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MANAGEMENT OF REDUCING ACTIVE POWER IN ELECTRIC NETWORK OF KHARTOUM

Abstract. The paper deals with the issue of reducing active power losses in the 110 kV electrical network of the Khartoum region of Sudan. We consider what effective measures that can reduce active power losses in the 110 kV electric network and propose two measures to be used to reduce active power losses. In the first measure, by using the capacitor banks and as a result of the program rastrwin3, the active power losses decreased slightly. In the second measure, when adding a Reactor, the active power losses decreased little bit. The experiments showed that the first measure (Capacitor banks) is more effective than the second measure (Reactor).

Keywords: management, control, measures, analysis, electricity, distribution, rastrwin3 program.

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УПРАВЛЕНИЕ СНИЖЕНИЕМ АКТИВНОЙ МОЩНОСТИ В ЭЛЕКТРИЧЕСКИХ СЕТЯХ ХАРТУМА

Аннотация. Рассматривается вопрос снижения потерь активной мощности в электрической сети 110 кВ Хартумского района Судана, а также эффективные меры, позволяющие снизить потери активной мощности в электрической сети. Обозначены две меры, которые необходимо использовать для снижения потерь активной мощности: батареи конденсаторные (БК) и добавление реактор энергоблока.

Ключевые слова: управление, контроль, меры, анализ, электроэнергия, распределение, программа rastrwin3.

Introduction

According to the concept of losses of active power and electricity during the transmission of electricity from the power plant generators to the consumer, about 12–18 % of all generated electricity is lost in the conductors of overhead and cable lines, as well as in the windings and steel cores of power transformers. When designing, it is necessary to strive to reduce electricity losses in all parts of the power system, since electricity losses lead to an increase in the capacity of power plants, which in turn affects the cost of electricity. In networks up to 10 kV, power losses are mainly due to the heating of the wires from the action of the current. Energy losses in networks of all voltage classes account for about 13 % of all generated electricity (2005 data). At the same time, the main share of losses (over 70 %) falls on networks with a voltage of 110 kV and below. Energy losses in 330–750 kV networks account for about 18 % of total losses. However, given the large power flows transmitted through these networks, the losses are quite large in absolute terms. Therefore, it is very important to reduce energy losses in EHV transmission lines. In accordance with the current regulatory documents, electricity losses are made up of technological losses during its transportation and losses caused by errors in the electricity metering system during its implementation. Technological losses of electricity are understood as the sum of two components: technical losses associated with physical processes in lines and other power trans-

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mission equipment, and losses due to the consumption of electricity for auxiliary needs of substations. Below we will consider only the technical losses of active power and energy in High tension lines transmissions. Their sum consists of losses for heating wires, losses for corona, losses in transformers, autotransformers, synchronous compensators and shunt reactors, leakage losses on insulators and ice melting. The given technical losses, in turn, can be divided into the following groups: load losses, depending on the load from the power transmission (losses for heating wires, load losses in transformers, autotransformers, synchronous compensators); conditionally constant losses, depending on the composition of the included equipment (losses in steel of transformers and autotransformers, losses in synchronous compensators and shunt reactors); losses depending on weather conditions, and therefore on the region in which the given power transmission takes place (losses for corona, for leakage through insulators, for melting ice). All these losses depend on the length of the line, the transmitted power, the composition of the equipment and other factors that are difficult to consider. Calculations of active power losses of energy should be carried out for each specific case, considering all its features. However, it should be noted that the main components of losses in power transmission are losses due to heating of wires.

Literature Review

The losses in transmission and distribution of electricity in Sudan (% of generation) as of 2014 amounted to 14.28 %, compared to the internationally accepted 10 %. So, it must be modernizing distribution networks to reduce electricity distribution losses. Highest value was 36.79 in 1997, and the lowest value was 3.22 in 1984. Based on the works [1–4], this paper proposes some methods to reduce electricity distribution losses in Sudan.

Methodology of the Research

Calculation of the effectiveness of measures to reduce active power losses in the 110 kV electrical network: The initial data: At high load voltage = -10 % of nominal, at low load voltage = 2 % of nominal.

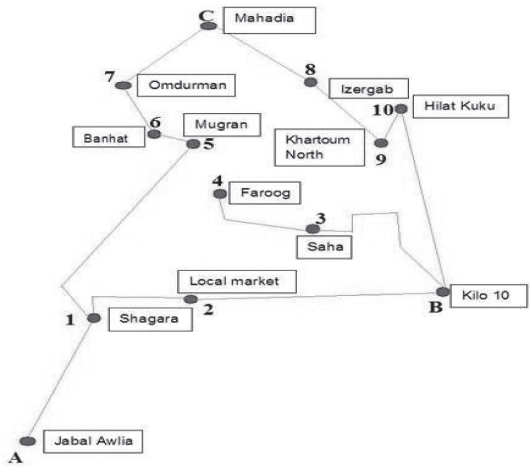


Figure 1. Part of Khartoum area
Source: Hereinafter the figures are compiled by the authors.

Table 1

Initial load powers*

Station	1	2	3	4	5	6	7	8	9	10
P, MW	94	93	65,1	84	90,8	115	140,2	107,5	0	62
Q, MVAR	21	50	32,3	17,3	26	77	71,6	43	0	37
S, MVA	96,317	105,589	72,673	85,763	94,449	138,381	157,425	115,78	0	72,201

**Source: Hereinafter the tables are compiled by the authors based on the research results.*

Table 2

Data on specific parameters of lines, as well as on active and inductive resistances of lines Fig 1

Line	B-3	3-4	A-1	1-2	1-5	5-6	6-7	C-7	C-8	8-9	9-10	B-10	B-2
$U_{narm.}$, кV	110	110	110	110	110	110	110	110	110	110	110	110	110
N	2	2	2	2	2	2	2	2	2	2	2	2	2
Wire brand	AC 240/32	AC 240/32	AC 240/32	AC 240/32	AC 240/32	AC 240/32	AC 240/32	AC 240/32	AC 240/32	AC 240/32	AC 240/32	AC 240/32	AC 240/32
r_0, Oh /km	0,118	0,118	0,118	0,118	0,118	0,118	0,118	0,118	0,118	0,118	0,118	0,118	0,118
x_0, Ohm/km	0,405	0,405	0,405	0,405	0,405	0,405	0,405	0,405	0,405	0,405	0,405	0,405	0,405
b_0, μCm /km	2,808	2,808	2,808	2,808	2,808	2,808	2,808	2,808	2,808	2,808	2,808	2,808	2,808
L, km	9,5	4,5	39	7,8	11	3,8	5,9	9,3	8	12	3,2	8,5	9
R, Ohm	0,561	0,266	2,301	0,460	0,649	0,224	0,348	0,549	0,472	0,708	0,189	0,502	0,531
X, Ohm	1,924	0,911	7,898	1,579	2,228	0,769	1,195	1,883	1,62	2,43	0,648	1,721	1,823
B, μ Cm	53,352	25,272	219,04	43,805	61,776	21,341	33,134	52,229	44,928	67,392	17,971	47,736	50,544

Where is: N – Number of transmission line; $r0$ – Line resistivity, Ohm/ m; $x0$ – line resistivity, Ohm/km; R – Active resistance, Ohm; X – Reactance Ohm, B – Reactive conductivity Cm; b_0 – specific capacitive conductivity Cm/Km.

We choose a transformer for a substation according of the formula:

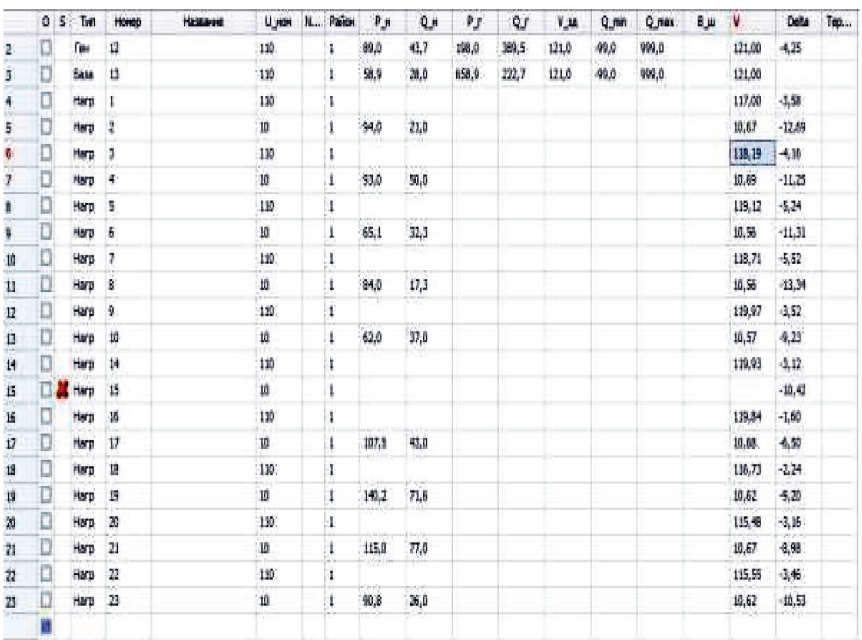
$$S_{T.norm} \geq \frac{S_B}{k_{\grave{a}b}\left(n_t - 1\right)}.$$

Table 3

Power at each substation and transformers

Station	1	2	3	4	5	6	7	8	9	10
$S_{мin}$, MVA	49.512	75.421	51.909	61.259	67.464	98.856	112.446	82.701	_	51.572
Mark (A)TP	TRDN-80000/110	TRDN -80000/110	TRDN -63000/110	TRDN -63000/110	TRDN -80000/110	TRDC-125000 /110	TRDC-125000 /110	TRDC-125000 /110	–	TRDN -63000/110

Calculation of load mode in the rastrwin 3 software environment:



	O	S	Тип	Номер	Название	U_ном	N...	Район	P_н	Q_н	P_г	Q_г	V_зд	Q_min	Q_max	B_ш	V	Delta	Тер...
2			Ген	12		110		1	89,0	43,7	108,0	389,5	121,0	-99,0	999,0		121,00	-4,25	
3			База	13		110		1	58,9	28,0	658,9	222,7	121,0	-99,0	999,0		121,00		
4			Нагр	1		110		1									117,00	-3,58	
5			Нагр	2		10		1	94,0	21,0							10,67	-12,69	
6			Нагр	3		110		1									118,19	-4,10	
7			Нагр	4		10		1	93,0	50,0							10,69	-11,25	
8			Нагр	5		110		1									119,12	-5,24	
9			Нагр	6		10		1	65,1	32,3							10,56	-11,31	
10			Нагр	7		110		1									118,71	-5,52	
11			Нагр	8		10		1	84,0	17,3							10,56	-13,34	
12			Нагр	9		110		1									119,97	-3,52	
13			Нагр	10		10		1	62,0	37,0							10,57	-9,23	
14			Нагр	14		110		1									119,93	-3,12	
15			Нагр	15		10		1										-10,43	
16			Нагр	16		110		1									119,84	-1,60	
17			Нагр	17		10		1	107,9	43,0							10,08	-6,50	
18			Нагр	18		110		1									116,73	-2,24	
19			Нагр	19		10		1	140,2	71,6							10,62	-5,20	
20			Нагр	20		110		1									115,48	-3,16	
21			Нагр	21		10		1	115,0	77,0							10,67	-8,98	
22			Нагр	22		110		1									115,55	-3,46	
23			Нагр	23		10		1	90,8	26,0							10,62	-10,53	

Figure 2. Branches in load mode

	O	S	Тип	N_нач	N_кон	N_п	I...	Название	R	X	B	Кт/r	N_анц	БД_...	P_нач	Q_нач	Na	Imax	I загр.
1			ЛЭП	11	1			-	2,30	7,90	-219,0				-166	-18		798	
2			Тр-р	1	2			-	0,87	22,00		0,096	13	3	-95	-38		503	
3			ЛЭП	1	3			-	0,46	1,58	-43,8				-58	104		589	
4			Тр-р	3	4			-	0,60	17,40		0,098	14	10	-94	-66		560	
5			ЛЭП	3	12			-	0,53	1,82	-50,5				36	172		858	
6			ЛЭП	12	5			-	0,56	1,92	-53,4				-151	-75		806	
7			Тр-р	5	6			-	0,87	22,00		0,095	12	3	-65	-42		376	
8			ЛЭП	5	7			-	0,27	0,91	-25,3				-85	-30		436	
9			Тр-р	7	8			-	0,87	22,00		0,093	11	3	-84	-30		436	
10			ЛЭП	12	9			-	0,50	1,72	-47,7				80	-96		598	
11			Тр-р	9	10			-	0,87	22,00		0,095	12	3	-62	-46		374	
12			ЛЭП	9	14			-	0,19	0,65	-18,0				143	-49		726	
13			ЛЭП	14	15			-	1,00	1,00									
14			ЛЭП	14	16			-	0,71	2,43	-67,9				143	-48		727	
15			Тр-р	16	17			-	0,40	11,10		0,093	11	9	-108	-54		582	
16			ЛЭП	16	13			-	0,47	1,62	-44,9				252	9		1 215	
17			ЛЭП	13	18			-	0,55	1,88	-52,2				-346	-179		1 860	
18			Тр-р	18	19			-	0,40	11,10		0,098	14	9	-141	-95		842	
19			ЛЭП	18	20			-	0,35	1,20	-33,1				-199	-65		1 037	
20			Тр-р	20	21			-	0,40	11,10		0,100	15	9	-116	-96		751	
21			ЛЭП	20	22			-	0,22	0,77	-21,3				-82	34		446	
22			Тр-р	22	23			-	0,60	17,40		0,096	13	10	-91	-39		495	
23			ЛЭП	22	1			-	0,65	2,23	-61,8				9	73		368	

Figure 3. Nodes in load mode

Узлы | Ветви | Анцапфы | Районы

	N...	Район	Nоб	Pген	Pнаг	Dp	Pпотр	Pвн	Tc	Pн мин	Pн max	Pг мин	Pг max
1	1			1 071	1 048	23,37	1 071						

Figure 4. Active power loses

Results

After adding all the data from the electrical network of Khartoum to the rastrwin3 program, we got active power losses are equal to 23,37 % as Figure 4, then we used two methods to reduce the losses in the network:

First method – when adding capacitor banks (CB):

Table 4

CB	Without	1.2·2	1.2·2	1.2·2	1.2·2	1.2·2	1.2·2	1.2·2	1.2·2	1.2·2	1.2·2	1.2·2
1	23.37	23.31	23.23	23.15	23.07	23.00	22.924	22.85	22.78	22.71	22.65	22.58
2	23.37	23.32	23.24	23.16	23.08	23.00	22.932	22.86	22.79	22.72	22.65	22.59
3	23.37	23.33	23.25	23.17	23.10	23.02	22.947	22.87	22.80	22.74	22.66	22.66
4	23.37	23.33	23.25	23.17	23.10	23.02	22.949	22.88	22.81	22.74	22.67	22.58
5	23.37	23.30	23.22	23.14	23.06	22.99	22.915	22.843	22.774	22.706	22.639	22.575
6	**23.37**	**23.28**	**23.21**	**23.13**	**23.05**	**22.98**	**22.907**	**22.837**	**22.768**	**22.701**	**22.635**	**22.571**
7	23.37	23.30	23.22	23.14	23.06	22.99	22.916	22.844	22.775	22.707	22.640	22.575
8	23.37	23.35	23.26	23.19	23.11	23.03	22.960	22.89	22.817	22.749	22.68	22.616
9	23.37	23.37	23.28	23.31	23.13	23.05	2.98	22.907	22.837	22.768	22.701	22.635
10	23.37	23.34	23.26	23.18	23.10	23.03	22.952	22.88	22.810	22.74	22.674	22.609

Results when adding capacitor banks to rastrwin3

The criterion for technical and economic comparison:

$$\tau = \frac{1}{3}T_{нб} + \frac{2}{3}\cdot\frac{T_{нб}^{2}}{8760} = \frac{1}{3}\cdot 4400 + \frac{2}{3}\cdot\frac{4400^{2}}{8760} = 2940{,}030\, h/\,year\ .$$

Before – Annual load losses:

$$\Delta A_{load} = \Delta P_{load}\cdot\tau = 23{,}37\cdot 2940{,}030 = 68708{,}501\left(MW\cdot h\right)/\,hour\ .$$

Total annual cost of reimbursement of losses:

$$И_{пот\Sigma} = c_{э}\cdot\Delta A_{load} = 2.83\cdot 68708{,}501 = 194445{,}058\, Th.rub./year\ .$$

$c_{э}$ – cost of electricity losses for the central region.

After – Annual load losses:

$$\Delta A_{load} = \Delta P_{load}\cdot\tau = 22{,}571\cdot 2940{,}030 = 66359{,}417\left(MW\cdot h\right)/\,hour\ .$$

Total annual cost of reimbursement of losses:

$$И_{пот\Sigma} = c_{э}\cdot\Delta A_{нагр} = 2{,}83\cdot 66359{,}417 = 187797{,}151\, Th.rub./\,year\ .$$

Total annual savings:

$$И_{пот\Sigma} = И_{пот\Sigma before} - И_{пот\Sigma after} = 194445{,}058 - 187797{,}151 = 6647{,}08\ Th.rub/\,year\,.$$

Capital of CB:

$$k_{CB1} = k_{CB.baz}\cdot\kappa_{Zones}\cdot\kappa_{def}\cdot n_{CB} = 375\cdot 1\cdot 8{,}3\cdot 22 = 68475\, Th.rub.$$

n_{CB} – numbers of CB.

KCB.baz – enlarged indicator of the cost of capacitor banks.

Kzones – 1.0 (for substations) – zonal coefficient for the central region (Khartoum).

Kdef is the deflation coefficient at the beginning of 2010.

Conclusion: As a result of the program rastrwin3 and with the help of the CB, the active power losses decreased slightly (23.37-22.571). The total annual savings is $6647{,}08\ Th.rub/\,year$.

Second method – when adding a Reactor:

Table 5

Results when adding a 5-ohm reactor on each line to rastrwin3

Line	Losses, MW
Without	23.37
1-2	**23.23**
B-2	23.51
B-3	23.52
3-4	23.41
B-10	23.30
10-9	23.66
9-8	23.66
C-8	24.88
C-7	28.17

Ending Table 5

Line	Losses, MW
7-6	24.76
6-5	23.46
5-1	23.37
A-1	23.53

Table 6

Results when adding reactor on line 1-2 to rastrwin3

Reactor, Ohm	Losses, MW
0.5	23.29
1	23.25
1.5	23.22
2	23.20
2.5	23.19
3	23.19
3.5	23.20
4	23.20
4.5	23.22
5	23.23
5.5	23.25
6	23.27
6.5	23.28
7	23.30
7.5	23.32
8	23.34
8.5	23.36
9	23.39
9.5	23.41
10	23.43

Conclusion: When adding a reactor, active power losses decreased little bit (23.37-23.23).

Conclusion

By using rastrwin3 program, which implements the calculation of active power losses from the results obtained, the losses are different in different activities, and with the addition of power lines, the active power losses are much reduced than in the CB, reactor, and another activity. You cannot get rid of losses, but to reduce them you need to take measures, such as:

- reduction of the current density in the wires of the line (within acceptable limits);
- the distribution of compensating devices along power transmission to reduce the length of the reactive power flow arm.

• the voltage regulation at the end of the line (for very long power lines). With a less losses, less budget.

It is about high losses in the transmission and distribution of electricity and their solutions in general, also mentioned in particular about Khartoum State (the capital of Sudan), and experiments were conducted to reduce the electrical loss in the Khartoum state network, by used two measures. In the first measure, by using the capacitor banks and as a result of the program rastrwin3, the active power losses decreased slightly (23.37-22.571). The total annual savings is 6647,08 thousand rub./year. In the second measure, when adding a Reactor, the active power losses decreased little bit (23.37-23.23). As we got the first measure (Capacitor banks), it is more effective than the second measure (Reactor).

After all this, the recommendations clarified, what are the suggestions and policies that require implementation to reform the electricity sector.

1. Organizing periodic measurement programs and taking remedial measures considering the measurement results as follows:

- improving the phenomenon of electrical imbalance;
- conducting a change cycle for loaded and non-loaded transformers (transformer rotation);
- monitor cable loading and upload handling;
- monitor and correct low voltage conditions;
- attention to the connection links at the various network points;
- inventory and renewal of dilapidated and old networks;
- study the existing operational conditions and prepare optimal operating modes;
- follow up and measure the power factor of various consumer segments;
- paying attention to planning and developing electrical networks;
- eliminate bottlenecks in medium and low voltage networks;

2. Implementation of deployment policies as part of a broad range of cross-cutting policy instruments. A policy mix tailored to meet Sudan conditions and the level of maturity of its varying sectors, aimed at strengthening firm-level capabilities, building a domestic industry, promoting education and research and facilitating.

3. By expanding regional grid integration and power trade through regional planning, harmonization of standards and procedures, equitable commercial terms, and coordination at power pool level.

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