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Investigation of Voltage Drop in the Primary Distribution Network of Ghazni City and Voltage Regulation in That Network

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Abstract: The medium voltage feeder of Ghazni city, feeding the subscribers of Ghazni city, has a peak load of 4.5MW. Voltage drop in the network limits the transmission power and increases the transmission power losses. All electrical appliances are designed to work at a certain voltage and at the same voltage can do their normal work. Voltage is one of the basic parameters of the regime in electrical cycles that must be kept constant to the necessary extent for the subscriber. Excessive voltage fluctuations, both up and down, can cause damage to consumers. The purpose of this study is to investigate how the voltage drops and voltage regulates in the 20kV distribution network in Ghazni city. In this research, real field figures obtained from Ghazni Breshna Company have been used in voltage drop calculations. Voltage drop in the primary distribution network of Ghazni city is in the range of 5.7%, which is the highest Losses compared to the standard. IEC60204-1 (Protection of Electrical Machinery and Equipment), which recommends in Section 5-13 that voltage losses from the supply point to the electrical load point should not normally exceed 5% of the rated voltage, indicates a 0.7% increase in voltage drop. Voltage failure in addition to the negative monetary effect reduces the quality of electrical energy.

Keywords: Voltage Drop, Distribution Network, Energy Quality, Power Losses

1. Introduction

Voltage drop, which is one of the problems of energy quality according to the definition of IEEE-1159-1995 standard, refers to the sudden reduction of the effective amount of voltage by 10% to 90% in half a cycle of up to one minute.

Power transmission in a distribution network is always accompanied by voltage losses [1]. On the other hand, the devices and devices that are connected to the distribution network are not able to work in any voltage range and must work in a standard range. Existing standards therefore require distribution companies to keep the voltage within a certain range. According to the standard allowed in Afghanistan distribution networks, the low voltage limit should not be less than 95% of the nominal value. This limitation causes voltage drop to become one of the problems of distribution networks.

In traditional distribution networks, the transmission network is connected to the distribution network through the above distribution substation. In a power distribution network, the above distribution substation is transferred to the distribution substations by medium voltage radial feeders and after amplification by the unloaded pulsator, the transformers of these substations are delivered to the subscribers through low voltage feeders. In each of these two parts, the voltage will be lost and if the length of the feeders is long and the transmission power is high, then the network may face the problem of voltage loss and this can become one of the major problems of the network that the company Distribution companies must find a solution. This problem is exacerbated when the network is operated during peak hours.

There are several ways to compensate for voltage losses along the feeder. One of the simplest and of course very effective methods that are always considered in the early stages of design is network reinforcement. The use of conductors with lower resistance can reduce mains voltage losses [2]. Also, in the very early stages of design, adjusting the transformer pulsars to maximum values can boost the grid voltage [3]. Other ways to compensate for voltage losses can be named as follows:

1) Inactive power compensation.
2) Use of voltage regulators.
3) Load correspondence.

2. Materials and Methods of Work

Research materials for this dissertation include the following two main sections:

1. Collecting information.
2. Examining the samples and analyzing them based on professional knowledge.

Data collection was done in two ways:

1. Field method (observational).
2. Documentary method.

3. Ghazni City Distribution Network

Ghazni province is connected to the National Power Supply Network of Afghanistan through the NEPS power supply system by a 220kV transmission line from Chamtaleh substation to Arghandi and from Arghandi to Ghazni shrine substation in 2016.

Ghazni Breshna has 11503 subscribers, according to Breshna, 27% of the population of Ghazni city has access to government electricity.

The central part of Ghazni province uses imported electricity. The electricity distributed to the center of Ghazni province through Breshna is about 6 MW. If the power transmission network is extended to the center and districts of the province, a capacity of about 100 MW of electricity is needed.

In the primary distribution (20 kV) network of Ghazni city, aluminum lines reinforced with ACSR steel - with a cross-section of 120mm^2 have been used. This type of conductor is used as an air transmission line and primary and secondary distribution lines.

Since the province, consumers are confronted with frequent power cuts, and fluctuating voltages and frequencies. The distribution Sector requires an economical system to provide electrical energy at a minimum voltage drop to reduce the voltage regulation. So, we require an economical way to provide the electrical energy to various consumers at minimum voltage drop and reduce the voltage regulation.

4. Literature Search

The study of strength losses and voltage profiles in distribution networks due to their urgency has been extensively researched and researched. This research uses the achievements of authors and scientists who have worked on the subject for separate elements of these networks. Here are some of these words:

Capacitors reduce the voltage drop by modifying the power factor (Cos Φ) and also reduce distribution network losses.

Therefore, by considering the factor of grid strength factor (Cos Φ) and also the price of capacitors, assuming their location and accurate installation, grid losses can be reduced to some extent. Usually, due to the high cost of capacitors, these devices are not only used to reduce network losses, but their other important effect is to improve the network voltage profile. On the other hand, by installing these capacitors, the voltage of consumers can be reduced to a small extent, thereby reducing consumer Losses without disturbing the system. [13, 14]

Improving and increasing the grid voltage to reduce Losses is usually not very popular, and this is because the distribution grid voltages are generally considered to be reasonably high from the very beginning of the design so that in some cases even A small reduction (up to 1%) in the voltage of the consumer side has reduced energy consumption and thus reduced network losses [4]. And with the privatization of the energy sector, there are technical constraints such as overload lines that reduce the voltage, as well as the allocation of electrical Losses and the proper management of services. [5]

5. Adverse Effects of Excessive Voltage Deviation of High Voltage Consumers

The power supply voltage at the subscriber location must be constant [6]. Excessive voltage fluctuations can cause damage to consumers. The reason for this is that electrical appliances are generally made for a certain voltage (nominal voltage) and if the voltage deviation at both ends of the consumers exceeds a certain tolerance, it can disrupt its working point. For example, low voltage reduces the light intensity of incandescent lamps, and excessive voltage increases, although it increases the brightness, but reduces the useful life of the lamp [4-6].

Motors operating at low voltages exceed the allowable current and gain more current, causing the motor to overheat even when the motor load is less than the nominal load [7]. Overvoltage increases heat loss in the motor iron, which results in Lossesd energy and damage to the motor. Therefore, the allowable limit for voltage changes in the distribution system has been determined [8].

6. Percentage of Voltage Drop in Different Parts of the Distribution Network

The allowable percentage of voltage drop in different parts of the distribution network is presented in the following figure and in the form of a table. [9-11]

Table 1. *Percentage of allowable voltage drop in different parts of the network.*

Rated voltage and mains status	The percentage value of voltage drop	
	Urban network	Rural network
20 kV distribution network	2%	4%
Transformer 20000/400 volts	3%	4%
400V distribution network	4%	4%
Joint split	1%	1%

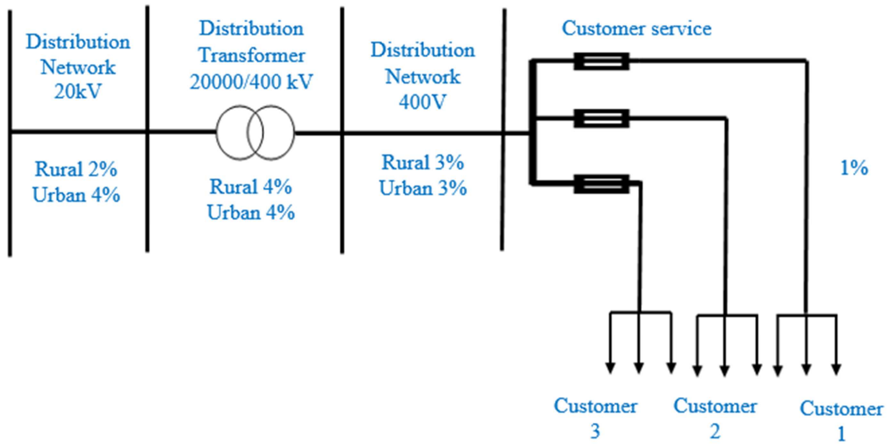

Figure 1. *Percentage of allowable voltage drop in different parts of the network.*

7. Calculation of Voltage Drop of Primary (20kv) Distribution Network in Ghazni City

The distribution network of Ghazni city has 38 transformers stations, which are listed in Appendix (1), and each transformer station has one transformer with a total capacity of 10.7 MVA.

We use the following formulas to calculate the voltage drop [12]:

$$\Delta U = \frac{(P_{R0} + Q_{X0})}{U} \cdot L \ + j\ \frac{(P_{X0} - Q_{R0})}{U} \cdot L \quad (1)$$

As seen in the above formula, to calculate the voltage drop, we need to find active and passive power. Therefore, to find active endurance and passive endurance, we consider the power factor obtained from the measuring instruments (COSΦ = 0.97).

$$P = S \cdot \mathrm{Cos}(\varphi) = S \cdot 0.97 \quad (2)$$

$$Q = S \cdot \sin arc(\cos\varphi) = S \cdot \mathrm{Sin}(14.06) = S \cdot 0.243 \quad (3)$$

To obtain the inactive power, we use the following formula:

$$x_0 = 0.145 \cdot \log \frac{2D_{CP}}{d_\Pi} \quad (4)$$

D_{cp}: is the distance between the phases. In Ghazni distribution network, this distance is (1) meter.

Dπ: line diameter. Which is received as follows:

$$S = \pi \cdot r^2 \quad (5)$$

$$S = F = 120\ MM^2; d = 2 \cdot r \Rightarrow r = \frac{d}{2}$$

$$120 = \pi \left(\frac{d}{2}\right)^2 \Rightarrow 120 = \pi \frac{d^2}{4}$$

$$d = \sqrt{\frac{480}{\pi}} = 12.36\ MM$$

$$x_0 = 0.145 \cdot \log \frac{2D_{CP}}{d_\Pi} = 0.145 \cdot \log \frac{2 \cdot 1000}{12.36} = 0.32 \quad (6)$$

As an example, we calculate the voltage drop across the transmission line from the first substation of the shrine to the first giant.

$$P = S \cdot 0.97 = 0.97 \cdot 10700 = 10379 kW$$

$$Q = S \cdot 0.243 = 0.243 \cdot 10700 = 2601.22 KVAR$$

$$\Delta U = \frac{(10379 \cdot 0.26 + 2601 \cdot 0.32) \cdot 1.86}{20} + j \frac{(10379 \cdot 0.32 - 2601 \cdot 0.26) \cdot 1.86}{20} = 328 + j246 V$$

Therefore, at the end of the route of the sub-station of Rouzeh-Giant, the first voltage value is equal to:

$$U_1 = U - \Delta U = 20 - (0.328 + J0.246) = 19.67 - j0.246 = 19.673kV$$

We receive the same voltage drop in each direction and move it in the table below.

Table 2. *The voltage drops of the Ghazni primary distribution network.*

No	Line Direction	Length (km)	General power (kVA)	Active power (kW)	Reactive Power (kVAR)	Active voltage drop (V)	Reactive voltage drop (V)	The voltage at the end Of Path (kV)	ΔU%
1	Rowza sub-station – First Giant	1.86	10700	10379	2600.1	327.95	245.71	19.67	0.09838
2	The first giant - the fourth transfer of Rowza	0.31	200	194	48.6	1.02	0.76	19.67	0.09835
3	first giant - second giant	0.56	10500	10185	2551.5	96.34	72.18	19.58	0.0979
4	Giant II - third Transformer of rowza	0.29	160	155.2	38.88	0.76	0.57	19.58	0.0979
5	Giant II - Giant III	1.24	10340	10029.8	2512.62	210.82	157.95	19.37	0.0968
6	Giant III - second Transformer of rowza	0.15	400	388	97.2	0.96	0.72	19.37	0.09685
7	third giant - fourth giant	0.99	9940	9641.8	2415.42	162.63	121.85	19.20	0.096
8	fourth giant - first transformer of rowza	0.51	200	194	48.6	1.68	1.26	19.20	0.096
9	fourth giant - fifth giant	2.88	9740	9447.8	2366.82	463.28	347.11	18.74	0.0937
10	Fifth Giant - Sixth Giant	0.61	2130	2066.1	517.59	21.42	16.05	18.72	0.0936
11	Six giant - Transformer of Khojah Baqal	0.65	160	155.2	38.88	1.72	1.29	18.72	0.0936
12	Giant VI – Transformer of Shahre kona	0.43	1970	1910.9	478.7	13.97	10.46	18.71	0.09355
13	Shahre kona transformer- Giant seventh	0.34	320	310.4	77.76	1.79	1.34	18.71	0.09355
14	Giant seventh –Transformer of Bahlol Gardens	0.65	160	155.2	38.88	1.73	1.29	18.70	0.0935
15	Seventh Giant –transformer of Bahlol	0.54	160	155.2	38.88	1.44	1.08	18.70	0.0935
16	Shahre kona transformer – Eighth Giant	0.17	1250	1212.5	303.75	3.55	2.66	18.70	0.0935
17	Giant VIII – Transformer of Diesel House	0.15	800	776	194.4	1.95	1.46	18.70	0.0935
18	Giant 8 - Transformer number (1) Hakim sahib	0.79	450	436.5	109.35	5.87	4.40	18.70	0.0935
19	Transfer No (1) Hakim Sahib - Transfer No (2) Hakim Sahib	0.64	200	194	48.6	2.12	1.59	18.70	0.0935
20	fifth giant ninth giant	0.28	7610	7381.7	1849.23	35.22	26.39	18.71	0.09355
21	Giant Ninth - Transformer Shamir Sahib	0.47	400	388	97.2	3.10	2.32	18.71	0.09355
22	Giant Ninth - Giant Ten	0.60	7210	6993.7	1752.03	71.01	53.20	18.64	0.0932
23	Giant 10 - Diesel House Transformer No (2)	0.32	1000	970	243	5.23	3.92	18.70	0.0935
24	Giant 10 - New Castle Transformer Khujah Roshanayee	0.24	160	155.2	38.88	0.62	0.47	18.64	0.0932
25	Tenth Giant - Eleventh Giant	0.25	6050	5868.5	1470.15	25.38	19.02	18.61	0.09305
26	Giant XI - Transformer Plan III	1.04	2210	2143.7	537.03	37.87	28.37	18.58	0.0929
27	Transformer Plan 3 - Khajeh Castle Transformer	0.91	200	194	48.6	2.99	2.24	18.57	0.09285
28	Transformer of the third plan - Seyed Ahmad Mecca Transformer	0.36	360	349.2	87.48	2.11	1.58	18.57	0.09285
29	Seyed Ahmad Mecca Transformer - Delivery Castle Transformer	0.48	200	194	48.6	1.57	1.17	18.57	0.09285
30	Transformer Plan III - Giant Twelfth	0.50	850	824.5	206.55	7.02	5.26	18.57	0.09285
31	Giant Twelfth - Transformer of Ahangaran Castle	0.62	200	194	48.6	2.05	1.54	18.57	0.09285
32	Twelfth Giant - Thirteenth Giant	0.61	650	630.5	157.95	6.57	4.93	18.56	0.0928
33	Giant 13 - Transformer Station Number One Khashik	0.51	200	194	48.6	1.69	1.27	18.56	0.0928
34	13th Giant - Fourteenth Giant	0.28	450	436.5	109.35	2.04	1.53	18.56	0.0928
35	Giant XIV - Transformer 2 khashik	0.05	200	194	48.6	0.18	0.13	18.56	0.0928
36	Giant XIV - Third Transformer of khashik	1.06	250	242.5	60.75	4.37	3.27	18.56	0.0928
37	Giant Eleven - Giant Fifteen	0.61	3840	3724.8	933.12	38.85	29.10	18.57	0.09285
38	Giant Fifteen - Giant Sixteen	0.29	2760	2677.2	670.68	13.20	9.89	18.56	0.0928
39	Giant XVI - Transformer Plan IV	0.45	800	776	194.4	5.98	4.48	18.56	0.0928
40	Sixteenth Giant - Seventeenth Giant	0.89	1960	1901.2	476.28	28.81	21.58	18.53	0.09265
41	Giant 17 - Transfer of the first Hyderabad	0.74	560	543.2	136.08	6.84	5.13	18.53	0.09265
42	Hyderabad First Transformer - Hyderabad Second Transformer	0.30	360	394.2	87.48	1.78	1.33	18.52	0.0926
43	Transformer Station 2 Hyderabad - Transformer Station Sanjatek	0.72	160	155.2	38.88	1.91	1.43	18.52	0.0926
44	seventeenth giant -eighteenth giant	0.14	1400	1358	340.2	3.24	2.43	18.53	0.09265
45	Giant 18th - Transformer Station Islamic Culture Center	0.51	200	194	48.6	1.68	1.26	18.53	0.09265
46	Eighteenth Giant - Nineteenth Giant	0.14	1200	1164	291.6	2.78	2.08	18.53	0.09265
47	Giant Nineteen - The first transfer of Faiz Mohammad Road	0.62	600	582	145.8	6.14	4.60	18.52	0.0926
48	first transformer of Feyz Mohammad road - second transformer of Feyz Mohammad road	0.44	400	388	97.2	2.94	2.20	18.52	0.0926
49	Giant Nineteen - Transformer of Qadam Qawad Nawabad	0.32	200	194	48.6	1.04	0.78	18.53	0.09265
50	Giant Nineteen - Giant Twenty	0.46	400	388	97.2	3.07	2.30	18.52	0.0926
51	Giant Twenty - Transformer of Qala-e-Qadam Hill	0.37	200	194	48.6	1.23	0.92	18.52	0.0926
52	Giant Twenty - Qadam Qadam Transformer	1.08	200	194	48.6	3.55	2.66	18.52	0.0926
53	Fifth Giant - Twenty-first Giant	0.28	1080	1047.6	262.44	5.05	3.87	18.57	0.09285
54	Giant Twenty-first - New Castle Rig Transformer	0.42	200	194	48.6	1.37	1.03	18.57	0.09285

No	Line Direction	Length (km)	General power (kVA)	Active power (kW)	Reactive Power (kVAR)	Active voltage drop (V)	Reactive voltage drop (V)	The voltage at the end Of Path (kV)	ΔU%
55	Twenty-first Giant - Twenty-second Giant	0.45	880	853.6	213.84	6.55	4.91	18.56	0.0928
56	Giant 22nd - Transformer of Mihanabad	0.16	160	155.2	38.88	0.41	0.31	18.56	0.0928
57	22nd Giant – 23rd Giant	0.33	720	698.4	174.96	3.96	2.96	18.56	0.0928
58	Giant 23rd - first Pashtun abad Transformer	0.13	360	349.2	87.48	0.78	0.59	18.56	0.0928
59	first Transformer of Pashtun abad - second Transformer of Pashtun abad	0.59	160	155.2	38.88	1.55	1.16	18.56	0.0928
60	Giant 23 - first Transformer of Amir Mohammad Khan Castle	1.28	360	349.2	87.48	7.60	5.70	18.55	0.09275
61	Amir Mohammad Khan Castle First Transformer - Amir Mohammad Khan Castle Second Transformer	0.70	200	194	48.6	2.32	1.73	18.55	0.09275
Total voltage drop		5.70615							

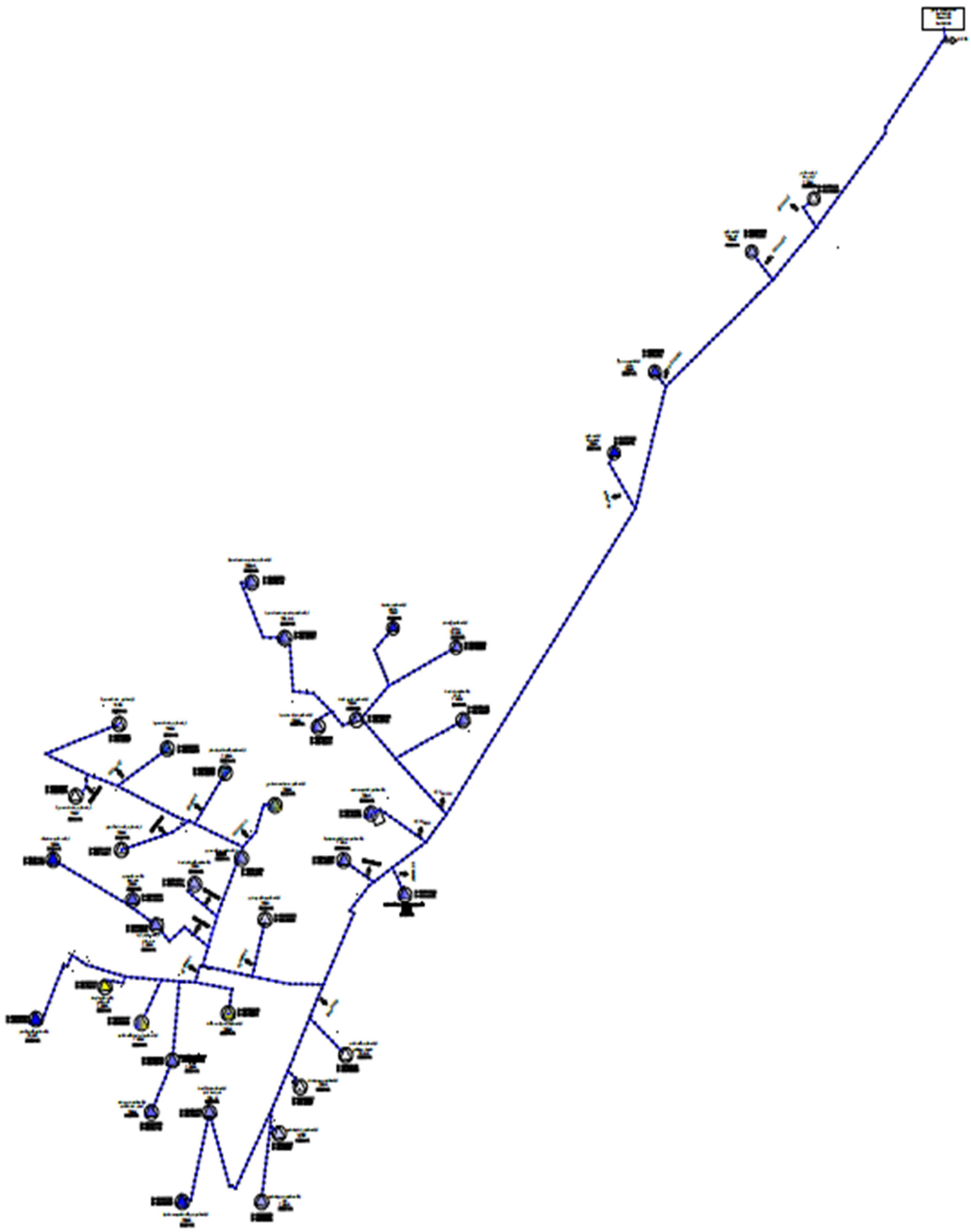

Figure 2. *The SLD (single line diagram) of Ghazni medium voltage network.*

At different loads, the voltage drop across transformers and transmission lines also changes, causing the mains voltage to change. The voltage control of distribution and transmission networks is mainly done by a pulse changer. The basis of pulse changer work is based on changing the transformer conversion ratio. In this way, with the branches that are installed in the high voltage gutter, it changes the number of turns of the coil and causes the output voltage of the transformer to change [15].

Pulse switches are widely used to control the mains voltage at different voltage levels. Voltage control is usually within the range of 15%. The voltage on each step of the switch usually varies between 1 and 2.5 percent [16]. Because the voltage changes in the 20kV network of Ghazni city do not exceed 15%, in this regard, the voltage drop in the network is controlled by the transformer puller, and the need to install equipment such as capacitors is not felt.

8. Discussion

According to the study done on reducing electrical energy losses and voltage regulation in the distribution network of Ghazni city and comparing this network with other networks, we can do the following with the research:

1. Before the energy reaches the final consumers, it changes its state 3 to 5 times, which causes energy and voltage losses at each stage.
2. Distances from production points to load centers, conductor size, load mixture, load and different factors, temperature, power factor, additional loads, low voltages, etc. have a great effect on Losses.
3. Includes all stages of electricity conversion, transmission system, and Losses energy utilization. These lesions, which exist in different parts, cannot be completely prevented but can be reduced as much as possible.
4. The amount of voltage drop in the primary distribution network of Ghazni city is higher than world standards and about 5.7 percent and we can control it using transformer pullers. Thus, by reducing the voltage drop, we can increase the length of the distribution network line or increase the load of the distribution network line.
5. Based on the available information and mathematical calculations, the voltage drops values in the primary distribution network of the city are low compared to the networks of other provinces of the country.

9. Conclusion

A closer look at the voltage drop problem is important because the economic value of the energy produced (and lost) is much higher than the revenue from energy sales, and calculations show that reducing Losses in the distribution system and releasing latent capacity is several times cheaper. It is from constructing stations to compensate for the same amount of strength lost.

This research, uses the computational method, a method that can be easily used to investigate the voltage drop in the primary distribution feeders.

The studies conducted in this study show that in the primary distribution network of Ghazni city, the voltage drop is approximately in the range of 5.7%, which can be controlled by using the tap changer transformers.

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