution System

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Abstract: ***This research study energy loss reduction in distribution system. This study carries out in the distribution system by using PSS/adept program as tool for simulation. The techniques considered for the reduction of technical losses increase power capacity of distribution system through addition of new equipment (transformer), and network reconfiguration based on optimal power flow, which enables the benefit-cost analysis assessment of energy loss reduction, that supports the investments. The considered costs are economic costs associated with loss reduction sources. The benefit is the reduction in energy loss costs in the distribution system. The benefits will be worked out against the costs which will show the economic justification of the investments in loss reduction sources. Al-Muthanna distribution system in Iraq is used in the simulation study to illustrate the method.***

Keywords: loss minimization, PSS/Adept 5.3.2 Program, benefit-cost analysis, optimal power flow

1. Introduction

Technical losses in term of energy are inevitable physical phenomenon. This loss happens during the transfer of energy in distribution system [1]. During this transfer process, some of the input energy is dissipated in conductors and transformers along the delivery route. The losses that occur in all conductors may three types of copper, dielectric and induction radiation losses of the three, copper losses record the highest of total distribution losses. Copper losses make up the I2R losses that are inherent in all conductors. This is because of the finite resistance of the conductors. These losses occur due to the current flowing in the electrical network. In alternating current (AC) system, the copper losses are higher due to skin effect [2].

In a typical distribution system, network losses account for about 8 percent to 12 percent of the total energy in the distribution system, which would cost millions of dollars every year [3]. Therefore, an energy loss in the network means an economic loss to the utility companies. They are construed as a loss of revenue by these companies. Therefore, loss minimization is one of the important objectives in operating the distribution system.

On the one hand, reducing losses may have an added value to the cost of capital expenditure. They, on the other hand, will help to reduce the amount of power transmitted in distribution system, and this will have wider benefits. Therefore, it yields the necessity of direct trade-off between the cost of capital expenditure and the benefits gained from loss reduction. To do that, the losses should be estimated as accurately as possible [4-7].

In this paper, researchers propose a method to evaluate the increasing power capacity of distribution system of loss reduction support based on the benefit-cost analysis. The costs are economic costs of loss reduction sources, which include capital investment and operating costs. The benefits from loss reduction supports are defined as the difference in the energy loss cost between the existing system and each option is the reduction of energy loss cost due to the choice.

The organization of the paper is as follows: The following section presents the procedure for optimal addition of loss reduction support based on power flow, and using cost-benefit analysis. In section 3 presents the simulation study for loss minimization of the Al-Muthanna distribution system is performed installation of substation of loss reduction supports for distribution Loss Minimization. Finally, conclusions are made in Section 4.

2. The Proposed Selection Methodology

In this method, the candidate positions of loss reduction sources will be first identified using an objective function with the minimum total cost objective including costs of loss reduction sources (substation). Followed by insertion of those equipment and network reconfiguration by changing its topology through resetting the status of switch located at certain of the network

The candidate locations for optimal allocations of loss reduction sources to the system were chosen. Then the loss reduction sources are installed to different candidate places one by one and at several candidate places. The cost-benefit analysis will then be worked out against the candidate locations of loss reduction sources, so as to arrive at the optimal plan to reduce losses in an iterative manner. The selected positions and sizes of substation are those which generate the system benefits larger than the costs involved which make the investment economically justifiable. The method will be presented in details in the paper and will be applied to the real distribution system of Al-Muthanna distribution system to find the optimal location of loss reduction sources.

3.1 Cost-Benefit Analysis

In this paper, loss reduction can be achieved by optimal network of loss reduction sources (substations, cables) to a distribution system. But this construction would require large investments. Therefore, the benefit of loss reduction should be high enough to meet the financial criteria [8].

This paper, the chosen method was Benefit/cost ratio (BCR) for performing economic evaluation. BCR was a technique for evaluating a case by comparing the economic costs with the economic benefits of the activity. The benefit/cost ratio was defined as the present value of the benefit divided by the present value of the cost. Mathematically, the present value of future cash flow is defined by the following formula:

$PV = FV/ (1+r)^t$ (1)

Where PV is the present value, FV is the future value, r is the discount rate; and t is the year in which FV is realized. The Present Value is an economic evaluation approach that uses the time value of money to convert future cash flow into a present value at a certain discount rate. Due to the time value of money, a hundred dollars today are more valuable than a hundred dollars in the future. For a recurring constant annual income / cost, the present value can be found using the following formula:

$PV_A = A \times PWF$ (2)

Where PV_A is the Present Value of the recurring annuity (A), PWF is the Present Worth Factor given by the following equation.

$PWF = [(1+r)^t -1] / [r (1+r)^t]$ (3)

The larger the BCR is, the better the case is. A case with a BCR < 1.0 cannot be financially justified. For example, BCR > 1.5 or 2 is a frequently used threshold [9].

3. The Simulation Study: Al-Muthanna Distribution System

High energy losses is one of the serious problems in the distribution systems in Iraq, where the distribution system are aging and the distribution lines are not always able to transmit the required active power due to the transfer capability limits. One typical example is the case of Al-Muthanna distribution system of Iraq [9]. The single-line diagram for this network is given in Fig.1

The network of Al Muthanna Iraq distribution system was chosen as a test distribution system, the test system for the case study consisting of 68-bus radial system. The system is under in base of 11-kV distribution systems.

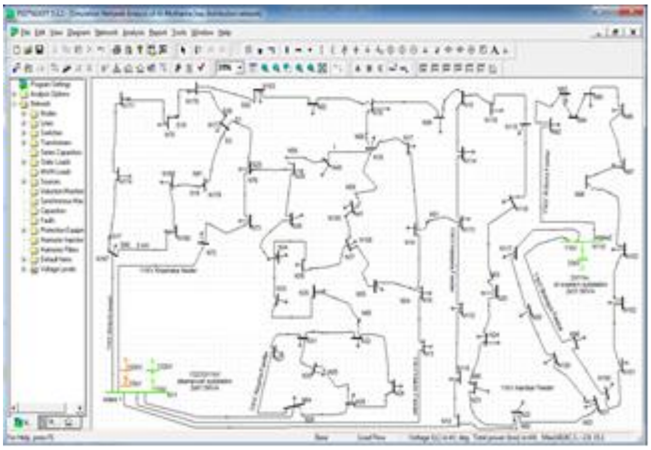

Figure 1: Single-line diagram of Al-Muthanna distribution system

Normally the network is fed by eight 11-kV underground feeders from two substations located in the area named as Al-Samawah Substation and Al-Western Substation. Al-Samawah Substation consists of (2) units of 61.5 MVA, 132/33/11 kV transformers connected to five 11-kV feeders and (48) static load. While, The Western Substation consists of 2 units of 31.5 MVA, 33/11 kV transformers connected to three 11-kV feeders and (19) static load. Also this network consists of (34) switches that can be opened or closed. The total power load connected to distribution network is 109.7-MVA. Distribution network data technically is be converted to meet with PSS/ADEPT parameter requirements. Then model of the present Al-Muthanna network is simulated, run load flow by using the model. Hence, determine power losses in each branch of the network. Also the candidate places for substation installation supports were defined. The identification of the candidate locations of substation installations is made according to where the highest power loss flows in the network. Candidate places are defined at least five places for loss reduction supports are shown on Fig.2.

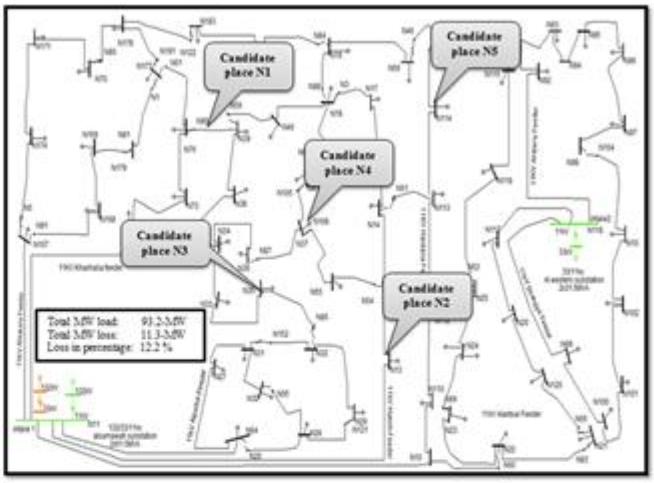

Figure2: Losses and candidate places for loss reduction supports

Once the candidate places for loss reduction supports are identified, substations are installed to different candidate places one by one and at several candidate places. After each installed of substation, the costs and benefits due to loss reduction support should be estimated according to benefit-cost analysis. We need to calculate benefits due to the reduced or "saved" losses from substation installations and costs of the substation installed, and then we compare benefits and costs with those substations. For the calculation of benefits from saved losses, from [9] we know that price for 1 kWh of energy at 11-kV voltage level is 0.06 \$. For the calculation of costs of 33/11-kV substation, according to [8] assume that investment cost of 1MVA is \$31.05, O&M cost of substance is \$ 53 per MVA in a month. Also, for the calculation of costs of 33-kV cable with size is 1×400 millimeter square XLPE is \$ 52.3 per meter, O&M cost of cable is \$ 56 per km in a month. Assume the economic life of the substations and cable is 20 years, and the interest rate of 2.0 % per year

3.2 Building New Substations

Five candidates of substation locations have been performed. However, only the significant substation locations will be shown in the following:

Step 1: The 33/11-kV substation of 31.5-MVA was installed at the candidate place N1 as indicated on the diagram in Fig. 2. Then network reconfiguration, 11 kV busbar of the substation (N77) was connected to 11 kV busbar of (N76, N177, N82, N39, and N34). Then switch statues, where switch S90, S1, S90, S1, S26, S90, S18, S26, and S23 were opened while the switches S3, S19, S97, S20, S8, S6, and S27 were normally closed. This figure is the network after implementation of substation as shown in Fig.3.

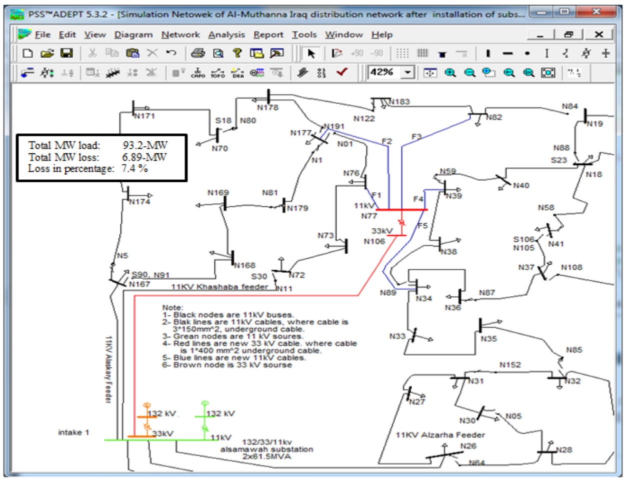

Figure3:Simulation network after installation of substation.

Perform a PSS/adept run, and calculate the total system loss. As a result of substation installation in the network, the loss was decreased from 11.38 MW (12.2%) to 6.89 MW (7.4%). This means that the loss reduction of this case is 4.49MW (11.38MW-6.89MW). The annual benefit of energy loss reduction in the network was calculated to be $ 1.11 million, the present value of the benefits of loss reduction was calculated to be $ 18.33 million, and the present value of the substation cost was calculated to be M$ 2.69 As a result we have positive benefit due to substation addition since the benefit was greater than the cost. Benefit/cost ratio is 7.7; this means that this case was successful and worthwhile for implementation.

Step 2: The two 33/11-kV substations of 31.5-MVA were installed at the candidate place N1 and N2 respectively as indicated on the diagram in Fig.2. Again network reconfiguration as shown in Fig.4. Perform a PSS/adept run, and calculate the total system loss. As a result of substation installations at this case, the loss was decreased from 11.38 MW (12.2%) to 1.72 MW (1.8%). This means that the loss reduction of this case is 9.66-MW (11.38-1.72), loss reduction represents an annual benefit of $ 2.38 million. The PV of the benefits of loss reduction was calculated to be M$ 39.4, and the PV of the total substation costs was calculated to be $ 4.58. This case is also successful as Benefit/cost ratio is 8.7.

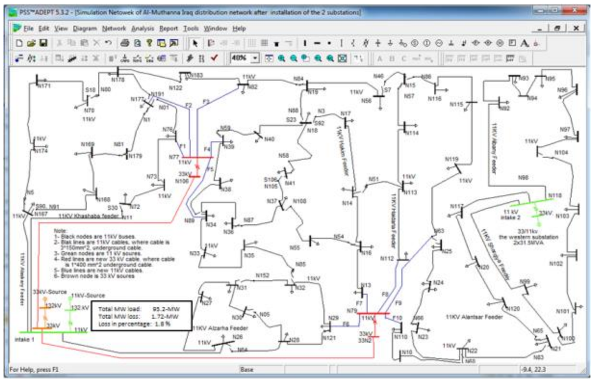

Figure4: Simulation network after installation of 2 substations

Step 3: It is still possible to reduce the loss a bit more than that of the previous step. The 33/11-kV substations of 31.5-MVA were installed at the candidate places N1, N2 and N3 respectively as shown in fig5. With this modification, the loss could be reduced to 1.58 MW (1.7%). The present value of the benefit of energy loss reduction was $ 41 million. The present value of the total substation costs was calculated to be $ 7 million. However, this case is also successful, but benefit/cost ratio is 5.8. Therefore, benefit/cost in this case is less than case 2.

Step 4: There is possibility to reduce losses maximally. For this need to add the 33/11-kV substation of 31.5-MVA at candidate places N1, N2, N4 and N5. With this way, the losses are reduced to 1.22 MW (1.3%). The present value of the benefits is M$ 41.5. The present value of the cost will be M$ 9.8. This case is again not successful since the benefit /cost ratio (4.2) is less than the case 2, even the losses could be maximally reduced.

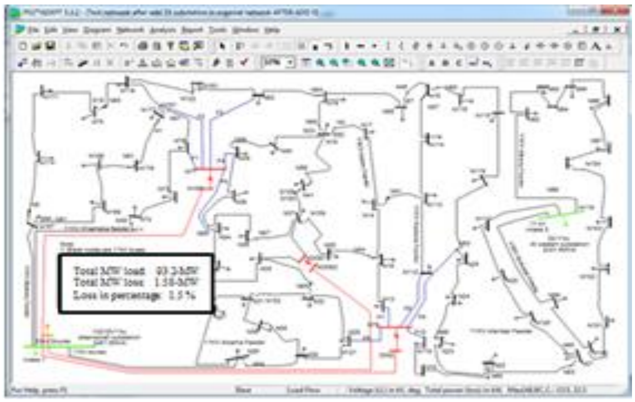

Figure5:Simulation network after installation of 3 substations

Finally, As a result of substation installations could observe, that addition of 33/11-kV substation at candidate places N1 and N2 gave successful results, while addition of substations at other candidate locations were not successful based on benefit/cost ratio even this action reduced losses more. For this case candidate places N1 and N2 will be chosen for successful addition of substations as only in this case the energy loss reduction becomes beneficial.

3.3 Final Selection of Substation Placement Plan

After performing all the simulations and analyzing the simulation results discussed in 3.2. We could arrive at the final plan for optimal substation placement for loss reduction. It is most beneficial to install the substations of 1×31.5-MVA at candidate places N1 and N2. In this supply, the energy losses reduction is saving the system owner about $2.3 million annually. In this work, it was found that an 85% reduction in energy losses which can be achieved through installation of two substations as shown in fig.3.

It could be observed from study that if we make investments for addition of substation in distribution system for loss reduction objective; the reduced losses would recover investment costs of the substation addition. However, this was not true for all the cases in the study and some cases were found to be not effective. the study, made on a real distribution system, have shown that in some cases, even though the losses are reduced, the investment cost could be so high, that it becomes economically not effective to implement such changes. It should also be noted that in simulation study, assumptions are made regarding, average peak-hours per year, the price of the energy , the investment cost for loss reduction support addition, as well as the economic life of the transformer. The results of benefit-cost analysis are based on these assumptions, hence are sensitive to these. If these assumptions are to be altered, the results of benefit-cost comparisons will likely change and unsuccessful iterations could become successful and vice versa. Fortunately, in a real system study, one can obtain a more precise data than those we assumed here for the illustration purpose.

4. Conclusions

In this paper, the proposed method is for increasing power capacity of distribution system by adding of new equipment, for energy loss reduction based on optimal power flow in couple with the cost-benefit analysis. The method was implemented on the example of real distribution system of one of the Iraq regions. The study has shown that the transformer could help to reduce the energy loss in the distribution network. The transformer cost could be off-set by the loss reduction. Therefore, an additional transformer is able to significantly improve the performance of distribution system and to reduce energy losses. Network reconfiguration should properly applies, but if not properly applies lead to create even more energy losses. Finally, good planning helps to ensure that installation of transformers are placed and operated properly

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Ahmed Hamzah Kadhim was born in Iraq in 1978. He received the B.S. degree in Electrical Engineering from Al-Mustansiria University, Iraq in 2001. During 2003-20011, he employed in Al-Muthanna Office, DG of Electricity Distribution South, Ministry of Electricity in Iraq. He worked in Electrical O&M Department. Then in 2012 Iraqi government sent him to Malaysia to study M.S. degree in Electrical Power engineering-Uniten University. Now he is doing a dissertation and its topic: “Assessment Technical Losses in Distribution System”.