Research on Strategy of Reducing Line Losses of Distribution Network Based on Regulating Running Aoltage

Jinhuan Zhang[1], Haixia An[1], Yunzhen He[2]

[1]*Department of Electric-Mechanical Engineering & Automation, Tianjin Vocational Institute, Tianjin 300410,China*

[2]*Department of Electronics and Information, TEDA-Tianjin Economic-Technological Development Area POLYTECHNIC, Tianjin 300457, China*

Email: zhjhgzm@126.com

Abstract: The line losses of distribution network directly affect power supply enterprise's economic efficiency. Firstly, the relation between line losses and running voltage is analyzed in the paper and a conclusion is drawn that line losses of distribution network are reduced through regulating running voltage. When Electricity quality is guaranteed, increasing properly running voltage can decrease line losses under the condition of the distribution transformer heavy-load operation and increasing properly running voltage can decrease line losses under the condition of the distribution transformer heavy-load operation. But the result is opposite when the distribution transformer is under the condition of light-load operation. Then, the function for running voltage and the least line loss is derived. Finally, dynamic power system experimentations are done. Experimentation results show that the proposed method is efficiency and applicable.

Keywords: distribution network; line losses; running voltage; energy-saving and cost-reducing

1. Introduction

Distribution networks can supply power to user. Due to impedance, electric energy loss is unavoidable in the process of its conversion and transfer. Line losses rate represented the ratio to the electric energy loss and the all. Reducing losses is important to economic operation of distribution networks and increase economic efficiency of power supply Company[1-2].The paper analyses the relation between running voltage and line losses under the safe running of our distribution networks .The method of decreasing losses are carried out through experimentations in dynamic power system.

2. The relation of running voltage and losses

The distribution networks losses includes the losses of line and transformers[3-4],Variable loss varies inversely with the square of running voltage. Traditional theory regards that line losses can be reduced by increasing running voltage in distribution network. But the author finds that line losses can be increased by increasing running voltage under the distribution transformers heavy-load operation. The reason is that invariable loss in the distribution transformer varies directly with the square of running voltage. If the load is high, the line losses can be decreased by increasing running voltage because the rate of variable loss is larger than the one of invariable loss. While the load is light, the line losses can be increased by increasing running voltage because the rate of invariable loss is larger than the one of variable loss. In a word, considering load the line loss is decreased only by means of regulating running voltage of the distribution networks [5-7].

3. The Mathematical Model between the running voltage and line losses

3.1 The objective function for the minimum total loss ratio

The line losses of power networks is the sum total of all component loss. Load Flow Calculation method is used to 35 kV and above complex power networks. The methods of normal root-mean-square electric current and equivalent resistance are used to 10 kV and below middle or low-voltage distribution power System. The paper provides the objective function for the minimum total loss ratio by method of equivalent resistance.

There are n lines and m transformers whose running voltage are equal in distribution networks, all transformers are running on condition of rated voltage being U_N before the running voltage isn't regulated.

Mathematical formula about m transformers' invariable losses:

$$\Delta P_{Fe} = \sum_{j=1}^{m} \Delta P_{Fej} = \left(U/U_N\right)^2 \sum_{j=1}^{m} P_{Fej} \tag{1}$$

In the equation (1): ΔP_{Fe} stands for the total invariable loss of the all transformers; ΔP_{Fej} stands for the invariable loss of the j transformer; P_{Fej} stands for the no-load loss of the j transformer; U_N stands for the rated voltage of the j transformer.

Mathematical formula about the total invariable loss of the line:

$$\Delta P_l = 3I_{l1}^2 R_{l1} + 3I_{l2}^2 R_{l2} + \cdots + 3I_{\ln}^2 R_{\ln} = \frac{S_1^2 R_{l1}}{U^2} + \frac{S_2^2 R_{l2}}{U^2} + \cdots + \frac{S_n^2 R_{\ln}}{U^2} = \sum_{i=1}^{n} \frac{S_i^2 R_{li}}{U^2} \quad (2)$$

In the equation(2): R_{li} stands for the equivalent resistance of the i line; ΔP_l stands for the total loss of the lines; U stands for the running voltage of the transformers; S_i stands for the total apparent power of the i line; I_{li} stands for the total current of the i line.

Mathematical formula about m transformers' variable losses:

$$\Delta P_{cu} = \sum_{j=1}^{m} \Delta P_{cuj} = \sum_{j=1}^{m} \left(\frac{U_N}{U}\right)^2 \left(\frac{S_j}{S_{Nj}}\right)^2 P_{cuj} \quad (3)$$

In the equation (3): ΔP_{cu} stands for the total variable loss of the all transformers; ΔP_{cuj} stands for the variable loss of the j transformer; S_j stands for the apparent power of the j transformer; S_{Nj} stands for the rated apparent power of the j transformer; P_{cuj} stands for the short-circuit loss of the j transformer.

Mathematical formula about the variation percentage of invariable loss:

$$\Delta P_{Fe}\% = \frac{\sum_{j=1}^{m}\left(\frac{U}{U_N}\right)^2 P_{Fej} - \sum_{j=1}^{m}\left(\frac{U_N}{U_N}\right)^2 P_{Fej}}{\sum_{j=1}^{m}\left(\frac{U_N}{U_N}\right)^2 P_{Fej}} * 100\% = \left[\left(\frac{U}{U_N}\right)^2 - 1\right] * 100\% \quad (4)$$

Mathematical formula about the variation percentage of line loss:

$$\Delta P_l\% = \frac{\frac{\sum_{i=1}^{n} S_i^2 R_{li}}{U^2} - \frac{\sum_{i=1}^{n} (s_i')^2 R_{li}}{U_N^2}}{\frac{\sum_{i=1}^{n} (s_i')^2 R_{li}}{U_N^2}} * 100\% = \left[\left(\frac{U_N}{U}\right)^2 - 1\right] * 100\% \quad (5)$$

In the equation(5): $S_i^{'}$ stands for the total apparent power of the all transformers in the i line when running is U_N .The small change of voltage lead to the small change of apparent power in power networks, and $S_i^{'} = S_i$ is feasible.

$$\Delta P_{cu}\% = \frac{\sum_{j=1}^{m}\left(\frac{U_N}{U}\right)^2\left(\frac{S_j}{S_{Nj}}\right)^2 P_{cuj} - \sum_{j=1}^{m}\left(\frac{U_N}{U_N}\right)^2\left(\frac{S_j^{'}}{S_{Nj}}\right)^2 P_{cuj}}{\sum_{j=1}^{m}\left(\frac{U_N}{U_N}\right)^2\left(\frac{S_j^{'}}{S_{Nj}}\right)^2 P_{cuj}} * 100\% = \left[\left(\frac{U_N}{U}\right)^2 - 1\right] * 100\% \quad (6)$$

Mathematical formula about the variation percentage of the total loss:

$$\Delta P\% = \left\{ C\left[\left(\frac{U}{U_N}\right)^2 - 1\right] + (1-C)\left[\left(\frac{U_N}{U}\right)^2 - 1\right]\right\} * 100\% \quad (7)$$

In the equation(6): $S_j^{'}$ stands for the apparent power of the j transformers when running is U_N ; $S_j^{'} = S_j$ is approximately considered.

In the equation (7): C stands for the ratio of the invariable loss to the total loss, 1-C stands for the ratio of the variable loss to the total loss.

Through the above analysis, the objective function for the minimum total loss ratio is found:

$$Min(\Delta P\%) = Min\left\{ C\left[\left(\frac{U}{U_N}\right)^2 - 1\right] + (1-C)\left[\left(\frac{U_N}{U}\right)^2 - 1\right]\right\} * 100\% \quad (8)$$

3.2 The method to optimal running $U^{'}$ based on the minimum variation percentage of the total loss

To calculate the differential of the equation (8) and the derivative equal 0 .

$$\frac{d(\Delta P\%)}{dU} = 0$$

$$U = U_N \sqrt[4]{\frac{1-C}{C}} \quad (9)$$

Mathematical formula about the minimum variation percentage of the total loss is obtained, while U in the equation (9) is taken into the (7) equation.

$$Min(\Delta P\%) = 2\sqrt{C(1-C)} - 1 \quad (10)$$

According to the equation (9), when the ratio of variable loss to the total loss is greater than 50%, the loss is decreased by increasing running voltage. In the equation (10), $C(1-C) \le 1/4$ and $Min(\Delta P\%) \le 0$ .The method of the optimal running voltage are:

(1) If U which comes from the equation (9) causes $U_{\min} \le U \le U_{\max}$ ($U_{\min}, U_{\max}$ stands for the maximum or minimum value of voltage which is safe), U' is the optimal running voltage, that is $U' = U$ .The equation of the minimum variation percentage of the total loss is: $Min(\Delta P\%) = 2\sqrt{C(1-C)} - 1$.

(2) If U which comes from the equation (9) causes $U \le U_{\min}$, that is $U' = U_{\min}$,The equation of the minimum variation percentage of the total loss is:

$$Min(\Delta P\%) = \left\{ C\left[\left(\frac{U_{\min}}{U_N}\right)^2 - 1\right] + (1-C)\left[\left(\frac{U_N}{U_{\min}}\right)^2 - 1\right]\right\} * 100\% \tag{11}$$

(3) If U which comes from the equation (9) causes $U \ge U_{\max}$, that is $U' = U_{\max}$, The equation of the minimum variation percentage of the total loss is:

$$Min(\Delta P\%) = \left\{ C\left[\left(\frac{U_{\max}}{U_N}\right)^2 - 1\right] + (1-C)\left[\left(\frac{U_N}{U_{\max}}\right)^2 - 1\right]\right\} * 100\% \tag{12}$$

3 Dynamic power system experimentations analysis

Decreasing loss strategy which is put forward in the paper is tested by data of the second transformer in substation which comes from myself distribution network, these data is in the Table 1.

Table 1. Distribution network parameters

Name of line	402 line	404 line	406 line	408 line	410 line
Active power quantity (kWh/24h)	35864	48240	28800	4320	14800
variable loss of the all transformers (kWh)	67	38	46	31	9
invariable loss of the all transformers (kWh)	151	134	146	31	210
loss of the all lines(kWh)	394	400	81	1	121

In according to the data of Table 1 and U_N=10.5kV, The below conclusion is obtained: C＝0.3613，1－C＝0.6387, U=12.1kV. Due to $U > U_{\max}$ and $U_{\max}$=10.7kV, that is $U' = U_{\max}$. U' can be regulated though transformer taps. Compare to $U' = U_{\max}$ ， the minimum variation percentage of the total loss is -0.97586％.Thus， Distribution network including the second transformer consumed 38366250kWh active power in 2005. In this year the saved electric energy are calculated：38366250×0.0097586＝374400.8873kwh； and If per kilowatt hour electric energy costs 0.45 yuan，the saved electric energy is converted into Renminbi :0.45×374400.8873＝168500 yuan.

4 Conclusion

Traditional theory regards that line losses can be reduced by increasing running voltage in distribution network. The relation between line losses and running voltage are analyzed in the paper and a conclusion is drawn that when the distribution transformer is under the condition of heavy-load operation, improving running voltage can decrease line losses while the result is opposite when the distribution transformer is under the condition of light-load operation. Finally, the method of determining running voltage with the least line loss is derived. The proposed method in the paper has been approved by testing results.

References

[1] DL/T 686－1999.Guide of calculator of grid energy loss [S].The Standard of China's Electric Power Industry,1999.
[2] KE Qing-feng.Line Loss Analysis of Power Distribution Network[J].Northeast Electric Power Technology, 2006,27(6):31-33.
[3] YUAN Hui-mei,GUO Xi-qing,YU Hai-bo. New Method for Calculating Energy Losses in Medium-voltage Distribution Systems[J].Automation of Electric Power Systems,2002,26(11):50-53.
[4] YU Wei-guo, XIONG You-jing, etal. Analysis on Technical Line Losses of Power Grids and Countermeasures to Reduce Line Losses[J].Power System Technology, 2006,30(18):54-57.
[5] Marinko Stojkov,KrllnoTrupinic,srete Nikolovski Teehnieal loss in power distribution network[J],IEEE Mediterranean Electro technical Conference,Malaga,2006:1048—1051.
[6] Wu Xiaomeng,Liu Jian,Yu Jianming. An improved approach to theoretical losses analysis of Field distribution network[C]//International Conference on Power Systems Techno1ogy, 2006: 933-938.
[7] J.Nazarko,Z.Styczyski,M.poplawski. The Approach to energy losses calculations in low voltage Distribution networks[C]//Engineering Society Winter Meeting. IEEE,2000.
[8] CUI Feng-liang, On-line Management System for the Line Loss of Power Network and Its Application[J],Automation of Electric PowerSystems,2002:26(3):73-75.

 978-1-935068-40-2 © 2010 SciRes.