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Analyzing Power Losses in Ghazni City's Electricity Distribution Network and Strategies for Minimizing Them

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Abstract: Electricity is a vital source of energy that plays a crucial role in the economic and social development of a country. However, the distribution of electricity from power plants to consumers is a complex process that involves a network of electricity transmission and distribution systems. These systems are susceptible to losses that occur at various stages of the distribution process, such as transmission, conversion, and distribution. Power losses in distribution systems can be caused by technical and non-technical factors. Technical factors include conductor resistance, voltage drops, and transformer losses, while non-technical factors include theft and defective equipment. These losses can have significant economic consequences, such as lower reliability, higher costs, and lower revenues for utilities. Therefore, it is important to study and analyze the causes of power losses in distribution systems and develop strategies to reduce them. In this research, real field data of Ghazni Breshna Company was used to calculate electricity losses. In the case of Ghazni city electricity distribution network, the research shows that there is an energy loss of 11.7%, which amounts to 1,093,736 kWh per year. This energy loss results in a financial loss of 6,835,850 Afghanis for Barshna Company. The real field data obtained from Ghazni Breshna Company was used for the energy loss calculations. Several strategies can be used to reduce power losses, including reducing technical losses by improving equipment and maintenance practices, reducing non-technical losses by combating theft and illegal connections, and increasing the efficiency of the distribution network. In addition, improving energy management practices such as demand response, load balancing, and power factor correction can also help reduce power losses. Reducing power losses in the electric distribution system is critical to improving electric power reliability and quality and minimizing economic losses for utilities. In addition, high investment in this area can contribute to the growth of the nation's economy. The results of this study demonstrate the importance of understanding power losses in distribution systems and the need for effective measures to minimize these losses.

Keywords: Technical and Non-technical Factors, Energy Management Practices, Economic Consequences, Power Losses

1. Introduction

The city of Ghazni was powered by two sets of diesel generators within the scope of government repairs of the center of Ghazni province from 1977 to 2017. This city benefited from imported electricity for the first time in 2017/12/31.

Currently, about 5 MW of electricity is distributed in Ghazni city and it is supposed to increase to 25 MW in the coming years. Primary and secondary distribution networks (kV20 and 0.4 kV) and distribution systems are developed sustainably so that they can feed new consumers.

If this development is not planned with the necessary standards and criteria in mind, low-quality equipment is used, maintenance and care are insufficient, and electricity theft still occurs, there are defects in the meter system, resulting in high losses of electrical energy. And low standards of quality and reliability will be in the systems.

As a result of the transmission of electrical energy by the power grid system from the source to the consumer, losses in major equipment (lines and transformers) will cause a certain amount of electrical energy to be absorbed by the active resistances of the equipment and transferred to the environment. The second component is passive resistors that convert electrical energy into electromagnetic energy. Most of the electrical energy is lost in the distribution networks of electrical systems. Technical losses occur as a result of the dispersion of electrical energy in conductors and equipment used in electrical energy transmission and distribution systems. The amount of this wasted energy mainly depends on the design of the lines, load characteristics in transmission and distribution lines, types of loads, electrical equipment (transformers), etc. It is not possible to completely prevent the aforementioned basic losses in the electric power system. However, these losses can be reduced to a certain extent with better design of lines, changing the location of distribution substations, installation of capacitors, use of transformers according to accepted technical standards, regular renewal of the system, etc. This research has been done to better understand the current situation of power losses and voltage regulation in the 20kV network of Ghazni city, and to find out how far the current system is responsive to people's demands. Losses of electrical energy reduce the effectiveness of power supply networks and systems, lack of comprehensive and comprehensive maintenance and care of the power supply system, and also cause both financial and economic impacts. So, on this basis, investigating the network power losses (20kV) in Ghazni city is considered very important and a serious need. If losses in the distribution network of Ghazni city are not prevented, for Breshna Company as the owner, the economic loss will reach approximately 1,093,736 kWh with an approximate value of 6,835,850 Afghanis. If energy losses and voltage are not controlled, in addition to financial losses, low-quality energy will be supplied to subscribers. And this causes the Breshna Company to lose subscribers and the subscribers turn to private electricity companies. Reducing losses causes:

Save money on wasted energy and reduce the price per unit of electricity. Because reducing the amount of voltage and energy losses improves the effectiveness, maintenance, and care of the electrical energy system and network and the work of industrial houses, and most importantly, the great financial and economic benefits that have been discussed so far about this issue in the distribution network. At the beginning of Ghazni city, no research has been done.

2. Materials and Methods of Work

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

i) Collecting information.

ii) Examining the samples and analyzing them based on professional knowledge.

Data collection was done in two ways:

i) Field method (observational).

ii) 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 the Chamtaleh substation to Arghandi and from Arghandi to the 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 electrical energy to various consumers at minimum voltage drop and reduce the voltage regulation.

4. Literature Search

Investigation of power losses in distribution networks has been widely researched due to its seriousness. This research has used the findings of authors and scientists who have worked on the subject for individual elements of these networks. Here we mention these works:

Transformers are one of the factors causing losses in distribution and super distribution networks. Because these types of equipment are used at different voltage levels in transmission and distribution networks and are also considered one of the key components of the network, it is necessary to take measures to reduce them [1].

Losses of transformers are divided into two categories: load and no load. No-load loss is independent of the load and takes an almost constant value, while load loss is dependent on the consumption characteristics and the curve of its changes, so by changing the load characteristics, the amount of these losses can be changed [2].

Distribution is often due to the radial structure, continuous changes in load, and the development of medium and low-voltage feeders to supply electricity to new applicants and design and implementation as soon as possible. or considered at the consumer's location [3].

Today, many methods are known to reduce the losses of power distribution networks, the most important of which are capacitors [4], improving the cross-section of conductors [5], increasing the network voltage [6], improving the efficiency and load management of transformers [7], and renewing the arrangement of the network (feeders) [8]. The correct use of each of these methods can reduce network losses to an acceptable level, although economic parameters always play a key role in this regard. According to these cases, much research has been conducted in different parts of the world to accurately identify the most economical methods of reducing losses in distribution networks.

By correcting the power factor (Cos Φ), capacitors reduce voltage losses and also reduce distribution network losses [9].

Therefore, by taking into account the power factor of the network (Cos Φ) and the price of the capacitors, assuming their accurate placement and installation, the network losses can be reduced to some extent. Usually, due to the high price of capacitors, these devices are not used only to reduce network losses, but their other important effect is to improve the network voltage profile [10]. On the other hand, by using the installation of these capacitors, the voltage of the consumers can be reduced to a small extent, thus reducing the losses of the consumers without disturbing the system.

Increasing the cross-section of the conductors used in the distribution lines can also reduce the network losses, but generally, the increase in related costs plays a very decisive role, so this method can only be used for some old lines that are close to capacity. The system is loaded from them, it uses newer routes when installing. In any case, the most important major obstacle in the way of such a method is the long return time of capital if this technique is used [11].

Improving and increasing the network voltage to reduce losses is usually not very popular and this is because the voltages of the distribution networks are generally considered high from the beginning of the design, so that even in some cases A small decrease (up to 1 percent) in the voltage of the consumer side has caused a decrease in energy consumption and, as a result, a decrease in network losses. And also, with the privatization of the energy sector, there are technical limitations such as overloading of the lines, which causes a decrease in voltage, as well as the allocation of electricity losses and proper management of services.

Improving the efficiency and load management of distribution transformers is one of the most suitable methods for reducing network losses, and despite its extensive development in many countries, unfortunately, these methods have not yet been used in our country [12, 13].

Even though the renovation of distribution feeders is a relatively new method, the use of this method is expanding over time, and especially in recent years, the use of combined methods of transformer load management along with the renovation of feeders and the use of digital measurement systems together It has had favorable results in developed countries.

5. Investigating Power Losses in the Primary Distribution Network of Ghazni City

Measurement and calculation of losses

The economic importance of reducing losses in distribution networks and the high percentage of electric energy losses in distribution networks in the country requires research and studies. But the first and most obvious question that is always raised is how much the number of casualties is. The answer to this question caused a large number of researchers to conduct significant studies and research related to this important issue, and the studies conducted in this field are almost as old as the electricity industry. The classic methods for calculating losses include the measurement method and the calculation method [14]:

5.1. Measurement Method

This method can be used when measuring devices installed at the input and output of the feeders, in other words, this method is applicable when the total input and output energy in the study period is available because, in this way, the number of losses can be determined. Determined the energy. One of the important points in such cases is how to be sure of the accuracy of the measurement equipment or how to be sure that the measured losses are consistent with reality. The amount of energy losses in the distribution network of Ghazni city for 2022 is shown in Tables 1-2 by period.

Table 1. *The amount of power loss in the distribution network of Ghazni city with the breakdown of meter reading periods in 2022.*

period	Name of the substation	Consumption during peak load time MW	HE INSTALLED THE CAPACITY OF THE EXISTING TRANSFORMERS ABOVE THE FEEDER IN THE DISTRIBUTION NETWORK OF GHAZNI CITY kVA	Total energy given to the distribution network kWh	The amount of energy read by measuring devices at the output of transformers kWh	The difference between the total energy supplied to the distribution network and the energy measured at the output of the feeders kWh	Total losses in the network in each period of 2022 %
Period1	Ghazni Rozah	4.5	10.7	2618879	2470404	148475	5.66941
Period2		4.3		2128040	1924590	203450	9.560441
Period3		4		1955199	1799017	156182	7.988036
Period4		4.35		2825750	2421830	403920	14.29426
Period5		4.7		3509660	3041710	467950	13.3332
Period6		4.65		2618879	2433740	274260	10.12777
Total losses		1654237 kW					

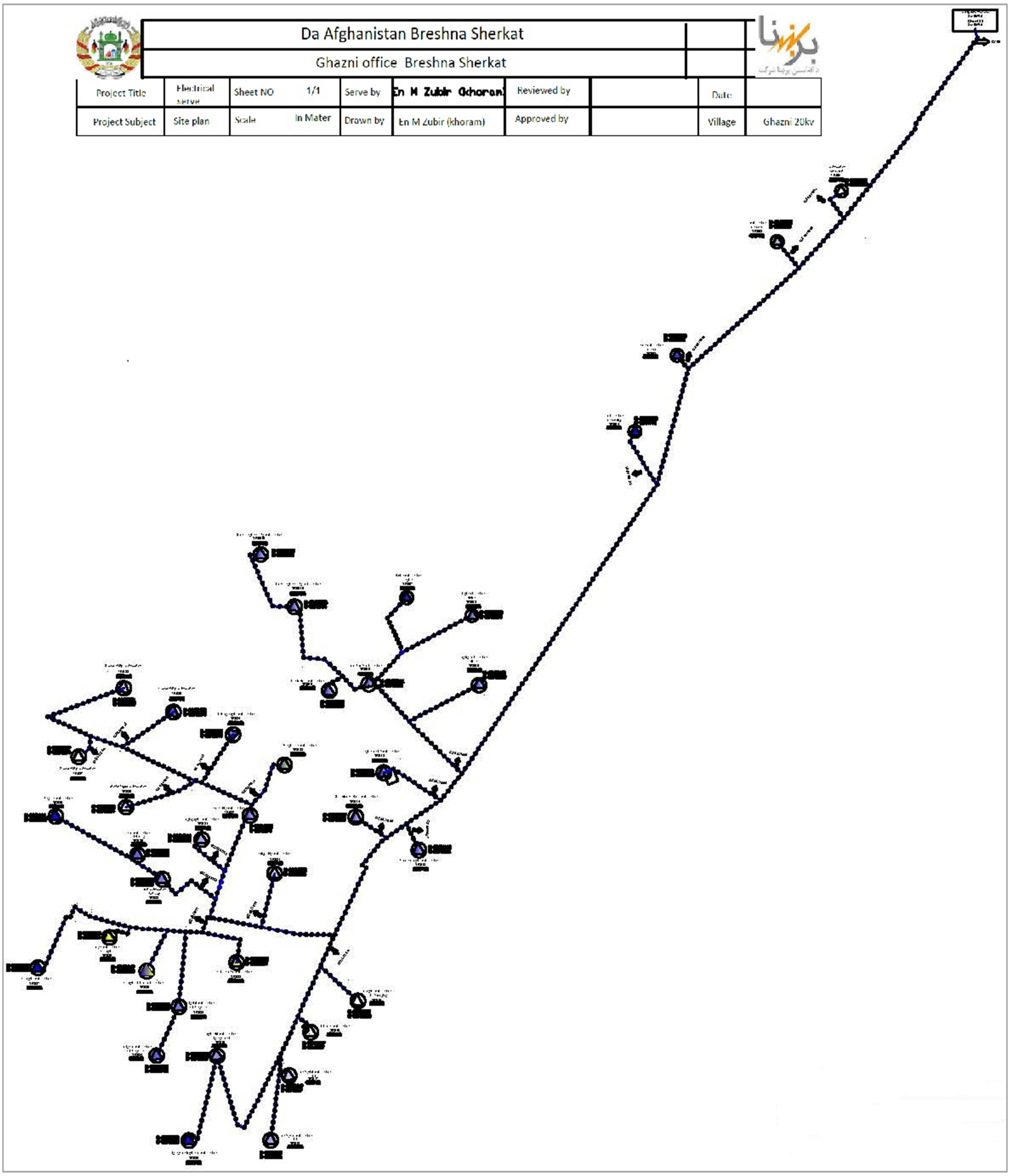

Figure 1. *The SLD (single line diagram) of the Ghazni medium voltage network. [16].*

It can be seen from the above graph that the number of losses in the first, second, and third rounds when the amount of load is less and the seasonal temperature changes are small. In the month of September, October, November, December, January, and February, when the weather becomes colder, the distribution network has the highest level of losses. So, we can say that seasonal changes and the aforementioned environmental factors can increase the number of power losses in the network.

The amount of energy loss in the primary distribution network of Ghazni city reached 1,654,237 kWh in 2022, which is approximately 11.7% of all energy distributed in the said network.

5.2. Calculation Method

To determine the energy loss through calculations, it is necessary to calculate its value with the help of power flow. Power flow in this method shows the maximum power losses in certain conditions, in such a case the calculated losses only include joule losses in transmission lines and load and unloaded losses of transformers.

Calculation of power and energy losses in the primary distribution network of Ghazni city

The distribution network of Ghazni city has 38 transformer stations and each transformer station has a transformer whose total capacity is 10.7 MVA.

Calculation of energy losses in lines

We use the following formulas to calculate energy waste in lines [15]:

$$\Delta Э_{\ell} = \Delta P_{\ell} \cdot \tau$$

$$\Delta P_1 = \frac{S^2}{U_H^2} \cdot r_0 \cdot l$$

$$\tau = \left(0.124 + \frac{T_{\max}}{10^4}\right)^2 \cdot 8760$$

Generally, in urban networks, the time of using maximum power [15] is considered. Because in the primary distribution network of Ghazni city 20kV, the cross-section of the line is 120mm^2, using the standard tables, we consider the specific resistance of the line to be 0.26 Ω/km.

$$\tau = (0.124 + T_{MAX}.10^{-4})^2.8760 = (0.124 + 4500.10^{-4})^2.8760 = 2886.2 \,{}^{hour}\!/\!_{year}$$

For example, we want to calculate the power and energy losses in the line from the Rouza substation to Jayant first, so I will have:

$$\Delta P_{\ell} = \frac{S^2}{U_H{}^2}.ro.l = \frac{10700^2}{20^2}.0.26.1.85 = 138.25kW$$

$$\Delta Э_{\ell} = \Delta P_{\ell} \cdot \tau = 137.67 \cdot 2886.2 = 395382 kWh / year$$

The calculations for the entire network were performed as above and the results are listed in the table:

Table 2. *The results of calculations to obtain power and energy losses of the primary distribution network of Ghazni city.*

No	Line Direction	Length (km)	General power (kVA)	ΔPl (kW)	Δз (kWh/Year)
1	Rowza sub-station – First Giant	1.86	10700	138.2532	2600.1
2	The first giant - the fourth transfer of Rowza	0.31	200	0.0080	48.6
3	first giant - second giant	0.56	10500	39.8529	2551.5
4	Giant II - third Transformer of row	0.29	160	0.0048	38.88
5	Giant II - Giant III	1.24	10340	85.8828	2512.62
6	Giant III - second Transformer of rowza	0.15	400	0.0151	97.2
7	third giant - fourth giant	0.99	9940	63.6887	2415.42
8	fourth giant - first transformer of rowza	0.51	200	0.0132	48.6
9	fourth giant - fifth giant	2.88	9740	177.7815	2366.82
10	Fifth Giant - Sixth Giant	0.61	2130	1.7975	517.59
11	Six giant - Transformer of Khojah Baqal	0.65	160	0.0108	38.88
12	Giant VI – Transformer of Shahre kona	0.43	1970	1.0840	478.7
13	Shahre kona transformer- Giant seventh	0.34	320	0.0226	77.76
14	Giant seventh –Transformer of Bahlol Gardens	0.65	160	0.0109	38.88
15	Seventh Giant –transformer of Bahlol	0.54	160	0.0091	38.88
16	Shahre Kona transformer – Eighth Giant	0.17	1250	0.1746	303.75
17	Giant VIII – Transformer of Diesel House	0.15	800	0.0615	194.4
18	Giant 8 - Transformer number (1) Hakim sahib	0.79	450	0.1041	109.35
19	Transfer No (1) Hakim Sahib - Transfer No (2) Hakim Sahib	0.64	200	0.0167	48.6
20	fifth giant ninth giant	0.28	7610	10.5588	1849.23
21	Giant Ninth-Transformer Shamir Sahib	0.47	400	0.0489	97.2
22	Giant Ninth - Giant Ten	0.60	7210	20.1707	1752.03
23	Giant 10 - Diesel House Transformer No (2)	0.32	1000	0.2061	243
24	Giant 10 - New Castle Transformer Khujah Roshanayee	0.24	160	0.0039	38.88
25	Tenth Giant - Eleventh Giant	0.25	6050	6.0497	1470.15
26	Giant XI - Transformer Plan III	1.04	2210	3.2970	537.03
27	Transformer Plan 3 - Khajeh Castle Transformer	0.91	200	0.0236	48.6
28	The transformer of the third plan - Seyed Ahmad Mecca Transformer	0.36	360	0.0299	87.48
29	Seyed Ahmad Mecca Transformer - Delivery Castle Transformer	0.48	200	0.0124	48.6
30	Transformer Plan III - Giant Twelfth	0.50	850	0.2352	206.55

No	Line Direction	Length (km)	General power (kVA)	ΔPl (kW)	Δз (kWh/Year)
31	Giant Twelfth - Transformer of Ahangaran Castle	0.62	200	0.0161	48.6
32	Twelfth Giant - Thirteenth Giant	0.61	650	0.1684	157.95
33	Giant 13 - Transformer Station Number One Khashik	0.51	200	0.0133	48.6
34	13th Giant - Fourteenth Giant	0.28	450	0.0362	109.35
35	Giant XIV - Transformer 2 khashik	0.05	200	0.0014	48.6
36	Giant XIV - Third Transformer of khashik	1.06	250	0.0430	60.75
37	Giant Eleven - Giant Fifteen	0.61	3840	5.8769	933.12
38	Giant Fifteen - Giant Sixteen	0.29	2760	1.4349	670.68
39	Giant XVI - Transformer Plan IV	0.45	800	0.1886	194.4
40	Sixteenth Giant - Seventeenth Giant	0.89	1960	2.2244	476.28
41	Giant 17 - Transfer of the first Hyderabad	0.74	560	0.1510	136.08
42	Hyderabad First Transformer - Hyderabad Second Transformer	0.30	360	0.0252	87.48
43	Transformer Station 2 Hyderabad - Transformer Station Sanjatek	0.72	160	0.0120	38.88
44	seventeenth giant -eighteenth giant	0.14	1400	0.1787	340.2
45	Giant 18th - Transformer Station Islamic Culture Center	0.51	200	0.0132	48.6
46	Eighteenth Giant - Nineteenth Giant	0.14	1200	0.1313	291.6
47	Giant Nineteen - The first transfer of Faiz Mohammad Road	0.62	600	0.1452	145.8
48	the first transformer of Feyz Mohammad road - second transformer of Feyz Mohammad road	0.44	400	0.0463	97.2
49	Giant Nineteen - Transformer of Qadam Qawad Nawabad	0.32	200	0.0082	48.6
50	Giant Nineteen - Giant Twenty	0.46	400	0.0483	97.2
51	Giant Twenty-Transformer of Qala-e-Qadam Hill	0.37	200	0.0097	48.6
52	Giant Twenty - Qadam Qadam Transformer	1.08	200	0.0280	48.6
53	Fifth Giant - Twenty-first Giant	0.28	1080	0.2147	262.44
54	Giant Twenty-first - New Castle Rig Transformer	0.42	200	0.0108	48.6
55	Twenty-first Giant - Twenty-second Giant	0.45	880	0.2272	213.84
56	Giant 22nd - Transformer of Mihanabad	0.16	160	0.0026	38.88
57	22nd Giant – 23rd Giant	0.33	720	0.1122	174.96
58	Giant 23rd - first Pashtun abad Transformer	0.13	360	0.0111	87.48
59	first Transformer of Pashtun abad - second Transformer of Pashtun abad	0.59	160	0.0098	38.88
60	Giant 23 - first Transformer of Amir Mohammad Khan Castle	1.28	360	0.1078	87.48
61	Amir Mohammad Khan Castle First Transformer - Amir Mohammad Khan Castle Second Transformer	0.70	200	0.0182	48.6
Total power losses				560	1618993

It can be seen from the above table that 1618993 kWh of energy is wasted in the primary distribution network of Ghazni city. If the results obtained with the results obtained from the measuring instruments and shown in Table 1 are compared, it shows a difference of 35244 kWh, which can be attributed to the lack of simultaneous reading of the meters, inaccuracy in the reading of the meters, and the number of losses in the measuring instruments. Giri knew. It can be said that the results of both methods (measurement method and mathematical calculation method) in Small networks are almost the same.

6. Discussion

According to the research conducted on more than the losses of electric energy and voltage regulation in the distribution network of Ghazni city and the comparison of this network with other networks, I can make the following dispute in connection with the desired research in the network:

i) From Table 1, it can be seen that with seasonal temperature changes, the amount of energy losses, if the weather gets colder, the distribution network of Ghazni city has the highest level of losses. Therefore, part of the losses of the medium voltage network of Ghazni city is due to climatic changes, so to solve this problem, we can act by involving environmental factors in the technical and mechanical calculations of the electricity distribution network.

ii) There are many methods to check and calculate power losses in distribution networks, and each of these methods has advantages and disadvantages. Choosing the right method to check the power loss depends on the operation time, the available information, the required accuracy, and the size of the network.

iii) Before the energy reaches the final consumers, it changes its state 3 to 5 times, which causes energy and voltage losses at each stage.

iv) Distances from production points to load centers, conductor size, load mix, load and different factors, temperature, power factor, additional loads, low voltages, etc. have a great effect on losses.

v) All phases of electrical energy conversion, transmission system, and use of electrical energy include losses. These losses, which exist in different sectors, cannot be completely prevented, but they can be reduced as much as possible.

7. Conclusion

A closer examination of the issue of losses is important because the economic value of the energy produced (and lost) is much higher than the income from energy sales, and calculations show that reducing losses in the distribution system and releasing latent capacity is several times cheaper than building the stations is to compensate for the same amount of power lost. In this research, using the energy information obtained from measuring meters at the input of medium voltage feeders of Ghazni city and the output of distribution power towers, which is easily applicable, and also using the calculation method, the method used to check losses in feeders' medium voltage and distribution transformers can be easily used and comparing the results of both methods in the small primary distribution network of Ghazni city are almost similar. The investigations conducted in this research show that in the primary distribution network of Ghazni city, approximately 11.7% of the energy distributed in 2022, which is 1,654,273 Kwh, has been wasted. The loss of electric energy needed by subscribers in the distribution network of Ghazni city, which is purchased from Uzbekistan at huge costs, imposes a lot of losses on the Breshna Company as the owner, and the amount of 6835850 Afghani is lost to the Ghazni Breshna Company every year. The amount of wasted energy in the distribution network of Ghazni city is not high compared to the distribution networks of other cities of Afghanistan, because the energy distributed in Ghazni city is low and in the range of MW 5 to MW 6, but the continuation of the current trend of electric energy distribution in Ghazni city, its destruction in the same way and without basic measures to reduce the losses of the electricity distribution network will cause the number of losses to increase and bring great financial losses to Breshna Company.

8. Overcoming Distribution Network Challenges

Despite all the problems and disadvantages of distribution networks, which are caused by their past insignificance towards them, we can by employing experts in this field and investing more effort and paying attention to the following suggestions in distribution networks (which will soon be These funds will be returned) to reduce or even eliminate problems and disadvantages.

1) Due to the variable seasonal climate of Ghazni and its influence from the weather changes of other central and southern provinces, it can be seen from the table 1 that the amount of losses in the distribution network of Ghazni city changes with the change of seasons. To minimize losses, factors such as environmental pollution, high temperature or high-temperature changes in the environment, environmental humidity, atmospheric precipitation, dew phenomenon, strong winds, freezing, and... Be considered.
2) All transformers in the network should be checked. And transformers with higher internal losses should be replaced.
3) The evolution in the design and monitoring of distribution networks, which is the installation of low-capacity transformers in the center of gravity of the load, making two circuits of the medium voltage aerial feeder, are among the main indicators in this field.
4) Covered lanes should be used on the road between Hyderabad-Khaja Ali and Hyderabad-Abdul Ali Mazari, etc., to prevent leakage during rain and humidity.
5) The number of no-load losses and the load state of transformers that have the same capacity but are made by different countries and companies is very different. Because the electricity supply network of Ghazni city is developing, it is necessary to be very careful in selecting and obtaining equipment, especially transformers from companies and countries.

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