Research on Low Voltage Control Measures of distribution Network

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2021 China International Conference on Electricity Distribution (CICED) | 978-1-7281-9229-1/21/$31.00 ©2021 IEEE | DOI: 10.1109/CICED50259.2021.9556836

***Abstract*—distribution network voltage is the main index of power quality, which has a direct impact on the safety and stability of distribution network and the safe operation of power equipment, power loss of transmission lines, industrial and agricultural safety production and people's daily electricity consumption. Based on the PSASP simulation software, the real-time simulation analysis of the voltage in the Nailin area is carried out. During the irrigation period，the simulation results show that the low voltage problem is serious，and the daily load fluctuation is obvious, so it is necessary to adopt the control measures which can adjust the voltage in both directions flexibly. After comparison, the line voltage regulator and SVG are proposed to be used. After low voltage control, the simulation results show that the low voltage problem is obviously improved . Finally, the management measures to improve the low voltage problem are put forward.**

Keywords— distribution network voltage, low voltage, PSASP, real-time simulation

I. INTRODUCTION

After startring the agricultural irrigation season in Naiman area, the regional load could increase by hundreds of thousands of kilowatts in a short time. After the end of agricultural irrigation on that day, the regional load gradually decreased, leading to large voltage fluctuation in summer and high voltage problem in autumn and winter, which seriously affected the normal power consumption of residents.

Aiming at the seasonal high and low voltage problems of the distribution network in Naiman area, a 10kV Nailin line simulation model was established on the PSASP simulation software platform to accurately reproduce the grid operation state at a certain moment. The voltage of the Nailin circuit under heavy load in summer, heavy load in winter and small load in winter are analyzed, and in-depth analysis of the specific causes of the voltage problem, after comparing different voltage governance measures, using line voltage regulator and SVG with governance, the simulation results show that the output and voltage of the Nailin line are obviously improved.

II. SUMMARY OF NETWORK STRUCTURE IN NAILIN AREA

The Nailin Line is 144.13km in length, including a main line with a total length of 24.91km, LGJ-150/35 line model, and 132 branch lines with a total length of 119.22km. There are 196 distribution transformers , including 75 distribution transformers belong to the power supply burea and 121 distribution transformers belong to users. There were 154 summer load data and 76 winter load data. The total load of the large load mode in summer is 3.45MW, the total load of the small load mode in summer is 0.95MW, the difference of load is 2.5MW, and the minimum load in winter is only 0.31MW.

III. ANALYSIS OF THE SIMULATION OF THE NAILIN LINE BEFORE LOW VOLTAGE CONTROL INTRODUCTION

According to the load characteristics of distribution network in Naiman area, three typical moments of 1 o 'clock on July 31, 9 o 'clock on July 31, and 3 o 'clock on November 25 were selected as small load mode in summer, large load mode in summer and small load mode in winter respectively for simulation analysis.

With bus-supplied load from the power production management system (PMS) and electricity information acquisition system. system voltage, transformer tap position, input of reactive power compensation device refer to PMS . According to 《Technical guidelines for distribution network》 QGDW10370 — 2016, 10kV operating range of 9.3 ~ 10.7 kV and 380V operating range of 353.4 ~ 406.6 V.

A. Simulation analysis of the line under high load in Summer

According to the power network energy management system of Tongliao region, at 9:00 a.m. on July 31, the main transformer of the 220kV substation in Kailu was operating at level 16, with the 220kV bus voltage was 219kV and the 66kV bus voltage was 64.81kV. The main transformer of the 66kV substation in Desheng operates at level 8 , with the 10kV bus voltage was 8.92kV.

The simulation results show that the outlet of the 10kV Nailin line is 8.93kV, the 10kV voltage of the terminal 471 pole of the trunk line is 7.67kV, the voltage drop is 1.26kV, the 10kV voltage of the lowest branch line is 7.64kV, the voltage drop is 1.29kV, and the 400V outlet voltage of the lowest distribution transformer is 242V.

B. Simulation analysis of the line under low load in Summer

EquationsAccording to the power network energy management system of Tongliao region, at 1:00 on July 31, the main transformer of the 220kV substation in Kailu

was operating at level 13, and the 220kV bus voltage was 228.68kV, and the 66kV bus voltage was 67.95kV. The main transformer of the 66kV substation in Desheng operates at level 8, with the 10kV bus voltage was 10.94kV.

The simulation results show that the outlet of the 10kV Nailin line is 10.94kV, the lowest branch line 10kV is 10.64kV, the voltage drop is only 0.3kV, and the 400V outlet voltage of the distribution transformer is on the high side, all located in 426~434V.

C. *Simulation analysis of the line under low load in winter*

According to the power grid energy management system of Tongliao region, at 3 o 'clock on November 25th, the main transformer of the 220kV substation in Kailu was operating at level 10, with the 220kV bus voltage was 232.29kV and the 66kV bus voltage was 66.71kV. The main transformer of the 66kV substation in Desheng operates at level 4, and the 10kV bus was 10.44kV.

The simulation results show that the outlet voltage of the 10kV Nailin line is 10.46kV, the lowest branch line 10kV is 10.32kV, the voltage drop is only 0.14kV, and the 400V outlet voltage of the station transformer is on the high side, all located at 413-417V.

IV. Analyze the Cause of Low Voltage

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A. *Load factor*

May to September in summer, the residential electricity load increased rapidly, while the agricultural drainage and irrigation transformers were put into operation one after another, which led to a sharp increase in the load of the power grid and caused great pressure on the power supply of the distribution network. At the same time, under the influence of high temperature and drought, the surge of civil air conditioner load also causes the transformer with small capacity in some areas to appear stage overload or overload operation, causing low voltage. In order to ensure the quality of the user's power supply voltage, the 10kV bus voltage is adjusted to the highest level, or even run off-side. After the end of drainage and irrigation, the load plummets and the 10kV voltage is not adjusted in time, which will cause the terminal voltage of the station area to exceed the nominal voltage value. In winter, the 10kV bus voltage, although not exceeding the limit, is still at a relatively high level, and most of the stations have too small loads, leading to excessively high 400V outlet voltage in the stations.

B. *The factor of distribution network structure*

The power supply radius of 10kV line shall meet the requirements of terminal voltage quality. In principle, the power supply radius of A+, A and B power supply areas shall not exceed 3km, C shall not exceed 5km, and D shall not exceed 15km. The Nailin Line belongs to Class D power supply area, with a total trunk line length of 24.91km and a branch line length of 119.22km, and the power supply radius is too long. At the same time, part of the branch line diameter is thin, the middle voltage line can not go deep into the end load center, which is also a factor causing the line end voltage low. According to statistics, there are 338 10kV lines in Tongliao Power supply Company whose power supply radius exceeds the design standard, and the number of lines exceeding the power supply radius accounts for 40.05%.

C. *The factor of reactive power compensation*

The number and capacity of reactive power equipment in distribution network are insufficient. No. 242 pole, No. 462 pole and No. 21 pole have been equipped with capacitors with a capacity of 300kVAR, and no inductive reactive power compensation device is installed. According to the survey, the reactive power compensation devices along the distribution network take adjusting the line power factor as the target for automatic switching, and in some cases, the voltage cannot be adjusted in time. Besides, the reactive power compensation equipment is greatly affected by the voltage level, and the effect of reactive power compensation equipment is limited when the voltage is too low.

V. Analysis of the Simulation of the Nailin Line After Low Voltage Control

There are overvoltage and undervoltage problems in the Nailin line, in addition, during the summer period of agricultural irrigation, the load fluctuates significantly between one day, so it is necessary to take measures that can flexibly adjust the voltage in both directions. Therefore, the voltage regulator of 10kV line should be considered to coordinate with the SVG device for voltage regulation.

The 10kV bus voltage of The Nalin line is out of limit in both large mode and small mode in summer. Therefore, it is considered to install SVG in the 10kV bus and part of the branch lines in Desheng Transformer, and install BSVR of the line at the main transformer outlet. The total capacity of the Nailin line distribution transformer is 12587kVA, and the maximum capacity of the 10kV line BSVR is 12500kVA. According to the load collection, the maximum load of the Nailin line in a year is 3450kVA, so the capacity meets the requirements. The simulation using BSVR, adjusting range -5%~15%, a total of 9 gears.Put BSVR at level 6, by the simulation results, installed after BSVR and SVG, 10kV bus of the 66kV substation in Desheng voltage is 9.26kV, the outlet of BSVR voltage is 10.27kV, the main line at the end of 471 pole is 9.31kV, the voltage drop is 0.96 kV. The lowest branch line voltage is 9.29kV, the voltage drop is 0.98kV. Minimum outlet voltage of distribution transformer 400V is 387V, meet the requirements.The treatment effect of 10kV voltage in some poles is shown in Table 1.

A. *Simulation analysis of the line under high load in summerLoad factor*

Put BSVR at level 6, by the simulation results, installed after BSVR and SVG, 10kV bus of the 66kV substation in Desheng voltage is 9.26kV, the outlet of BSVR voltage is 10.27kV, the main line at the end of 471 pole is 9.31kV, the voltage drop is 0.96 kV. The lowest branch line voltage is 9.29kV, the voltage drop is 0.98kV.

Minimum outlet voltage of distribution transformer 400V is 387V, meet the requirements.The treatment effect of 10kV voltage in some poles is shown in Table I.

TABLE I. TREATMENT EFFECT OF 10KV VOLTAGE IN PART OF THE POLE

Pole Number	*Voltage before treatment（kV）*	*Voltage after treatment（kV）*
#117 pole	8.37	9.84
#177 pole	8.10	9.64
#234 pole	7.92	9.50
#305 pole	7.78	9.40
#352 pole	7.74	9.37
#427 pole	7.69	9.33
#471 pole	7.67	9.31

B. Simulation analysis of the line under low load in summer

Put BSVR at level 1, by the simulation results, installed after BSVR and SVG, 10kV bus of the 66kV substation in Desheng voltage is 10.52 kV, the outlet of BSVR voltage is 10.01 kV, the main line at the end of 471 pole is 9.71 kV, the voltage drop is 0.3 kV. The lowest branch line voltage is 9.68 kV, the voltage is 0.33 kV. Distribution transformer outlet voltage levels between 384 ~ 396 v, all within a reasonable range.The treatment effect of 10kV voltage in some poles is shown in Table II.

TABLE II. TREATMENT EFFECT OF 10KV VOLTAGE IN PART OF THE POLE

Pole Number	*Voltage before treatment（kV）*	*Voltage after treatment（kV）*
#117 pole	10.84	9.90
#177 pole	10.78	9.84
#234 pole	10.74	9.79
#305 pole	10.70	9.75
#352 pole	10.70	9.74
#427 pole	10.68	9.72
#471 pole	10.67	9.71

C. Simulation analysis of the line under low load in winter

Put BSVR at level 1, by the simulation results, installed after BSVR, 10kV bus of the 66kV substation in Desheng voltage is 10.46kV, he outlet of BSVR voltage is 9.96kV, the main line at the end of 471 pole is 9.8kV, and the outlet voltage of the 400V of the station transformer is all located at about 394V, which was within a reasonable range.The treatment effect of 10kV voltage in some poles is shown in Table III.

TABLE III. TREATMENT EFFECT OF 10KV VOLTAGE IN PART OF THE POLE

Pole Number	*Voltage before treatment（kV）*	*Voltage after treatment（kV）*
#117 pole	10.41	9.91
#177 pole	10.39	9.88
#234 pole	10.37	9.86
#305 pole	10.35	9.85
#352 pole	10.34	9.83
#427 pole	10.33	9.83
#471 pole	10.33	9.82

According to the simulation results, Desheng 10 kv bus need to install SVG device, and in 10 kv outlet side line BSVR for installation. All the way down to the appropriate typical running gear, can ensure the 10 kv voltage operation in a reasonable range.High load in summer some distribution transformer 400 v low voltage, installing SVG device with voltage control voltage regulator, which can effectively solve the problem of voltage.

VI. CONCLUSION AND SUGGESTION

A. Conclusion

The problem of low voltage and over voltage exists in the distribution network in Tongliao region throughout the year, so adopting flexible measures adjust the voltage bidirectional should be taken for treatment. Therefore, it is suggested to adopt the 10kV BSVR and SVG device to cooperate with the treatment scheme. An SVG device should be installed at the bus side of 10kV substation with bus voltage out-of-limit to ensure that the 10kV bus voltage operates within a reasonable range. A 10kV BSVR is installed at the lower (upper) limit of the distribution line voltage to improve the overall voltage level of the distribution line; For the 400V voltage in the area still exceeding the lower limit (upper limit) due to high load (low load), partition governance can be carried out in combination with low-voltage SVG device.

B. Suggestion

- Determine the initial tap position of the distribution transformer tap scientifically and reasonably. For the 66kV substation, the main transformer shall be adjusted to the highest operating gear before the agricultural irrigation load is put into operation in summer, and the main transformer tap shall be adjusted to the rated gear and below according to the specific conditions before the load is withdrawn and during winter. For distribution transformers, the tap position from the first end of the line is set as 10.5kV in principle, the tap position from the middle part of the line is set as 10kV, the tap position at the end of the line is set as 9.5kV. According to the situation of 10kV outlet voltage, line load and low-voltage line, determine the three-stage distribution, and timely adjust the distribution transformer tap switch according to the seasonal changes of the load.

- From the perspective of long-term consideration, it is suggested to implement such measures as increasing capacity with distribution transformation, adding new distribution points, reforming distribution lines, and cutting and reforming some loads in the load concentration area, so as to fundamentally solve the problem of low voltage in Tongliao region.

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