Vol.(6),No.(1),(2018),52-63
MUTHANNA JOURNAL OF ENGINEERING AND TECHNOLOGY (MJET)
مجلة المثنى للهندسة والتكنولوجيا
Journal homepage:www.muthjet.com
Print ISSN:2572-0317, Online ISSN:2572-0325

Study the Effects of Improving Power Factor on Electrical Distribution Network in Al- Muthanna Governorate

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ARTICLE INFO

Received: 05/12/2017

Accepted: 22/01/2018

Keywords
Power Factor, Relative Power

ABSTRACT
This paper represents analysis and study the effects about improve power factor for an electric distribution network in Al- Muthanna governorate, and show method Calculation of power factor, apparent power, reactive power and current, compare these results with regard to before and after the improved power factor in the electric distribution network in Al- Muthanna governorate. This paper represents the results of the improvement of the power factor by increasing the efficiency and the capacity of the electrical system...etc. Calculation of the percentage of the reduction of electric power losses and calculating the monthly cost of this reduction The difference in the apparent power between before and after improvement is 19.5 MVA from the change of power factor in 78 feeders of the electric distribution network of Al-Muthanna Governorate.

دراسة تأثيرات تحسين معامل القدرة على شبكة توزيع الطاقة الكهربائية في محافظة المثنى

الخلاصة

تمثل هذه الورقة تحليل ودراسة التاثيرات تحسين معامل القدرة لشبكة التوزيع الكهربائي في محافظة المثنى.وعرض طريقة حساب معامل القدرة، القوة الظاهرة، الطاقة التفاعلية والحالية، مقارنة هذه النتائج بين قبل وبعد تحسين معامل القدرة لشبكة التوزيع الكهربائية في محافظة المثنى. تقدم هذه الورقة نتائج تحسين معامل القدرة: زيادة كفاءة وقدرة النظام الكهربائي ... الخ. حساب نسبة تخفيض خسائر الطاقة الكهربائية وحساب تكلفة هذا التخفيض شهريا" . الفرق في القوة الظاهرة بين قبل وبعد التحسن هو ١٩/٥ م.ف.ا من تغير معامل القدرة في ٧٨ مغذي لشبكة توزيع الكهرباء محافظة المثنى

الكلمات الافتتاحية

معامل القدرة، القدرة الغير فاعلة

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DOI: 10.18081/mjet/2018-6/52-63

Introduction:

The electrical system consists of three major components, are generation, transmission, and electric power distribution Network, where the electric power is produced in the power stations and transferred through the electric transformers stations(substation) by increasing the voltage and reducing the current to its lowest possible value. Power factor correction or improve power factor improvement is a process of changing the angle, which will reduce the power losses

The angle or Phase difference between the voltages and the current in the transmission line and Distribution Network. Apparent power consists of active power and reactive power. The Phase-difference effects the value of the active power. The power loss is reduced by adding capacitors to the transmission networks or distribution for improving the power factor due to the capacitor controls in voltages, phase, Capacitors bank is the best method for power factor correction because they are affordable and simple design. Not only that but also, they have no moving parts, unlike some other devices used for the same purpose**.**

Power capacitors bank provide many benefits: Reduced electric utility bills, increased system capacity, improved voltage, reduced losses**.**[1] During the transmission and distribution process in the electric power network, it produces a decrease in voltages and an increase in power losses resulting in an increase in the costs of electricity. Power factor correction is increasing power factor, this increase produces a reduction in the reactive power, current, power losses, economic costs, and protect electrical appliances.

Mathematical Equations:

1. Calculation method of power factor:

The difference between the voltages and the current show by the following equations: [2]

$$V=V_m \cdot \sin(wt+\varphi) \quad (1)$$

$$I=I_m \cdot \sin(wt) \quad (2)$$

Where:

$\boldsymbol{\varphi}$: Phase Difference or phase displacement

V_m is maxed voltage,

I_m is maxed current,

w is frequency.

Active or real power is voltage multiplied by current. With only resistive load with no inductive or capacitive components, the voltage and current curves intersect the zero coordinate at the same point as in (Fig. 1A)[3], the voltages and the current are in phases and the electric power is positive and higher. In (Fig. 1B)[3] Show ($\boldsymbol{\varphi}$ = 90°) the active power =zero (purely reactive load) . In (Fig. 1C)[3] Show ($\boldsymbol{\varphi}$ = 45°) the phase a difference between voltage and current, so it generates active and reactive power.

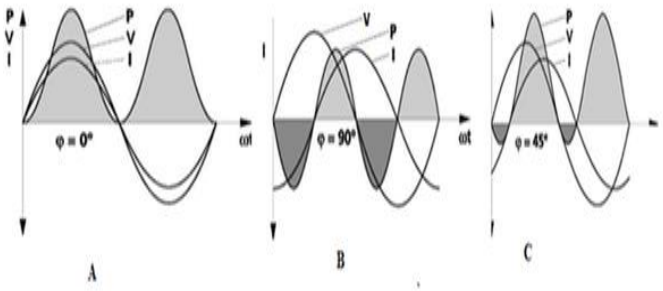

Figure 1: A. Voltage, current and power curve for a purely resistive load. (φ = 0°) . B. Voltage, current and power curves for a purely reactive load (φ = 90°) .C. Voltage, current and power with a resistive and an inductive load (φ = 45°)

When the angle $\boldsymbol{\varphi}$ is increased, it takes more current to deliver the same amount of active power [4]. In general, The following formulas can be used to calculate change on phase difference, reactive power, active power ,angle before and after adding

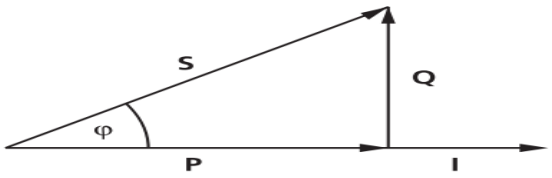

Figure 2: Power triangle [٣][5]

In Figure2 shows, the three-axis power triangle (apparent power, active power, reactive power) and the variable angle to reduce improve the power factor.

The active power is given by following formula[**6**]:

$$P(KW)=\sqrt{3}.\ V\ .I.\ \cos\varphi \quad (3)$$

Where:

Measurement: voltage(volt) current (amper)

$\boldsymbol{\varphi}$ in rad .

The reactive power is given by following formula[**3**][**6**]:

$$Q(KVAR)=\sqrt{3}.\ V\ .I\ \ \sin\varphi \quad (4)$$

Apparent Power is given by following formula [**3**]:

$$\boldsymbol{S}(\ KVA)=\sqrt{3}.V\ .\ I \quad (5)$$

Power factor P.F= $\cos\varphi$ is given by following formula [7]:

$$\cos\varphi=\frac{P}{S}\quad,\quad \cos\varphi\leq 1 \quad (6)$$

Mathematical equations between$\tan\varphi$ and $\cos\varphi$:[3]

$$\tan\varphi=\frac{Q}{P} \quad (7)$$

$$\cos\varphi=\sqrt{\frac{1}{1+\tan^2\varphi}} \quad (8)$$

After improving Power Factor: Add capacitors to load:

Power factor 2 given by the formula [**3**]: PF2 =cos φ_2

$$Q_C=Q_1-Q_2 \ , \quad Q_C=P*(\tan\varphi_1 - \tan\varphi_2) \qquad (9)$$

Where: QC NEW capacitor

$$\tan\varphi=\frac{Q_2}{P}\rightarrow \varphi_2=\tan^{-1}\frac{Q_1-Q_C}{P}=\tan^{-1}\frac{Q_1-(\text{Number of capacitors}*\text{Value})}{P} \qquad (10)$$

Increasing the current and increasing the reactive power give negative results such as Overloads of the transformer, Temperature rise of the supply cables, Additional losses, and large voltage drops [8]. In order to control active power and improve the quality of electrical power, we need to reduce reactive power by adding capacitors in parallel with the load. It is important to get power factor equal to 1.

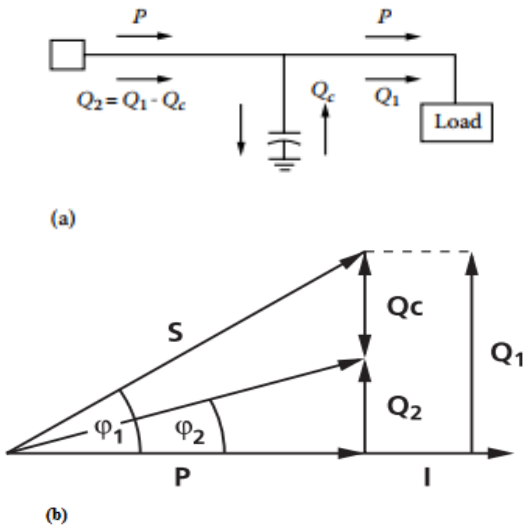

Figure 3: a) Illustration of power factor correction [9] b) Power triangle showing the effect of correction [6].

In" Fig3a" shows Illustration of power factor correction. In "Fiq3b" showsPower triangle after power factor correction by adding a capacitor, therefore, the reactive power reduced. The reactive power QC (additional) given by the capacitor is to reduce the reactive power. Reducing the reactive power produced by an increase in the power factor will lead to reducing the current, so will reduce the losses.

2. Reduction of distribution power losses:

Losses in Electrical power distribution decreases by adding capacitors resulting an increase in the power factor. These losses in electrical distribution are the total loss of transformers losses and cable losses, because of the length of the feeder and the number of transformers and other networks reasons. In the following formula power losses [10]: are calculated

$$P_{LOSSES}= 3.I^2.R \qquad (10)$$

Reducing current in electrical distribution networks resulting in a reduction of power loss. Adding capacitors to the network (correction of the power factor) is one of the ways to reduce power losses and therefore reduce economic losses. The equations below are the relationship between the reduction of power loss and the power factor before and after correction: [6]

$$\Delta P_{LOSSES}=P_{1\ LOSSES}-P_{2\ LOSSES}$$

$$=\frac{R.P^2}{V^2\ .\cos\emptyset_1}-\frac{R\ .P^2}{V^2\ \cos\emptyset_2}$$

$$\frac{\Delta P_{LOSSES}}{P_{1LOSSES}}=\left[1-\left(\frac{\cos\emptyset_1}{\cos\emptyset_2}\right)^2\right] \qquad (11)$$

Loss Reduction percentage Given by formula: [1]

$$\text{Loss Reduction\%}=\left[1-\left(\frac{PF_1\ \text{initial}}{P.F_2\ \text{final}}\right)^2\right]*100\% \qquad (12)$$

Always the prices calculated for the energy per hour KWH and the difficulty of calculation for the apparent power KVA because the calculation depends on pure active power and pure current.

Therefore, we calculate ratio $\left[\frac{\Delta P_{LOSSES}}{P_{1LOSSES}}\right]$is percentage is the reduction in losses.

This reduction (energy losses) will lead to cost reduction in the electrical network and the average price in Iraq, choose 120 Iraqi dinars per kilowatt - hour.

The electrical distribution network of Al-Muthanna Governorate:

Al-Muthanna Governorate consists of three main cities; the center Samawah, Rumaitha, and Khadr which include the villages, which are connected to these cities. Distribution Directorate of Muthanna Governorate is responsible for the Distribution of electrical power. Electrical distribution network in Al-muthanna Governorate consists of substations (132/33 KV, 33 /11KV, 132/11KV)and feeders, as shown in the chart Figure4. A number of consumers of the year 2015 were 91387 consumers [11]. Adding Capacitors to electrical distribution networks at the 11/0.433KV transformer in 78 feeders in increasing power factor. In Figure (4) the scheme of electric distribution in Al- muthanna Governorate shows substations (Transformers) of 132/33 KV and 33/11KVand 132 /11 KV and transmission lines 132, 33 and 11 and the apparent power of each substation, 78 Feeders11kv written by Red color, each feeder contains a number of electrical transformers 11/4.33 KV. the capacitors have been added on 11/4.33 KV transformers on the 78 feeders in the distribution network of Al-muthanna result: improve the power factor, currents(A), apparent power (KVA) and reactive power (Q)(KVAR), therefore calculate power loss and Saving Cost. First, we studied loads (currents) in distribution networks, power factor, and then we tested the necessary and practical calculations of changes after power factor correction.

As shown in Appendix1 and Appendix2 changes of current, reactive power and cost in each feeder with regard to before and after improving power factor for group 11/4.33kv in feeder's network. Improvement is increased the power factor after adding capacitors. Power factor correction reduces in apparent power, the current and power losses. Finally, it contributes effectively is reducing economic costs.

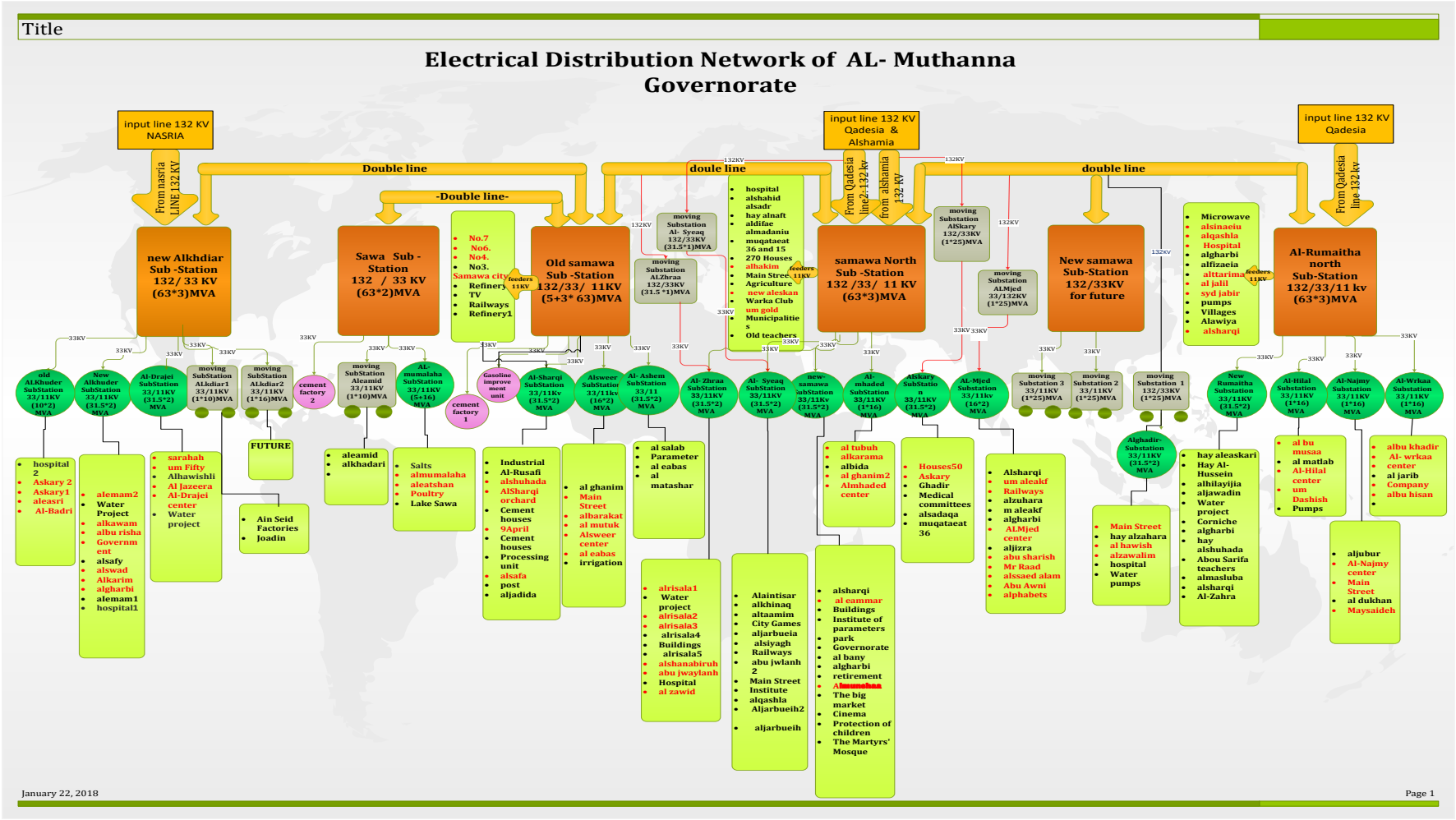

Figure 4: Electrical Distribution Network of Al-muthanna Governorate by program Microsoft Office- Visi

Effects and Calculation of variables after the power factor improvement on the electrical grid:

Calculate all the parameters on the network after improving power factor and cost reduction of losses

In the Appendix1: as an example: new Samaw Substation 33/11 KV : al eammar Feeder V= 11KV p=3.5MW , P.F 1=0.88,Number of capacitors25 ,Value of capacitor=5KVr

After the power factor correction can calculate as follows:

$$\varphi_2 = \tan^{-1}\frac{Q_1 - Q_C}{P} = \tan^{-1}\frac{Q_1 - (\text{Number of capacitors} * \text{Value})}{P}$$

$$Q_2 = \tan^{-1}\frac{1.900 - \frac{25 * 5\text{kvr}}{1000}}{3.5} = 26.8\ 915$$

$$PF_2 = \cos 26.8915 = 0.89186 \cong 0.89$$

$$I_2 = \frac{P}{\sqrt{3}\ .V.\cos\varphi} = \frac{3.5*10^6}{\sqrt{3}*11*1000*0.89186} = 205.9766 \cong 206$$

$$I_1 = \frac{P}{\sqrt{3}\ .V.\cos\varphi} = \frac{3.5*10^6}{\sqrt{3}*11*1000*0.88} = 208.7 \cong 209$$

$$S_2\ \text{MVA} = \sqrt{3}.V\ .\ I_2 =$$

$$\sqrt{3}*11*\frac{205.9766}{1000} = 3.924\ \text{MVA}$$

$$Q_2 = S_2.\sin\varphi = 3.924 * \sin(26.8915) = 1.7748 \cong 1.775$$

$P_2 = S_2 \cos(26.8915) = 3.924 * 0.89 = 3.49 \cong 3.5$, $p_2 = P_1$

In the Appendix2: new Samaw Substation 33/11 KV : al eammar Feeder V= 11KV p=3.5MW , P.F 1=0.88 ,PF2 =0.89

$$\%\ \text{Loss Reduction} = \left[1 - \left(\frac{088}{0.89}\right)^2\right] * 100\%$$

$$= 2.2345\ \% = 0.02234$$

Electrical energy (KWH): 0.02234 *1000=22.34 KWH

Suppose that the average operation hours is (14 hours):

The daily reduction Electrical energy (KWH) in day =22.34*14=312.76

Choose 120 Iraqi dinars per kilowatt-hour : saving daily cost (Iraqi dinars) =312.76*120=37531.2Iraqi dinar [12]

Saving cost monthly (Iraqi dinars) = 37531.2*30=1125936

Δ S Apparent power =S1- S2=4.001-3.924=0.007

Result and Discussions:

Effects of adding the capacitors on the electrical grid For the consumer can be explained by following factors:

1.Effect current, apparent power, reactive of power network capacity:

As the reading in Appendix1active power is constant, reduce the current this result present in "Fig5", increase power factor as in "Fig 6",reduce the apparent power as in "Fig8" reduce the reactive power as in "Fig7"The addition of capacitors to the feeders (78 feeders) in Electric Distribution Network of Al-Muthanna therefore Improvement of power factor will lead to improvement in the electrical quality that reaches the consumer more reliably , voltage, current, Frequency, and power is obtained.

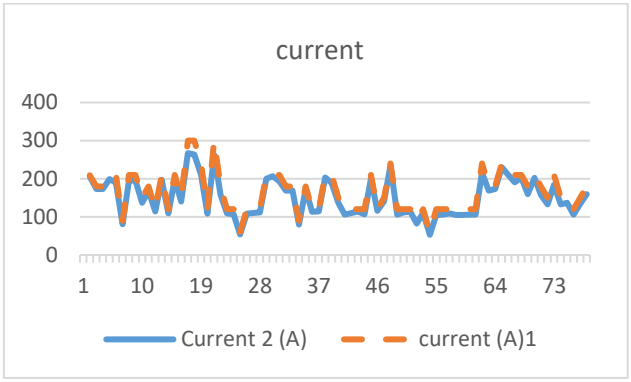

Figure 5:current 1before correction and current 2after correction

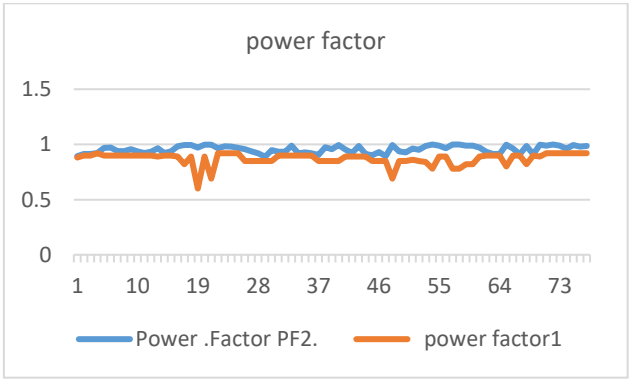

Figure 6: power factor 1before correction and power factor 2after correction

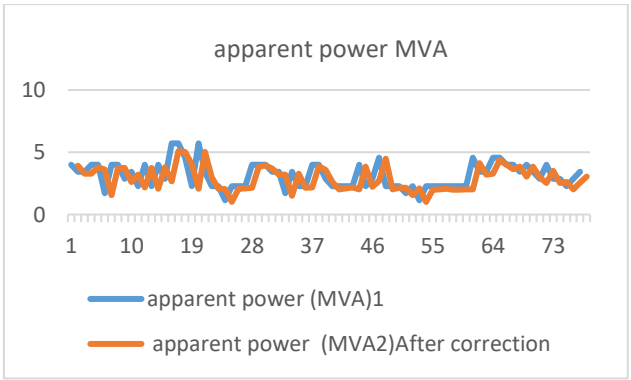

Figure 7: Apparent power 1before correction and Apparent power2after correction

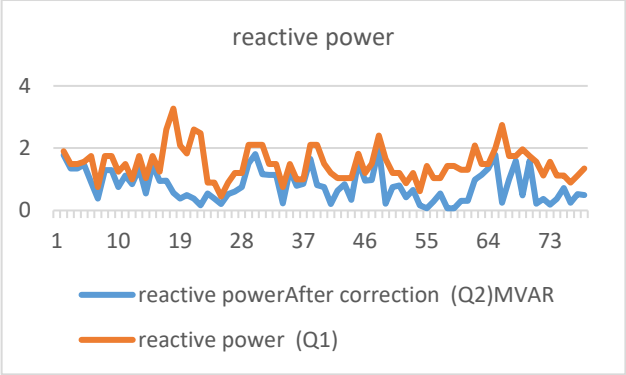

Figure 8: Reactive power 1before correction and reactive power2after correction

2. power losses reduction and economic losses(Saving Cost):
From Appendix2 shows that reduction in apparent power, reduction of electrical losses by decreasing currents after improving power factor, calculation of the cost of electric energy for this reduction and calculation of the economic profits of each feeder. Reducing the current; therefore reducing the load on the network and more protection for the conductors and transformers in this network will be gained.

Total daily reduction and total monthly reduction for all these feeders in electrical distribution network are in Table 2after power factor correction.

The Different in total apparent power is 19.5 MVA through a change in the power factor of 78 feeders in Muthanna electricity distribution network. Total Cost Reduce losses per month for 14 hours is(623263032) Iraqi Dinar

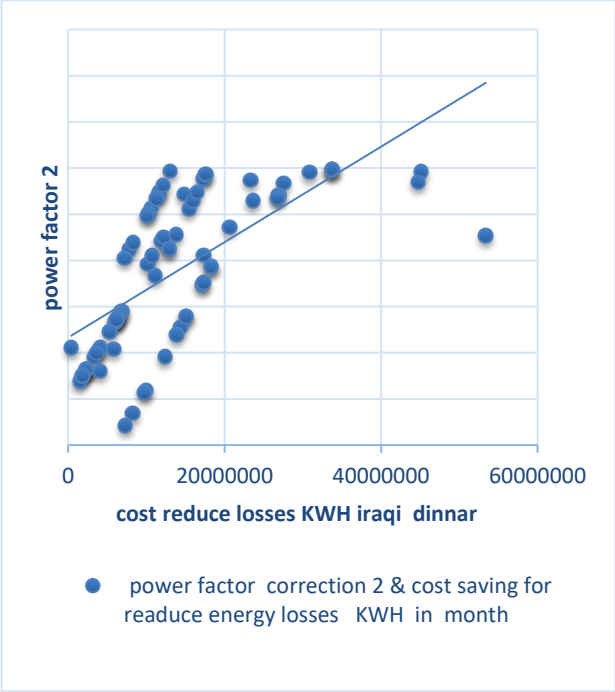

Figure 9: shows the relationship between the power factor and the cost of reducing losses (saving money)

In "Fig9", the increase in the power factor is directly proportional to the cost of reducing losses
In general, benefits of the power factor correction are:
1. Stability of the electrical system in and increasing efficiency of the electrical power system.
2. Protection of electrical equipment (transformers, wires, etc.) from the risk of high temperatures in this equipment because of high current
3. increase network capacity.
4. saving cost by reducing electrical losses

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Appendix 1:: power factor, reactive power, apparent power, current for Electrical distribution networks in AL-Muthanna Governorate and compare between

1. Before the power factor correction

QC

2. After the power factor correction

Electrical Sub-Station	١١KV feeder	power factor1	current (A)1	active power (MW)	apparent power (MVA)1	reactive power (Q1	Number of capacitors	Capacitor Value (KVAR)	Power .Factor PF2.	Current 2 (A)	apparent power (MVA2) After correction	reactive power After correction (Q2)MVAR	reactive power Qc= Q1-Q2
new samaw SubStation	al eammar	0.88	209	3.5	4.001	1.900	5	25	0.892	206	3.924	1.775	0.125
new samaw SubStation	almunshaa	0.9	180	3	3.429	1.495	6	25	0.913	173	3.288	1.345	0.15
Askary SubStation	Askary	0.9	180	3	3.429	1.495	6	25	0.913	173	3.288	1.345	0.15
Askary SubStation	houses50	0.92	210	3.5	4.001	1.568	4	25	0.922	199	3.795	1.468	0.10
old alkhdiar SubStation	Al-Badri	0.899	210	3.5	4.001	1.752	34	25	0.968	190	3.614	0.902	0.85
old alkhdiar SubStation	aleasri	0.899	90	1.5	1.715	0.751	15	25	0.970	81	1.546	0.376	0.38
old alkhdiar SubStation	Askary1	0.9	210	3.5	4.001	1.744	18	25	0.938	196	3.732	1.294	0.45
old alkhdiar SubStation	Askary 2	0.9	210	3.5	4.001	1.744	18	25	0.938	196	3.732	1.294	0.45
new alkhdiar SubStation	Government	0.9	150	2.5	2.858	1.246	20	25	0.958	137	2.609	0.746	0.50
new alkhdiar SubStation	algharbi	0.9	180	3	3.429	1.495	15	25	0.937	168	3.202	1.120	0.38
new alkhdiar SubStation	aIemam	0.9	120	2	2.286	0.997	6	25	0.921	114	2.172	0.847	0.15
new alkhdiar SubStation	albu risha	0.9	210	3.5	4.001	1.744	16	25	0.934	197	3.749	1.344	0.40
new alkhdiar SubStation	alkarim	0.89	120	2	2.286	1.042	20	25	0.965	109	2.072	0.542	0.50
new alkhdiar SubStation	alkawam	0.9	210	3.5	4.001	1.744	11	25	0.922	199	3.796	1.469	0.28
new alkhdiar SubStation	alswad	0.9	150	2.5	2.858	1.246	12	25	0.935	140	2.673	0.946	0.30
Al-Rumaitha north SubStation	alsinaeiu	0.89	300	5	5.716	2.606	66	25	0.982	267	5.091	0.956	1.65
Al-Rumaitha north SubStation	alsharqi	0.82	300	5	5.716	3.271	108	25	0.994	264	5.033	0.571	2.70
Al-Rumaitha north SubStation	al jalil	0.89	240	4	4.573	2.085	68	25	0.995	211	4.018	0.385	1.70
Al-Rumaitha north SubStation	alqashla	0.6	120	2	2.286	1.829	93	25	0.971	108	2.061	0.496	1.33
Al-Rumaitha north SubStation	syd jabir	0.89	300	5	5.716	2.606	89	25	0.997	263	5.015	0.381	2.23
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1. Before the power factor correction

QC

2. After the power factor correction

Electrical Sub-Station	١١KV feeder	power factor1	current (A)1	active power (MW)	apparent power (MVA)1	reactive power (Q1	Number of capacitors	Capacitor Value (KVAR)	Power .Factor PF2.	Current 2 (A)	apparent power (MVA2) After correction	reactive power After correction (Q2)MVAR	reactive power Qc= Q1-Q2
Al-Rumaitha north SubStation	syd jabir	0.89	300	5	5.716	2.606	89	25	0.997	263	5.015	0.381	2.23
Al-Rumaitha north SubStation	syd jabir	0.89	300	5	5.716	2.606	89	25	0.997	263	5.015	0.381	2.23
Al-Rumaitha north SubStation	Hospital	0.69	180	3	3.429	2.482	106	25	0.998	158	3.005	0.168	2.31
Al-Rumaitha north SubStation	alttarima	0.92	120	2	2.286	0.896	14	25	0.965	109	2.073	0.546	0.35
AL-wrkaa SubStation	albu khadir	0.92	120	2	2.286	0.896	51	25	0.983	107	2.036	0.379	0.52
Al-wrkaa SubStation	Al-wrkaacenter	0.92	60	1	1.143	0.448	26	25	0.980	54	1.020	0.202	0.25
Al-wrkaa SubStation	albu hisan	0.92	120	2	2.286	0.896	15	25	0.968	108	2.067	0.521	0.38
Al-wrkaa SubStation	al jarib	0.85	120	2	2.286	1.204	24	25	0.957	110	2.089	0.604	0.60
Al-wrkaa SubStation	Company	0.85	120	2	2.286	1.204	18	25	0.936	112	2.138	0.754	0.45
Alghadir-SubStation	alzawalim	0.85	210	3.5	4.001	2.108	24	25	0.918	200	3.811	1.508	0.60
Alghadir-SubStation	Main Street	0.85	210	3.5	4.001	2.108	12	25	0.888	207	3.939	1.808	0.30
Alghadir-SubStation	al hawish	0.85	210	3.5	4.001	2.108	38	25	0.949	193	3.686	1.158	0.95
Al- Zhraa SubStation	alrisala1	0.9	180	3	3.429	1.495	14	25	0.934	169	3.211	1.145	0.35
Al- Zhraa SubStation	alrisala2	0.9	180	3	3.429	1.495	14	25	0.934	169	3.211	1.145	0.35
Al- Zhraa SubStation	alrisala3	0.9	90	1.5	1.715	0.747	39	25	0.989	80	1.517	0.228	0.52
Al- Zhraa SubStation	al zawid	0.9	180	3	3.429	1.495	8	25	0.918	172	3.268	1.295	0.20
Al- Zhraa SubStation	abu jwaylanh	0.9	120	2	2.286	0.997	8	25	0.929	113	2.153	0.797	0.20
Al- Zhraa SubStation	alshanabiruh	0.9	120	2	2.286	0.997	74	25	0.920	114	2.174	0.853	0.14
AL-mumalaha SubStation	Poultry	0.85	210	3.5	4.001	2.108	18	25	0.904	203	3.873	1.658	0.45
AL-mumalaha SubStation	almumalaha	0.85	210	3.5	4.001	2.108	52	25	0.974	189	3.592	0.808	1.30
AL-mumalaha SubStation	aleatshan	0.85	150	2.5	2.858	1.505	30	25	0.957	137	2.612	0.755	0.75
ALMjed SubStation	um aleakf	0.85	120	2	2.286	1.204	40	25	0.995	106	2.010	0.204	1.00
ALMjed SubStation	Railways	0.89	120	2	2.286	1.042	67	25	0.953	110	2.098	0.633	0.41
ALMjed SubStation	alghabat	0.89	120	2	2.286	1.042	8 QC	25	0.922	114	2.170	0.842	0.20

1. Before the power factor correction

2. After the power factor correction

Electrical Sub-Station	١١KV feeder	power	current (A)1	active power (MW)	apparent powe	reactive powe	Number of	Capacitor Value	Power .Fac	Current 2 (A)	apparent power (MVA2)	reactive power	reactive powe

		factor1			r (MVA)1	r (Q1	capacitors	(KVAR)	tor PF2.		After correction	After correction (Q2)MVAR	r Qc= Q1-Q2
ALMjed SubStation	abu sharish	0.89	120	2	2.286	1.042	28	25	0.986	107	2.029	0.342	0.70
ALMjed SubStation	alssaed alam	0.89	210	3.5	4.001	1.824	10	25	0.912	201	3.838	1.574	0.25
ALMjed SubStation	Mr Raad	0.85	120	2	2.286	1.204	10	25	0.903	116	2.216	0.954	0.25
ALMjed SubStation	ALMjed center	0.85	150	2.5	2.858	1.505	21	25	0.931	141	2.685	0.980	0.53
Alsweer SubStation	Alsweer center	0.69	120	2	2.286	1.655	75	25	0.994	106	2.012	0.220	1.43
Alsweer SubStation	albarakat	0.85	120	2	2.286	1.204	18	25	0.936	112	2.138	0.754	0.45
Alsweer SubStation	al eabas	0.85	120	2	2.286	1.204	16	25	0.928	113	2.156	0.804	0.40
Alsweer SubStation	al ghanim	0.86	90	1.5	1.715	0.875	18	25	0.962	82	1.559	0.425	0.45
Alsweer SubStation	al mutuk	0.85	120	2	2.286	1.204	22	25	0.950	110	2.104	0.654	0.55
Alsweer SubStation	Main Street	0.84	60	1	1.143	0.620	18	25	0.986	53	1.014	0.170	0.45
Al-Najmy SubStation	Main Street	0.78	120	2	2.286	1.431	60	25	0.999	105	2.001	0.069	1.36
Al-Najmy SubStation	Al-Najmy center	0.89	120	2	2.286	1.042	30	25	0.989	106	2.021	0.292	0.75
Al-Najmy SubStation	Maysaideh	0.89	120	2	2.286	1.042	20	25	0.965	109	2.072	0.542	0.50
Al-mhaded SubStation	Almhaded center	0.78	120	2	2.286	1.431	60	25	0.999	105	2.001	0.069	1.36
Al-mhaded SubStation	alkarama	0.78	120	2	2.286	1.431	60	25	0.999	105	2.001	0.069	1.36
Al-mhaded SubStation	al ghanim2	0.82	120	2	2.286	1.309	40	25	0.988	106	2.024	0.309	1.00
Al-mhaded SubStation	al tubuh	0.82	120	2	2.286	1.309	40	25	0.988	106	2.024	0.309	1.00
samawaNorth SubStation	um gold	0.89	240	4	4.573	2.085	44	25	0.971	216	4.119	0.985	1.10
samawa NorthSubStation	alhakim	0.9	180	3	3.429	1.495	14	25	0.934	169	3.211	1.145	0.35
samawaNorth SubStation	new aleskan	0.9	180	3	3.429	1.495	6	25	0.913	173	3.288	1.345	0.15
Al-Sharqi SubStation	alsafa	0.9	240	4	4.573	1.993	8	25	0.913	230	4.384	1.793	0.20
Al-Sharqi SubStation	AlSharqi orchard	0.8	240	4	4.573	2.744	100	25	0.998	210	4.007	0.244	2.50
Al-Sharqi SubStation	01-Apr	0.9	210	3.5	4.001	1.744	30	25	0.962	191	3.638	0.994	0.75
Al-Sharqi SubStation	alshuhada	0.9	210	3.5	4.001	1.744	6	25	0.910	202	3.846	1.594	0.15
		1. Before the power factor correction					QC		2. After the power factor correction				
Electrical Sub-Station	١١KV feeder	power	current (A)1	active power (MW)	apparent power	reactive power	Number of capacitors	Capacitor Value	Power .Fac	Current 2 (A)	apparent power (MVA2) After	reactive power After correcti	reactive power

		factor1			(MVA)1	r (Q1		(KVAR)	tor PF2.		correction	on (Q2)MVAR	Qc= Q1-Q2
Old samawa SubStation	No7. Samawa	0.82	180	3	3.429	1.963	59	25	0.987	160	3.039	0.488	1.48
Old samawa SubStation	No6. Samawa	0.9	210	3.5	4.001	1.744	6	25	0.910	202	3.846	1.594	0.15
Old samawa SubStation	No4. Samawa	0.89	180	3	3.429	1.564	54	25	0.997	158	3.008	0.214	1.35
Al-Hilal SubStation	Al-Hilal center	0.92	150	2.5	2.858	1.120	30	25	0.989	133	2.527	0.370	0.75
Al-Hilal SubStation	um Dashish	0.92	210	3.5	4.001	1.568	70	25	0.999	184	3.505	0.182	1.39
Al-Hilal SubStation	al bu musaa	0.92	150	2.5	2.858	1.120	30	25	0.989	133	2.527	0.370	0.75
Al-Drajei SubStation	sarahah	0.92	150	2.5	2.858	1.120	16	25	0.961	137	2.602	0.720	0.40
Al-Drajei SubStation	Al-Drajei center	0.92	120	2	2.286	0.896	26	25	0.993	106	2.015	0.246	0.65
Al-Drajei SubStation	om Fifty	0.92	150	2.5	2.858	1.120	24	25	0.979	134	2.554	0.520	0.60
Al-Drajei SubStation	Al Jazeera	0.92	180	3	3.429	1.344	34	25	0.987	160	3.040	0.494	0.85

Appendix 2: Reduction of power loss, apparent power, cost (Iraqi dinar) for energy KWH in day and month for each feeder

Electrical Sub-Station	**feeder**	**A ratio reduction of power loss (MW)**	**a reduction of power loss %**	**apparent power (MVA) 1**	**apparent power (MVA)2After correction**	**ΔSApparen $= S_1 - S_2$**	**power losses KWH in day**	**Saving COST KWH Dinar per DAY**	**COST KWH Dinar per month**
new samaw SubStation	al eammar	0.02234	2.234%	4.001	3.924	0.077	312.76	37531.2	1125936
new samaw SubStation	almunshaa	0.02722	2.722%	3.429	3.288	0.142	381.08	45729.6	1371888
Askary SubStation	Askary	0.02722	2.722%	3.429	3.288	0.142	381.08	45729.6	1371888
Askary SubStation	houses50	0.00468	0.468%	4.001	3.795	0.206	65.52	7862.4	235872
old alkhdiar SubStation	Al-Badri	0.13809	13.809%	4.001	3.614	0.387	1933.26	231991.2	6959736
old alkhdiar SubStation	aleasri	0.14103	14.103%	1.715	1.546	0.168	1974.42	236930.4	7107912
old alkhdiar SubStation	Askary1	0.07928	7.928%	4.001	3.732	0.269	1109.92	133190.4	3995712
old alkhdiar SubStation	Askary 2	0.07928	7.928%	4.001	3.732	0.269	1109.92	133190.4	3995712
new alkhdiar SubStation	Government	0.11793	11.793%	2.858	2.609	0.249	1651.02	198122.4	5943672
new alkhdiar SubStation	algharbi	0.07713	7.713%	3.429	3.202	0.227	1079.82	129578.4	3887352
new alkhdiar SubStation	aIemam	0.04487	4.487%	2.286	2.172	0.115	628.18	75381.6	2261448
new alkhdiar SubStation	albu risha	0.07056	7.056%	4.001	3.749	0.252	987.84	118540.8	3556224
new alkhdiar SubStation	alkarim	0.14963	14.963%	2.286	2.072	0.214	2094.82	251378.4	7541352
new alkhdiar SubStation	alkawam	0.04731	4.731%	4.001	3.796	0.205	662.34	79480.8	2384424
new alkhdiar SubStation	alswad	0.07409	7.409%	2.858	2.673	0.185	1037.26	124471.2	3734136

Al-Rumaitha north SubStation	alsinaeiu	0.17893	17.893%	5.716	5.091	0.625	2505.02	300602.4	9018072
Al-Rumaitha north SubStation	alsharqi	0.31882	31.882%	5.716	5.033	0.683	4463.48	535617.6	16068528
Al-Rumaitha north SubStation	al jalil	0.20056	20.056%	4.573	4.018	0.554	2807.84	336940.8	10108224
Al-Rumaitha north SubStation	alqashla	0.61786	61.786%	2.286	2.061	0.226	8650.04	1038004.8	31140144
Al-Rumaitha north SubStation	syd jabir	0.20330	20.330%	5.716	5.015	0.701	2846.2	341544	10246320
Al-Rumaitha north SubStation	Hospital	0.52241	52.241%	3.429	3.005	0.425	7313.74	877648.8	26329464
Al-Rumaitha north SubStation	alttarima	0.09051	9.051%	2.286	2.073	0.213	1267.14	152056.8	4561704
AL-wrkaa SubStation	albu khadir	0.12321	12.321%	2.286	2.036	0.251	1724.94	206992.8	6209784
Al-wrkaa SubStation	Al-wrkaacenter	0.11907	11.907%	1.143	1.020	0.123	1666.98	200037.6	6001128
Al-wrkaa SubStation	albu hisan	0.09615	9.615%	2.286	2.067	0.220	1346.1	161532	4845960
Al-wrkaa SubStation	al jarib	0.21152	21.152%	2.286	2.089	0.197	2961.28	355353.6	10660608
Al-wrkaa SubStation	Company	0.17471	17.471%	2.286	2.138	0.149	2445.94	293512.8	8805384
Alghadir-SubStation	alzawalim	0.14343	14.343%	4.001	3.811	0.190	2008.02	240962.4	7228872
Electrical Sub-Station	feeder	A ratio reduction of power loss (MW)	a reduction of power loss %	apparent power (MVA) 1	apparent power (MVA)2After correction	$\Delta S_{Apparen} = S_1 - S_2$	power losses KWH in day	Saving COST KWH Dinar per DAY	COST KWH Dinar per month)
Alghadir-SubStation	Main Street	0.08477	8.477%	4.001	3.939	0.062	1186.78	142413.6	4272408
Alghadir-SubStation	al hawish	0.19845	19.845%	4.001	3.686	0.315	2778.3	333396	10001880
Al-Zhraa SubStation	alrisala1	0.07204	7.204%	3.429	3.211	0.218	1008.56	121027.2	3630816
Al-Zhraa SubStation	alrisala2	0.07204	7.204%	3.429	3.211	0.218	1008.56	121027.2	3630816
Al-Zhraa SubStation	alrisala3	0.17136	17.136%	1.715	1.517	0.198	2399.04	287884.8	8636544
Al-Zhraa SubStation	al zawid	0.03910	3.910%	3.429	3.268	0.162	547.4	65688	1970640
Al-Zhraa SubStation	abu jwaylanh	0.06151	6.151%	2.286	2.153	0.134	861.14	103336.8	3100104
Al-Zhraa SubStation	alshanabiruh	0.04251	4.251%	2.286	2.174	0.112	595.14	71416.8	2142504
AL-mumalaha SubStation	Poultry	0.11543	11.543%	4.001	3.873	0.128	1616.02	193922.4	5817672
AL-mumalaha SubStation	almumalaha	0.23903	23.903%	4.001	3.592	0.409	3346.42	401570.4	12047112
AL-mumalaha SubStation	aleatshan	0.21152	21.152%	2.858	2.612	0.246	2961.28	355353.6	10660608
ALMjed SubStation	um aleakf	0.26995	26.995%	2.286	2.010	0.276	3779.3	453516	13605480
ALMjed SubStation	Railways	0.12867	12.867%	2.286	2.098	0.189	1801.38	216165.6	6484968
ALMjed SubStation	alghabat	0.06735	6.735%	2.286	2.170	0.116	942.9	113148	3394440
ALMjed SubStation	abu sharish	0.18468	18.468%	2.286	2.029	0.257	2585.52	310262.4	9307872
ALMjed SubStation	alssaed alam	0.04764	4.764%	4.001	3.838	0.163	666.96	80035.2	2401056
ALMjed SubStation	Mr Raad	0.11298	11.298%	2.286	2.216	0.070	1581.72	189806.4	5694192
ALMjed SubStation	ALMjed center	0.16637	16.637%	2.858	2.685	0.172	2329.18	279501.6	8385048

ALMjed SubStation	Abu Awni	0.09529	9.529%	4.573	4.476	0.097	1334.06	160087.2	4802616
Alsweer SubStation	Alsweer center	0.51813	51.813%	2.286	2.012	0.274	7253.82	870458.4	26113752
Alsweer SubStation	albarakat	0.17471	17.471%	2.286	2.138	0.149	2445.94	293512.8	8805384
Alsweer SubStation	al eabas	0.16063	16.063%	2.286	2.156	0.131	2248.82	269858.4	8095752
Alsweer SubStation	al ghanim	0.20102	20.102%	1.715	1.559	0.156	2814.28	337713.6	10131408
Alsweer SubStation	al mutuk	0.20015	20.015%	2.286	2.104	0.182	2802.1	336252	10087560
Alsweer SubStation	Main Street	0.27395	27.395%	1.143	1.014	0.129	3835.3	460236	13807080
Al-Najmy SubStation	Main Street	0.39087	39.087%	2.286	2.001	0.285	5472.18	656661.6	19699848
Al-Najmy SubStation	Al-Najmy center	0.19096	19.096%	2.286	2.021	0.265	2673.44	320812.8	9624384
Al-Najmy SubStation	Maysaideh	0.14963	14.963%	2.286	2.072	0.214	2094.82	251378.4	7541352
Al-mhaded SubStation	Almhaded center	0.39087	39.087%	2.286	2.001	0.285	5472.18	656661.6	19699848
Al-mhaded SubStation	alkarama	0.39087	39.087%	2.286	2.001	0.285	5472.18	656661.6	19699848
Electrical Sub-Station	feeder	A ratio reduction of power loss (MW)	a reduction of power loss %	apparent power (MVA) 1	apparent power (MVA)2After correction	$\Delta S_{Apparen} = S_1 - S_2$	power losses KWH in day	Saving COST KWH Dinar per DAY	COST KWH Dinar per month
Al-mhaded SubStation	al ghanim2	0.31159	31.159%	2.286	2.024	0.263	4362.26	523471.2	15704136
Al-mhaded SubStation	al tubuh	0.31159	31.159%	2.286	2.024	0.263	4362.26	523471.2	15704136
samawaNorth SubStation	um gold	0.15987	15.987%	4.573	4.119	0.453	2238.18	268581.6	8057448
samawa NorthSubStation	alhakim	0.07204	7.204%	3.429	3.211	0.218	1008.56	121027.2	3630816
samawaNorth SubStation	new aleskan	0.02722	2.722%	3.429	3.288	0.142	381.08	45729.6	1371888
Al-Sharqi SubStation	alsafa	0.02722	2.722%	4.573	4.384	0.189	381.08	45729.6	1371888
Al-Sharqi SubStation	AlSharqi orchard	0.35763	35.763%	4.573	4.007	0.565	5006.82	600818.4	18024552
Al-Sharqi SubStation	01-Apr	0.12467	12.467%	4.001	3.638	0.363	1745.38	209445.6	6283368
Al-Sharqi SubStation	alshuhada	0.02199	2.199%	4.001	3.846	0.155	307.86	36943.2	1108296
Old samawa SubStation	No7. Samawa	0.30982	30.982%	3.429	3.039	0.390	4337.48	520497.6	15614928
Old samawa SubStation	No6. Samawa	0.02199	2.199%	4.001	3.846	0.155	307.86	36943.2	1108296
Old samawa SubStation	No4. Samawa	0.20388	20.388%	3.429	3.008	0.422	2854.32	342518.4	10275552
Al-Hilal SubStation	Al-Hilal center	0.13505	13.505%	2.858	2.527	0.331	1890.7	226884	6806520
Al-Hilal SubStation	um Dashish	0.15131	15.131%	4.001	3.505	0.496	2118.34	254200.8	7626024
Al-Hilal SubStation	al bu musaa	0.13505	13.505%	2.858	2.527	0.331	1890.7	226884	6806520
Al-Drajei SubStation	sarahah	0.08339	8.339%	2.858	2.602	0.256	1167.46	140095.2	4202856
Al-Drajei SubStation	Al-Drajei center	0.14079	14.079%	2.286	2.015	0.271	1971.06	236527.2	7095816
Al-Drajei SubStation	om Fifty	0.11697	11.697%	2.858	2.554	0.304	1637.58	196509.6	5895288
Al-Drajei SubStation	Al Jazeera	0.13064	13.064%	3.429	3.040	0.389	1828.96	219475.2	6584256
Total		12.336		241.1	221.6	19.5	173128.62	20775434.4	623263032