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Yatta's Medium Voltage Network Analysis and Enhancement

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Abstract

This paper presents analysis and proposes solution scenarios for Yatta city (Y.C.) electrical network which experiences maximum demand exceeds the main feeder capacity and an inferior power factor for the industrial loads of the acceptable range. The maximum demand of the first feeder is covered by proposing new interconnection points and the installation of alternative energy source of photovoltaic (PV) generation units. The power factor of the system was improved by installing capacitor banks for industrial loads. As a result of applied solution related to interconnection points, the total load demand was fairly distributed and the transformer's life time is increased. Due to distributed PV generation, the utility capacity is also increased and the transformers' life time is increased by 4-5 years. A Simulation model using ETAP is implemented and the network capacity and load flow are studied that verify the proposed solutions. The obtained simulation results demonstrate the technical feasibility of these proposed solutions. .

Keywords: *Distribution Network, PV, ETAP, Electrical network, Power Transformers, Power Factor Correction.*

1. Introduction

It may indeed be true to say that distribution networks have always been changed due to continuous alteration and variation of load. By doing engineering studies such as design, development and preparation of future comprehensive plans, the distribution networks can be optimized. There are several steps to prepare the comprehensive plans. Chiefly, is the data collection from the network, their electrical load, and assessment of its peripherals. Next, some essential studies for future plans are organized by doing special analysis, such as predicting load, load flow and fault analysis [1].

The main goals of this work is to analyze the network where the mid size town in Palestine is taken as case study. Per Sathiyan Arayanan [2] description of the distribution load flow is required for the demand side and distribution management system which encompasses studies of the dispersed generation and load scheduling. This work starts by analyzing the network, then determine the problems, and closes by proposing some solutions scenarios. The described work site is the mid-size town of Y.C. which located at 12 km south of Hebron city in Palestine, with population of around 105 thousand of people, and area of about 24,500 acres [3]. The network configuration is radial with medium voltage level of 33kV and the network has some ring connections. The main transmission line passes through Al-Fawwar Camp, Al-Reheia until Al-Metiana road junction, then distributes to the most of transformers in the city, and the main protective device is the Auto-Recloser which interconnect Y.C. network with Israel Electricity Company (IEC).

This work aims at analyzing the network, conduct the required load calculations and propose several solutions scenarios to operate the network in optimal configuration.

2. Problem Statement and Methodology

Y.C. electrical network experiencing two troubling issues; firstly, the maximum demand of the network is higher than the main feeder capacity, implying that the main feeder can't cover the maximum demand of the network. Secondly, the power factor for the industrial loads is below the acceptable range. This work will start by analyzing the loads of Y.C. network, and then followed in building medium voltage network scheme using AutoCAD software, and finally analyzing the network using ETAP software [5-9].

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3. System Analysis

3.1. Load Demand Analysis

The average load in this study case for Y.C. in 2015 is about 7.548 MW which equal 8.386 MVA when subjected to 0.90 power factor. However, the maximum demand is 15.7 MVA. This loads takes three forms, general, special and mixed (general and special) loads. The general loads classified as residential, educational, and commercial loads while special loads classified as industrial and hospital loads. The mixed load however is a combination between the two classifications. Table 1 summaries the features and differences between the three forms. Fig.1 illustrates the maximum load and transformers rating for each of these load forms.

Table 1. Y.C. Network Loads Details

Load Categories	General Loads	Special Loads	Mixed Loads
Maximum Load Range of Transformer	(24% - 40%)	(32% - 51%)	(28% - 38%)
No. of Transformers	65	33	11
Total Transformers rating (MVA)	20.96	17.44	3.72
Maximum Load (MVA)	7.305	7.107	1.292
Load Type	10% constant KVA 90% constant Z	90% constant KVA 10% constant Z	50% constant KVA 50% constant Z
Total Avg. Load (MVA)	3.902	3.796	0.690
Percentage of Total Load	47%	45%	8%
Power Factor Range	(92%-97%)	(66%-87%)	(83%-90%)

Fig. 1: Maximum load and transformers rating for each load category.

3.2. Building Medium Voltage Network Scheme

The single line diagram of the actual electrical network of Y.C. is displayed on fig. 2, where transformers location, transmission line and cables paths and lengths, and interconnection point are presented. The mentioned diagram gives overall estimation and the possibilities for improvement.

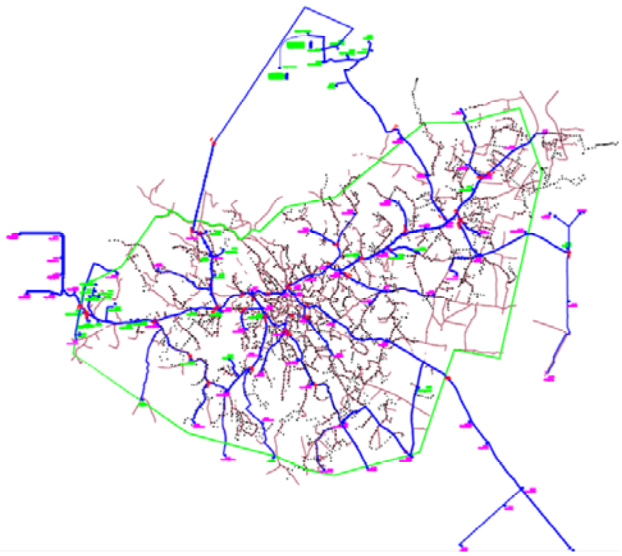

Fig. 2: Yatta's medium voltage network scheme.

3.3. Analysis of network using ETAP 11

Converting the mentioned in fig.2 medium voltage network scheme into a single line diagram (SLD) using ETAP software package generates the electrical model displayed on fig.3 with all electrical ring connection, transformers, cables, transmission lines, and end connections to load categories according to load categories mentioned in table 1.

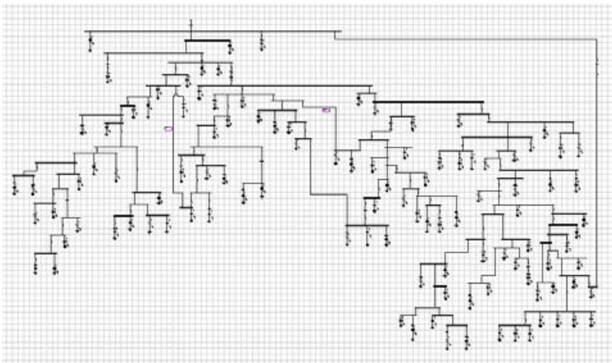

Fig. 3: Single Line Diagram for Yatta city using ETAP Software.

Based on the established **n**etwork the total buses, transmission lines, cables, and transformers are listed in Table 2.

Table 2. ETAP Input Data

Input Data	Number	Total Length (km)
Buses	247 (138 bus for 33 kV , 109 bus for 0.4 kV)	-
Transmission Lines	75 (67 with 50 mm^2, 1 with 95 mm^2 ,7 with 120 mm^2)	40.288
Cables	64 (62 with 50 mm^2, 2 with 95 mm^2)	23.924
Transformers	109	-

The assessment of the network simulation analysis is being summarized as in table 3, where the following can be stated:

Table 3: **ETAP results at maximum load in present case**

Item	MW	MVAR	MVA	PF %
Source (swing buses)	13.032	6.250	14.454	90.17 lagging
Source (non-swing buses)	0.000	0.000	0.000	
Total demand	13.032	6.250	14.454	90.17 lagging
Total motor load	5.576	4.899	7.422	75.13 lagging
Total static load	7.270	2.919	7.834	92.80 lagging
Total constant load	0.000	0.000	0.000	
Total generic load	0.000	0.000	0.000	
Apparent losses	0.186	-1.568		
System mismatch	000	000		
Number of iteration: 3				

- There are no fully loaded transformers, cables, and transmission lines.
- Voltage drop values are acceptable for cables, Transmission lines, and Transformers according to IEC standard.
- Acceptable range of occurred network losses.
- Acceptable power factor range for general loads, while for motor loads the actual power factor is below the allowed limits.

After analyzing the network, two issues have been identified:

a. The maximum capacity of the main feeder at interconnection point is 250A, due to small cross section of the feeder, and the maximum current demand for Y.C. network in 2015 exceeds this limit. This is more illustrated in fig. 5.

b. The power factor for special loads is below the allowable limit as well shown in. Fig. 6. for industrial feeders .

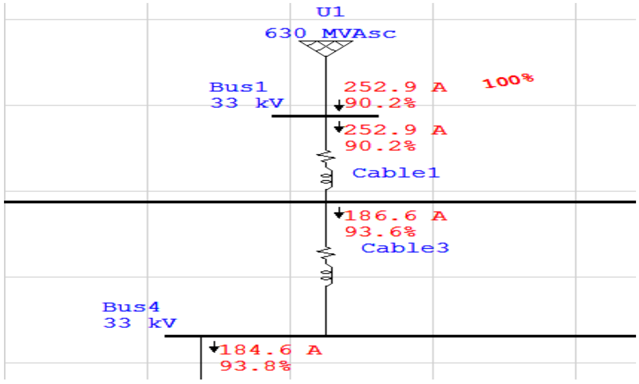

Fig. 5. Maximum current at interconnection point for present case

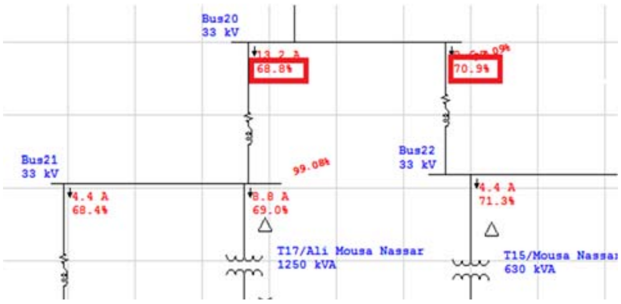

Fig. 6. Power factor for industrial load feeders

5. Scenarios for Proposed Solutions

Scenario one: Adding another interconnection points to IEC, adding capacitor banks for industrial loads, dividing Y.C. network into zones, then making ring connections. This solution is applicable and profitable because ring connection will satisfy continuity of service for costumers, and increase the reliability. The suggested solution is by adding two interconnection points; first point at the Zeef bus, and the second at Khallet Al-Maiia village. This solution leads to dividing the network to three zones as shown in Fig. 7.

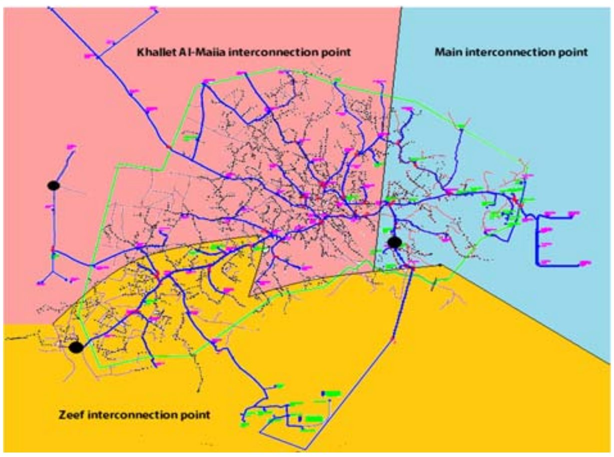

Fig. 7:. Yatta's medium voltage scheme after adding 2 interconnection points.

As for the second problem SELCO needs to impose industrial loads to install capacitor banks in order to improve the power factor to be greater than 0.9 at the low voltage side. Sizing the capacitor banks can be calculated according to equation (2) as:

$$Q_C=P*(\tan \emptyset_1- \tan \emptyset_2) \tag{1}$$

Where P is the active power in kW and $\emptyset1$ & $\emptyset2$ are the phase angle after and before installing the capacitors. Qc is the capacitive reactive power that to be consumed from the network in kVAR. Figure 8 shows the three interconnection points after installing capacitor banks.

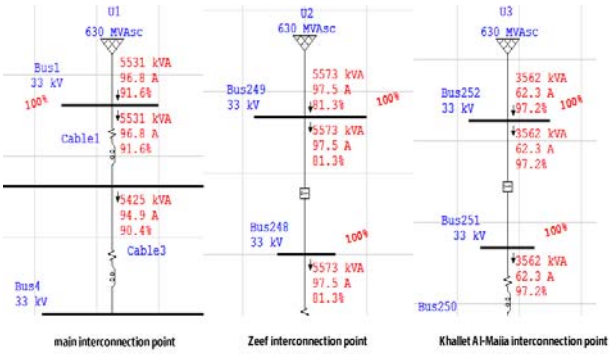

Fig. 8: Interconnection points after installing capacitor banks.

The status summary of Y.C. network before and after adding interconnection points and capacitor banks are stated in table 3.

Table 3. State of network before and after adding interconnection points

Value	Before	After		
Interconnection point	U1	U1	U2	U3
MVA	14.454	5208	4855	3545
Ampere	252.9	91.1	84.9	62
%Power Factor	90.2	97.2	*92.8	97.7

* Still below the acceptable optimized range due to industrial loads concentration.

Scenario two: Installation of Solar Photovoltaic (PV) systems.

This will enable the city to avoid redesign the network and in realizing three connecting points, owned by residential, governmental, and industrial customers. PV power installation is mentioned in many articles as mentioned in [11,12] for Deseret and remote areas to an auxiliary installation beside electrical grid or diesel generators [13]. This scenario provides network connectivity and independency on the Israeli network.

As for solar radiation, Palestine is located between the longitudes 34.15° and 35.40° east and between the latitudes 29.30° and 33.15° north. It has a high solar energy potential, where the daily average of solar radiation intensity on horizontal surface is around 5.4 kWh/m^2, while the total annually sunshine hours amounts to about 3000, and this is sufficient to produce sustainable solar energy. Therefore, building PV distribution generation for residential, government, and industrial buildings seems to be an idealistic and feasible solution [4]. In Y.C. network there are 8219 residential customer, 39 government and educational customer, 34 industrial customer, and about 150 lightning poles on the main streets.

Table 4. Summary of calculations for PV system scenario

Category	# of units	Suggested system size (kW)	Suggested % of installation	Total rated installatio n (KW)
residential	8219	5	10%	4110
Government and civil institutions	39	10	60%	234
industrial	34	50	60%	1020
Lighting street poles	150	0.5	100%	75
PV stations	1	1000	100%	1000
Total				6439

Table 4 lists the calculated PV system parameters for each load category. Table 5 reports the average demand, average loading of transformers, and losses before and after installing the PV systems using ETAP software.

Fig. 9. and 10 show the PV system contribution of total load demand in Y.C. network.

Table 5. Effects of the PV system on the network

Energy status	Before PV	After PV	% of Reduction
MVA (at interconnection point)	7.4	5.9	20.27%
Avg. Loading of transformers	18.87%	15.24%	3.62%
losses (MW)	0.051	0.036	29.41%

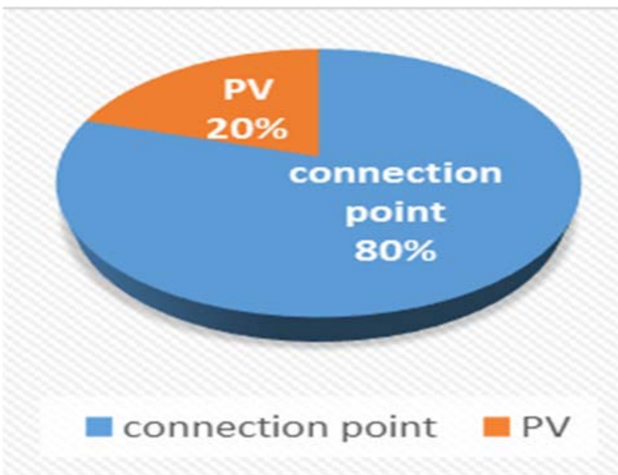

Fig. 9: PV system contribution to the total load demand

The advantages of this scenario can be summarized as follow:

- The total PV generated to the network power can be exceed 6.4 MW with the suggested percentage of installation such generators
- Reduction in average power demand from the grid with ~ 1.5 MW.
- 20% of total power consumption can be provided from the PV generators
- Transformers lodging level is reduced by 3.62%
- Copper losses are reduced by 29.4%

Taking into account the advantages of 2nd scenario, the transformers should be fully loaded after 15 years, while without PV systems installation, the rated load should be reached after 11 years, which considering 9% annual load growth. Therefore, the critical point of transformers loading will be delayed with 4 years as illustrated in Fig. 11.

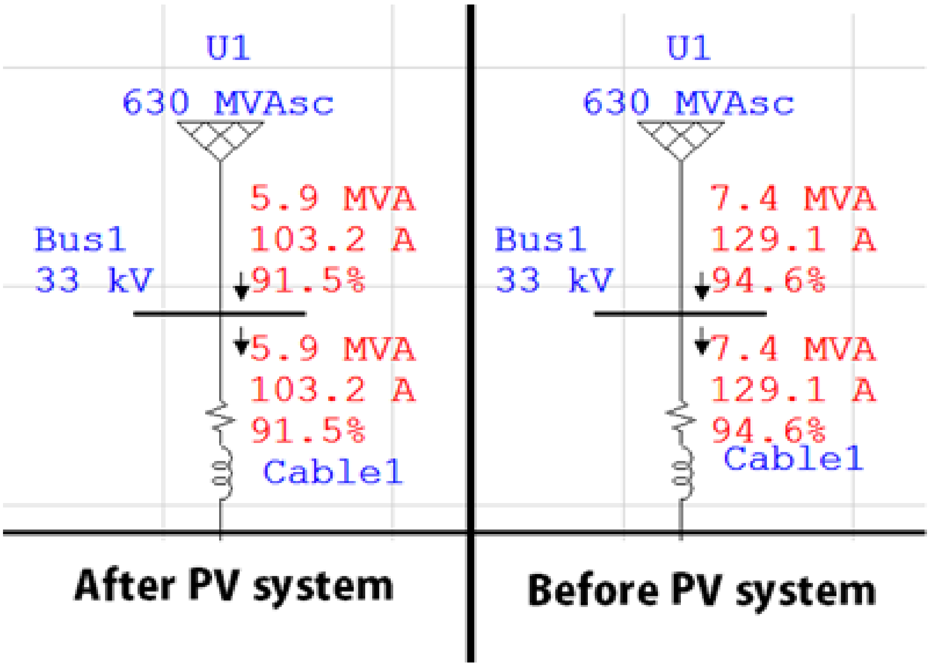

Fig. 10: Interconnection point state before and after adding PV system.

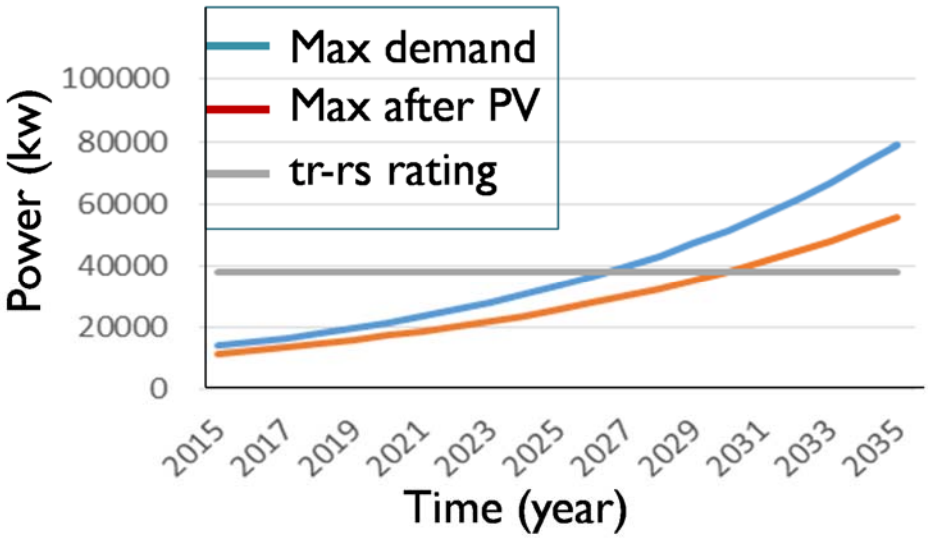

Fig. 11: Maximum demand before and after installing PV system.

6. Conclusions

In this work improving the electrical power network of Y.C in Palestine is considered. Initially the network has been analyzed where two major issues related to over loading and capacity factor has been identified. Two proposed solutions related to rearrangement the system configuration with respect to the transformers loading, power feeders and power factor correction techniques is realized by applying two engineering scenarios. Scenarios one focuses on adding new interconnection points which results in increasing the network quality and system reliability. In addition to installing capacitors banks, it enhances the system power factor. Scenarios two consider installing capacitor banks for industrial loads to improve the power factor by as large as 90%. As a result of proposed scenarios the average load demand for 2015 is predicted to be around 7.548 MVA while the maximum demand is 15.7 MVA which means increasing the system capacity, reliability and long life time. It is recommended that the deployment of the two proposed solutions is thoroughly communicated with the local Southern electrical company (SELCO) who can further assess their techno economical feasibility hoping to improve the quality of delivered energy in Y.C. In addition to proposed conventional solutions, installing distributed generators mainly Photovoltaic generators for domestic, public and industrial sectors should enhance the power quality, network life time, reduced looses and postpone reaching the transformers maximum loading with additional 4 years .

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