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doi:10.15199/48.2023.02.14

# Voltage Upgrading of Power Distribution Network in Basra City from 11 kV to 33 kV

***Abstract**. Among the plans of Ministry of Electricity MOE in Iraq to evolve the power distribution sector is to replace the conventional 33/11/0.416 kV system by a new 33/0.416 kV system. The main reasons for that are the huge increase in demand for electricity especially in city center where the demand is increasing vertically for the same geographical area, and the lack of available locations to install additional 33/11 kV substations.*
*This work presents the design of distribution network with proposed 33/0.416 kV system for reliable power supply with better voltage profile, improved power factor, lower losses, and lower cost. The method involves local zoning of area, calculating total load, computing total number, size, and location of distribution transformers, and calculating length and size of cables.The 33 kV intermediate station in the proposed system require a land area about 66% less than the area required for the installation of the conventional 33/11 kV substation. This allows installing the 33 kV intermediate stations in locations that provides the best result from the technical point of view. The line loading about 3 times increase when upgrade the operating voltage to 33kV and can be meet the increase load demand in future without needs to install new substation and new distribution feeders. The GIS software is used to locate the distribution transformers and lying of the underground cables. CYME software is used to simulate the electric distribution system and conduct the load flow and other analyses.*

***Streszczenie.** Wśród planów Ministerstwa Energii Elektrycznej MOE w Iraku dotyczących rozwoju sektora dystrybucji energii jest zastąpienie konwencjonalnego systemu 33/11/0,416 kV nowym systemem 33/0,416 kV. Głównym tego powodem jest ogromny wzrost zapotrzebowania na energię elektryczną, zwłaszcza w centrum miasta, gdzie popyt rośnie w pionie dla tego samego obszaru geograficznego oraz brak dostępnych lokalizacji do zainstalowania dodatkowych stacji 33/11 kV. W pracy przedstawiono projekt sieci dystrybucyjnej z proponowanym systemem 33/0,416 kV zapewniającym niezawodne zasilanie o lepszym profilu napięciowym, lepszym współczynniku mocy, niższych stratach i niższych kosztach. Metoda obejmuje lokalne strefowanie obszaru, obliczanie całkowitego obciążenia, obliczanie całkowitej liczby, rozmiaru i lokalizacji transformatorów rozdzielczych oraz obliczanie długości i rozmiaru kabli. Stacja pośrednia 33 kV w proponowanym systemie wymaga powierzchni lądowej o około 66% mniejszej niż powierzchnia wymagana do zainstalowania konwencjonalnej podstacji 33/11 kV. Pozwala to na zainstalowanie stacji pośrednich 33 kV w lokalizacjach zapewniających najlepszy wynik z technicznego punktu widzenia. Obciążenie linii wzrasta około 3 razy po podniesieniu napięcia roboczego do 33kV i może w przyszłości zaspokoić rosnące zapotrzebowanie na obciążenie bez konieczności instalowania nowej podstacji i nowych linii dystrybucyjnych. Oprogramowanie GIS służy do lokalizacji transformatorów rozdzielczych i układania kabli podziemnych. Oprogramowanie CYME służy do symulacji systemu dystrybucji energii elektrycznej i przeprowadzania przepływu obciążenia oraz innych analiz* **(Modernizacja napięcia sieci dystrybucji energii w mieście Basra z 11 kV do 33 kV)**

**Keywords:** Power distribution network voltage upgrading, CYME software, Voltage profile, Power losses.
**Słowa kluczowe:** Modernizacja napięcia sieci dystrybucyjnej, oprogramowanie CYME, profil napięcia, straty mocy.

## Introduction

To The design of distribution networks faces various constraints and challenges, including consumer related ones to achieve acceptable standard of reliability, quality, and safety at low cost [1, 2]. The fast growth in load demand especially in the same region (vertical increase) requires estimating the capacities of distribution transformers, and choosing the proper location to achieve the lowest voltage drop and losses [3, 4]. Because most of distribution systems are located in neighbourhoods and residential areas; therefore, the size of the distribution networks depends on the urban planning and design of the residential areas. This requires determining the optimal path of feeders that are feeding the distribution transformers [5, 6]. In addition to provide the optimum locations for distribution substations [7, 8], to achieve the greatest results from a technical point of view; including voltage drop and losses [9, 10]. Also achieving the minimum length of cables and conductors required to deliver power to customers [11, 12] as well as the inability to build 33/11 kV substations in load center because there is no enough space to install the 33/11 kV substation components [13, 14].

## Conventional 33/11/0.416 kV system and proposed 33/0.416 kV system

Conventional distribution system according to ministry of electricity MOE in Iraq includes 33 kV transmission lines outgoing from 132/33 kV substations to 33/11 kV substations. The 33/11 kV substations usually consist of two 33/11 kV power transformers with two sections supplying number of 11 kV outgoing distribution feeders from each section according to the capacity of the power transformer [15]. The 11 kV feeders supply the 11/0.416 kV distribution transformers to supply consumers [16, 17]. The main part of proposed 33/0.416 kV distribution system is the 33 kV intermediate station, which consists of two 33 kV sections, each one is supplied by a 33 kV feeder from the 132/33 kV substation. The 33 kV feeders outgoing from the intermediate station supply the 33/0.416 kV distribution transformers to supply consumers. The saving in the area needed for installation of 33 kV intermediate station with respect to 33/11 kV substation about 66%. The capacity of 33 kV intimidate station is only limited by the capacity of **the** feeder conductors [18]. While the capacity of 33/11 kV substations is dependent on the capacity of the power transformer and also the feeder conductors [19, 20].

## Methodology

The design of electrical distribution network requires the following calculations [21, 22, 23]:

### Local zoning:

Dividing the area for which a distribution network is to be designed into multiple areas, using (GIS) and the AutoCAD software to show the locations of different types of consumers (residential, commercial, industrial, etc.) as well as streets, and service buildings.

### Load calculation:

The max load demand can be calculated by [24]:

$$Max.load\ dmand = k \times Arae\ of\ cunsumer\ facilities \tag{1}$$

Where: $k$: (40-200) $Watt/m^2$ according the area of consumer facilities - MOE.

(2) $$Max.load\ dmand\ on\ transformer = Max.\,load\ demand \times D.F$$

Where: $D.F$ : Diversity factor according to IEC- 60439.

**The rating of distribution transformer:**

The rating of the distribution transformer is obtained by dividing the total load demand of by the power factor:

(3) $$kVA = \frac{P}{\cos\theta}$$

Where: $kVA$: Distribution transformer capacity.; $p$ : Load demand on transformer in kW; $\cos\theta$ : Power factor.

From available locations within the urban design of the area, in which it is possible to install distribution transformers 33/0.416 kV in order to achieve the lowest voltage drop on the low voltage network.

(4) $$Min.\,dist.\,of\ \ F = \sum_{j=1}^{k} kVA\,load$$

$$V_{\min} \le V_{Load}$$

Where: $F$ : Objective function (minimum distance between distribution transformer and loads).; $j$ : Number of Available locations within the urban design of the area is possible to install distribution transformers 33/0.416 kV.; $kVA\ Load$ : Load demand of consumers.

After summation of loads at each possible locations choses the capacity of costumer transformers for each location. The capacity of 33/0.146 kV distribution transformers available are (250, 400, 630, and 1000) kVA according to MOE.

(5) $$Transformers\ Capacity\ (kVA)\ at\ loacation\ \ p(i) = \sum_{i=1}^{k}\ \sum_{j=1}^{m} kVA\,Load$$

Where: i = number of distribution transformers. ; j= (250, 400, 630, 1000) kVA.

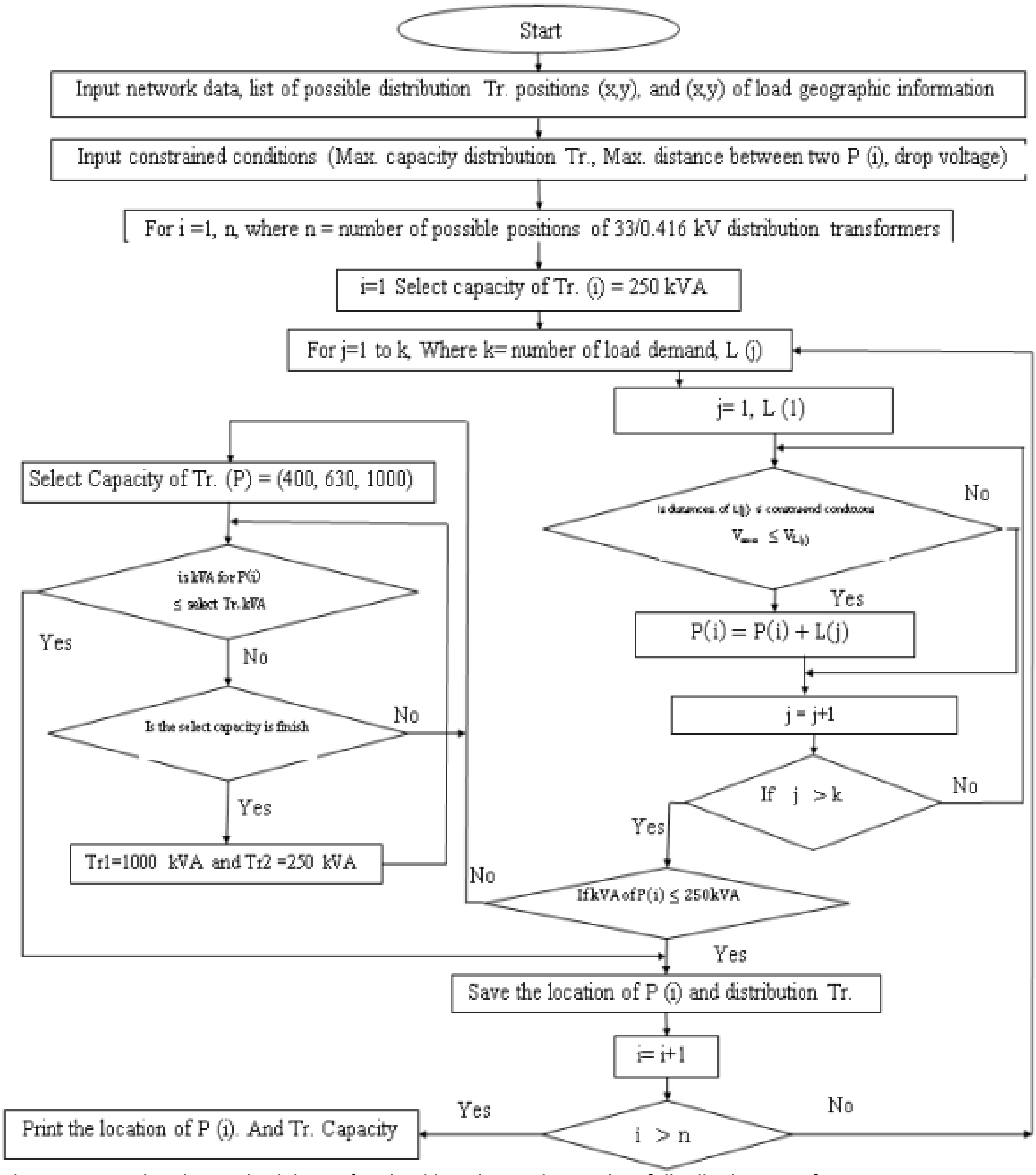


Fig.1. Flow chart representing the methodology of optimal location and capacity of distribution transformers

The flow chart representing the methodology of optimal location and capacity of distribution transformers is as shown in (Fig.1)
Percentage loading of distribution transformer is obtained from the expression:

(6) $$Distrbution.transformer\ loading\% = \frac{Total\ load\ demand\ kVA}{Rating\ of\ the\ trandformer\ kVA} \times 100$$

Total loses of transformer include no load losses and copper losses at load:

(7) $$Toatl\ losses = No\ load\ losses + Copper\ losses\ at\ load$$

**The size of cable conductors and feeder loading:**

The load current of the cable can be calculated by:

(8) $$I = \frac{P}{\sqrt{3} \times V \times COS(\theta)}$$

Where: $I$: The current in Amp.; $P$ : The power in kW.; $V$: The voltage in V.; $COS(\theta)$ : The power factor.

Cable conductors size according to IEC 60228 class/2 standard /MOE.

(9)
$$Feeder\ loading\% = Actual\ load\ current\ of\ feeder\ at\ rate\ voltage \big/ Rating\ current\ of\ feeder\ at\ rate\ voltage \times 100\%$$

Where: Rating current of feeder at 11 kV and 33 kV is 300 Amp according MOE.

The line loading can be calculated by:

(10) $$kVA/m = \frac{\sqrt{3} \times V(L-L) \times I}{L}$$

Where: $L$: Distribution feeder length in m; $I$ : Load current of distribution feeder in Amp; $V_{L-L}$: The operating voltage (L-L) in kV.

**Cost of Energy Losses:**

The following empirical formula [25] is used to estimate the annual cost of active power losses after load flow simulation:

(11) $$Cost = P_{loss\ \max.} \times L_{fls} \times T \times CF$$

Where:v $P_{loss\ \max.}$: Power loss at the peak load (kW); $L_{fls}$ : Loss factor; $T$ : Time interval (h).; $CF$ : Tariff cost ($/kW) in this paper 0.03 $/kWh according MOE.

The loss factor is a measure of real power loss over time and at a specific location:

(12) $$Losses\ Factor = K \times LDF \times (1-K) \times LDF^2$$

Where: K is a constant for distribution network and taken as 0.15 for distribution system [26].

(13) $$LDF = \frac{A\mathrm{var}ge\ load}{Load\ Fcator}$$

**Case study: Design of 5-Mail Distribution Network**

The 5-Mail network in center of Basra city is considered as case study in this work. The 5-Mail network consists of 33/11/0.416 kV system including. This network was simulated using CYME software. At the beginning the existing network in its conventional state was analysed with present load. A new 5-mail network with proposed 33/0.416 kV system was designed and analysed after re-placing the 33/11 kV substations with 33 kV intermediate stations and the 11/0.416 kV distribution transformers with 33/0.416 kV distribution transformers. The reduction in losses and reduction in voltage drop was calculated for the proposed 5-Mail network before and after re-locating the 33/0.416 kV distribution transformers with change in there capacity.

**The Conventional 5-Mail 33/11/0.416 kV System with 33/11 kV Substation**

The 5-Mail distribution network with 33/11 kV substation in the center of Basra city, consist of two 33/11 kV, 31.5 MVA power transformers supplied by two 33 kV feeders from the 132/33kV substation. The 11 kV outgoing overhead distribution feeders are twelve, five 11 kV feeders supplied from one 11 kV section and seven are supplied from the other 11 kV section. The total length of the 11 kV overhead lines of network feeders is 15.2 km with ACSR 120/20 conductors according to DIN 48204-MOE and 3.9 km of underground lines with (3×150) mm2, 11 kV cable according to IEC 60228 class/2 standard-MOE. The 11/0.416 kV distribution transformers supplied from 11 kV distribution feeders are used to feed consumers. The data of 5-Mail distribution network and calculation results are given in table 1.

Table 1 Data MOE and calculation results for 5-mail network with 33/11/0.416 kV system

| Feeder ID | Load At 11 kV (Amp) | Feeder loading (%) | Number of 11/0.416 kV distribution transformers | | No load transformers losses (kW) | Losses of transformers at average load (kW) | Total losses of transformers (kW) |
|---|---|---|---|---|---|---|---|
| | | | 250 (kVA) | 400 (kVA) | | | |
| SENAA'YAH_5MEIL | 179 | 60 | 6 | 9 | 12.18 | 33.75 | 45.93 |
| ALMSHAEL | 151 | 50 | 1 | 10 | 9.85 | 27.41 | 37.26 |
| 4_SHWARAA | 175 | 58 | 5 | 17 | 18.89 | 32.27 | 51.16 |
| ALRUDHA | 160 | 53 | 6 | 10 | 13.1 | 30.06 | 43.16 |
| ALBALAM | 240 | 80 | 3 | 17 | 17.59 | 43.85 | 61.44 |
| ALNBRAS | 146 | 49 | 2 | 9 | 9.58 | 26.78 | 36.36 |
| ALNEDHAL | 136 | 45 | 1 | 8 | 8.01 | 24.74 | 32.75 |
| AL_QETHARA | 232 | 77 | 4 | 16 | 17.32 | 42.64 | 59.96 |
| ALHAFEDH | 190 | 63 | 1 | 9 | 8.93 | 34.52 | 43.45 |
| ALPALADYAH | 137 | 46 | 4 | 15 | 16.4 | 25.21 | 41.61 |
| ALBEDHAN | 136 | 45 | 13 | 6 | 13.97 | 26.78 | 40.75 |
| AL JMA'YAH | 201 | 67 | 2 | 17 | 16.94 | 36.54 | 53.48 |
| SUM | 2083 | | 48 | 143 | 162.76 | 33.75 | 547.31 |

The 5-mail distribution network and substation simulated using CYME software, as shown in (Fig. 2.a. and b).

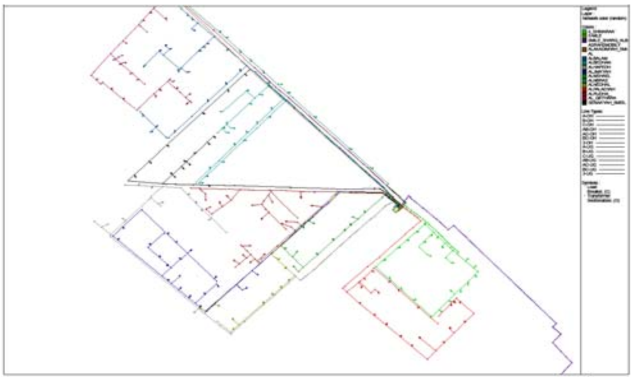

Fig.2.a. The existing 5-mail 33/11/0.416 kV network simulated using CYME

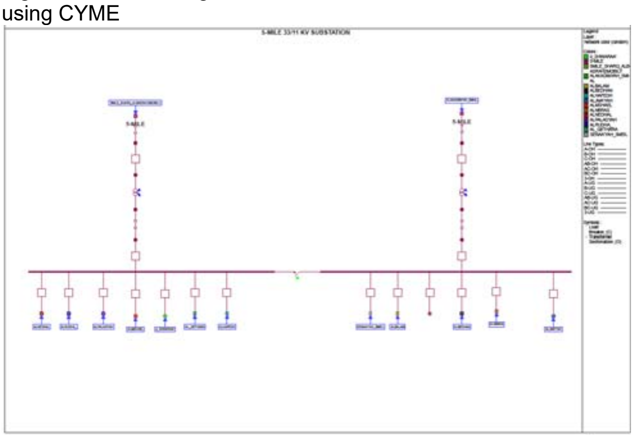

Fig.2.b. The existing 5-mail 33/11 kV substation and switchgear simulated using CYME

**The proposed 5-Mail 33/0.416 kV System**

A new 5-Mail 33/0.416 kV System is proposed by upgrading the operating voltage of the existing 5-mail network to 33 kV. In the proposed system 33 kV intermediate station is used instated of 33/11 kV substation. The 33 kV intermediate station consist of two 33 kV sections one of them feeding five 33 kV distribution feeders and the other section feeding seven 33 kV distribution feeders. The twelve 33 kV distribution feeders with (3×150 mm2), 33 kV underground cable supplied the consumers by 33/0.416 kV distribution transformers installed in the same location and with same capacity of 11/0.416 kV distribution transformers. Design results for the proposed 5-mail 33/0.416 kV system at present load is given in table 2.

**The Proposed 5-Mail 33/0.416 kV System after Re-locating the 33/0.416 kV Distribution Transformers**

In this case the 33/0.416 kV distribution transformers are relocated and then the demand load are distributed between these transformers. In 5-mail proposed network the number of 250 kVA, 33/0.416 kV distribution transformers is 8, the number of 400 kVA, 33/0.416 kV is 13, the number of 630 kVA, 33/0.416 kV is 52, and the number of 1000 kVA, 33/0.416 kVA is 15. The total losses of 33/0.416 kV distribution transformers reduced from 569 kW to 473.53 kW about 16.78%.

The total length of 5-mail network distribution feeders reduced from 19 km to 15.6 km about 17.9 % after re-location of distribution transformers. The design results for 5-mail proposed network after re-location of 33/0.416 kV distribution is given in table 3.

The percentage loading of 33/0.416 kV distribution transformers and total kVA connected after and before re-location of distribution transformers are given in table 4.

Table 2 Design results for 5-mail network for the proposed 33/0.416 kV system at present load

| Feeder ID | Load at 33 kV (Amp) | Feeder loading (%) | Number of 33/0.416 kV distribution transformer | | No load transformers losses (kW) | Losses of transformers at average load | Total losses of transformers |
|---|---|---|---|---|---|---|---|
| | | | 250 (kVA) | 400 (kVA) | | | |
| SENAA'YAH_5MEIL | 58 | 19 | 6 | 9 | 14.07 | 33.02 | 47.09 |
| ALMSHAEL | 49 | 16 | 1 | 10 | 11.27 | 27.44 | 38.71 |
| 4_SHWARAA' | 57 | 19 | 5 | 17 | 21.7 | 32.07 | 53.77 |
| ALRUDHA | 52 | 17 | 6 | 10 | 15.12 | 29.65 | 44.77 |
| ALBALAM | 78 | 26 | 3 | 17 | 20.16 | 44.05 | 64.21 |
| ALNBRAS | 47 | 16 | 2 | 9 | 10.99 | 26.46 | 37.45 |
| ALNEDHAL | 44 | 15 | 1 | 8 | 9.17 | 24.67 | 33.84 |
| AL_QETHARA | 74 | 25 | 4 | 16 | 19.88 | 41.93 | 61.81 |
| ALHAFEDH | 62 | 21 | 1 | 9 | 10.22 | 34.57 | 44.79 |
| ALPALADYAH | 45 | 15 | 4 | 15 | 18.83 | 25.38 | 44.21 |
| ALBEDHAN | 44 | 15 | 13 | 6 | 16.31 | 25.79 | 42.10 |
| AL_ JMA'YAH | 66 | 22 | 2 | 17 | 19.39 | 36.82 | 56.21 |
| SUM | 676 | | 48 | 143 | 187.11 | 381.84 | 568.95 |

Table 3 Design results for the 5-mail proposed 33/0.416 kV system after re-location of 33/0.416 kV distribution transformers

| Feeder ID | Load at 33 kV (Amp) | Number of 33/ 0.416 kV distribution transformer | | | | No load transformers losses (kW) | Losses of transformers at average load (kW) | Total losses of transformers (kW) |
|---|---|---|---|---|---|---|---|---|
| | | 250 (kVA) | 400 (kVA) | 630 (kVA) | 1000 (kVA) | | | |
| SENAA'YAH_5MEIL | 58.84 | 4 | 1 | 2 | 2 | 10.77 | 30.82 | 41.59 |
| ALMSHAEL | 50.28 | 0 | 0 | 5 | 0 | 7.25 | 25.14 | 32.39 |
| 4_SHWARAA' | 58.20 | 2 | 1 | 7 | 0 | 12.74 | 29.93 | 42.67 |
| ALRUDHA | 53.27 | 0 | 1 | 1 | 4 | 9.98 | 26.51 | 36.49 |
| ALBALAM | 79.51 | 1 | 2 | 7 | 0 | 13.02 | 40.80 | 53.84 |
| ALNBRAS | 48.46 | 0 | 3 | 4 | 0 | 8.95 | 25.13 | 34.08 |
| ALNEDHAL | 45.27 | 0 | 1 | 3 | 1 | 7.27 | 22.83 | 30.10 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| AL_QETHARA | 76.31 | 0 | 2 | 7 | 1 | 14.12 | 38.61 | 52.73 |
| ALHAFEDH | 63.01 | 1 | 1 | 1 | 3 | 8.88 | 31.85 | 40.73 |
| ALPALADYAH | 45.59 | 0 | 0 | 1 | 4 | 8.93 | 22.46 | 31.39 |
| ALBEDHAN | 45.05 | 0 | 1 | 6 | 0 | 9.75 | 22.77 | 32.52 |
| AL JMA'YAH | 66.81 | 0 | 0 | 8 | 0 | 11.6 | 33.40 | 45.00 |
| SUM | 690.60 | 8 | 13 | 52 | 15 | 123.26 | 350.27 | 473.53 |

Table 4 Loading of 33/0.416 kV transformers and the total kVA connected of 5-mail proposed 33/0.416 kV

| Feeder ID | Before re-location of distribution transformers | | After re-location of distribution transformers | |
|---|---|---|---|---|
| | Sum of distribution Transformers kVA connected | Loading of distribution Transformer (%) | Sum of distribution Transformers kVA connected | Loading of distribution Transformer (%) |
| SENAA'YAH_5MEIL | 5100 | 64.74 | 4660 | 72.2 |
| ALMSHAEL | 4250 | 65.88 | 3150 | 91.4 |
| 4_SHWARAA' | 8050 | 40.31 | 5310 | 62.7 |
| ALRUDHA | 5500 | 54.01 | 5030 | 60.5 |
| ALBALAM | 7550 | 59.33 | 5460 | 83.4 |
| ALNBRAS | 4100 | 65.50 | 3720 | 74.6 |
| ALNEDHAL | 3450 | 72.87 | 3290 | 78.7 |
| AL_QETHARA | 7400 | 57.44 | 6210 | 70.3 |
| ALHAFEDH | 3850 | 91.57 | 4280 | 84.1 |
| ALPALADYAH | 7000 | 36.73 | 4630 | 56.3 |
| ALBEDHAN | 5650 | 44.57 | 4180 | 61.7 |
| AL JMA'YAH | 7300 | 51.42 | 5040 | 75.9 |
| SUM | 69200 | | 54960 | |

The sum of 11/0.416 kV distribution transformers capacity which are connected to 5-mail proposed network is 69200 kVA reduced to 54960 kVA after re-location of the 33/0.416 kV distribution transformers and selecting the suitable capacity for demand loads and the location to reduce drop voltage on low voltage distribution feeders. The worst case of loaded distribution transformer does not exceed 91.4%. The load density in VA/m^2 of the 5-mail proposed 33/0.416 kV system network before and after re-location of distribution transformers is shown in figure 3.a and b.

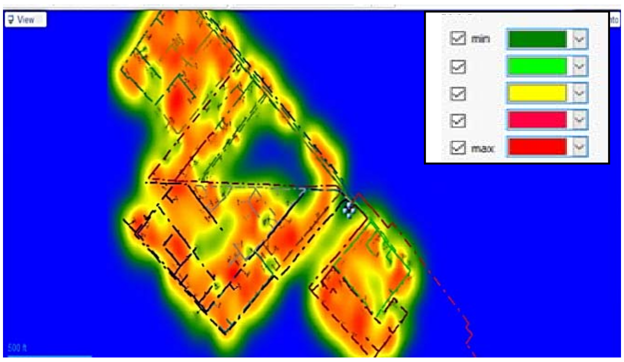


Fig.3.a. Load density of 5-mail proposed 33/0.416 kV network before re-location of 33/0.416 kV distribution transformer using CYME

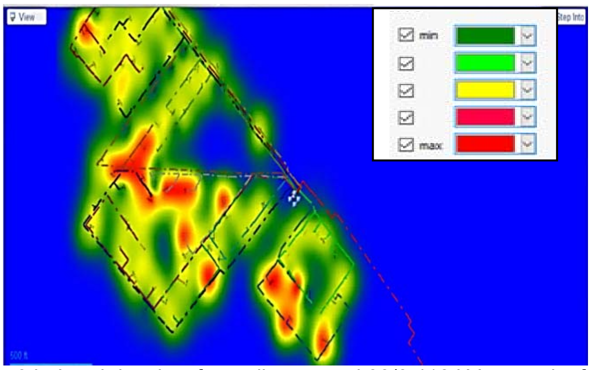


Fig.3.b. Load density of 5-mail proposed 33/0.416 kV network after re-location of 33/0.416 kV distribution transformers using CYME

## Results and Discussion

Voltage/per phase of distribution transformers at end point of 5-mail feeders for; conventional 33/11/0.416 kV system, proposed 33/0.416 kV system, and the proposed 33/0.416 kV system after relocation of 33/0.416 kV distribution transformer are given in table 5.

From the results of analyses the voltage at end points of 5-mail network feeders are below the acceptable limits (±10%) of the rated voltage 240 V. A senaa'yah-5 mail 11 kV feeder is the worst case of voltage drop about 18% this voltage drop reduced to 1.3% when upgrading operating voltage to 33 kV, as shown in (Fig.4.) and (Fig.5.) The voltage drop at end point of al senaa'yah-5mail 33 kV feeder is 0.5% after re-location of 33/0.416 kV distribution transformers.

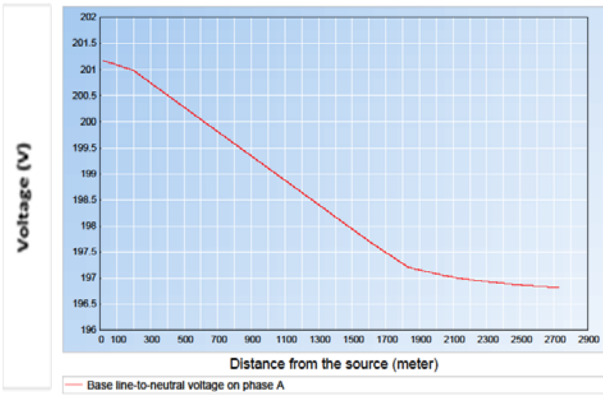


Fig.4. Voltage profile of senaa'yah-5mail 11 kV feeder

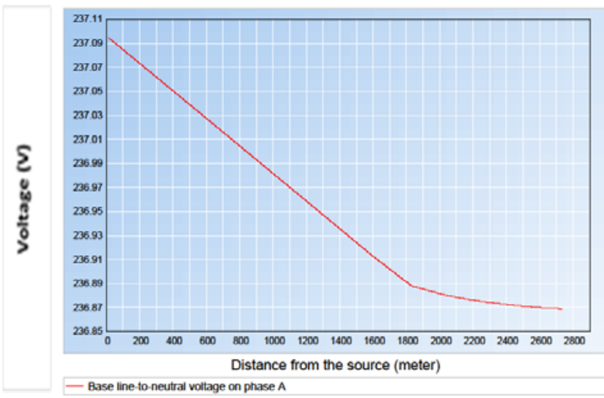


Fig.5. Voltage profile of senaa'yah-5mail 33 kV feeder

Table 5 Comparison Voltage /per phase at end point of feeder at distribution transformers of 5-mail conventional 33/11/0.416 kV system, the proposed 33/0.416 kV system, and the proposed 33/0.416 kV system after re-location of distribution transformers

| Feeder ID | Voltage /per phase at end point of feeder at distribution transformers | | |
|---|---|---|---|
| | Conventional 33/11/0.416 kV system | The proposed 33/0.416 kV system | The proposed 33/0.416 kV system after re-location of 33/0.416 kV distribution transformers |
| 4_SHWARAA' | 207.6 | 238.1 | 239.4 |
| AL_BALAM | 200 | 237 | 238.9 |
| AL_BEDHAN | 199.8 | 237 | 238.9 |
| AL_HAFEDH | 207 | 238.2 | 239.2 |
| AL_JMA'YAH | 200.4 | 237 | 238.9 |
| AL_MSHAEL | 208 | 238.1 | 239.3 |
| AL_NBRAS | 199.8 | 237 | 238.9 |
| AL_NEDHAL | 208 | 238.1 | 239.3 |
| AL_PALADYAH | 207.8 | 238 | 239.4 |
| AL_RUDHA | 208.1 | 238 | 239.3 |
| AL_QETHARA | 204.7 | 237.9 | 239.1 |
| SENAA'YAH_5MAIL | 196.8 | 236.9 | 238.8 |

Table 6 Comparison total feeders losses of 5-mail network 33/11/0.416 kV system and the proposed 33/0.416 kV system

| Feeder ID | Total feeder losses for Conventional 33/11/0.416 kV System (kW) | Total feeder losses for the proposed 33/0.416 kV System (kW) | Total feeder losses for proposed 33/0.416 kV system after re-location of 33/0.416 kV distribution transformers (kW) |
|---|---|---|---|
| 4_SHWARAA' | 5.67 | 0.5 | 0.24 |
| AL_BALAM | 21.12 | 1.7 | 2.09 |
| AL_BEDHAN | 12.46 | 1 | 1.2 |
| AL_HAFEDH | 14.03 | 0.91 | 1.15 |
| AL_JMA'YAH | 8.16 | 0.79 | 1.01 |
| AL_MSHAEL | 2.44 | 0.19 | 0.26 |
| AL_NBRAS | 9.15 | 0.56 | 0.89 |
| AL_NEDHAL | 2.7 | 0.26 | 0.32 |
| AL_PALADYAH | 3.24 | 0.22 | 0.24 |
| AL_RUDHA | 2.88 | 0.25 | 0.32 |
| AL_QETHARA | 45.37 | 2.91 | 3.72 |
| SENAA'YAH_5MAIL | 41.75 | 2.39 | 2.05 |

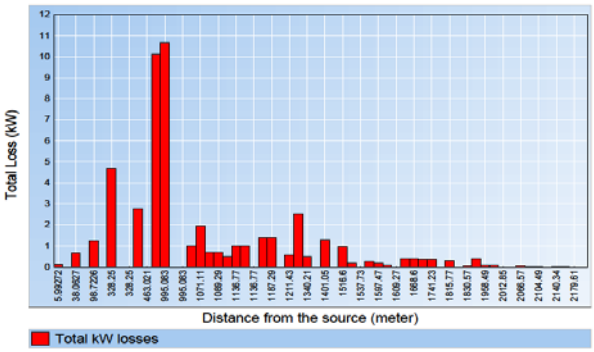

Fig.6. Total losses of Al- qethara 11 kV feeder

The total feeders losses of 5-mail network for; conventional 33/11/0.416 kV system, the proposed 33/0.416 kV system, and the proposed 33/04.16 kV system after relocation of 33/0.416 kV distribution transformers are given in table 6.

The losses of feeder 33 kV Al-qethara is reduced from 45.37 kW to 2.91 kW about 93.6% when upgrading the operating voltage to 33 kV, as shown in (Fig.6.) and (Fig. 7.). The kVA/m of 5 mail network feeders at present load are given in table 7.

The total losses of 5-mail network is reduced from 4.8% of total active power supply for 33/11/0.416 kV system to 2.3% of total active power supply for the proposed 33/0.416 kV system, and to 1.5% of the total active power supply for the proposed 33/0.416 kV system after re-location of 33/0.416 kV distribution transformers, as given in table 8.

The capital cost (cost of equipments, components, and implementation) according to MOE is given in table 9.

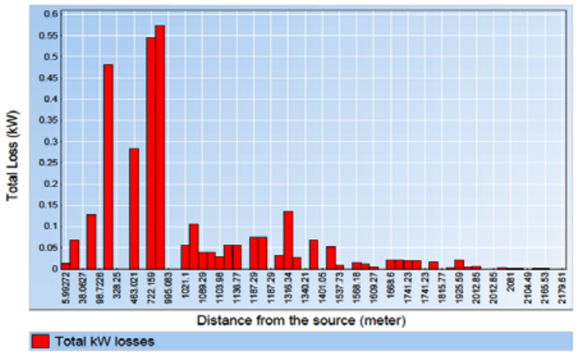

Fig.7. Total losses of Al-qethara 33 kV feeder

Table 7 Comparison the kVA/m of 5 mail network feeders at existing load with 33/11/0.416 kV system, full loading feeder capacity with 33/11/0.416 kV system, and full loading feeders capacity with 33/0.416 kV system

| Feeder ID | Total length (km) | Total load (kVA) | Conventional 33/11/0.416 kV system | | The proposed 33/0.416 kV system |
|---|---|---|---|---|---|
| | | | kVA/m at existing load | kVA/m at feeder rate | kVA/m at feeder rate |
| SENAA'YAH_5MEIL | 3.084 | 2807.4 | 0.91 | 1.85 | 5.56 |
| ALMSHAEL | 0.382 | 2489.0 | 6.52 | 14.96 | 44.89 |
| 4_SHWARAA | 1.570 | 2882.3 | 1.84 | 3.64 | 10.92 |
| ALRUDHA | 0.856 | 2637.4 | 3.08 | 6.68 | 20.03 |
| ALBALAM | 2.299 | 3812.6 | 1.66 | 2.49 | 7.46 |
| ALNBRAS | 1.607 | 2323.0 | 1.45 | 3.56 | 10.67 |
| ALNEDHAL | 0.632 | 2241.7 | 3.55 | 9.04 | 27.13 |
| AL_QETHARA | 2.682 | 3781.2 | 1.41 | 2.13 | 6.39 |
| ALHAFEDH | 0.903 | 3119.5 | 3.45 | 6.33 | 18.99 |
| ALPALADYAH | 0.83 | 2257.0 | 2.72 | 6.89 | 20.66 |
| ALBEDHAN | 3.18 | 2160.4 | 0.68 | 1.80 | 5.39 |
| AL JMA'YAH | 1.01 | 3203.2 | 3.17 | 5.66 | 16.98 |

Table 8 Comparison of total losses of; 5-mail conventional 33/11/0.416 kV system, the proposed 33/0.416 kV system, and the proposed 33/0.416 kV system after re-location of distribution transformers

| | Conventional 33/11/0.416 kV system | The proposed 33/0.416 kV system | The proposed 33/0.416 kV system with re-location of distribution Tr. |
|---|---|---|---|
| Total losses of 33/11 kV power transformer (kW) | 265.18 | 0.0 | 0.0 |
| Total losses of 11/0.416 kV distribution transformer (kW) | 547.3 | 0.0 | 0.0 |
| Total losses of 33/0.416 kV distribution transformer (kW) | 0.000 | 569.0 | 473.5 |
| Total losses of overhead lines (kW) | 626.4 | 0.0 | 0.0 |
| Total losses of underground cable (kW) | 154.5 | 253.5 | 114.1 |
| Total losses (kW) | 1,593.4 | 822.5 | 587.6 |
| Ratio of total losses to the active power supply (%) | 4.8 | 2.3 | 1.5 |

Table 9 Compression of the cost of equipments and installation of 5-mail; existing 33/11/0.416 kV system, proposed 33/0.416 kV system, proposed 33/0.416 kV system after re-location of distribution transformers

| | | Conventional 33/11/0.416 kV system | | | Proposed 33/0.416 kV system | | | Proposed 33/0.416 kV system after re-location of 33/0.416 kV distribution transformers | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Quantity | Cost ($) | Total cost ($) | Quantity | Cost ($) | Total cost ( $) | Quantity | Cost ( $) | Total cost($) |
| Substation | | 1 | 4,000,000 | 4,000,000 | 1 | 1,724,000 | 1,724,000 | 1 | 1,724,00 | 1,724,000 |
| Overhead (km ) | | 15.5 | 27,627 | 419,350 | 0.00 | 0 | 0 | 0.00 | 0 | 0.00 |
| Underground (km ) | | 3.9 | 97,668 | 376,803 | 19.4 | 132,077 | 2,514,350 | 15.6 | 132,077 | 2,059,344.58 |
| Distribution Transformer /0.416 kV | 100 (kVA) | 0 | 4,310 | 0 | 0 | 5,200.00 | 0 | 0 | 5,200.00 | 0 |
| | 250 (kVA) | 48 | 6,896 | 331,008 | 48 | 12,759 | 612,432 | 8 | 12,759.0 | 102,072 |
| | 400 (kVA) | 143 | 7,069 | 1,010,867 | 143 | 15,172 | 2,169,596 | 13 | 15,172.0 | 197,236 |
| | 630 (kVA) | 0 | 11,380 | 0 | 0 | 18,800 | 0 | 52 | 18,800.0 | 977,600 |
| | 1000 (kVA) | 0 | 17,241 | 0 | 0 | 24,138 | 0 | 15 | 24,138.0 | 362,070 |
| Total cost of equipments and installation ($) | | | | 6,138,028.38 | | | 7,020,377.9 | | | 5,422,322.5 |
| Total losses (MW.h/year) | | | | 9,163.73 | | | 2,220.56 | | | 999.35 |
| Total losses cost (k$ /year) | | | | 274.91 | | | 66.62 | | | 29.98 |

## Conclusion

The analyses results of 5-mail network at present load show considerable reduction in voltage drop and total losses in the proposed 33/0.416 kV system. The voltage drop at far points of 11 kV feeders in the conventional 33/11/0.416 system reduced from (18% -13.33%) to (1.3% - 0.75%) when the operating voltage of the network upgraded to 33 kV in the proposed 33/0.416 kV system. Further reduction to (0.5% - 0.25%) is obtained after re-location of 33/0.416 kV distribution transformers of the 5-mail proposed 33/0.416 kV system. The feeder loading reduced from (80% - 45%) to (25-15) when the operating voltage of the network upgraded to 33 kV in the proposed 33/0.416 kV system. The kVA/m of 5-mail network feeders at present load (0.7 - 6.5), the kVA/m at full load capacity of 5- mail network feeders with conventional 33/11/0.416 system (1.8 – 15), and the kVA/m at full load capacity of 5-mail network feeders with the proposed 33/0.416 kV system (5.4 - 44.9). The total losses of 5-mail network are reduced from 4.8% of total active power supply for 33/11/0.416 kV system to 2.3% of total active power supply for the proposed 33/0.416 kV system, and to 1.5% of the total active power supply for the proposed 33/0.416 kV system after re-location of 33/0.416 kV distribution transformers. The capital cost (cost of equipments, components, and installation) according to MOE is increased about 12.6% when the operating voltage upgraded to 33 kV with the same configuration of network and the same number and capacity of distribution transformers installed in the 33/11/0.416 kV system. While the capital cost (cost of equipments, components, and installation) is reduced about 11.7% after re-location of 33/0.416 kV distribution transforms in the proposed 33/0.416 kV system.

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