An-Najah National University
Faculty of Graduate Studies

Optimum Design and Performance Analysis of a Proposed Palestinian Electrical Network

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DEDICATION

الى روح والدي الحبيب طيب الله ثراه , الى والدتي الحبيبه الغاليه , الى زوجتي وبناتي , الى اخي وخواتي , الذين عشت بينهم و سعدت بهم و معهم .

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الإقـــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Optimum Design and Performance Analysis of a Proposed Palestinian Electrical Network

اقر بأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص، باستثناء مـــا تمــت الإشارة إليه حيثما ورد، وان هذه الرسالة ككل، أو أي جزء منها لم يقدم من قبل لنيل أية درجة علمية أو بحث علمي أو بحثي لدى أية مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's name:	**اسم الطالب:**
Signature:	**التوقيع:**
Date:	**التاريخ:**

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Abstract

High voltage electrical transmission lines are important; as transmission lines are the main carrier of electrical energy, to all types of society residential, commercial, and industrial activities.

Many scenarios for the location of the connection point to the external grid, and many configurations for each scenario are considered. The selected optimum network has minimum total annual cost. This network functioned successfully under several conditions like minimum load, post fault, and future increased loads, for which load flow studies were performed to check the technical performance of the network under these conditions.

In this thesis we have successfully designed an integrated electrical network with standard voltages, low power losses, high quality electrical energy, high reliability, source diversity, good voltage level, and low transmission cost.

This well integrated network allows for future connection to the seven Arab country grid, and eventually supplies end users with low cost electrical energy.

Chapter 1
Introduction

As a result of several years of Israeli military occupation of the Palestinian Territories, the Palestinian economy suffers from major distortions and underdevelopment. During the Israeli occupation, the infrastructures of the West Bank were largely neglected, if not destroyed by the occupation.

The lack of an adequate infrastructure for nearly fifty years delayed any real development in electricity network.

Electricity sector in the Palestinian land, shows a high vulnerability to political shocks. The influence of the conflict on the electricity sector goes beyond direct destruction. It results in a modification of electricity consumption, a deceleration in the growth rate, and the retardation of a "healthy" recovery.

The lack of investment and public expenditure, high prices, and high transmission losses, constitute fundamental problems for the electricity sector. The quality of the electrical services is inadequate and below standard. [1]

Energy priorities require the rehabilitation and development of the electricity system, rural electrification, and utilization of renewable energy and energy conservation, particularly in the building sector.

This thesis will lay out the various configurations for an AC HV network design for the West Bank, choose the optimum configuration from technical and economical points of view, analyze the load flow in the selected configuration for the network, and optimize the selected design.

Gaza was not considered, for it is closer to Egypt than to West Bank or Jordan

The following Fig 1.1 shows the governorates in West Bank:

Fig. (1.1): Palestinian Governorates

Palestinian Electric Authority, has completed a small scale interconnection project (supply projects), one between Egypt and Rafah with 17 MW capacity, and the other between Jordan and Jericho with 20

MW capacity. In my opinion, Palestinian Electric Authority cant provide the citizens of Palestine with reliable, secure, and low cost electricity, by purchasing it from IEC, as Israel is not the cheapest country in electricity cost in the region (because fuel for generation is imported from outside). Fig 1.2 reflects electricity cost (Cents of dollars / kwh) in neighbouring countries :

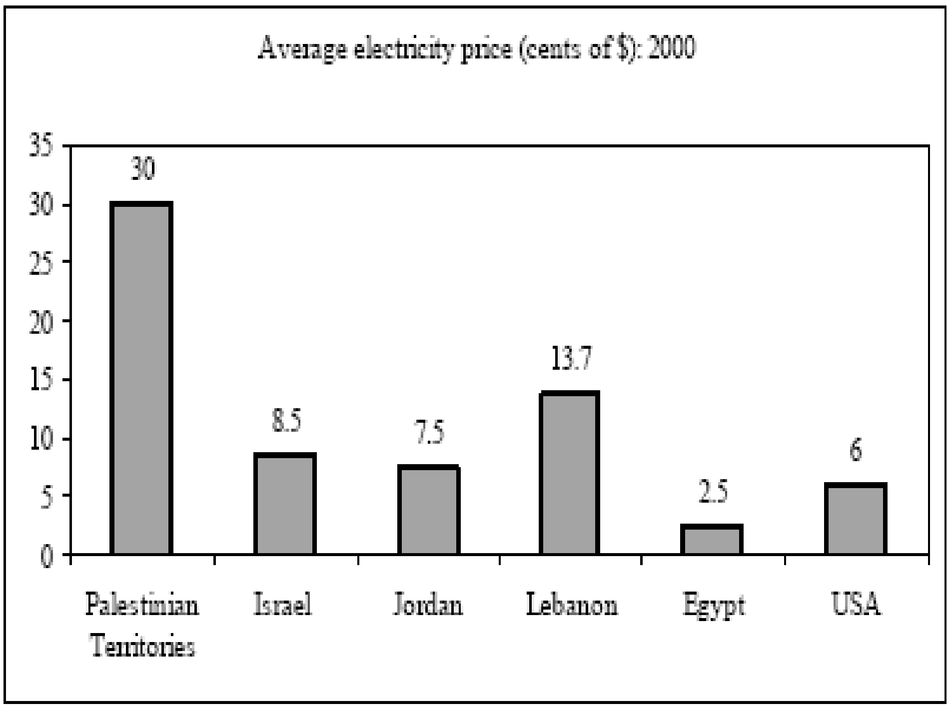


Fig. (1.2): Average electricity (cents of dollars): 2000. **[1]**

In 2008, PEA will be a full member of the 7 countries interconnection project to be the country number eight; the countries are Jordan, Egypt, Syria, Lebanon, Iraq, Libya and Turkey. This membership will allow Palestine to be connected to the grid of these countries at a large scale, That is connecting Gaza to Egypt and West Bank to Jordan. [2]

Suggested configurations have connection points to a grid, or connection points plus generation plant in order to increase reliability, and reduce supply dependency. Selection of points of generation or connection to the grid is based on technical knowledge and the information given by PEA on Jan,17th, 2008.

However, we all know that the political situation interferes with various important matters, which are not technical. PEA themselves can’t help certain decisions made by Israelies, regarding the electric supply.

Chapter 2

2-1 Present Situation

At present, the west bank, which is without primary energy sources, is completely landlocked and dependent on Israel for electrical and fuel supplies.

Because the West bank borders Jordan, and Gaza borders Egypt, getting electrical energy and fuel supplies through Jordan and Egypt respectively, is very feasible. Actually, this started to happen.

At present, Palestinians can't have their own electrical plants, as and where they like because Israelis close all borders, control most areas prohibiting new constructions, and moreover, have destroyed many electrical facilities (Lines, Transformers, and Generators).

One reason for considering Jordan as the main supplier for energy is security of supply, which here means stability, cheaper rates, and continuity.

Although it is far more difficult to determine the best option for supplying energy due to many uncertainties in the present situation, the seven grid connection seems to provide more security at more affordable prices

Security is important for any future investments or industrial development.

Now, we have on going solar energy project, to alter our sources of energy, but they can't succeed with Israelis constraints.

Fig 2.1 below shows the major IEC supply points to West Bank.

Three IEC 161 kVsubstations are supplying all the West Bank needs from electric power.

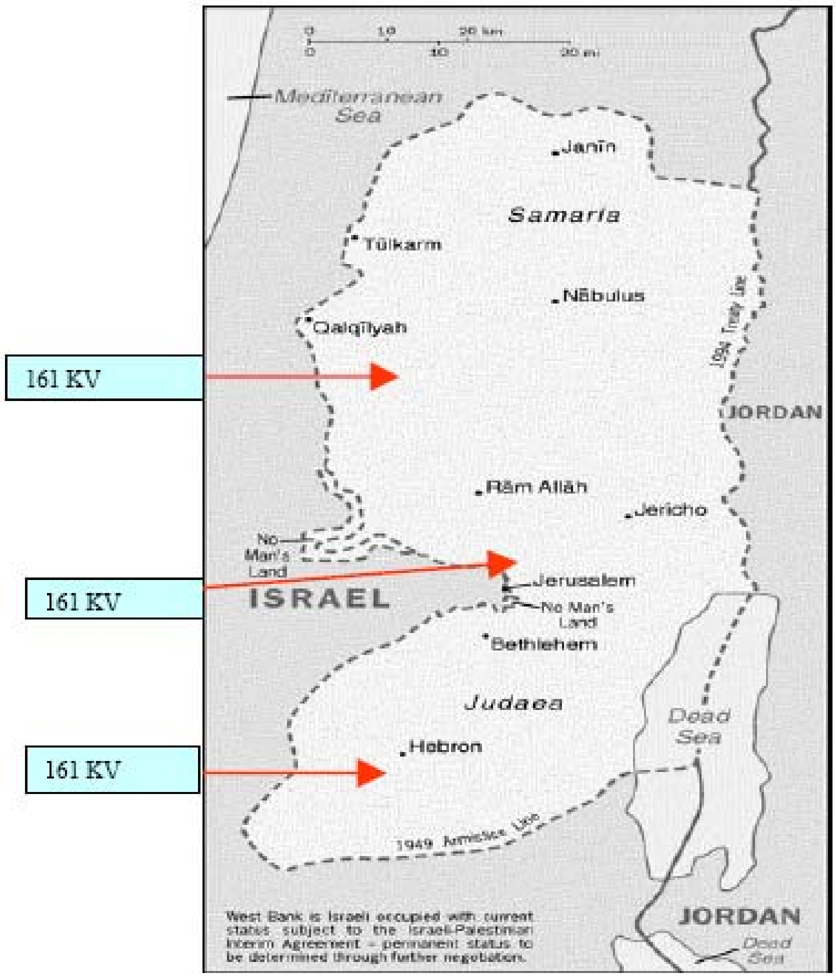


Fig. (2.1): Main IEC Feeders to West Bank. [1]

This gives the impression that Israel from start wanted to supply its settlement, and only to reduce costs, Israelis supplied the West Bank cities and towns.

Some loads in the north are fed directly from 161 kV substations inside Israel like Tulkarem and Qalqelia. Same thing with Jenin and Tubas are supplied by 33 kV feeders from Beisan in Israel.

In the north, there are about 120 connection points of 125 MVA total capacity. In the center there are about 25 points of 380 MVA total capacity. In the south there are about 45 connection points with total capacity of 95 MVA.

These connection points are mixed between medium voltage and low voltage.

Present Palestinian electric load is in the vicinity of 500MW; meanwhile the Israel Electric Company IEC had a demand of electricity in the capacity of 9497 MW in 2005. [1]

Fig 2.2 is a drawing of west bank IEC MV cables supplying load centers:

Fig. (2.2): Electric Supply System in Palestine[2]

The Palestinian load in the occupied territories is equal to 7% of IEC electricity generation as shown in Fig 2.3 :

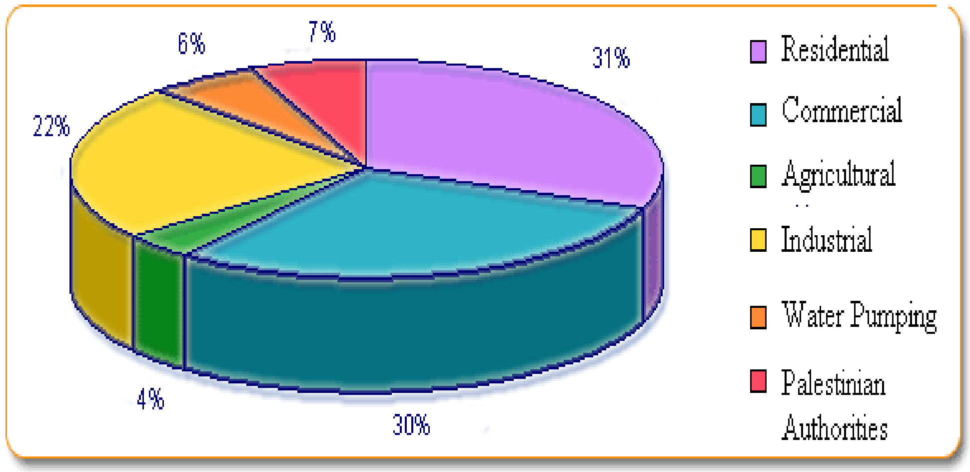


Fig. (2.3): IEC electricity generation

The peak of energy consumption in the Palestinian land occurs in summer time. Taking Qalqelia for an example, Maximum load is in August.

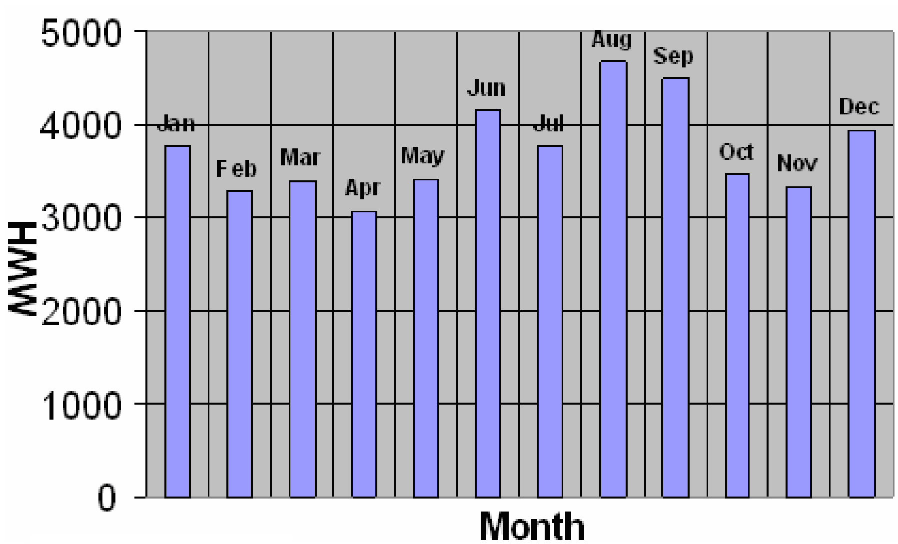


Fig. (2.4): Yearly load curve for the city of Qalqelia.

Fig 2.5 below shows the daily load curve for Qalqelia. Peak times are basically typical for all cities.

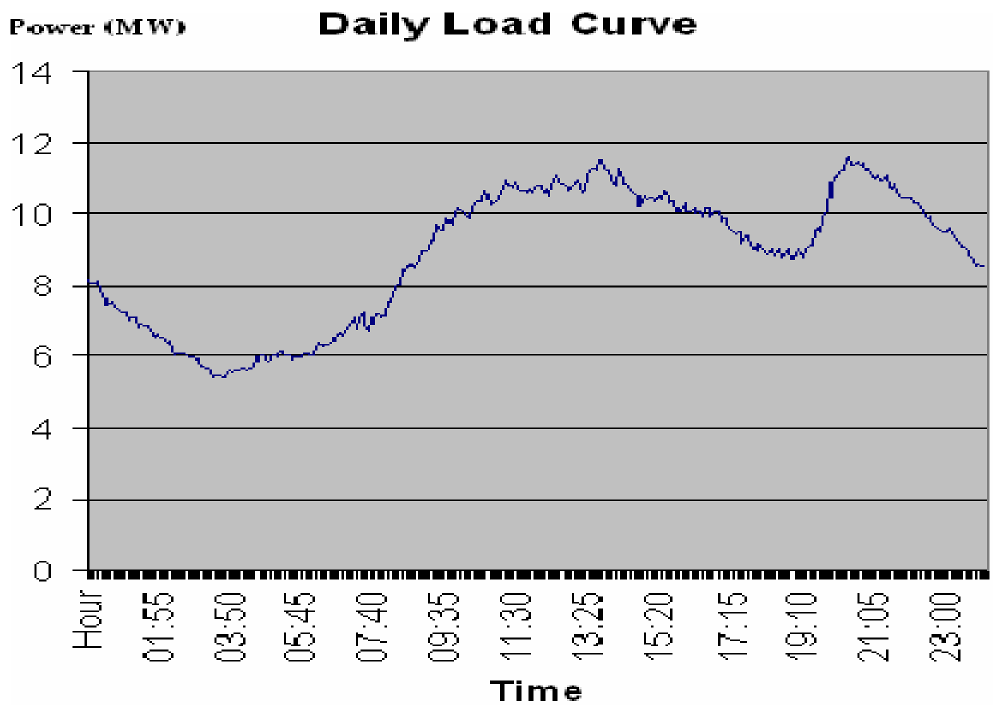


Fig. (2.5): Daily load curve. [1]

About 30% of west bank electrical needs are taken directly from Israeli Electric Company, and the remaining is taken from IEC through local power utilities. Now, power distribution is carried out by four power utilities.

The first power utility is the Northern Electricity Distribution company (NEDCO).Connection point is in Areil settlement, at the north of nablus,

The second is the Jerusalem District Electric Company (JDECO) in the center which has a satisfactory performance in reducing trade margins and collection performance. Connection point is in Atarot near Jerusalem

The third is Hebron Electric Power Company (HEPCO), around Hebron, which is having financial problems.

The fourth is the Southern Electric Company (SELCO) in the rest of the southern area. SELCO consists of municipalities of Dura, Yatta, Dahariah, Beit Ummer and Halhul.

In order to reduce fragmentation and increase efficiency, the existing fragmented distribution system in the West Bank will be consolidated into three new commercially oriented regional utilities :

- Southern Electricity Company, established in 2002 with the assistance of the World Bank, which will serve Hebron and southern regions of the West Bank.
- Northern Electricity Distribution Company (NEDCO), established in 2008 with the assistance of Norway and Sweden. This will serve Nablus, Tulkarem, Jenin and other northern regions of the West Bank.
- Jerusalem District Electric Company (JDECO).This will serve the central regions of West Bank

The first two companies are owned by the municipalities and village Councils in the respective regions. The new utilities would own the distribution networks, be responsible for service delivery and operations within their regions. [3]

Development of the main transmission network is considered green field project (Environmentally friendly), as high voltage IEC facilities that supply territories use non standard transmission voltage. Also, as the Palestinian utility is relatively small and perform at substantial lower standards than regional counterparts, huge scope of improvement will be realized when Palestinian electric utilities are integrated and stable.[3]

In addition to above utilities, Palestinian authority connected Palestinian power grid to that of Jordan at Jericho through a 33 kV overhead line which can withstand 132 kV. So Jericho will be disconnected from IEC and connected to Jordan , in addition to JEDCO.

The electrical networks in West Bank and Gaza Strip are all considered as distribution networks. The ranges of voltages of these networks are 400 volt, 6.6 kV, 11kV, 22kV, and 33kV.

In the West Bank there are 700 km of 11 and 6.6 kV networks, 400 km of 33 kV networks and 5000 km of 400 volt networks . Ninety percent of the networks are overhead lines.

IEC supplies electricity to the electrified communities at 33kV overhead lines or 22 kV overhead lines. Electricity is purchased from IEC and then distributed to the consumers.

The largest company in the West Bank is Jerusalem district Electricity Company (JDECO), it supplies electricity to around 120,000 consumers that serves 500,000 inhabitants.

The municipality companies of Nablus, Hebron, Jenin, Tulkarem and Qalqiliah are supplying electricity to around 92,000 consumers, that serves about 435,000 inhabitants.

Table 2.1 shows electricity profile in the region.

Table (2.1): An electricity profile of the region provides the main information related to the electricity sector of each country [1]

Main electricity profile of the Palestinian Territories and other countries in the region

Electric Companies	
Palestine	Palestine Electric Company (PEC). Established in 1999, 33% public shareholders, 67% private shareholders. The Gaza Power Generating Company (GPGC), with a production capacity of 140 MW, is the sole Palestinian producer of electricity. Jerusalem Electricity Distribution Co and North West Bank Electricity Distribution Co.
Israel	Electric Company (IEC). Founded in 1923 as The Electric Company of Palestine
Jordan	National Electric Power Company (NEPCO).
Lebanon	Electricité du Leban (established in 1954).
Syria	Ministry of Electricity (Syria).
Egypt	Egyptian Electricity Holding Company (EEHC).
USA	General Electric Company.
Market structure	
Palestine	The mission of the Palestine Electric Company (PEC) consists of owning and operating high voltage lines, exchanging electricity with neighbouring countries, purchasing electricity from the IPPs and supplying electricity to the distribution facilities.
Israel	IEC currently has the monopole for generation, transmission and distribution. The Electricity Sector Law of 1996 requires the company to privatize; private production is expected to increase by 20% by 2006
Jordan	The electricity sector is a state-owned utility consisting of the Zarqa power plant (400 MW) and the Aqaba power plant (650 MW). Jordan plans to maintain ownership of transmission assets, but will privatize power generation assets and distribution subsidiary.
Lebanon	Electricité du Leban has the monopole for generation, transmission and distribution. In 2002, the Lebanese Parliament approved a draft law to privatize the electricity sector. Plans for privatization have been postponed.
Egypt	Seven regional state-owned power production and distribution companies under the control of the Egyptian Electricity Holding Company (EEHC), the successor to the Egyptian Electricity Authority (EEA). Considering limited privatization of the electrical power sector (Egypt has several privately-owned power plants under construction).
Production facilities	
Palestine	On 15 March 2004 started commercial operation of generating 140 MW using combined cycle power plants[7].
Israel	20 power stations, including 7 major thermal plants.
Electricity production according to fuel source	
Palestine	A diesel power plant which will soon be able to use natural gas.
Israel	70% of the electricity generated by the IEC is from coal-fired power plants, 25% from fuel oil-fired units, and the remaining portion from gasoline and IPP. The IEC aims to generate 40% of its electricity from gas by 2006.
Jordan	99.7% thermal, 0.3% hydroelectric. Plans to convert the country's major oil-fired plants to natural gas.
Lebanon	Dominated by fuel & diesel (88.1% is thermal), with some hydroelectric power (11.9%).
Syria	80% thermal, 20% hydroelectric. Plans to convert the country's major oil-fired plants to natural gas.
Egypt	84% is thermal (natural gas), 16% hydroelectric (mostly from the Aswan Hugh Dam).
USA	76% is thermal (35% coal, 19% natural gas, 18% "dual-fired," 4% petroleum), 11% hydro, 11% nuclear, and 2% "other renewable energy types" (geothermal, solar, wind).
Future production perspective (capacity & technology)	
Palestine	Natural gas will replace diesel oil once it becomes available. Electricity demand is projected to reach 781 MW as a peak demand by 2015.
Israel	Plans to expand installed power capacity to 15 GW by 2010.
Lebanon	Plans to expand installed power capacity to 2100 MW by 2012.
Syria	Aims to add 3,000 MW of power generating capacity by 2010.
Egypt	Plans to add 4.5 GW by 2007.

Main electricity profile for the Palestinian Territories and other countries in the region (continued).

	Consumers
Palestine	Palestine Electric Co. production covers the Gaza strip only. Municipal companies in Nablus, Hebron, Jenin, Tulkarem & Qalqilia supply around 73,000 consumers (435,000 inhabitants). Another large company in the West Bank is the Jerusalem District Electric Company (JDEC). This company supplies electricity to around 90,000 consumers, which represents 500,000 inhabitants.
Israel	IEC production covers 2.1 million consumers, 1.8 million of whom are residents.
	Electric grid in 2000
Palestine	Distribution networks only. 700 km of 11 & 6.6 KV, 400 KM of 33 KV and 5000 KM of 400 volt networks. 90% is overhead line. There are 22 KV networks used by the Israel Electric Corporation (IEC) in the West Bank.
Israel	Closed-loop system of 1'645 miles, includes EHV-400KV and 161 KV (in addition to the electric grid in the West Bank and the Gaza Strip). Lebanon: 620 miles.
	Electric interconnection
Palestine	Plan to connect Palestine with Jordan and Egypt.
Israel	Israel has expressed an interest in the idea of a regional power network. Talks were held with Jordan but this project has been put on hold due to political pressures.
Jordan	A project to link the electricity power grids of Syria, Egypt, and Jordan was completed creating a network of approximately 45 GW. The connection cost was estimated at $US 240 million.
Lebanon	A six-way grid linking Jordan, Syria, Iraq, Egypt and Turkey with Lebanon, which will allow Lebanon to receive 300 MW in the short-term and close to 600 MW in the medium to long-term.
Syria and Egypt	In March 2001, a project to link the electric power grids of Syria, Egypt, and Jordan was completed resulting in a network of approximately 45 GW. The link between Jordan and Syria is via a 400-kilovolt cable, while the Jordan-Egypt link is via an underwater cable in the Red Sea. Egypt also activated a link to Libya's electric power grid in December 1999.
USA	Interconnection with Canada and possible future interconnection with Mexico.
	Cooperation
Palestine	A project of cooperation between Jordan, Israel and the Palestinian Territories based on transferring water from the Red Sea to the Dead Sea and building power generation plants and desalination plants in order to supply electricity and fresh water to the three countries.
Israel	In addition to the Red Sea project, the IEC are looking into a wind power project in partnership with Syria.
Jordan and Syria	The two countries are seeking funding for a joint $ 420 million hydroelectric dam project.

2-2 Energy Consumption in the West Bank

Most recent indicators show that electricity consumption in Palestine could be estimated at 680 kWh on per capita basis. By world standard, it is considered as very low. As a base of comparison, a country like Jordan, the annual per capita consumption amount to 1045 kWh. Estimate for Israel would yield a per capita consumption of 5167 kWh that is nearly ten times that of the West Bank.

Average per capita consumption also varies between the different regions in the West Bank.

The following tables provide basic information concerning the consumption and consumers for the various districts in the West Bank for 2007/ 2008.

Table (2.2): Energy Consumption [4]

Area /	Energy Consumption (per capita) (kWh / year)
Jenin town	446
Tul-Karem town	579
Nablus system	700
Hebron system	520
Qalqiliah town	651
JDECO	510
GEDCO	607

Explanation for this low consumption include insufficient capacity of power sources, high prices of electrical energy supplied by the Israel Electric Corporation and inadequate quality of electrical energy .[4]

Table 2.3 indicates the Energy consumption in the main districts of the West Bank.

Table (2.3): Energy consumption in main districts [4]

Area/district	Energy Purchased (kWh/year)	NO of Consumers		
		Residential	Industrial and Commercial	Total
Jenin	59947520	10700	130	10830
Tul-karem	71237520	11300	200	11500
Nablus	256818065	30739	8093	38832
Hebron	258674520	16120	7586	23706
Qalqiliah	51946083	5205	1548	6753
Jerusalem				124000

Peak loads for these districts have been estimated as shown in table 2.4 ;

Table (2.4): Peak loads in main districts [4]

Area / district	Peak Load (MW)
Jenin	15
Tul-karem	15
Nablus	60
Hebron	55
Qalqiliah	12
Jerusalem	165

Power losses are quite high in the West Bank and Gaza strip, a key source of technical losses results from the low power factors found in the West Bank. Non-technical losses result from theft, unpaid bills and any other illegal ways of accessing the network. [4]

2-3 Rates and Tariff Structure in the West Bank

Average price paid by the "consumers" (i.e., the municipalities and the Jerusalem District Electrical Company) in the West Bank was **0.42** NIS/kWh or $ **0.093** U.S. The average price for end-users (households) was about **0.68** NIS/kWh ($ **0.15** U.S). [4]

Although the selling price dictated by the Israel Electric Cooperation was fixed, cost of generating (when generation sources were available) and distributing energy varied between the different municipalities. Cost to the end - users varied in the same proportion.

Table 2.5 shows the difference in average prices between the main municipalities (households):-

Table (2.5): Municipality Average rate [4]

Municipality	Average Rate (end-users)	
	NIS	US $
Jenin	0.6	0.13
Tul-karem	0.62	0.12
Nablus	0.72	0.15
Hebron	0.65	0.14
Qalqiliah	0.65	0.14
Jerusalem	0.6	0.13

The following data, shown in table 2.6 obtained from the municipalities shows the continuous changing in the tariff set by the IEC.

Table (2.6): Tariff change [4]

Period	Tariff per kWh	
	NIS	$ US *
January - May 1998	0.21	0.046
June - December 1998	0.23	0.051
January - June l999	0.24	0.053
July - October 1999	0.245	0.054
November-December 1999	0.25	0.054
January - May 2000	0.273	0.06
June - December 2000	0.277	0.061
November 2001	0.29	0.064
December 2002	0.295	0.065
January 2004	0.305	0.068

1 US $ = 4.5 NIS

Tariff Structure is in most cases fairly simple using flat rates (No night tariff and peak penalty are available) and limited number of client categories. Discounts are provided to clients that pay “in time”.

Table 2.7 below provides additional information on the rate structure in the municipalities:

Table (2.7)*: Municipality of Jenin [4]

Category	Rate	
	NIS	US $
Residential	0.6	0.133
Commercial and industrial	0.58	0.13

*** Municipality of Tul-karem**

Category	Rate	
	NIS	US $
Residential, Commercial, industrial	0.6	0.122

*** Municipality of Nablus**

Category	Rate	
	NIS	US $
Commercial and residential (0÷50 kWh)	0.72	0.144
Commercial and residential (50 + kWh)	0.78	0.151
Industrial (0 ÷ 100 kWh)	0.72	0.133
Industrial (101+ kWh)	0.63	0.14

*** Municipality of Hebron**

Category	Rate	
	NIS	US $
Residential	0.65	0.144
Commercial and Industrial	0.6	0.133

*** Municipality of Qalqiliah**

Category	Rate	
	NIS	US $
Residential, Industrial and Commercial	0.65	0.144

*** Jerusalem District Electricity Company**

Category	Rate	
	NIS	US $
Residential	0.6	0.129
Industrial and commercial	0.6	0.133

Chapter 3

3-1 Disadvantages of present situation

The following points sum up the drawbacks for present electrical distribution system :

1-As connection is sometimes done on LV side, expansion is not possible without high losses. This will contribute to the existing network deficiencies, like low voltage and high losses.

2-During INTIFADA, the economical situation deteriorated and collection of electric bills by municipalities also deteriorated, the thing that affected maintenance and upgrading of existing network, resulting in overloading and outages in addition to increased losses and higher voltage drop. Rapid build up in interest charge made external urgent support necessary to solve financial problem in electrical utilities.

Now, the losses are about 25% to 30%.

The following figure 3.1 indicates the transmission losses in neighboring countries [1] :

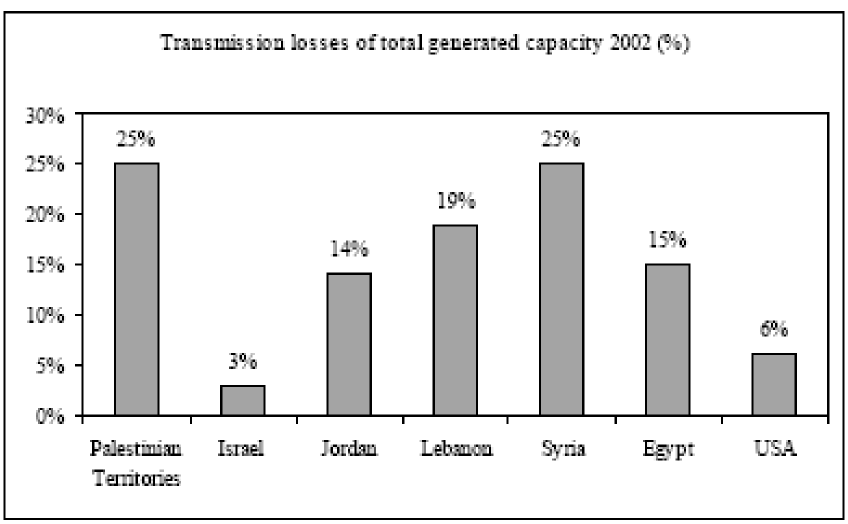


Fig. (3.1): Portion of transmission losses out of total generated capacity

3-Fragmentation and discontinuity of existing distribution system, makes it impossible to use diversity factors between loads, which can reduce max demand and cost of connection.

4-Moreover, in case of faults on some feeders, the existing distribution system doesn't allow back up from remaining connection points, as they are not connected. JEDCO is excluded from above argument (they have reasonable integrity and connectivity), but of course it is not connected to remaining of west bank areas.

5-Insuffecient supply. Average annual increase in power consumption is around 6.4% for years 1999 to 2005. IEC refuses most Palestinian requests to increase capacity of existing connection points or adding new connection points, resulting in load shedding like what happened in Tulkarem at summer 2008.

Nablus area will be severely affected by this bottle neck as it is the load center of the north.

6-Although purchase prices from Israel are the same, the retail prices vary.

7-The uncertainty of the existing situation, made this work seems to be like making a bench mark for optimized design, focusing on technical issues and actual locations of load centers.

The various configurations assumed freedom to construct an electrical network, and proposed High Voltage AC transmission ACSR overhead lines that form an integrated grid through out the West Bank.

8-Absenc of technical, financial and institutional capacities for utilities.

9-Due to theft, technical losses, and inefficient billing, lower amounts billed to customers than amounts of electricity purchased from IEC

Low cash collection rates worsen the difficulty to upgrade existing network . [3]

3-2 Load forecast

Despite all political trouble, the demand for electricity continued to increase at a rate of 6.4%. Households in West Bank consumed 60% to 70% of total electric consumption.[3]

The current unpredictable political and economical situation makes it difficult to predict exactly the electrical future demand. According to world bank reports, the future demand overtakes existing supply capacity in year 2008 at the latest.[3]

Our philosophy is to avoid dependency on Israeli networks and work on investments in power supply facilities, and long term cooperation commitments with Egypt and Jordan.

The future demand in the Palestinian terretorities is difficult to estimate from trend of previous consumption record, for the following reasons:

1- In past years, many consumers didn't pay electric bills, and for that reason, consumed electricity audaciously and more than they would if they had to pay. This indicates less actual capacity required than the records state.

2- Most of requests for more connection or capacity were denied from IEC. This indicates that actual capacity required in previous years is more than what records state.

3- The poor economical circumstances, affected the usage of electricity negatively. This indicates that actual capacity is more than what records state.

The demand in year 2025 is estimated by PEA [5] to be around 1012MW. This estimation was considered in this study .

Proper design of any electric utility will ensure security and cost effectiveness. Usually higher security means higher cost. Security means diversification of supply sources from variety of power and fuel markets.

3-3 Distribution Development

As mentioned earlier, the existing fragmented distribution system in the West Bank will be consolidated into three new commercially oriented regional utilities.

The techno-economic analysis that was carried out by Acres International on the "Feasibility Study for Electric Transmission & Distribution – West Bank and Gaza" October 2005 to determine the most economic number of Bulk Supply Points (BSP's), has indicated that seven bulk supply points would be the most economic alternative to supply the load in West Bank, (Nablus, Jenin, Hebron, Ramallah, Jerusalem, Tulkarm/Qalqilya, and Bethlehem).[2]

Acres International study considered all alternatives some of which are just impractical to be implemented . They didn't consider any ring connection in the south leaving Jericho out of the integrated utility .

Later, PEA report [5] on the proposed network connection in the West Bank suggested nine substations to supply the loads (Jericho sub station wasn't specified)

This study considered the independence of supply from IEC as a major issue, and took advantage of the opportunity offered by the new Middle East grid. A permanent, well integrated network is the target, having in mind the idea that when peace is finally accomplished, we will face very high rate of energy demand growth.

As future Palestinian loads are hard to estimate, and that we look forward to low level of losses and running cost, a sub station in every district is proposed (total of eleven s/s including Salfit and Tubas), to make sure that all areas are covered even if mass Palestinian population dwelling takes place as a result of refugees coming back.

This is also important for replacing of hundreds of connection points . Jericho is considered as a connection point to the Jordanian grid. As this is a permanent, well integrated transmission network it will provide reliable supply of electricity to the load centers and thus accelerate economic development.

3-4 Environmental Impact

Overall, once the work is completed, there will be a significant net positive social and environmental impacts to the people of the West Bank.

Limited negative environmental and social impacts will occur for short periods during the works. By careful pre-planning by the organisation contracted to undertake the rehabilitation works all the negative impacts can be addressed through an Environmental management plan. Compensation issues arising from damage or destruction to assets will be also evaluated and looked into.

The bulk of the impacts fall under construction phase works, mainly excavation works for site preparation, foundations (transmission towers and poles) and transformers and stringing of overhead cables.

The secondary or indirect impacts of the line installation works will be disruptions to traffic, pedestrians, and safety issues where right of ways are located along pedestrian pathways and where they may block access to private and/or public property in both residential and commercial areas.

These impacts can be minimized, in terms of severity and duration, by ensuring that the excavation and construction works are limited to short working sections, and that works are carried out rapidly and efficiently.

The remainder of the impacts will be site specific, and generally within the operating sites of PEA and regional distribution companies.

Chapter 4

4-1 Load information in west bank

Table 4.1 below figures the load forecasting for year 2025 taken from PEA[5]. Peak demand values are determined assuming a 1.0 diversity factor.[5]

This is reasonable because all load centers share the same time zone, close to each other, and supply customers with similar cultural requirements. [5]

Table (4.1): Load information in year 2025

Governorate	Load in year 2025 in (MW)
Jenin	57.9
Tubas	16.9
Tulkarem	67.2
Qalqelia	30.5
Nablus	120.4
Salfit	12
Ramallah	170.8
Jericho	32
Jerusalem	135.7 + 73.5
Beithlehem	117.3
Hebron	178.7
Total	1013 Appx

4-2 Power factor

To avoid penalties by IEC, electric utilities install capacitors on their panels. It is really difficult to estimate power factor of existing loads, as utilities keep adding capacitors until power factor above 0.92 is reached. No accurate records are kept.

Recently, electric utilities required the new consumers to correct the power factor especially for loads like fluorescent lamps , air-conditioning systems , and large motors.

The following power factor values were assumed, based on the nature of the loads as shown in table 4.2

Table (4.2) :Existing load Power factor

Governorates	Pmax	PF	Smax	Tan θ	Qmax=P tan θ
Jenin	57.9	0.8	72.37	0.75	43.42
Tubas	16.9	0.85	19.88	0.62	10.46
Tulkarem	67.2	0.8	84	0.75	50.4
Qalqelia	30.5	0.8	38.12	0.75	22.87
Nablus	120.4	0.85	141.65	0.62	74.528
Salfit	12	0.85	14.12	0.62	10.2
Ramallah	170.8	0.85	200.94	0.62	105.73
Jericho	32	0.85	37.64	0.62	19.8
Jerusalem	209.2	0.85	246	0.62	129.49
Beithlehem	117.3	0.85	138	0.62	72.61
Hebron	178.7	0.85	210.24	0.62	110.62
Total	1012.9		1203		650

4-3 Balance of real power

In general, balance of real power is performed, in order to estimate the power to be generated.

Generated power in the network must equal the power consumed by loads plus power losses in the transmission lines and transformers.

$\sum$ P generated = $\sum$ P loads + $\sum$ P losses in lines and transformers

$\sum$ P generated = 0.9$\sum$ P loads + 0.075$\sum$ P loads……………. (1)

Where : the 0.9 is the diversity that is likely to be, and

0.075 is a factor used to estimate the. losses in the network.

Using equation (1) the value of P generated is :

$$\sum P \text{ generated} = 0.9(1012) + 0.075(1012)$$

$$= 987 \text{ Mw}$$

This value is used as the total power to be generated . Nevertheless , because we are dealing with future loads forecasted by PEA[5] , a total load of 1012 MW is considered in this study .

4-4 Scenarios for location of grid connection and /or generator location

In this thesis, three different scenarios are suggested :

Scenario A: Connection to the seven Arab countries network through Jordanian grid at Jericho

Scenario B: Connection to the seven Arab countries network through Jordanian grid at Jericho with a generation plant at Nablus area.

Scenario C : A generation plant at Ramallah.

As far as design configurations are concerned, six different radial and ring configuration are considered for each scenario. The criteria for designing various configuration was to go along main roads and to transmit energy in one direction (not to transfer energy forward and backward)

Figure 4.1 through 4.3 below reflect the three scenarios and the six configurations for each.

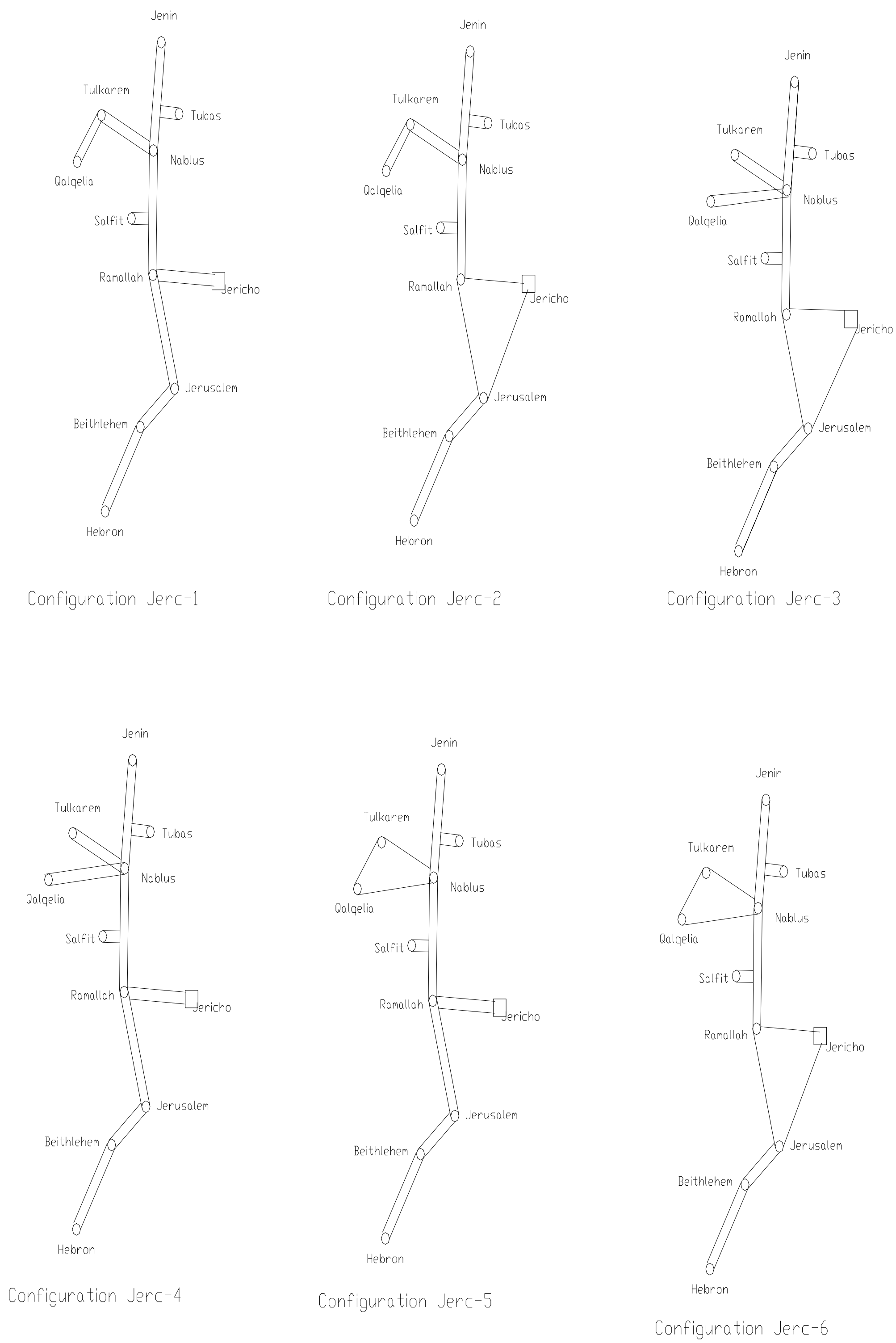


Fig. (4.1): Scenario A

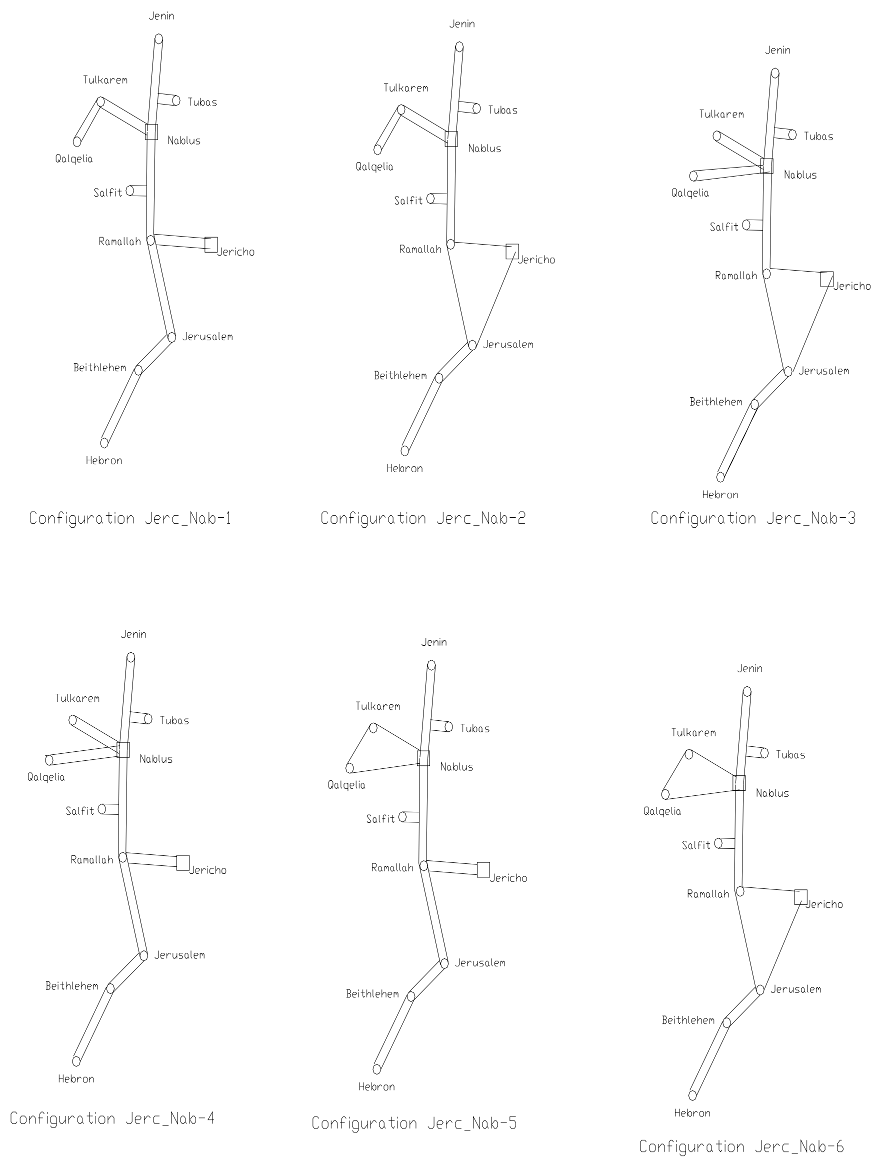


Fig. (4.2): Scenario B

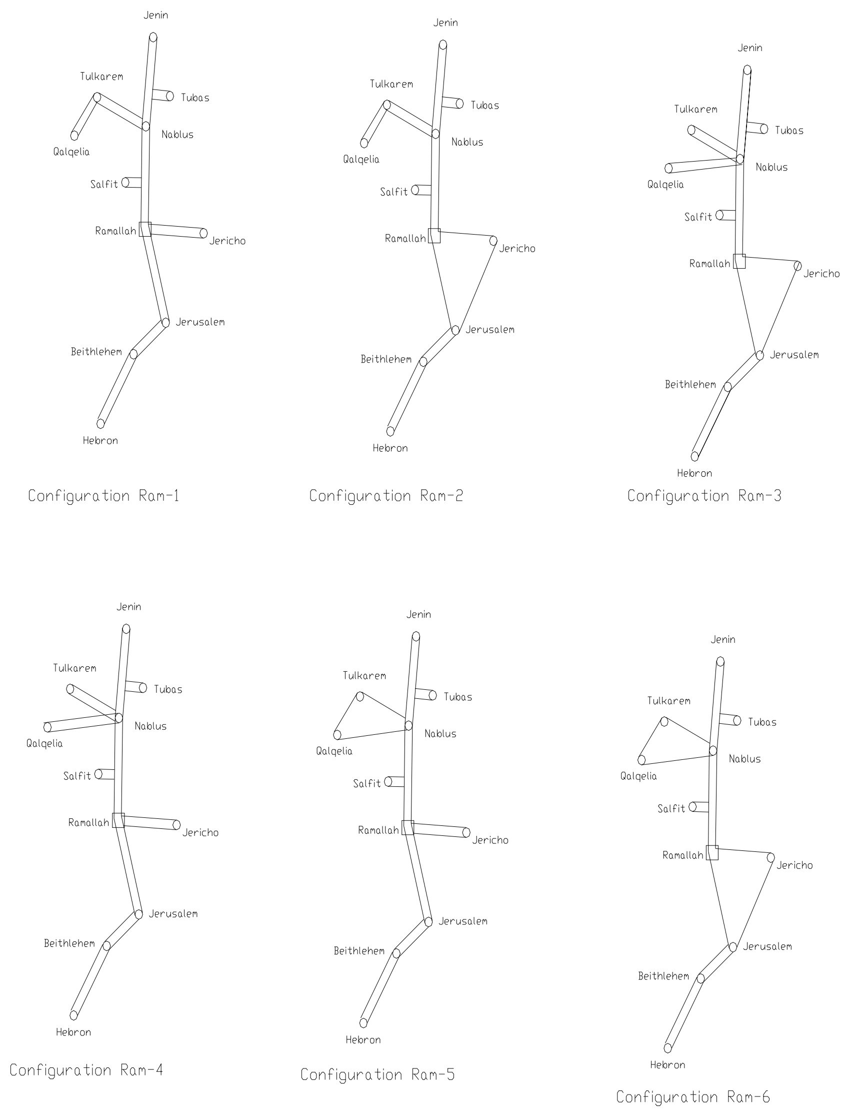


Fig. (4.3): Scenario C

Chapter 5
Balance of reactive power

The reactive power flow increases the current and eventually conductors size and power losses. Instead, reactive power sources like capacitors can supply part of the reactive power when installed near loads.

Israeli Electric Company penalizes Palestinian Electric Utilities when power factor drops below 0.92. Therefore, it is important to improve power factor of our loads for the above reasons.

The following analysis determines the economic power factor at which the various configurations in every scenario are to be operated. The radial configuration used for determining the economic power factor is called the primary configuration.

5-1 Scenario A – Jericho

In this scenario the Palestinian grid is connected to Jordanian grid at Jericho.

(The connection point to outer grid is at Jericho)

Balance of reactive power for primary configuration Jer-1

This configuration is a radial one (Ref Fig 5.1 page 35), that is, all overhead cables (i.e. Transmission lines) connection between sub stations do not have ring arrangements. As it is used to calculate the economic power factor, it's called primary configuration.

The power flow (P) in every branch is calculated, and used in equation 2 to determine the least required voltages [6] :

$V = 1000/\sqrt{(500/L + 2500/P)}$…………………………(2)

Where:

P - Power flow in the branch in MW

L – Length of branch in km.

The calculated branch voltages are shown in table 5.2.

The reactive power Q generated from station, transmission lines, and Reactive power sources, must equal the reactive power consumed by load, transmission lines, and transformers:

Generated Q = Consumed Q

$Q_{station} + Q_{tranmission\ lines} + Q_{reactive\ power\ sources} = Q_{load} + Q_{trans\ lines} + Q_{transformer}$

The reactive power generated by transmission lines is assumed to be equal to the reactive power consumed by the lines.

Thus,

$Q_{reactive\ power\ sources} = Qload + Qtransformer - Qstation$

Here, diversity on reactive power is considered, as it is possible to add capacitors if later on needed,

$Q_{reactive\ power\ sources} = 0.9\ Qload + \sum Mi \times 0.1 \times Si - Qstation$ [6] …(3)

Where : Mi is the number of transformers that power will go through

: Si is the apparent power flow

Pge = 987 MW

PF = 0.9 (power factor of turbo generator)

θ = Cos^{-1} (0.9) = 25.8

Tan θ = 0.484

Qstation = 478 MVAR

Qload = 650 MVAR

Q transformers = 244.07 MVAR

Thus

$Q_{reactive\ power\ sources}$ = 351 MVAR appx

Qeconomical = Qload _ Qrps

= 650 MVAR _ 351 MVAR

= 299 MVAR

Where Qeconomical is the economical reactive power received by loads from network. To calculate economical power factor, we recall the equation:

P.F.econ = $Cos[Tan^{-1}$ (Qecon / P load)]

= $Cos[Tan^{-1}$ (299/987)]

= 0.957

Table 5.1 page 34, indicates new values of S for Jericho primary configuration Jer-1, based on the economical power factor calculation.

Where:

Q_{new} = the new reactive power taken by the loads from the network

Q_{rps} = the calculated reactive power generated by reactive power sources

Qstd = the standard reactive power generated by reactive power sources.

Qstn = the new reactive power received by the loads from the network

Table (5.1): New S for Jer Scenario

Govern-orates	Pmax	Qold	Qnew	Q rps	Q std	Q stn	New S
Jenin	57.9	43.4	17.4	25.9	6 × 4	19.4	57.9+J19.42
Tubas	16.9	10.46	5.1	5.3	2.9× 2	4.6	16.9+J4.66
Tulkarem	67.2	50.4	20.29	30.11	6 × 5	20.4	67.2+J20.4
Qalqelia	30.5	22.8	9.21	13.66	6 × 2	10.8	30.5+J10.87
Nablus	120.4	74.52	36.36	38.17	6 × 6	38.52	120.4+J38.52
Salfit	12	10.2	3.62	6.58	6 × 1	4.2	12+J4.2
Ramalla	170.8	105.7	51.58	54.15	6 × 9	51.73	170.8+J51.73
Jericho	32	19.8	9.66	10.14	2.9+6	10.9	32+J10.9
Jerusalem	209.2	129.49	63.17	66.32	6 × 11	63.49	209.2+J63.49
Beithlehem	117.3	72.61	35.42	37.18	6 × 6	36.6	117.3+J36.6
Hebron	178.7	110.62	53.96	56.66	6×9+2.9	53.72	178.7+J53.72
Total							1013+J314.5

Note: Qnew is based on PFecono of 0.957

Table 5.2 below is a summary of Jericho primary configuration Jer-1

Table (5.2): Summary of Jer-1

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated voltages kV	Design voltages kV
Jer-Ram	980.9+J303.6	35	35×2	1	1	243	230
Ram-Jsm	505.2+J153.8	18	18×2	1	-	174.8	230
Jsm-BL	296+J90.32	10.3	10.3×2	1	-	132.47	230
BL-Heb	178.7+J53.72	16.5	16.5×2	1	-	150.26	230
Ram-Sal	304.9+J98.07	24	24×2	1	-	185.59	230
Sal-Nab	292.9+J93.87	28	28×2	-	-	172.68	230
Nab-Tub	74.8+J24.08	20	20×2	1	1	130.83	132
Nab-Tk	97.7+J31.27	25	25×2	1	-	148.19	230
Tub-Jen	57.9+J19.42	29	29×2	1	-	121.11	132
Tkm-Qal	30.5+J10.87	25	25×2	1	-	99.03	230
		230.8		9	2		

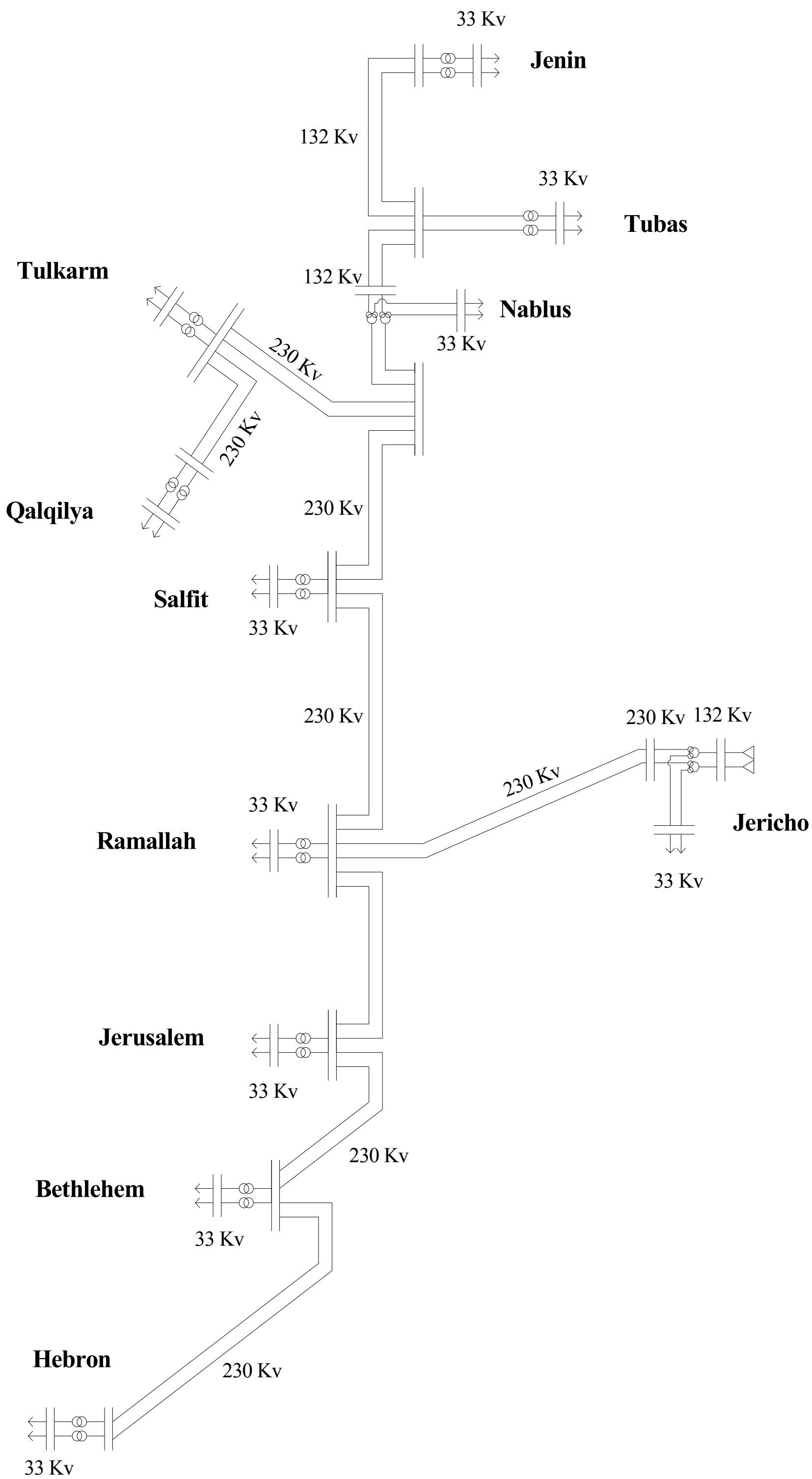

33 Kv
Jenin
132 Kv
33 Kv
Tubas
Tulkarm
132 Kv
Nablus
33 Kv
230 Kv
230 Kv
Qalqilya
230 Kv
Salfit
33 Kv
230 Kv
230 Kv
132 Kv
230 Kv
33 Kv
Jericho
Ramallah
33 Kv
Jerusalem
33 Kv
230 Kv
Bethlehem
33 Kv
Hebron
230 Kv
33 Kv

Fig. (5.1): Jer-1

5-2 Scenario B – Jericho/Nablus

In this scenario, two supply points are assumed (Ref Fig 5.2 page 39). In Jericho, there is a connection to the Jordanian grid, and in Nablus, 460 MW generation plant is assumed, which is basically enough to supply northern load centers.

Balance of reactive power for primary configuration Jer/Nab-1

A radial configuration is used to calculate the economic power factor.

The power flow is calculated and the results are used in equation (2) to get the branches voltage. The calculated branches voltage are shown in table 5.4

$Qrps = 0.9\ Qload + \sum Mi \times 0.1 \times Si - Qstation$....................(3)

Pgen = 987 MW

PF = 0.9

θ = 25.8

$\tan\theta$ = 0.484

Qstation = 478 MVAR

Qload = 650 MVAR

Q transformers = 222.66 MVAR

Thus:

Qrps = 329.62 MVAR appx

Qeconomical = Qload – Qrps

= 650 MVAR – 329.6 MVAR

= 320.4 MVAR

P.F.econ = $\mathrm{Cos}[\ \mathrm{Tan}^{-1}(Q_{econ} / P_{load})]$

= $\mathrm{Cos}[\mathrm{Tan}^{-1}(320.4/988)]$

= 0.951

Table 5.3 below indicates new S for Jericho/Nablus primary configuration Jer/Nab -1 based on the economical power factor calculations

Table (5.3): New S for Jer/Nab scenario

Govern-orates	Pmax	Qold	Qnew	Q rps	Q std	Q stn	New S
Jenin	57.9	43.42	18.76	24.66	4×6	19.42	57.9+J19.42
Tubas	16.9	10.46	5.475	4.98	2.9	7.56	16.9+J7.56
Tulkarem	67.2	50.4	21.77	28.63	4×6+2.9	23.5	67.2+J23.5
Qalqelia	30.5	22.875	9.88	13	2×6	10.875	30.5+J10.875
Nablus	120.4	74.528	39.01	35.52	5×6+2.9	41.628	120.4+J41.628
Salfit	12	10.2	3.88	6.32	6	4.2	12+J4.2
Ramalla	170.8	105.73	55.34	50.39	8×6	57.73	170.8+J57.7
Jericho	32	19.8	10.37	9.43	6+2.9	10.9	32+J10.9
Jerusalem	209.2	129.49	67.78	61.7	10×6	69.49	209.2+J69.5
Beithlehem	117.3	72.6	38.01	34.59	5×6+2.9	39.7	117.3+J39.7
Hebron	178.7	110.6	57.9	52.7	8×6+2.9	59.7	178.7+J59.7
Total							

Note: Qnew is based on PFecono of 0.951

Table 5.4 below is a summary of Jericho/Nablus primary configuration

Table (5.4): Summary of Jer/Nab-1

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated voltages kV	Design voltages kV
Tub-Jen	57.9+J19.42	29	29×2	1	-	128.65	230
Nab-Tub	74.8+J26.98	20	20×2	1	1	130.83	230
Nab-Tkm	97.7+J34.4	25	25×2	1	-	148.11	230
Tkm-Qal	30.5+J10.875	25	25×2	1	-	99.03	230
Nab-Sal	167.1+J119.6	28	28×2	1	-	174.5	230
Sal-Ram	155.1+J115.5	24	24×2	1	-	164.5	230
Jer-Ram	520.9+J111.1	35	35×2	-	1	228.9	230
Ram-Jsm	505.2+J168.9	18	18×2	1	-	174.8	230
Jsm-BL	296+J99.4	10.3	10.3×2	1		132.47	230
BL-Heb	178.7+J59.7	16.5	16.5×2	1		150.26	230
Total			461	9	2		

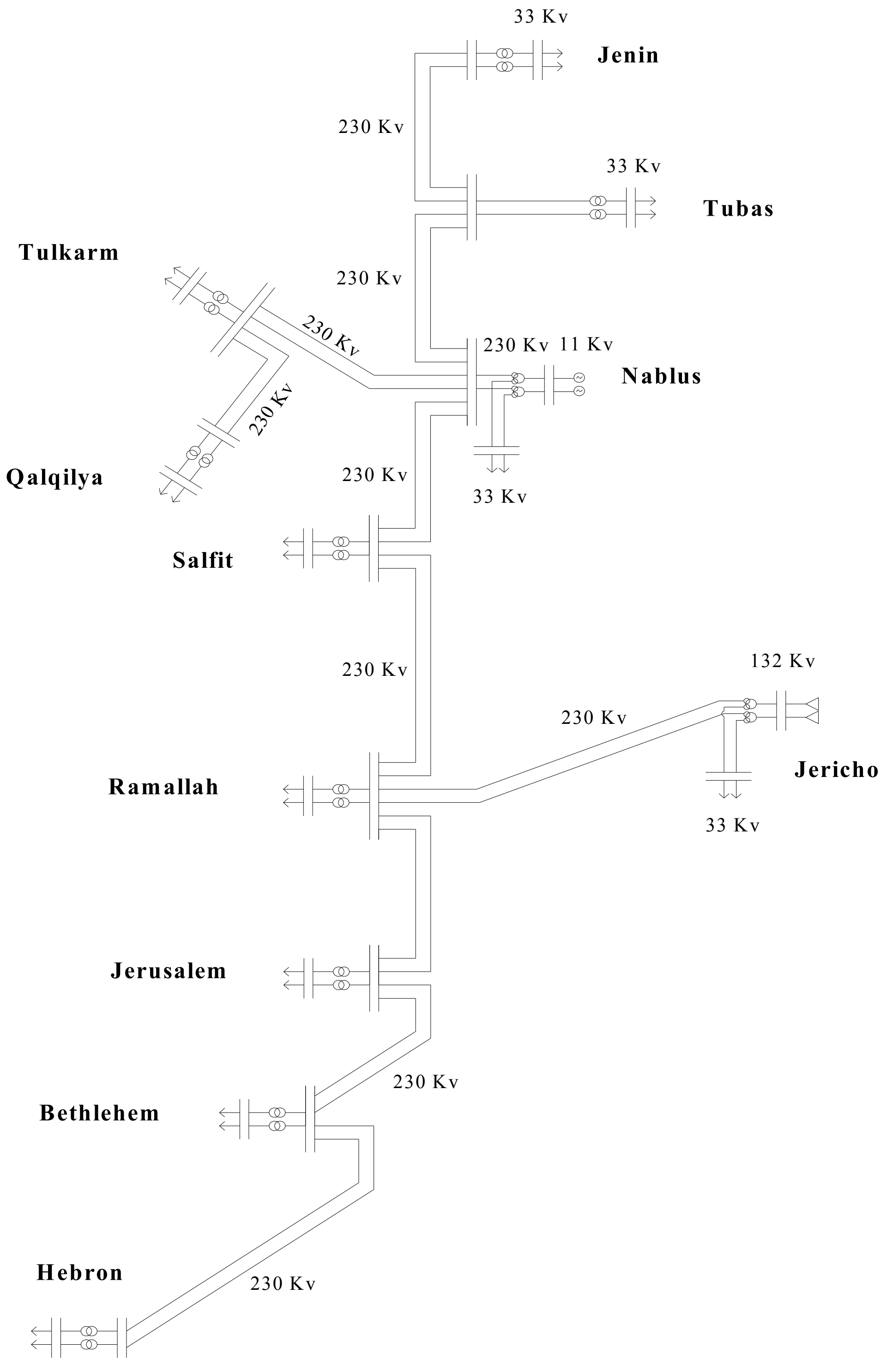


Fig. (5.2) Jer/Nab-1

5-3 Scenario C– Ramallah

In this configuration (Ref Fig 5.3 page 43), there is one main connection point between Palestinian network and the Jordanian grid, which is at Ramallah.

Balance of reactive power for primary configuration Ram-1

The power flow (P) in every branch is calculated, and used in equation (2) to determine branches voltage. The branch voltages are shown in table 5.6.

Reactive power Q generated from station, transmission lines, and reactive power sources must equal Reactive power consumed by load, transmission lines, and transformers

$$Q_{rps} = 0.9\, Q_{load} + \sum M_i \times 0.1 \times S_i - Q_{station} \qquad (3)$$

Pgen = 987 MW

PF = 0.9

θ = 25.8

$\tan\theta = 0.484$

Qstation = 478 MVAR

Qload = 650 MVAR

Q transformers = 229.73 MVAR

Thus

Qrps = 336.69 MVAR approximately

Qeconomical = Qload – Qrps

= 650 MVAR – 336 MVAR

= 313.31 MVAR

This is the economical reactive power received by loads from the network. To calculate the economical power factor, we recall the equation:

$$P.F.econ = \cos[\tan^{-1}(Q_{econ} / P_{load})]$$

$$= \cos[\tan^{-1}(313.31/988)]$$

$$= 0.953$$

Table 5.5 below indicates the new S for Ramallah primary configuration Ram-1, based on the economical power factor calculations:

Table (5.5): New S for Ramallah scenario

Govern-orates	Pmax	Qold	Qnew	Q rps	Q std	Q stn	New S
Jenin	57.9	43.4	18.35	25.7	6×4	19.42	57.9+J19.42
Tubas	16.9	10.46	5.35	5.11	2.9×2	4.66	16.9+J4.66
Tulkarem	67.2	50.4	21.3	29.1	6×5	20.4	67.2+J20.4
Qalqelia	30.5	22.8	9.66	13.215	6×2	10.875	30.5+J10.87
Nablus	120.4	74.52	38.16	36.36	6×6	38.52	120.4+J38.52
Salfit	12	10.2	3.8	6.4	6×1	4.2	12+J4.2
Ramalla	170.8	105.7	54.14	51.56	6×8+2.9	54.8	170.8+J54.8
Jericho	32	19.8	10.14	9.66	6+2.9	10.9	32+J10.9
Jerusalem	209.2	129.49	66.32	63.17	6×10+2.9	66.59	209.2+J66.59
Beithlehem	117.3	72.61	37.18	35.42	6×5+2.9	39.7	117.3+J39.7
Hebron	178.7	110.62	56.64	53.98	6×8+2.9	59.7	178.7+J59.7
Total							1013+J329.8

Note: Qnew is based on PFecono of 0.953

Table 5.6 below is a summary of Ramallah primary configuration Ram-1;

Table (5.6): Summary of Ram-1

Line	Power flow	Distan-ce km	Length of T.L km	No of two winding trans	No of three winding trans	Calculated voltages kV	Design voltages kV
Ram-Jer	32+J10.9	35	35×2	1	1	104	230
Ram-Jsm	505.2+J165.99	18	18×2	1	-	174.8	230
Jsm-BL	296+J99.4	10.3	10.3×2	1	-	132.47	230
BL-Heb	178.7+J59.7	16.5	16.5×2	1	-	150.26	230
Ram-Sal	304.9+J98.07	24	24×2	1	-	185.59	230
Sal-Nab	292.9+J93.87	28	28×2	-	1	172.68	230
Nab-Tkm	97.7+J31.275	25	25×2	1	-	148.11	230
Tkm-Qal	30.5+J10.875	25	25×2	1	-	99.03	230
Nab-Tub	74.8+J24.08	20	20×2	1	-	130.8	132
Tub-Jen	57.9+J19.42	29	29×2	1	-	121.11	132
Total			461.6	9	2		

These corrected loads are carried for the next chapter, where all configurations of all scenarios are examined for further analysis.

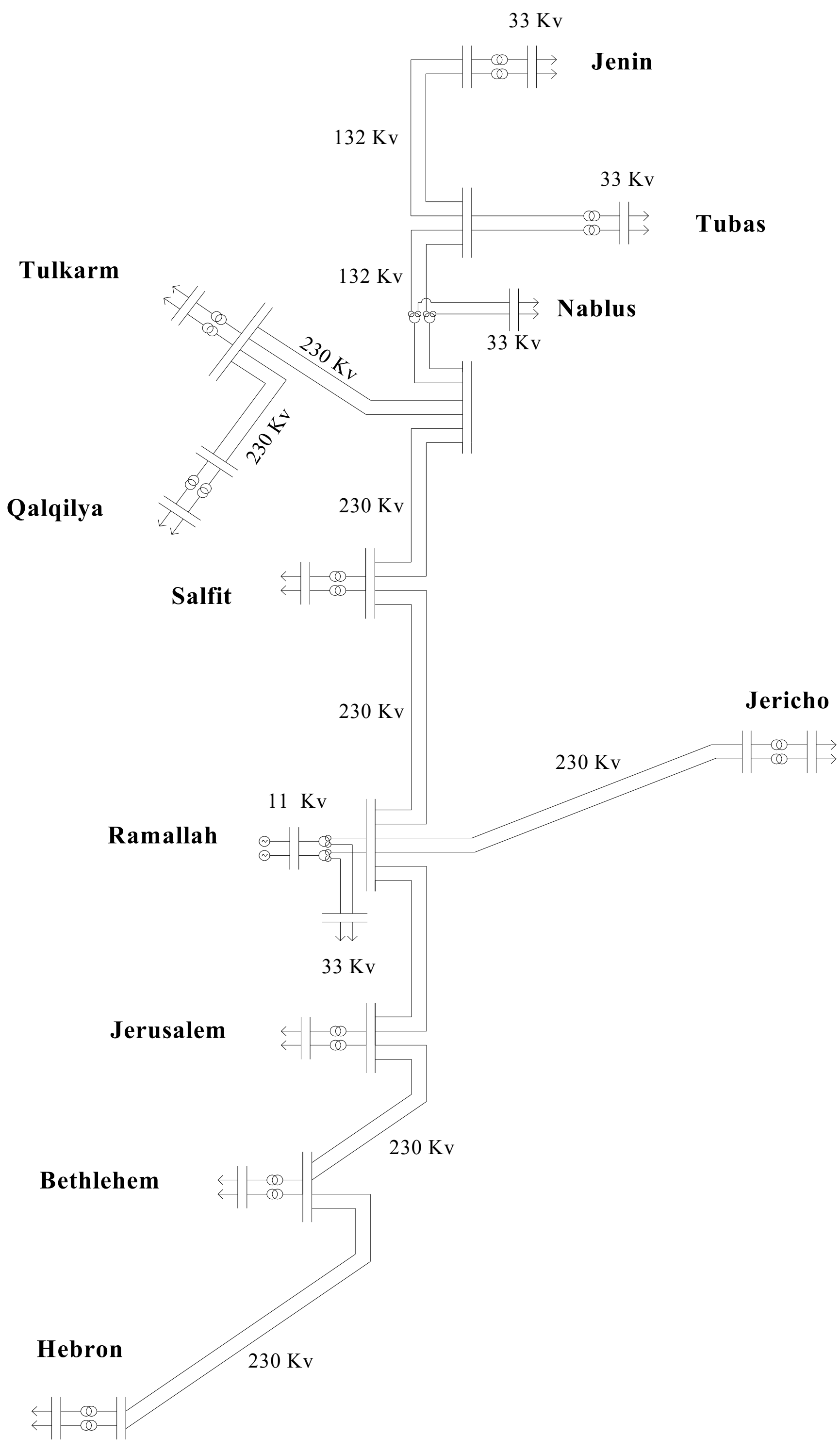

33 Kv
Jenin
132 Kv
33 Kv
Tubas
Tulkarm
132 Kv
Nablus
33 Kv
230 Kv
230 Kv
Qalqilya
230 Kv
Salfit
230 Kv
Jericho
230 Kv
11 Kv
Ramallah
33 Kv
Jerusalem
Bethlehem
230 Kv
Hebron
230 Kv

Fig. (5.3): Ram-1

Chapter 6
Primary choice of configurations

In order to find the the optimum configuration of the suggested network, five more configurations are designed and studied for every scenario. Thus every scenario will have six configurations including the primary radial one. Figure 6.1 below indicates all configurations for scenario A - Jericho

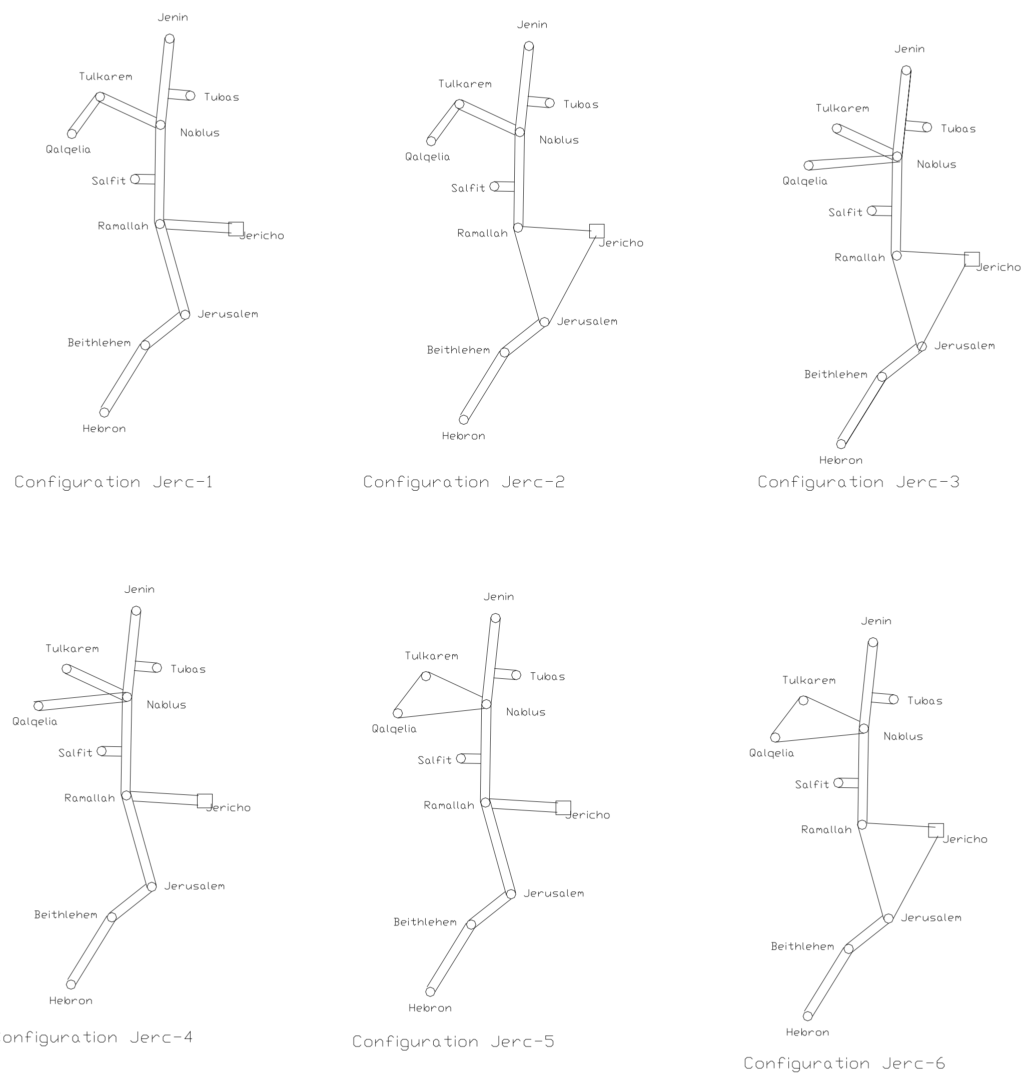


Fig. (6.1): Scenario A - Jericho

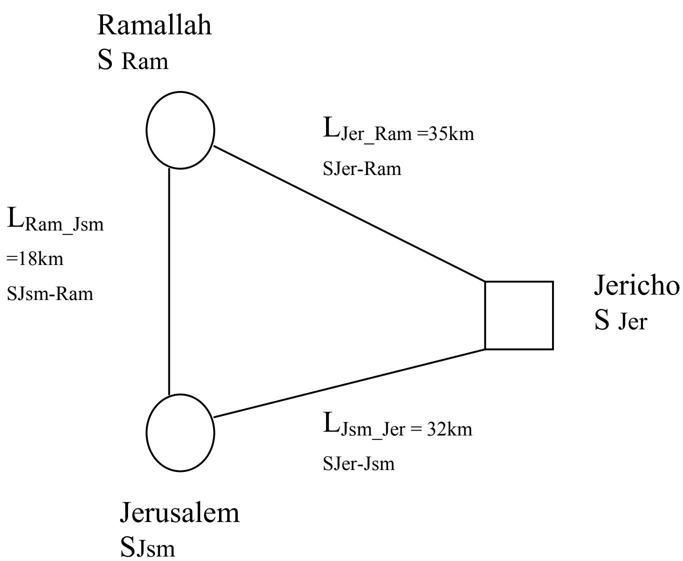
6-1 Scenario A– Jericho,

6-1-1 Configuration Jer-2

In this configuration, a ring is introduced in the south between Jericho, Ramallah, and Jerusalem as shown in fig 6.2.

Here, the following nodal equation is used to calculate power flow in the ring.

$S_{Jer-Rm} = \{S_{Rm}\ [L_{Rm-Jsm}+L_{Jsm-Jer}] + S_{Jsm}\ [L_{Jsm-Jer}]\} / \{L_{Jer-Rm}+L_{Rm-Jsm}+L_{Jsm-Jer}\}$ ……………………………..(4)



=470.01 + J 146.03 MVA

$S_{Jer-Jsm}$ =510.89 + J 157.59 MVA

$S_{Jsm-Ram}$ =5.69 + J3.78 MVA

The rest of branches power flow is found according to KCL.

Using equation (2) branches voltage are calculated and reflected in table 16.

Table 6.1 includes a summary of power flow, transmission line length and number of transformers for this configuration.

Table (6.1): Summary of Jer-2

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated Voltages kV	Design voltages kV
Jer- Ram	470 +J146	35	35×1	-	1	225.85	230 kv
Jer – Jsm	510.9+J157.6	32	32×1	-	-	220.76	230 kv
Ram- Jsm	5.69 + J 3.78	18	18×1	-	-	Ditto	230 kv
Jsm - BL	296+J90.32	10.3	10.32×2	1	-	132.47	230 kv
BL- Heb	178.7+J53.72	16.5	16.5×2	1	-	150.26	230 kv
Ram - Sal	304.9+J98	24	24 ×2	1		185.59	230 kv
Sal - Nab	292.9+J93.87	28	28×2	-	-	172.68	230 kv
Nab- Tkm	97.7+J31.27	25	25×2	1	1	148.11	230 kv
Tkm - Qal	30.5+J10.87	25	25×2	1	-	9.031	230 kv
Nab -Tub	74.8+J24.08	20	20×2	1	-	130.83	132 kv
Tub - Jen	57.9+J19.42	29	29×2	1	-	121.11	132 kv
Total		262.8	440.6	7	2		

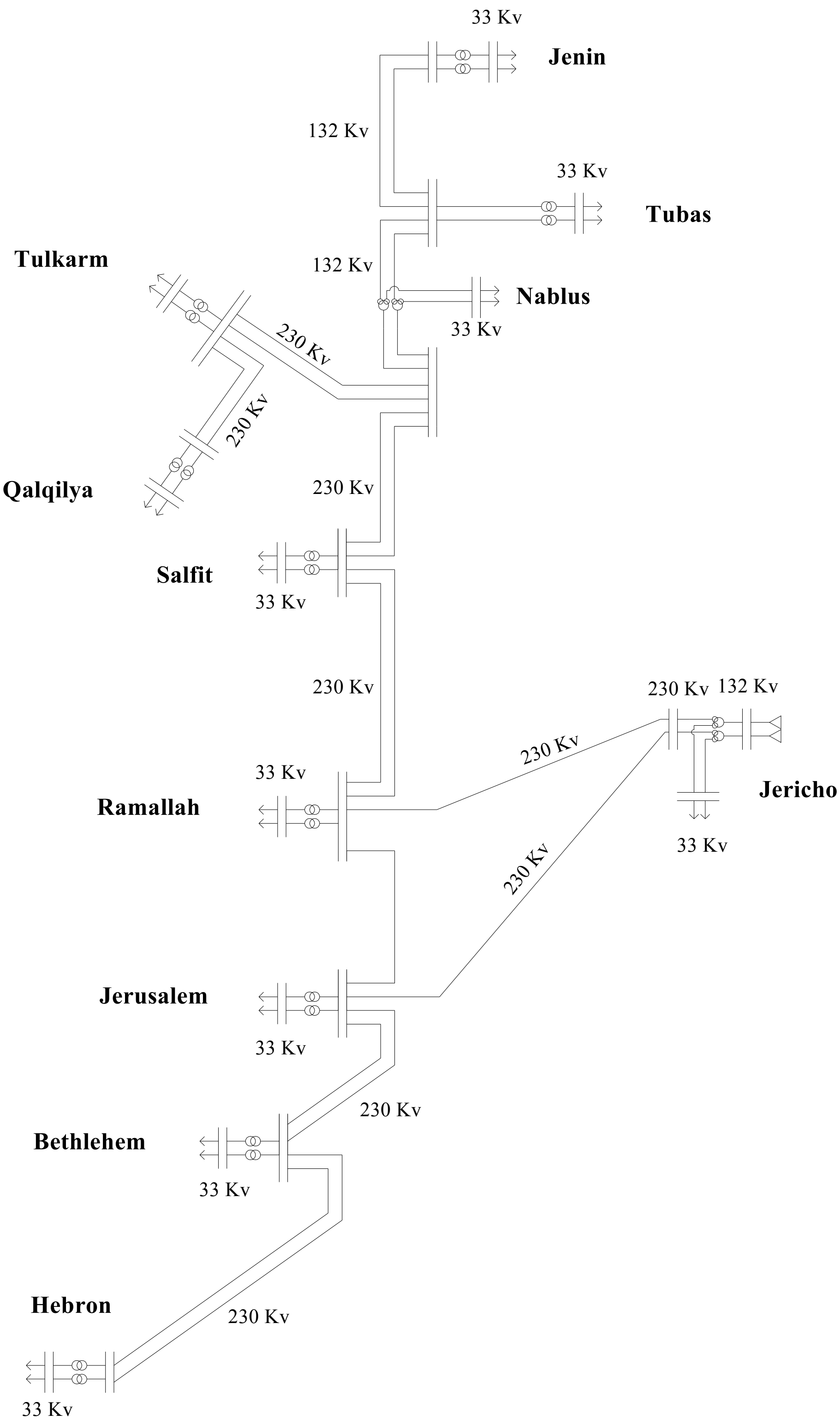

33 Kv
Jenin
132 Kv
33 Kv
Tubas
Tulkarm
132 Kv
Nablus
33 Kv
230 Kv
230 Kv
Qalqilya
230 Kv
Salfit
33 Kv
230 Kv
230 Kv
132 Kv
230 Kv
33 Kv
Jericho
Ramallah
33 Kv
230 Kv
Jerusalem
33 Kv
230 Kv
Bethlehem
33 Kv
Hebron
230 Kv
33 Kv

Fig. (6.2): Jer-2

6-1-2 Configuration Jer-3

This configuration has a ring in the south, but Qalqelia and Tulkarem are supplied from Nablus with separate overhead lines, as shown in Fig 6.3 on the following page .

Power flow for all branches were calculated, and plugged into equation (2), the calculated voltages are reflected into table 6.2.

Table (6.2): Summary of Jer-3

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated Voltages kV	Design voltages
Jer- Ram	470+J146	35	35×1	1	1	225.85	230 kv
Jer – Jsm	510.9+J157.6	32	32×1	1	-	220.76	230 kv
Jsm – BL	296+J90.32	10.3	10.3×2	1	-	132.47	230 kv
BL-Heb	178.7+J53.72	16.5	16.5×2	1	-	150.26	230 kv
Ram-Sal	304.9+J98.08	24	24×2	1	-	185.59	230 kv
Sal-Nab	292.9+J93.87	28	28×2	-	1	172.68	230 kv
Nab-Tub	74.8+J24.08	20	20×2	1	-	130.83	132 kv
Tub-Jen	57.9+J19.42	29	29×2	1	-	121.11	132 kv
Nab- Tkm	67.2+J20.4	25	25×2	1	-	132.22	230 kv
Nab-Qal	30.5+J10.87	31	31×2	1	-	100.97	230 kv
Ram - Jsm	5.69+J3.78	18	18×1	-	-	Ditto	230 kv
Total			452.6	9	2		

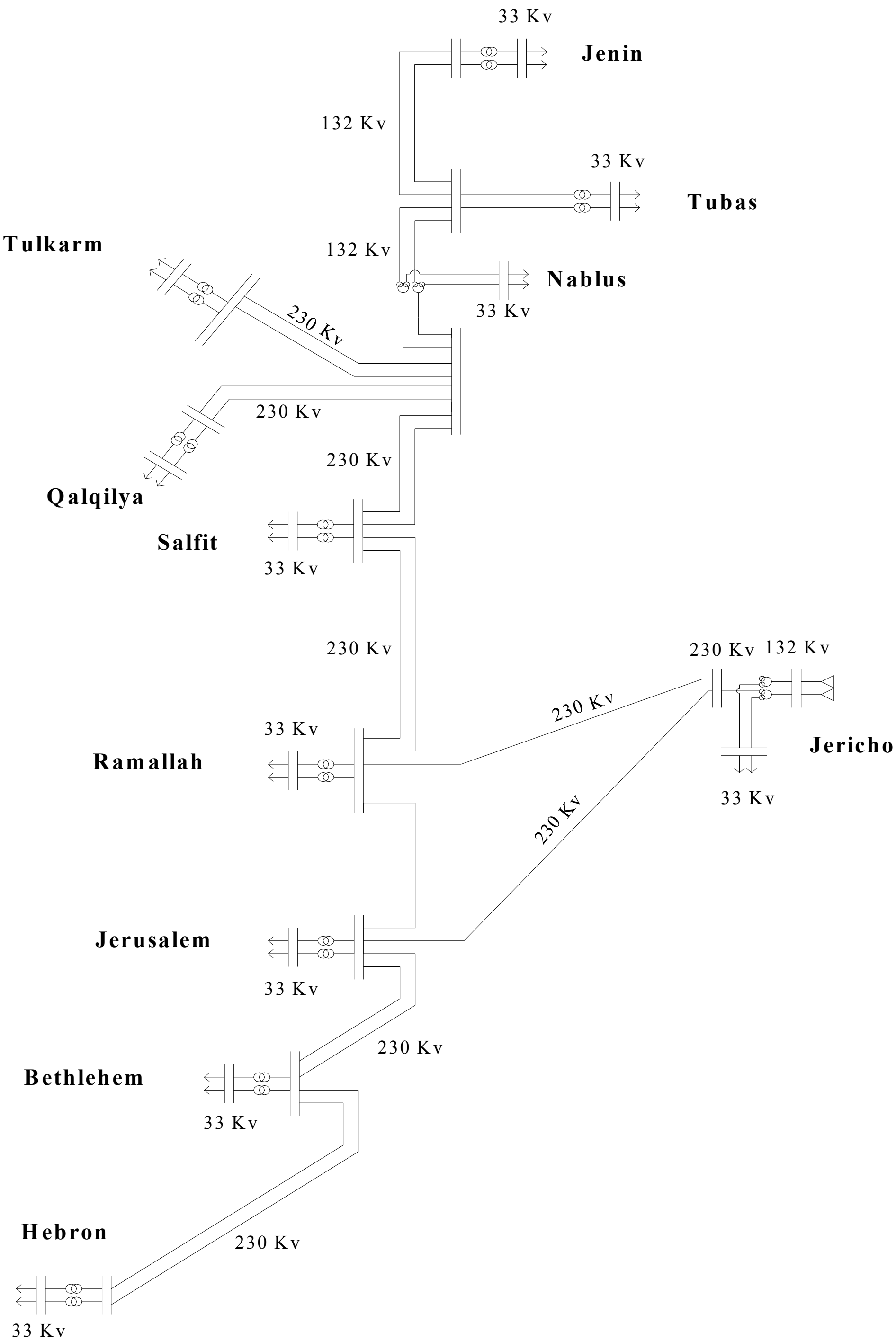

33 Kv
Jenin
132 Kv
33 Kv
Tubas
Tulkarm
132 Kv
Nablus
33 Kv
230 Kv
230 Kv
230 Kv
Qalqilya
Salfit
33 Kv
230 Kv
230 Kv
132 Kv
230 Kv
33 Kv
Ramallah
Jericho
33 Kv
230 Kv
Jerusalem
33 Kv
230 Kv
Bethlehem
33 Kv
Hebron
230 Kv
33 Kv

Fig. (6.3): Jer-3

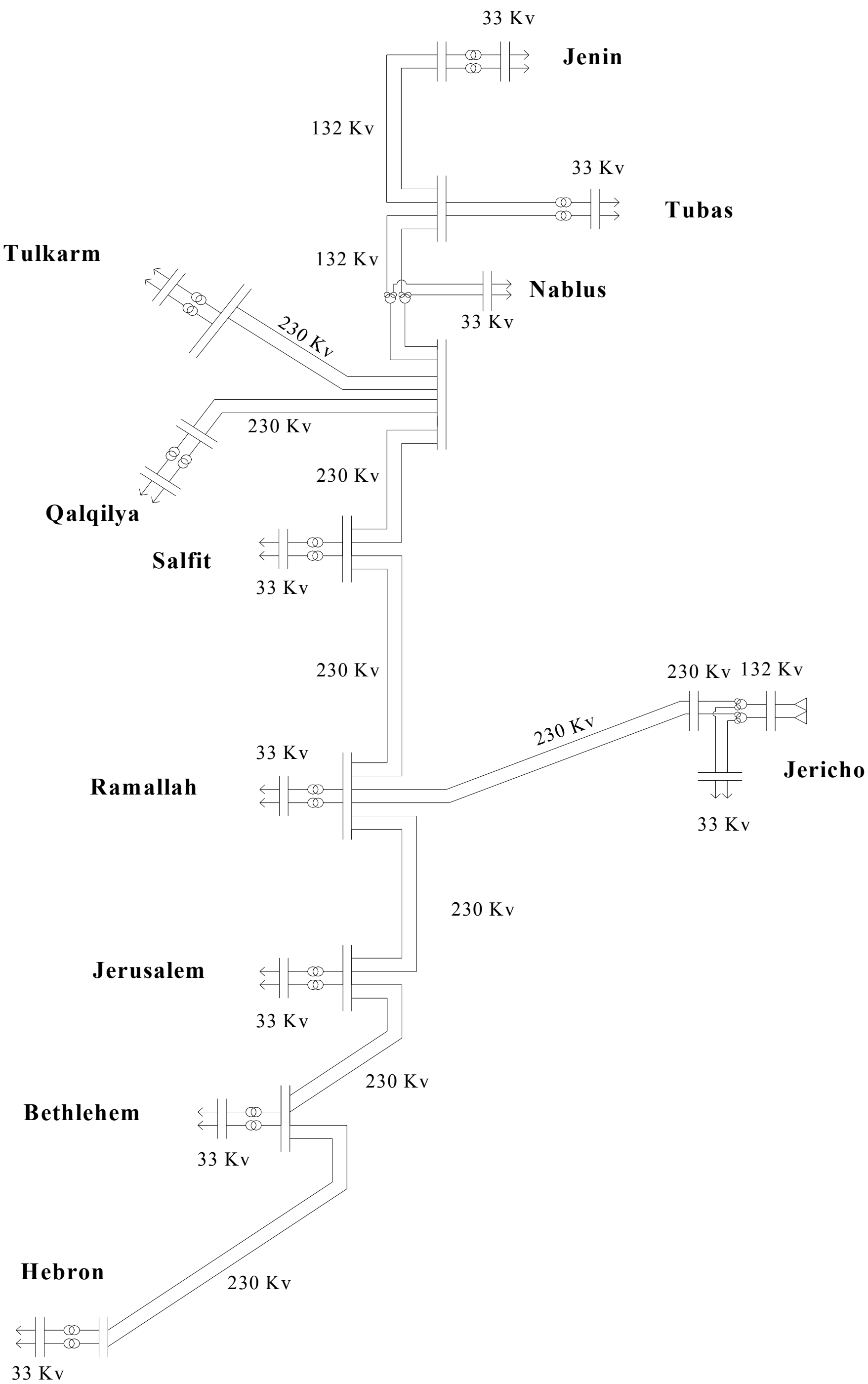
6-1-3 Configuration Jer-4

As shown in Fig 6.4, this configuration has no rings, and power flow is calculated according to KCL easily.

The voltages of the branches are calculated from equation (2) and reflected in table 6.3 below.

Table (6.3): Summary of Jer-4

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated voltages kV	Design voltages kV
Jer – Ram	980.9+J303.6	35	35×2	1	1	243	230 kv
Ram - Jsm	505.2+J153.8	18	18×2	1	-	174.8	230 kv
Jsm - BL	296+J90.32	10.3	10.3×2	1	-	132.47	230 kv
BL - Heb	178.7+J53.72	16.5	16.5×2	1	-	150.26	230 kv
Ram – Sal	304.9+J98.07	24	24×2	1	-	185.59	230 kv
Sal – Nab	292.9+J93.87	28	28×2	-	1	172.68	230 kv
Nab – Tub	74.8+J24.08	20	20×2	1	-	130.83	132 kv
Tub – Jen	57.9+J19.42	29	29×2	1	-	121.11	132 kv
Nab –Tkm	67.2+J20.4	25	25×2	1	-	132.22	230 kv
Nab – Qal	30.5+J10.87	31	31×2	1	-	100.97	230 kv
Total			473.6	9	2		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Jenin
132 Kv
33 Kv
Tubas
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132 Kv
Nablus
33 Kv
230 Kv
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Qalqilya
Salfit
33 Kv
230 Kv
230 Kv
132 Kv
230 Kv
33 Kv
Ramallah
Jericho
33 Kv
230 Kv
Jerusalem
33 Kv
230 Kv
Bethlehem
33 Kv
Hebron
230 Kv
33 Kv

Fig. (6.4): Jer-4

6-1-4 Configuration Jer-5

In this configuration, a ring in the north is introduced between Nablus, Tulkarem and Qalqelia. The rest of branches are radial, as shown in Fig 6.5.

Ring branches power flow is calculated from the following nodal equation:

S_{Nab-Tm}={S_{Tm}[LTm-Qal+LQal-Nab]+S_{Qal}[LQal-Nab]}/{LNab-Tm+LTm-Qal+LQal-Nab}

= 58.132 + J 18.266 MVA

The same nodal equation is used to calculate power flow from Nablus

to Qalqelia,

$S_{Nab-Qal}$ = 39.568 +J 13.01 MVA

Using KCL yields

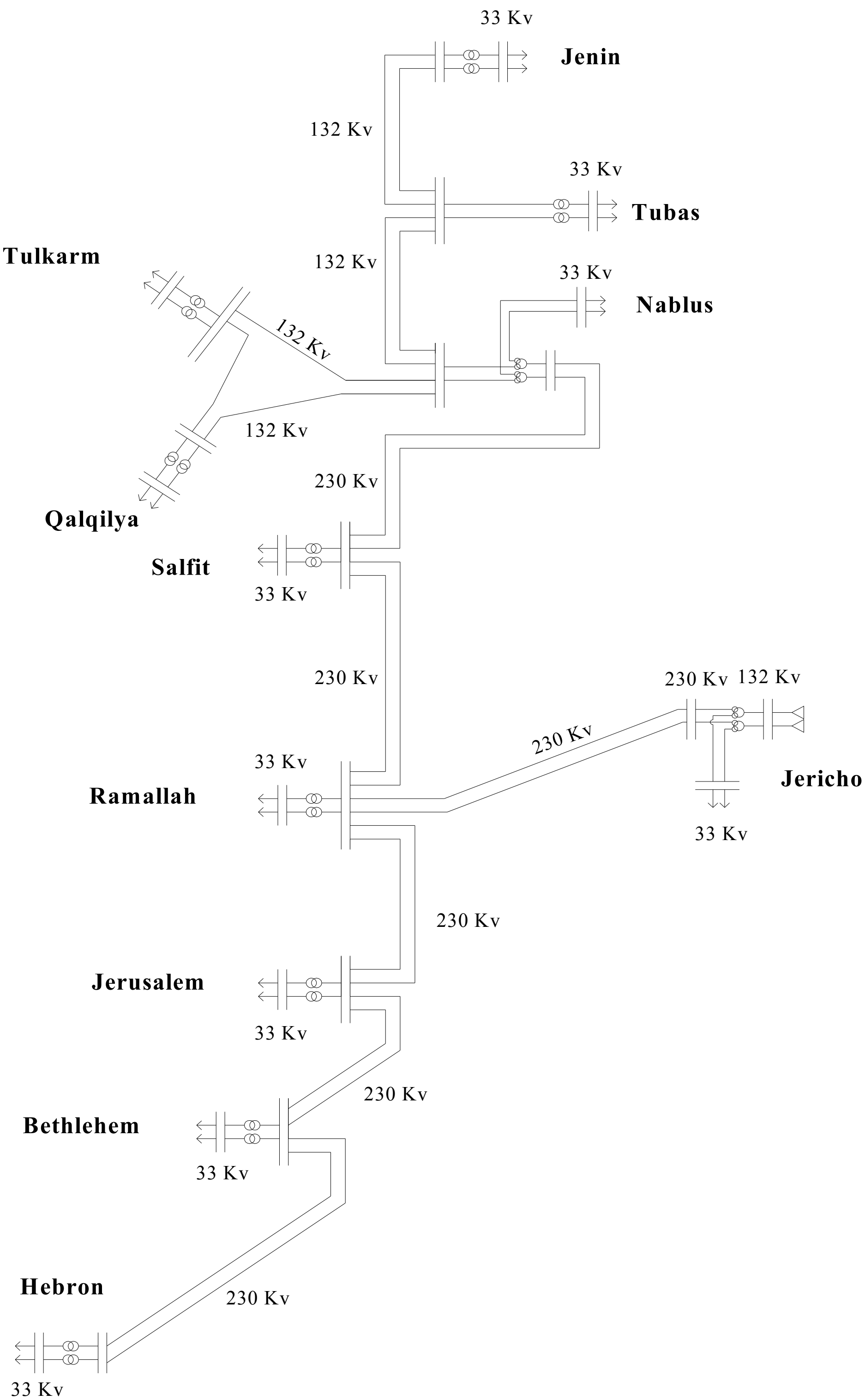
$S_{Qal-Tkm}$= 9.068 +J 2.135 MVA

The rest of branches power flow, are calculated from KCL.

Using equation (2) the branches voltage are calculated and reflected in table 6.4.

Table (6.4): Summary of Jer-5

Line	Power flow	Distance km	Length of T.L.	No of two winding trans	No of three winding trans	Calculated Voltages kV	Design voltages kV
Jer - Ram	980.9+J303.62	35	35×2	1	1	243	230 kv
Ram - Jsm	505.2+J153.81	18	18×2	1	-	174.8	230 kv
Jsm - BL	296+J90.32	10.3	10.3×2	1	-	132.47	230 kv
BL - Heb	178.7+J53.72	16.5	16.5×2	1	-	150.26	230 kv
Ram - Sal	304.9+J98.07	24	24×2	1	-	185.59	230 kv
Sal - Nab	292.9+J93.87	28	28×2	-	1	172.68	230 kv
Nab - Tub	74.8+J24.08	20	20×2	1	-	130.83	132 kv
Tub - Jen	57.9+J19.42	29	29×2	1	-	121.11	132 kv
Nab-Tkm	58.1+J18.2	25	25×1	1	-	125.98	132 kv
Nab - Qal	39.57+J13.01	31	31×1	1	-	112.29	132 kv
Qal - Tkm	9.06+J2.135	25	25×1	-	-	Ditto	132 kv
Total			442.6	9	2		


33 Kv
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Tulkarm
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33 Kv
Nablus
132 Kv
132 Kv
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Qalqilya
Salfit
33 Kv
230 Kv
230 Kv
132 Kv
230 Kv
33 Kv
Jericho
Ramallah
33 Kv
230 Kv
Jerusalem
33 Kv
230 Kv
Bethlehem
33 Kv
Hebron
230 Kv
33 Kv

Fig. (6.5): Jer-5

6-1-5 Configuration Jer-6

Two rings are introduced in this configuration. One in the north between Nablus, Tulkarem, and Qalqelia and one in the south between Jericho, Ramallah and Jerusalem, as shown in Fig 6.6. Power flow is calculated in the rings using nodal equations and in radial connections using KCL, then equation 2 is used to calculate branches voltage. The results are reflected in table 6.5 below.

Table (6.5): Summary of Jer-6

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated voltages kV	Design voltages kV
Jer - Ram	470.01+J146.03	35	35×1	1	1	225.85	230 kv
Jer - Jsm	510.89+J157.59	32	32×1	1	-	220.76	230 kv
Ram-Jsm	5.69+J3.78	18	18×1	-	-	Ditto	230 kv
Jsm - BL	296+J90.32	10.3	10.3×2	1	-	132.47	230 kv
BL-Heb	178.7+J53.72	16.5	16.5×2	1	-	150.26	230 kv
Ram-Sal	304.9+J98.08	24	24×2	1	-	185.59	230 kv
Sal-Nab	292.9+J93.87	28	28×2	-	1	172.68	230 kv
Nab-Tub	74.8+J24.08	20	20×2	1	-	130.83	132 kv
Tub-Jen	57.9+J19.42	29	29×2	1	-	121.11	132 kv
Nab-Tkm	58.1+J18.2	25	25×1	1	-	125.98	132 kv
Nab-Qal	39.5+J13.01	31	31×1	1	-	112.29	132 kv
Qal-Tkm	9.06+J2.1	25	25×1	-	-	Ditto	132 kv
Total			421.6	9	2		

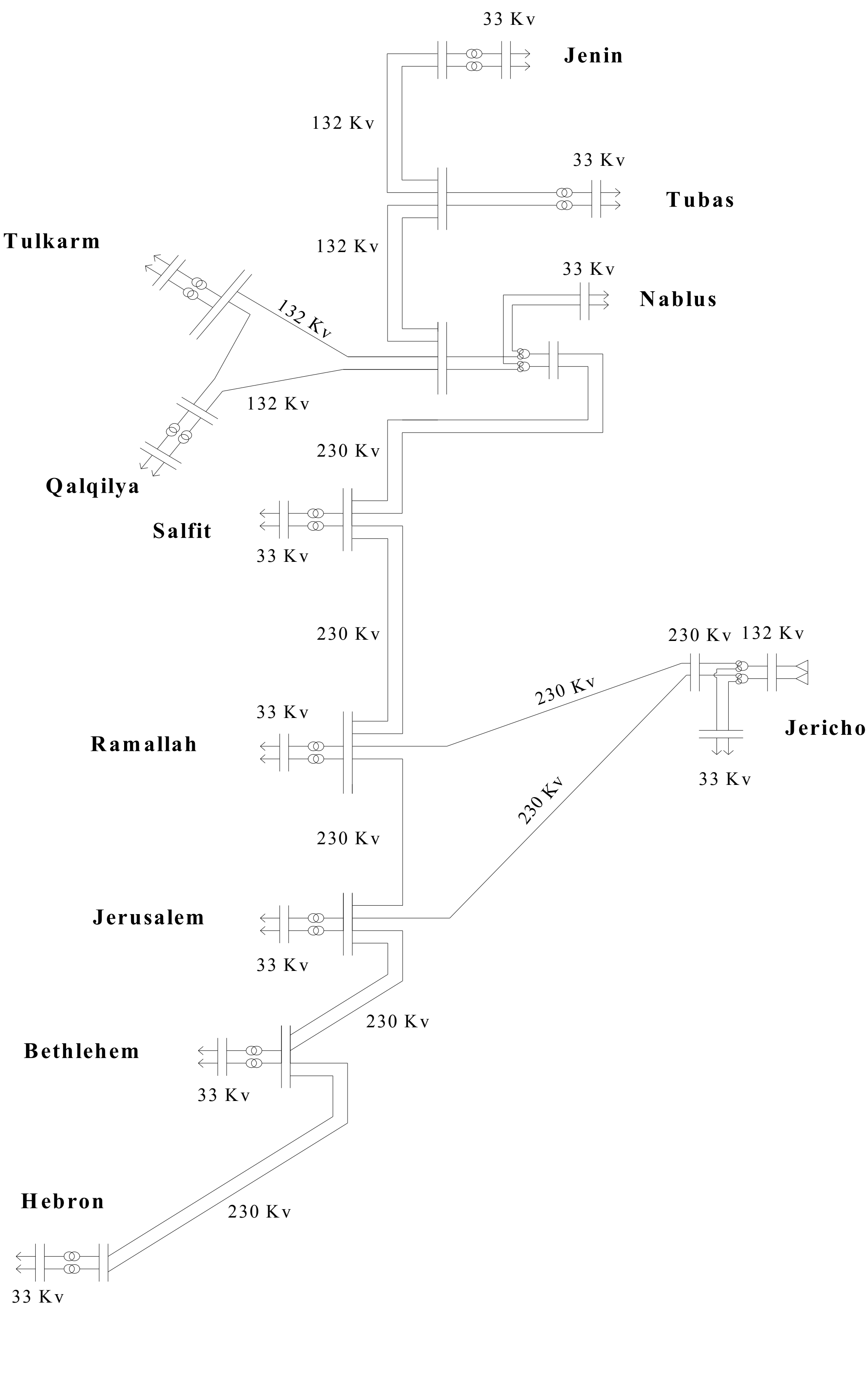

33 Kv
Jenin
132 Kv
33 Kv
Tubas
Tulkarm
132 Kv
33 Kv
Nablus
132 Kv
132 Kv
230 Kv
Qalqilya
Salfit
33 Kv
230 Kv
230 Kv
132 Kv
230 Kv
33 Kv
Ramallah
Jericho
33 Kv
230 Kv
230 Kv
Jerusalem
33 Kv
230 Kv
Bethlehem
33 Kv
Hebron
230 Kv
33 Kv

Fig. (6.6): Jer-6

Summary of Scenario A- Jericho

Table 6.6 summarizes all the total length of transmission lines, and the number of transformers in each configuration, to help identify and select the configuration with least cost.

Table (6.6): Summary of scenario A configurations

Config	Distance km	Length of T.L. km	Voltage kV	Two winding trans	Voltage ratio	three winding trans	Voltage ratio
1 Jer-1	49	49×2	132	2	132/33	1	132/33/230
	181.8	181.8×2	230	7	230/33	1	230/33/132
Total		461.6					
2 Jer-2	49	98	132	2	132/33	1	132/230/33
	213.8	342.6	230	7	230/33	1	230/33/132
Total		440.6					
3 Jer-3	49	98	132	2	132/33	1	230/132/33
	219.8	354.6	230	7	230/33	1	132/33/230
Total		452.6					
4 Jer-4	49	98	132	2	132/33	1	230/132/33
	187.8	375.6	230	7	230/33	1	132/33/230
Total		473.6					
5 Jer-5	130	179	132	4	132/33	1	132/230/33
	131.8	263.6	230	5	230/33	1	230/132/33
Total		442.6					
6 Jer-6	130	179	132	4	132/33	1	132/33/230
	163.8	242.6	230	5	230/33	1	230/132/33
Total		421.6					

The configurations with least number of transformers and transmission lines length in all ring and all radial configurations will be selected. This implies that configuration Jer-6 (Ring) and configuration Jer-1(Radial) will be chosen for further economical analysis.

6-2 Scenario B– Jericho/Nablus

In this scenario, a generating plant at Nablus and a connection to the Jordanian grid at Jericho is suggested. This scenario is designed and considered with the same configurations used with Scenario-A in order to determine the shortest length of transmission lines and least number of transformers.

Fig. (6.7): Scenario- B Jer/Nab

6-2-1 Configuration Jer/Nab-2

This configuration is shown in Fig 6.8. The power flow is calculated in every branch and used to calculate the voltages in the branches using equation 2.

Table 22 reflects the calculated voltages, length of transmission lines, and number of required transformers.

Table (6.7): summary of Jer/Nab-2

Line	Power flow	Distance km	Length of T.L.	No of two winding trans	No of three winding trans	Calculated voltages kV	Design voltages kV
Tub-Jen	57.9+J19.42	29	29×2	1	-	128.65	230
Nab-Tub	74.8+J26.98	20	20×2	1	1	130.83	230
Nab-Tkm	97.7+J34.4	25	25×2	1	-	148.11	230
Tkm-Qal	30.5+J10.875	25	25×2	1	-	99.03	230
Nab-Sal	167.1+J119.6	28	28×2	1	-	174.5	230
Sal-Ram	155.1+J115.5	24	24×2	1	-	164.5	230
Jer-Ram	199.42+J29.61	35	35×2	-	1	193.09	230
Jer-Jsm	321.48+J81.53	32	32×1	1	-	206.72	230
Jsm-BL	296+J99.4	10.3	10.3×2	1		132.47	230
BL-Heb	178.7+J59.7	16.5	16.5×2	1		150.26	230
Ram-Jsm	183.7+J87.37	18	18×1	-	-	Ditto	230
Total		262.8	440.6	9	2		

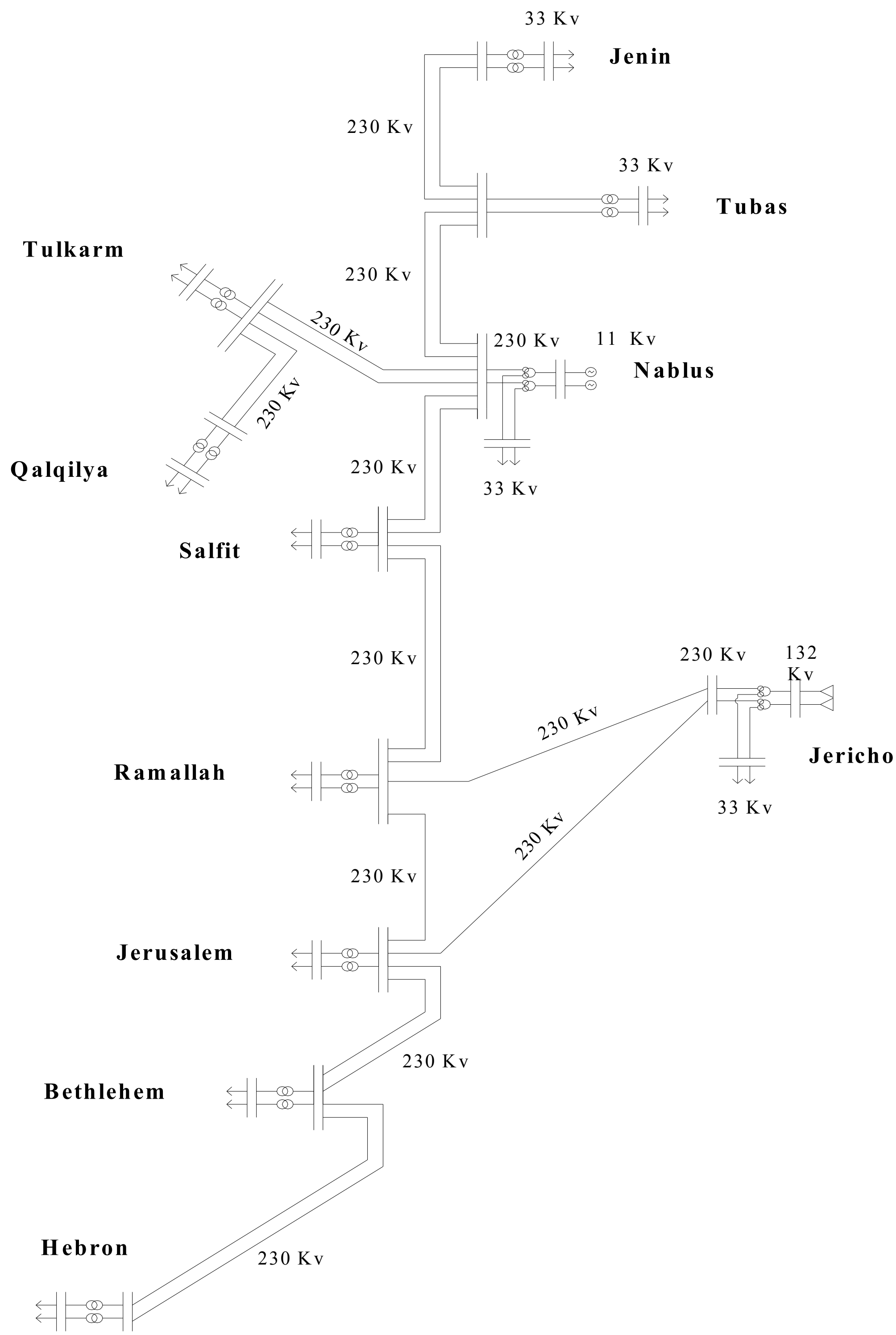


Fig. (6.8): Jer/Nab-2

6-2-2 Configuration Jer/Nab-3

This configuration is shown in Fig 6.9. The power flow in every branch is calculated and used to calculate the voltages of branches using equation 2. Calculated voltages and other important information are reflected in table 6.8.

Table (6.8): Summary of Jer/Nab-3

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated voltages kV	Design voltages kV
Tub-Jen	57.9+J19.42	29	29×2	1	-	128.65	230
Nab-Tub	74.8+J26.98	20	20×2	1	1	130.83	230
Nab-Tkm	67.2+J23.5	25	25×2	1	-	132.22	230
Nab-Qal	30.5+J10.875	31	31×2	1	-	100.97	230
Nab-Sal	167.1+J119.6	28	28×2	1	-	174.5	230
Sal-Ram	155.1+J115.5	24	24×2	1	-	164.5	230
Jer-Ram	199.42+J29.61	35	35×1	-	1	193.09	230
Jer-Jsm	321.48+J81.53	32	32×1	1	-	206.72	230
Jsm-BL	296+J99.4	10.3	10.3×2	1	-	132.47	230
BL-Heb	178.7+J59.7	16.5	16.5×2	1	-	150.26	230
Ram-Jsm	183.7+J87.37	18	18×1	-	-	Ditto	230
Total			452.6	9	2		

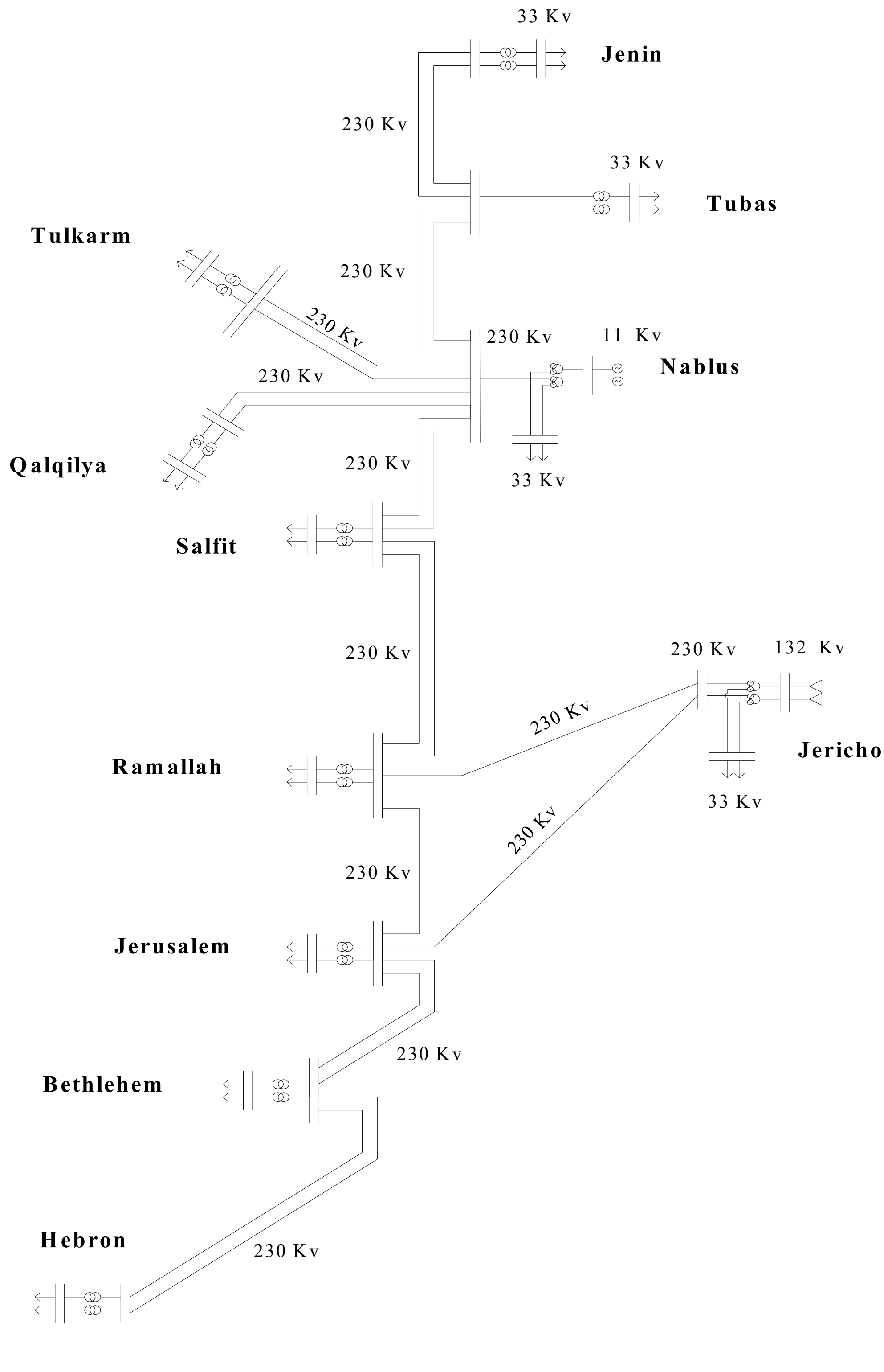


Fig. (6.9): Jer/Nab-3

6-2-3 Configuration Jer/Nab-4

This configuration is shown in Fig 6.10. The power flow in branches and accordingly the voltages are similar to that of the primary configuration except for Nab-Tkm and Nab-Qal branches. The results are listed in table 6.9 below.

Table (6.9): Summary of Jer/Nab-4

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated voltages kV	Design voltages kV
Tub-Jen	57.9+J19.42	29	29×2	1	-	128.65	230
Nab-Tub	74.8+J26.98	20	20×2	1	1	130.83	230
Nab-Tkm	67.2+J23.5	25	25×2	1	-	132.22	230
Nab-Qal	30.5+J10.875	31	31×2	1	-	100.97	230
Nab-Sal	167.1+J119.6	28	28×2	1	-	174.5	230
Sal-Ram	155.1+J115.5	24	24×2	1	-	164.5	230
Jer-Ram	520.9+J111.14	35	35×2	-	1	228.9	230
Ram-Jsm	505.2+J168.9	18	18×2	1	-	174.8	230
Jsm-BL	296+J99.4	10.3	10.3×2	1	-	132.47	230
BL-Heb	178.7+J59.7	16.5	16.5×2	1	-	150.26	230
Total		236.8	473.6	9	2		

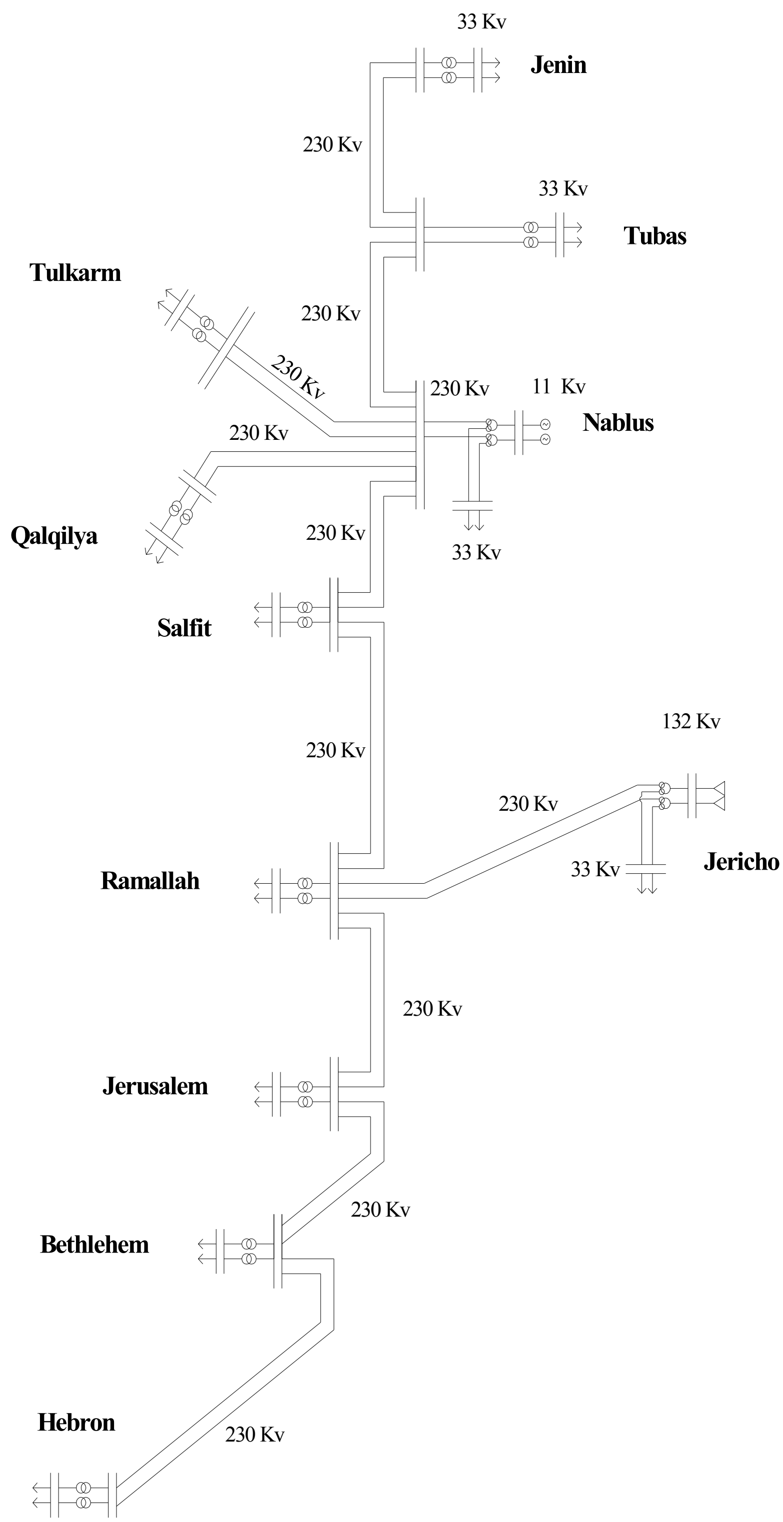


Fig. (6.10): Jer/Nab-4

6-2-4 Configuration Jer/Nab-5

This configuration is shown in Fig 6.11. In this configuration, a ring is introduced in the north between Tulkarem, Qalqelia and Nablus. Power flows are calculated and values used to calculate branches voltage.

Table (6.10): Summary of Jer/Nab-5

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated voltages kV	Design voltages kV
Tub-Jen	57.9+J19.42	29	29×2	1	-	128.65	230
Nab-Tub	74.8+J26.98	20	20×2	1	1	130.83	230
Nab-Tkm	58.13+J20.41	25	25×1	1	-	125.98	230
Nab-Qal	39.56+J13.96	31	31×1	1	-	112.29	230
Qal-Tkm	9.06+J3.091	25	25×1	-	-	Ditto	230
Nab-Sal	167.1+J119.6	28	28×2	1	-	174.5	230
Sal-Ram	155.1+J115.5	24	24×2	1	-	164.5	230
Jer-Ram	520.9+J111.14	35	35×2	-	1	228.9	230
Ram-Jsm	505.2+J168.9	18	18×2	1	-	174.8	230
Jsm-BL	296+J99.4	10.3	10.3×2	1	-	132.47	230
BL-Heb		16.5	16.5×2	1	-	150.26	230
Total			442.6	9	2		

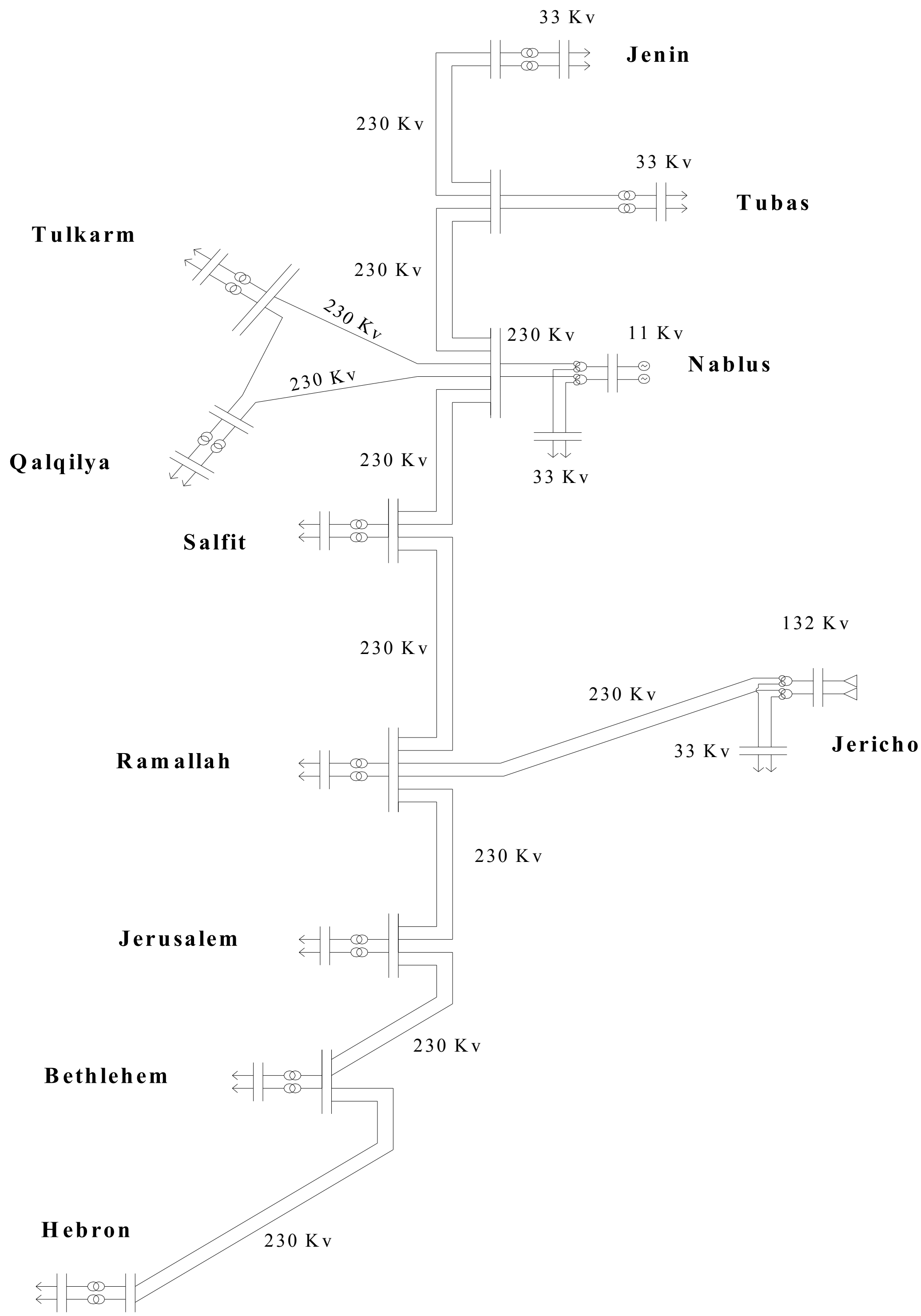


Fig. (6.11) Jer/Nab-5

6-2-5 Configuration Jer/Nab-6

This configuration is shown in Fig 6.12. Power flows and voltages are calculated. Voltages and other important information are figured in table 6.11.

Table (6.11): Summary of Jer/Nab-6

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated Voltages kV	Design voltages kV
Jer-Ram	199.42+J29.61	35	35×1	1	1	193.09	230
Jer-Jsm	321.4+J81.53	32	32×1	1	-	206.72	230
Ram-Jsm	183.72+j87.37	18	18×1	-	-	Ditto	230
Nab-Tkm	58.13+J20.41	25	25×1	1	-	125.98	230
Nab-Qal	39.56+J13.96	31	31×1	1	-	112.29	230
Qal-Tkm	9.06+J3.091	25	25×1	-	-	Ditto	230
Nab-Tub	74.8+J26.98	20	20×2	1	1	130.83	230
Tub-Jen	57.9+J19.42	29	29×2	1	-	128.65	230
Nab-Sal	167.1+J119.6	28	28×2	1	-	174.56	230
Sal-Ram	155.1+J115.5	24	24×2	1	-	164.51	230
Jsm-BL	296+J99.4	10.3	10.3×2	1	-	132.47	230
BL-Heb	178.7+J59.7	16.5	16.5×2	1	-	150.26	230
Total		293.8	421.6	9	2		

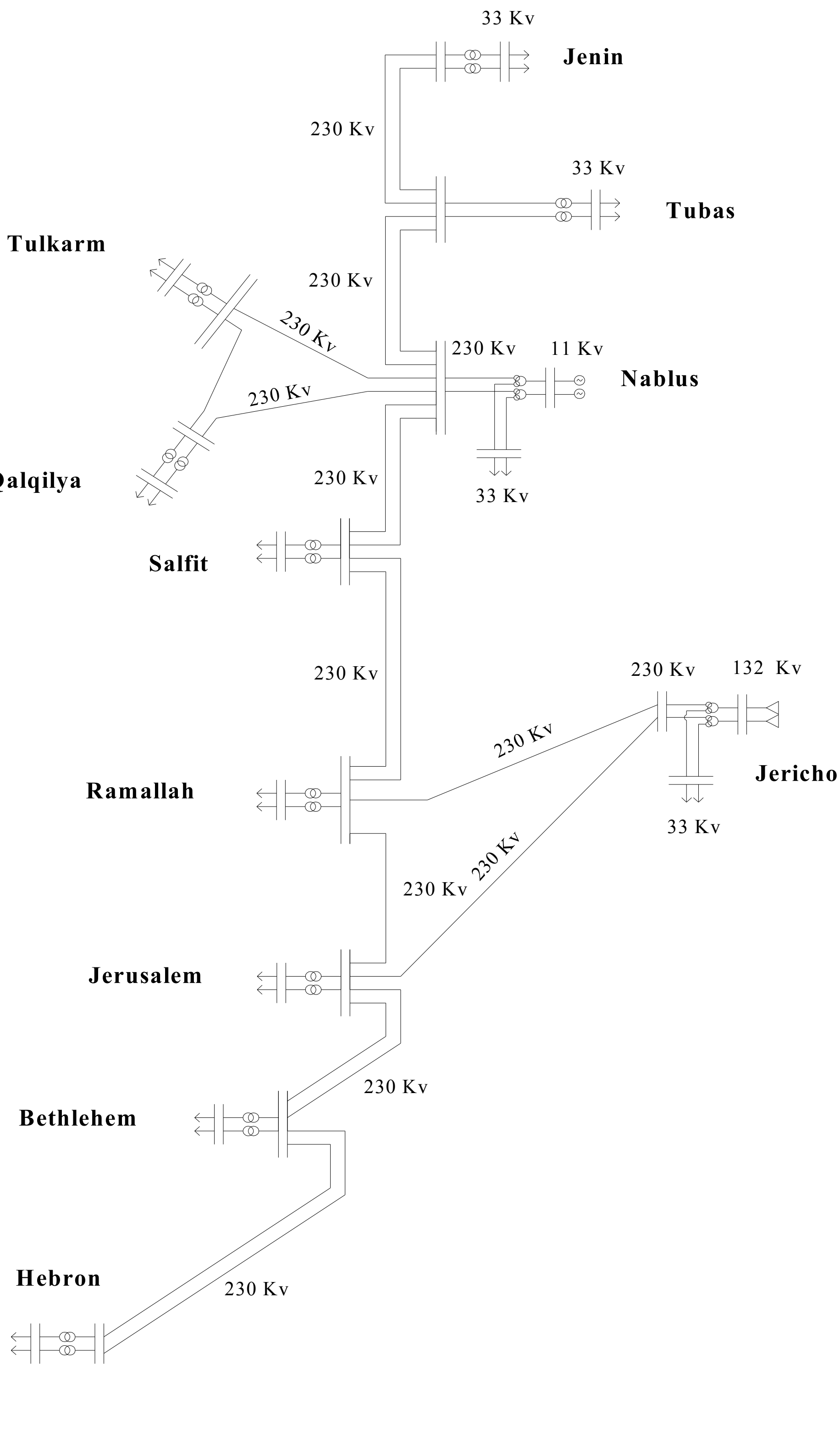


Fig. (6.12): Jer/Nab-6

Table 6.12 below summarizes all total length of transmission lines and number of transformers in all configurations of the scenario B-Nablus/Jericho, to help identify and select the configuration with least cost.

Table (6.12): Summary of scenario Nablus-Jericho configurations

Config	Distance km	Length of T.L. km	Voltage kV	Two wind trans	Voltage ratio	three wind trans	Voltage ratio
1 Jer/Nab-1	230.8	461.6	230	9	230/33	1 1	11/33/230 132/33/230
2 Jer/Nab-2	262.8	440.6	230	9	230/33	1 1	11/33/230 132/33/230
3 Jer/Nab-3	268.8	452.6	230	9	230/33	1 1	11/33/230 132/33/230
4 Jer/Nab-4	236.8	473.6	230	9	230/33	1 1	11/33/230 132/33/230
5 Jer/Nab-5	261.8	442.6	230	9	230/33	1 1	11/33/230 132/33/230
6 Jer/Nab-6	293.8	421.6	230	9	230/33	1 1	11/33/230 132/33/230

The configuration with the least cable length in all rings and all radials are selected. So, configuration Jer/Nab-6 (Ring) and configuration Jer/Nab-1 (Radial) are selected for further analysis.

6-3 Scenario C– Ramallah

In this scenario, the Palestinian network is connected to a generator (Power plant) at Ramallah. Same configurations applied to previous scenarios will be applied here to determine the configuration with least transmission lines length and least number of transformers.

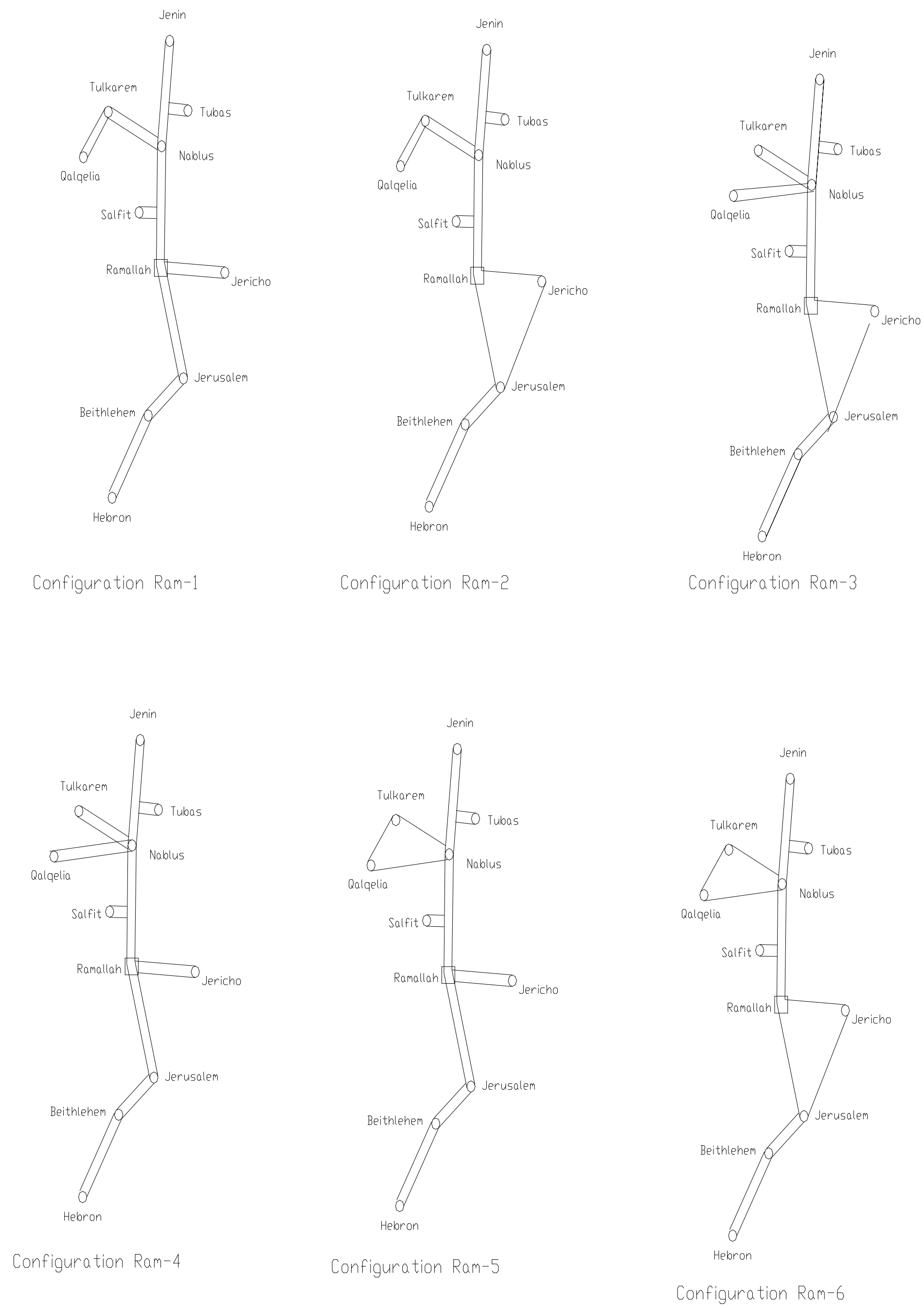


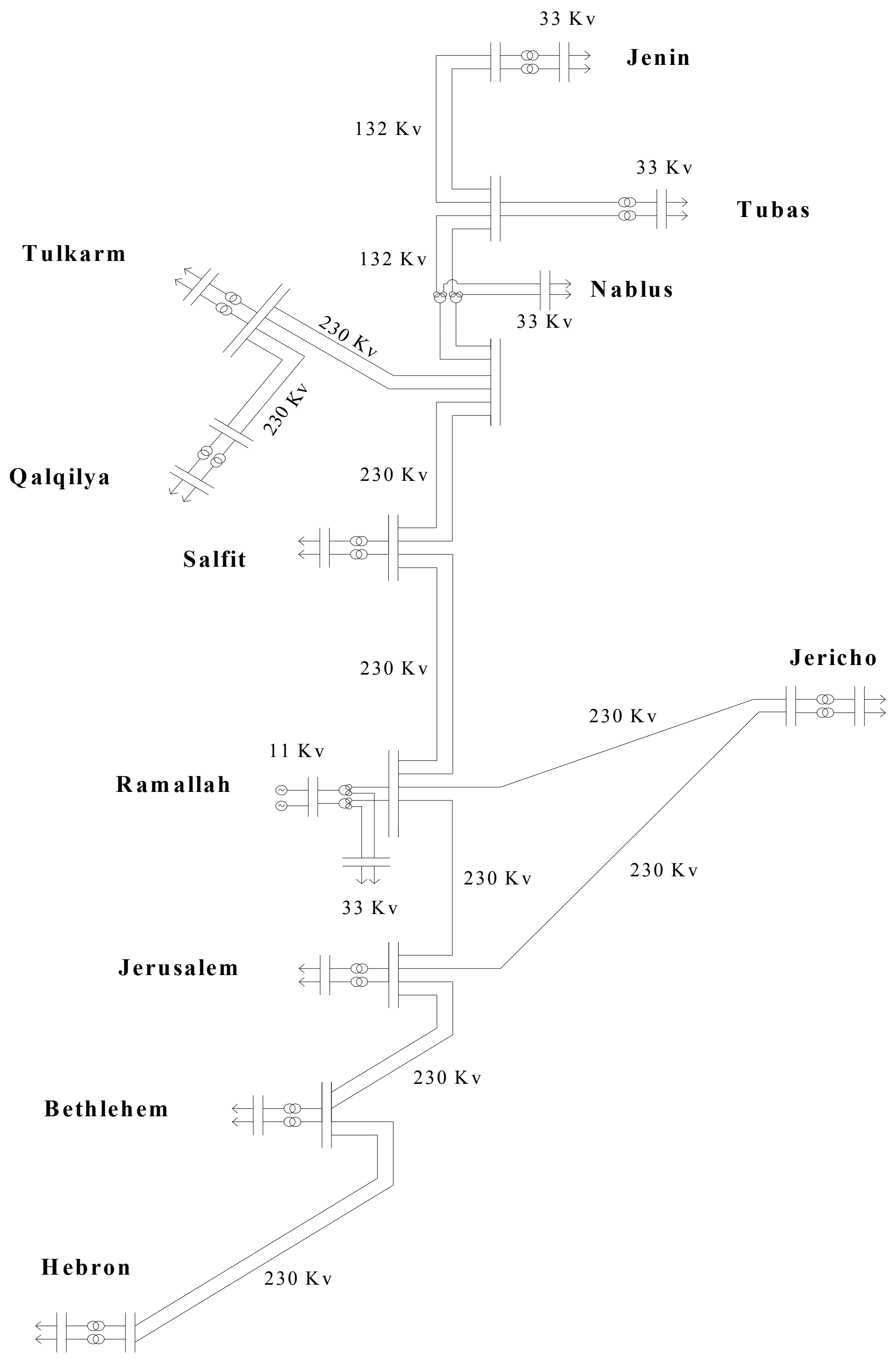
Fig. (6.13): Scenario C

6-3-1 Configuration Ram-2

This configuration is shown in Fig 6.14. Power flow and voltages are calculated. Voltages and other important information are reflected in table 6.13

Table (6.13): Summary of Ram-2

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated voltages kV	Design voltages kV
Ram-Jer	125.8+J41.56	35	35×1	1	1	171.1	230
Ram-Jsm	411.4+J135.32	18	18×1	1	-	171.87	230
Jsm-BL	296+J99.4	10.3	10.3×2	1	-	132.47	230
BL-Heb	178.7+J59.7	16.5	16.5×2	1	-	150.26	230
Ram-Sal	304.9+J98.07	24	24×2	1	-	185.59	230
Sal-Nab	292.9+J93.87	28	28×2	-	1	172.68	230
Nab-Tkm	97.7+J31.275	25	25×2	1	-	148.11	230
Tkm-Qal	30.5+J10.875	25	25×2	1	-	99.03	230
Nab-Tub	74.8+J24.08	20	20×2	1	-	130.8	132
Tub-Jen	57.9+J19.42	29	29×2	1	-	121.11	132
Jer-Jsm	93.8+J30.66	32	32×1	-	-		230
Total		262.8	440.6	9	2		



33 Kv
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132 Kv
33 Kv
Tubas
Tulkarm
132 Kv
Nablus
33 Kv
230 Kv
230 Kv
Qalqilya
230 Kv
Salfit
230 Kv
Jericho
230 Kv
11 Kv
Ramallah
230 Kv
230 Kv
33 Kv
Jerusalem
230 Kv
Bethlehem
Hebron
230 Kv

Fig. (6.14): Ram-2

6-3-2 Configuration Ram-3

This configuration is shown in Fig 6.15. Power flows and voltages are calculated. Voltages and other important information are reflected in table 6.14

Table (6.14): Summary of Ram-3

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated voltages kV	Design voltages kV
Nab-Tkm	67.2+J20.4	25	25×2	1	-	132.32	230
Nab-Qal	30.5+J10.875	31	31×2	1	-	100.97	230
Ram-Jer	125.8+J41.56	35	35×1	1	1	171.1	230
Ram-Jsm	411.4+J135.32	18	18×1	1	-	171.87	230
Jer-Jsm	93.8+J30.66	32	32×1	-	-		230
Jsm-BL	296+J99.4	10.3	10.3×2	1	-	132.47	230
BL-Heb	178.7+J59.7	16.5	16.5×2	1	-	150.26	230
Ram-Sal	304.9+J98.07	24	24×2	1	-	185.59	230
Sal-Nab	292.9+J93.87	28	28×2	-	1	172.68	230
Nab-Tub	74.8+J24.08	20	20×2	1	-	130.8	132
Tub-Jen	57.9+J19.42	29	29×2	1	-	121.11	132
Total		268.8	452.6	9	2		

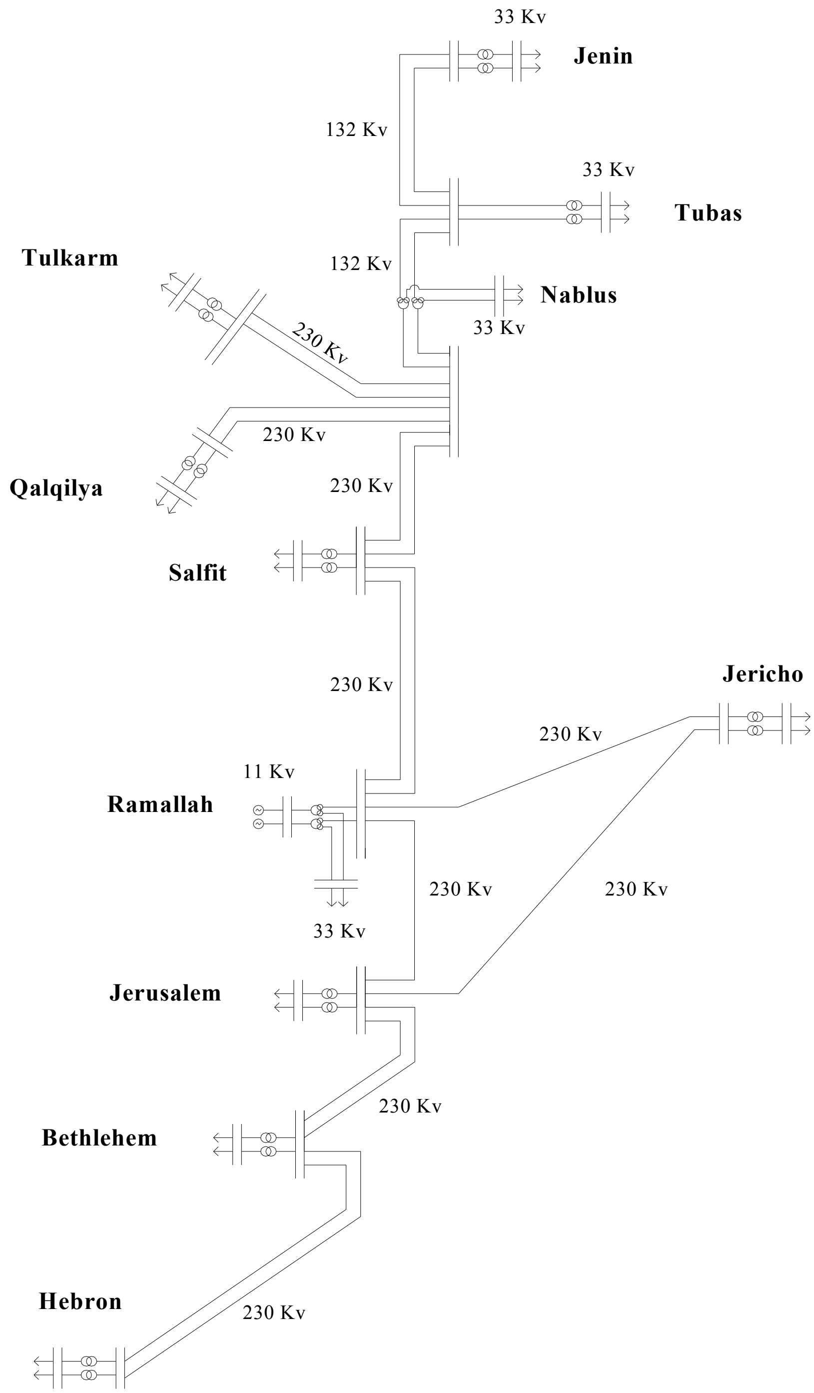
33 Kv
Jenin
132 Kv
33 Kv
Tubas
Tulkarm
132 Kv
Nablus
33 Kv
230 Kv
230 Kv
Qalqilya
230 Kv
Salfit
230 Kv
Jericho
230 Kv
11 Kv
Ramallah
230 Kv
230 Kv
33 Kv
Jerusalem
230 Kv
Bethlehem
Hebron
230 Kv

Fig. (6.15): Ram-3

6-3-3 Configuration Ram-4

This configuration is shown in Fig 6.16. Power flow and voltages are calculated. Voltages and other information are reflected in table 6.15

Table (6.15): Summary of Ram-4

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated Voltages kV	Design voltages kV
Ram-Jer	32+J10.9	35	35×2	1	1	104	230
Ram-Jsm	505.2+J165.99	18	18×2	1	-	174.8	230
Jsm-BL	296+J99.4	10.3	10.3×2	1	-	132.47	230
BL-Heb	178.7+J59.7	16.5	16.5×2	1	-	150.26	230
Ram-Sal	304.9+J98.07	24	24×2	1	-	185.59	230
Sal-Nab	292.9+J93.87	28	28×2	-	1	172.68	230
Nab-Tkm	67.2+J20.4	25	25×2	1	-	132.22	230
Nab-Qal	30.5+J10.875	31	31×2	1	-	100.97	230
Nab-Tub	74.8+J24.08	20	20×2	1	-	130.8	132
Tub-Jen	57.9+J19.42	29	29×2	1	-	121.11	132
Total			473.6	9	2		

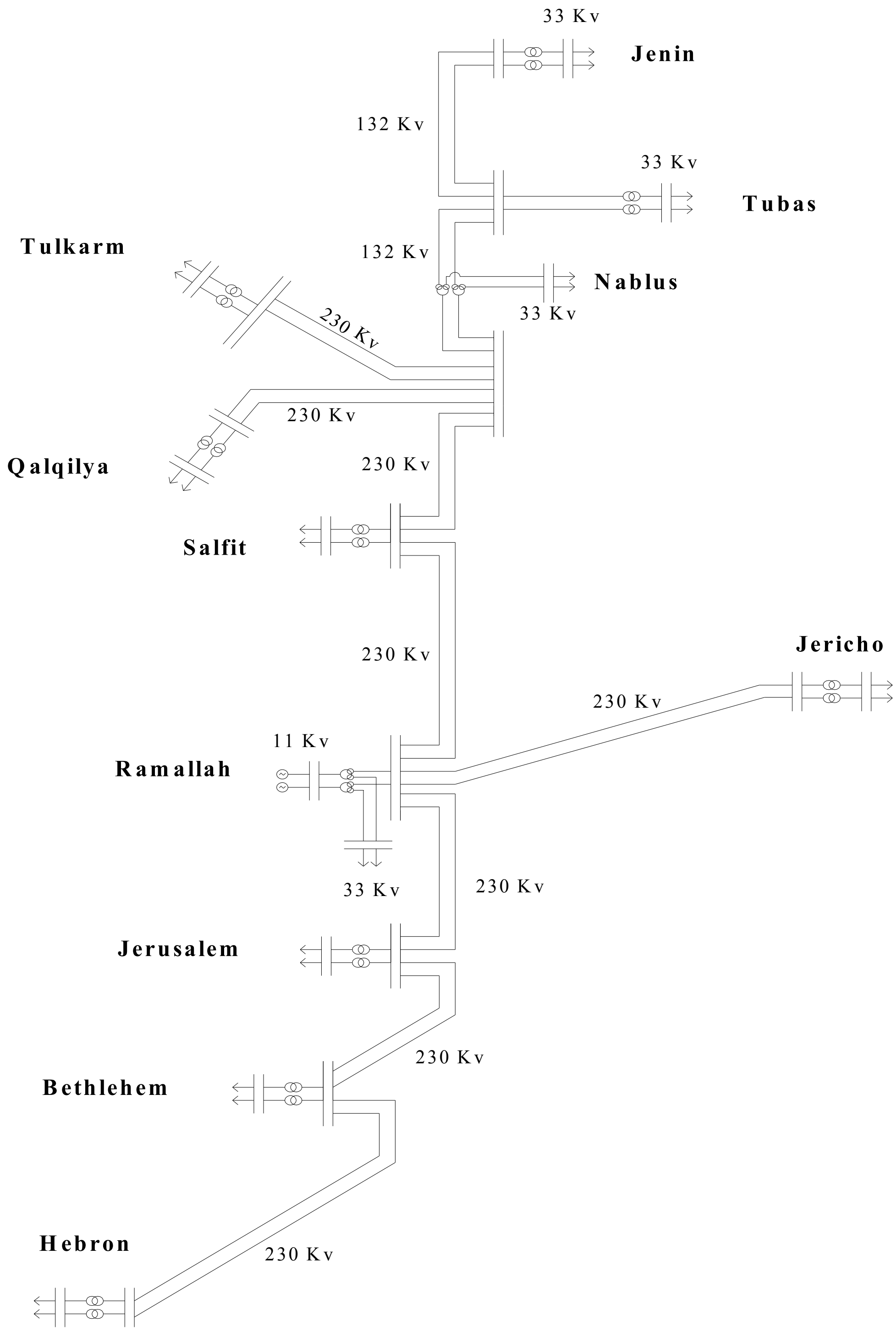
33 Kv
Jenin
132 Kv
33 Kv
Tubas
Tulkarm
132 Kv
Nablus
33 Kv
230 Kv
230 Kv
Qalqilya
230 Kv
Salfit
230 Kv
Jericho
230 Kv
11 Kv
Ramallah
33 Kv
230 Kv
Jerusalem
230 Kv
Bethlehem
Hebron
230 Kv

Fig. (6.16): Ram-4

6-3-4 Configuration Ram-5

This configuration is shown in Fig 6.17. Power flow and voltages are calculated. Voltages and other important information are reflected in table 6.16 below.

Table (6.16): Summary of Ramallah configuration Ram-5

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated Voltages kV	Design voltages kV
Ram-Jer	32+J10.9	35	35×2	1	1	104	230
Ram-Jsm	505.2+J165.99	18	18×2	1	-	174.8	230
Jsm-BL	296+J99.4	10.3	10.3×2	1	-	132.47	230
BL-Heb	178.7+J59.7	16.5	16.5×2	1	-	150.26	230
Ram-Sal	304.9+J98.07	24	24×2	1	-	185.59	230
Sal-Nab	292.9+J93.87	28	28×2	-	1	172.68	230
Nab-Tub	74.8+J24.08	20	20×2	1	-	130.8	132
Tub-Jen	57.9+J19.42	29	29×2	1	-	121.11	132
Nab-Tkm	58.132+J18.26	25	25×2	1	-	125.98	230
Nab-Qal	39.56+J13.01	31	31×2	1	-	112.29	230
Qal-Tkm	9.06+J2.134	25	25×1	-	-	Ditto	230
Total			442	9	2		

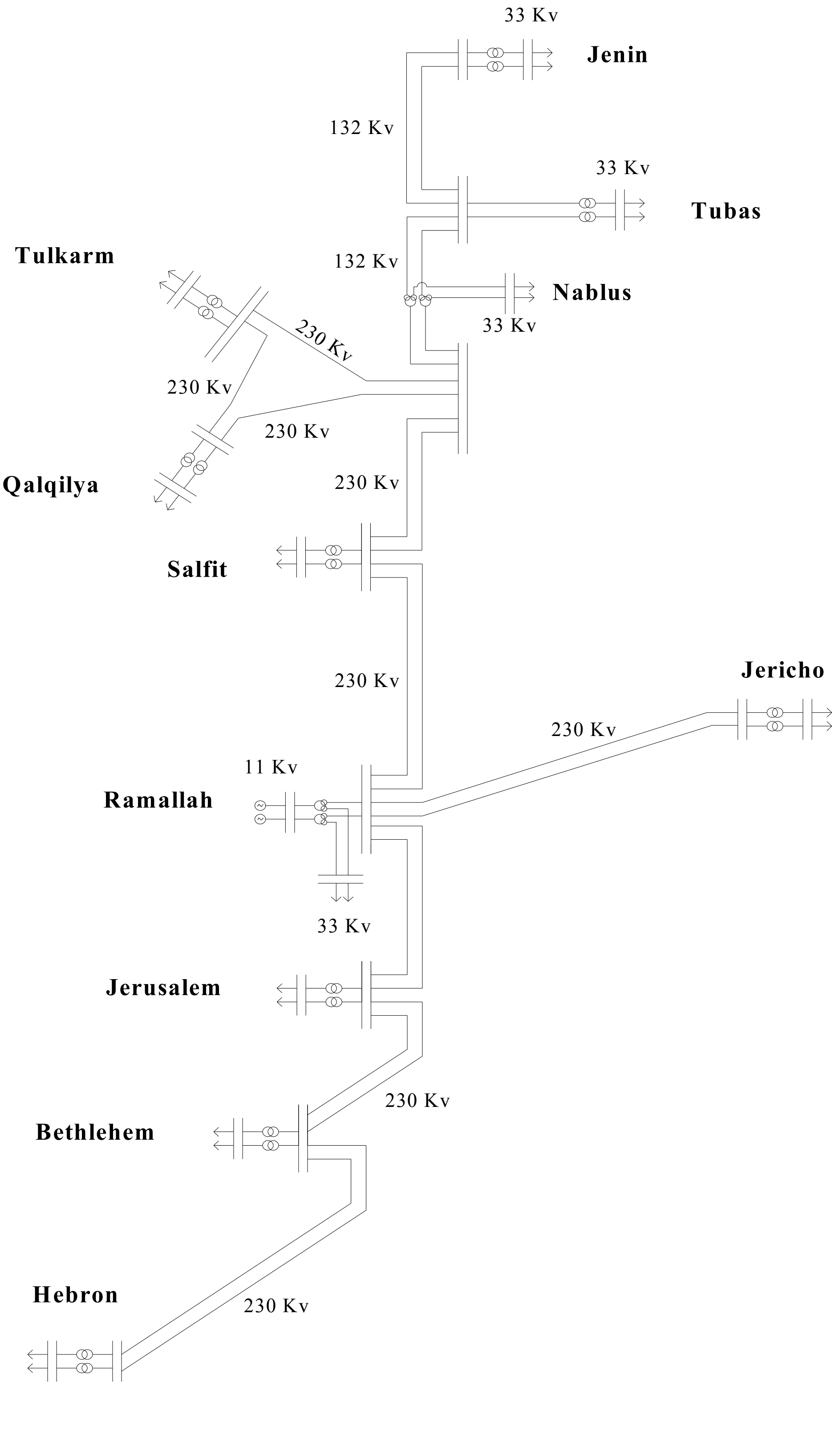
33 Kv
Jenin
132 Kv
33 Kv
Tubas
Tulkarm
132 Kv
Nablus
33 Kv
230 Kv
230 Kv
230 Kv
Qalqilya
230 Kv
Salfit
230 Kv
Jericho
230 Kv
11 Kv
Ramallah
33 Kv
Jerusalem
230 Kv
Bethlehem
Hebron
230 Kv

Fig. (6.17): Ram-5

6-3-5 Configuration Ram-6

This configuration is shown in Fig 6.18. Power flows and voltages are calculated. Voltages and other important information are reflected in table 6.17

Table (6.17): Summary of Ram-6

Line	Power flow	Distance km	Length of T.L. km	No of two winding trans	No of three winding trans	Calculated Voltages kV	Design voltages kV
Nab-Tkm	58.1+J18.2	25	25×1	1	-	125.8	230
Nab-Qal	39.5+J13.01	31	31×1	1	-	112.29	230
Qal-Tkm	9.06+J2.13	25	25×1	-	-	Ditto	230
Ram-Jer	125.8+J41.56	35	35×1	1	1	171.1	230
Ram-Jsm	411.4+J135.32	18	18×1	1	-	171.87	230
Jer-Jsm	93.8+J30.66	32	32×1	-	-	Ditto	230
Jsm-BL	296+J99.4	10.3	10.3×2	1	-	132.47	230
BL-Heb	178.7+J59.7	16.5	16.5×2	1	-	150.26	230
Ram-Sal	304.9+J98.07	24	24×2	1	-	185.59	230
Sal-Nab	292.9+J93.87	28	28×2	-	1	172.68	230
Nab-Tub	74.8+J24.08	20	20×2	1	-	130.8	132
Tub-Jen	57.9+J19.42	29	29×2	1	-	121.11	132
Total		293.8	421.6	9	2		

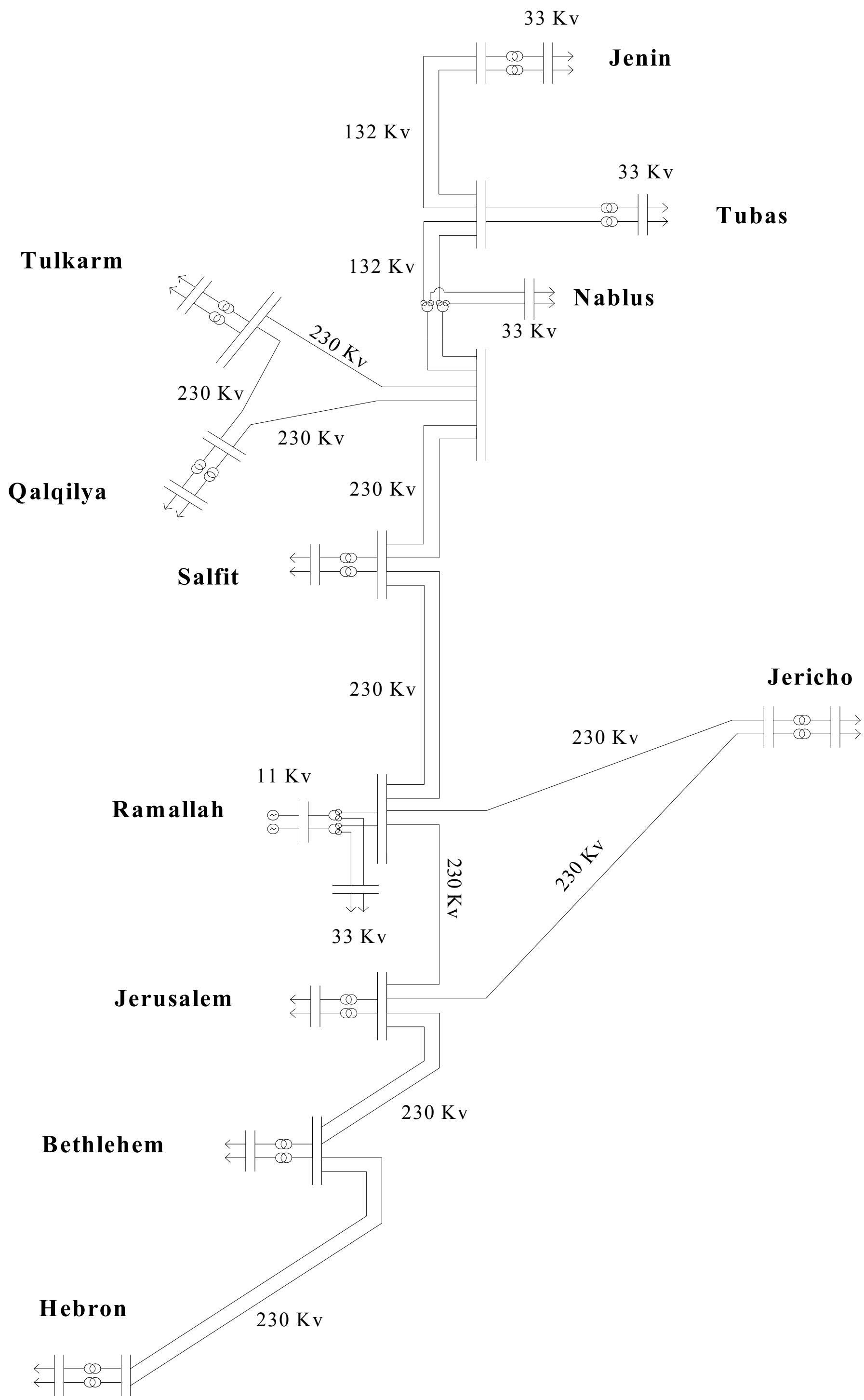
33 Kv
Jenin
132 Kv
33 Kv
Tubas
Tulkarm
132 Kv
Nablus
230 Kv
33 Kv
230 Kv
230 Kv
Qalqilya
230 Kv
Salfit
230 Kv
Jericho
230 Kv
11 Kv
Ramallah
230 Kv
230 Kv
33 Kv
Jerusalem
230 Kv
Bethlehem
Hebron
230 Kv

Fig. (6.18): Ram-6

Table 6.18 summarizes all total length of cable and number of transformers in all configurations of the scenario C- Ramallah, to help identify and select the configuration with least cost.

Table (6.18): Summary of Scenario C – Ram configurations

Config	Distance km	Length of T.L. km	Voltage kV	Two wind trans	Voltage ratio	Three wind trans	Voltage ratio
1 Ram-1	49	98	132	2	132/33	1	11/33/230
	181.5	363	230	7	230/33	1	230/132/33
Total	230.5	461.6					
4 Ram-4	49	98	132	2	132/33	1	230/132/33
	187.8	375.6	230	7	230/33	1	11/33/230
Total	236.8	473.6					
5 Ram-5	49	98	132	2	132/33	1	230/132/33
	212.8	344.6	230	7	230/33	1	11/33/230
Total	261.8	442.6					
2 Ram-2	49	98	132	2	132/33	1	230/132/33
	213.8	342.6	230	7	230/33	1	11/33/230
Total	262.8	440.6					
3 Ram-3	49	98	132	2	132/33	1	230/132/33
	219.8	354.6	230	7	230/33	1	11/33/230
Total	268.8	452.6					
6 Ram-6	49	98	132	2	132/33	1	11/33/230
	244.8	323.6	230	7	230/33	1	230/132/33
Total	293.8	421.6					

The configurations with least cable length in all ring and all radial designs are selected. So, configuration Ram- 6 (Ring) and configuration Ram-1(Radial) are selected for further analysis.

In the next chapter, the selected configurations from all scenarios are to be subjected for further economical analysis to decide the one with least cost.

Chapter 7
Economical analysis

In this chapter, the radial and ring configurations with the least transmission lines length, and number of transformers in all scenarios are selected for further analysis, to determine the one with least operational cost of all.

So, configurations number one and six of each scenario are economically analyzed to determine the capital cost and yearly running cost.

According to equation 5, the yearly cost is determined :

Yearly cost = CRF× Capital cost + yearly running cost……….(5)

Where:

CRF : Capital Recovery Factor = 0.12 [6]

Yearly running cost from

transmission lines + switchgear + transformer + power losses

<u>Scenario A-Jericho</u>

Economical analysis of Jericho configuration Jer-6

To find the capital cost and annual running cost of Jer-6 (Refer to Fig 6.6) the equipment used in the design must be selected in order to be estimated.

This equipment is (1) transformers (2) overhead lines (3) switchgear.

As far as substations are concerned, each substation will have two transformers, each one has 70% of full load rating.

7-1 Capital cost for Jer-6

(1) Transformers

Table 7.1 shows transformer's selection and other information for Jer-6

Table (7.1): Jer-6 transformers

District	Load MVA S	Trans Rating MVA	Standard Trans rating MVA	Rated voltage kV	Type	Required No of trans
Jenin	61.07	43.62	40	132/33	2 wind	2 × 40
Tubas	17.53	12.52	16	132/22	2 wind	2 × 16
Tulkarem	70.23	50.16	63	230/33	2 wind	2 × 63
Qalqelia	32.38	23.13	25	230/33	2 wind	2 × 25
Nablus	307.5	219.6	225	230/132/33	3 wind	2 × 225
Salfit	12.71	9.079	16	230/33	2 wind	2 ×16
Ramallah	178.5	127.5	150	230/33	2 wind	2 × 150
Jericho	1061	757.6	4 × 200	132/230/33	3 wind	8 × 200
Jerusalem	218.6	156.1	2 ×80	230/33	2 wind	4 × 80
Beithlehm	122.9	87.79	100	230/33	2 wind	2 × 100
Hebron	186.6	133.3	150	230/33	2 wind	2 × 150

The capital cost for the selected transformers in the above configuration (Jer-6) is listed in table 7.2. [5]

Table (7.2): Jer-6 transformers cost

	132/33 kv				230/33 kv			
District	Trans Rating MVA	Type	No of Tran	Cost KUS $	Trans Rating MVA	Type	No of Trans	Cost K US $
Jenin	40	2 wind	2	2×618	-	-	-	-
Tubas	16	2 wind	2	2×374				
Talkarem	-	-	-	-	63	2 wind	2	2×1127
Qalqelia	-	-	-	-	25	2 wind	2	2×630
Nablus	-	-	-	-	225	3 wind	2	2×2472×1.1
Salfit	-	-	-	-	16	2 wind	2	2×504
Ramallah	-	-	-	-	150	2 wind	2	2×1938
Jericho	-	-	-	-	200	3 wind	8	8×2303×1.1
Jerusalem	-	-	-	-	80	2 wind	4	4×1320
Beithlehem	-	-	-	-	100	2 wind	2	2×1520
Hebron	-	-	-	-	150	2 wind	2	2×1938
Total				1,984				46,299

(2) Overhead lines

Table 7.3 shows O.H. lines selection for Jer-6. Aluminum conductors steel reinforced (ACSR) are used. [7]

In ring lines we have single circuits as power can flow from both directions of the ring, while radial lines have double circuit to provide continuity in case of a fault.

Table (7.3): Jer-6 overhead transmission lines.

Line	Load MVA	Ckt norm. current A	Post fault current A	Required cross section mm^2	Standard cross section mm^2	Type	Max current /phase
Jer-Ram	492.2	1236	2577	1841	4×565	4×Finch	4×906
Jer-Jsm	534.6	1342	2577	1841	4×565	4×Finch	4×906
Ram-Jsm	6.831	17.15	1342	958.6	2×529	2×Moose	2×874
Jsm-BL	309.5	388.5	776.9	554.9	565	Finch	906
BL-Heb	186.6	234.2	468.4	334.6	381	Bison	718
Ram-Sal	320.3	402	804	574.3	565	Finch	906
Sa-Nab	307.6	386.1	772.2	551.6	565	Finch	906
Nab-Tub	78.58	171.9	343.7	245.5	381	Bison	718
Tub-Jen	61.07	133.6	267.1	190.8	381	Bison	718
Nab-Tkm	60.88	266.3	448.2	320.1	381	Bison	718
Nab-Qal	41.59	181.9	448.2	320.1	381	Bison	718
Qal-Tkm	9.3	40.67	266.3	190.2	381	Bison	718

The criteria of selection of transmission lines, enables the ring and radial circuits to carry the maximum currents in normal operation, and also carry post fault current in case of faults. This is to satisfy N-1 planning criterion and maximum electrical field gradient on conductor surface. [5]

The conductor cross sectional area is obtained from equation 6.

Cross section in mm^2 = post fault current / 1.4 …………….(6)

Where 1.4 is the economical current density [6]

The capital cost of the selected O.H. lines – with steel lattice tower, is reflected in table 7.4 below. The cost is based on PEA report late 2007.[5]

Table (7.4): Jer-6 Overhead lines cost

Line	Type	Length km	Cost K US $
Jer-Ram	4×Finch	35	35×2×143
Jer-Jsm	4×Finch	32	32×2×143
Ram-Jsm	2×Moose	18	18×138
Jsm-BL	Finch	10.3	10.3×163
BL-Heb	Bison	16.5	16.5×142
Ram-Sal	Finch	24	24×163
Sa-Nab	Finch	28	28×163
Nab-Tub	Bison	20	20×142
Tub-Jen	Bison	29	29×142
Nab-Tkm	Bison	25	25×89
Nab-Qal	Bison	31	31×89
Qal-Tkm	Bison	25	25×89
Total			48,311

(3) Switchgear

Table 7.5 on the following page , shows the switchgears selected for Jer-6, and for clarity reasons, the cost is included also in this table. As PEA report has indicated the cost for line bay and transformer bay, the type of switchgear is classified here in terms of the number of bays and the voltage level. [5]

For example : B / 230 / 16×2

A means 4 line bays

B means 6 line bays

C means 8 line bays

D means 10 line bays

E means 12 line bays

230 or 132 indicate the voltage of the primary(high) voltage.

16×2 means the MVA and number of transformer respectively.

Table (7.5): Jer-6 switchgear cost

132 kV switch gear

Type	Cost K US $	District
A/132/40×2	3160	Jenin
A/132/63×2	3160	Talkarem
A/132/25×2	3160	Qalqelia
B/132/16×2	4160	Salfit
	13,640	

230 kV switch gear

Type	Cost K US$	District
B/230/16×2	6555	Tubas
B/230/150×2	6555	Ramallah
B/230/80×4	8615	Jerusalem
B/230/100×2	6555	Beithlehem
A/230/150×2	4735	Hebron
C/230-132-33/225×2	10440	Nablus
B/11-33-230/200×8	14910	Jericho
	58,365	

Table 7.6 summarizes the total capital costs for Jer-6.

Table (7.6): Jer-6 capital cost

Element	Capital cost $	Capital cost $
Transmission Lines	48,311,000	
132 kv switch gear	13,640,000	
230 kv switch gear	-	58,365,000
132 kv transformer	1,984,000	
230 kv transformer	-	46,299,000
Sub total		
Total	$168,600,000	

Running cost for Jer-6

Yearly running cost, includes the following costs :

1- Transmission line running cost

2- Transformer running cost

3- switchgear running cost

4- Power losses running cost

We now calculate each one as follows:

1- Transmission line running cost :

This cost is a percentage of the transmission line capital cost and is selected to be 2.8% [8].

= 2.8% × Transmission line capital cost………………..(7)

= 2.8% × $48,311,000

= $ 1,352,700

2- Transformer running cost :

This cost is a percentage of the transformers capital cost taking into account the operating voltage. This value is taken as 8.8% for 132 kV transformers and 7.8% for 230 kV transformers. [8]

= 8.8% × Transf capital cost(132 Kv) + 7.8% ×Transf capital cost(230Kv)………………… (8)

= 8.8% × $1,984,000 + 7.8% × $46,299,000

= $ 3,785,900

3- Switchgear running cost :

This cost is a percentage of the switchgear capital cost taking into account the operating voltage. This value is taken 8.8% for 132 kV switchgear and 7.8% for 230 kV switchgear. [8]

= 8.8% × S.G. capital cost(132 Kv) + 7.8% × S.G. capital cost(230Kv)

= 8.8% × 13,640,000 + 7.8% × 58,365,000

= $ 5,752,500

4- Power losses running cost :

The power losses running cost is divided into constant and variable.

yearly running cost = (cost/MWh) (MWh constant + MWh variable)

Where:

Cost/MWH is estimated at U S $ 140 .

MWh constant is the constant energy power losses in MWh

MWh variable is the variable energy power losses in MWh.

4-1 The constant power losses running cost is the running cost of the excitation branch losses of the transformer named P_{oc} of transformer. [9]

Constant power losses running cost = $\sum$ Poc × Time. [8] ……….(9)

Where: Time = 8760 hour, is the number of hours per year.

Table 7.7 below shows the P_{oc} of transformers in Jer-6 [8]

Table (7.7): Jer-6 transformer P_{oc}

District	Transformer (MVA)	Poc (kW)	Notes
Jenin	2 × 40	2× 41.19	132 kV 2 wind
Tubas	2 × 16	2 × 21	132 kV 2 wind
Talkarem	2 × 63	2 × 82	230 kV 2 wind
Qalqelia	2× 25	2 × 31.25	230 kV 2 wind
Nablus	2 × 225	2 ×135	230 kV3 wind
Salfit	2× 16	2 × 20	230 kV 2 wind
Ramallah	2 × 150	2 × 157.8	230 kV2 wind
Jericho	8 × 200	8 × 125	230 kV3 wind
Jerusalem	4 × 80	4 × 105	230 kV2 wind
Beithlehem	2 × 100	2 × 115	230 kV 2 wind
Hebron	2 × 150	2 × 157.8	230 kV 2 wind
Total		2942.1	

So, the, constant power losses are:

$= \sum P_{oc} \times \text{Time}$

$= 2{,}942 \text{ kW} \times 8760 \text{ hr}$

$= 25{,}772{,}000 \text{ kWh}$

4-2 Variable Power losses running cost Jer-6

The variable part of power losses running cost, is mainly because of copper losses of conductors, and transformers.

4-2-1 Conductor's variable power losses running cost.

The equation used for calculating the Conductors variable power

losses are : $\Delta P = [\, P^2 + Q^2 / V^2 \,].\, R$ ……………………………(10)

where :

P : Active power

Q : Reactive power

V : Voltage

R : Resistance

Using [9], the following resistances result :

Finch - 0.0856 Ω / mile

Moose - 0.0924 Ω / mile

Bison - 0.125 Ω / mile

When these values are used in equation 10 above, the variable power losses for conductors are calculated and listed in table 7.8 ;

Table (7.8): Jer-6 conductor variable power losses

Conductor	losses
1- Jer- Ram	2143 kW
2- Jer-Jsm	2312 kW
3- Ram-Jsm	458.47 kW
4- Jsm-BL	498.92 kW
5- Bl-Heb	424.24 kW
6- Ram-Sal	1245.1 kW
7- Sal-Nab	1339.7 kW
8- Nab-Tub	276.86 kW
9- Tub-Jen	242.47 kW
10- Nab-Tkm	415.46 kW
11- Nab-Qal	240.4 kW
12- Qal-Tkm	9.69 kW
Total	9601.7 kW

4-2-2 Transformer variable power losses running cost

The same equation 10 is used for calculating 2 winding transformer variable power losses.

But for 3 winding transformers, equation (11) is used:

$$= (P_H^2+Q_H^2/V_H^2).R_H + (P_M^2+Q_M^2/V_H^2).R_M + (P_L^2+Q_L^2/V_H^2).\ R_L \qquad (11)$$

The resistances of transformers are plugged into equations (10) and (11) and the following losses result :

Table (7.9): Jer-6 transformer variable power losses

	Location	Transformer	losses
1	Jenin	2 wind 2 × 40 MVA	321.07 kW
2	Tubas	2 wind 2× 16 MVA	73.198 kW
3	Tulkarem	2 wind 2× 63 MVA	181.8 kW
4	Qalqelia	2 wind 2×25 MVA	66.39 kW
5	Nablus	3 wind 2×225 MVA	395.7 kW
6	Salfit	2 wind 2×16 MVA	11.26 kW
7	Ramalah	2 wind 2×150 MVA	325.11 kW
8	Jericho	3 wind 8×200 MVA	2340.2 kW
9	Jerusalem	2 wind 4×80 MVA	655 kW
10	Beithlehem	2 wind 2×100 MVA	271.15 kW
11	Hebron	2 wind 2×150 MVA	355.44 kW
	Total		4996.3 kW

The total variable power losses for Jer-6 equal those of transformers and conductors.

= { 9601.7 kW + 4996.3 kW }

To calculate the total variable power losses running cost, we first estimate the duration of operation throughout the year using the following equation :

$\tau = 8760\,(0.124 + 0.0001\times T_{max})$……………………………(12)

where : T_{max} is the hours of operation with maximum load.

τ is hours of operation with maximum power losses.

T_{max} is estimated from local municipalities load curve to be around 4000 hours [2]. Plugging this value into equation 12 will yield :

τ = 2405 hours

However , total variable energy losses are equal to

= τ (conductor variable power loss+transformer variable power loss)…. (13)

and this equals to

= 2405 Hr (9601.7 kW + 4996.3 kW)

= 35,108 MWH

Accordingly, the yearly, <u>constant</u> and <u>variable</u> energy losses running cost is

P.L running cost = (cost/MWh) (MWh constant + MWh variable)……(14)

= $140 (35,108 MWh + 25,772 MWh)

= $ 8.5232 \times 10^6$ / year

Summary

Using equation 5 , and taking Capital Recovery Factor as 0.12[6], the following items are calculated and listed in table 7.10 .

Table (7.10): Jer-6 yearly cost

1	Capital recovery factor × Capital cost	$ 0.12×168,600,000
2	Yearly running cost of transformers	$ 3,785,900
3	Yearly running cost of switchgear	$ 5,752,500
4	Yearly running cost of Transmission lines.	$1,352,700
5	Yearly running cost of variable and constant power losses	$ 8.5232 × 10^6
	Total yearly cost	$ 39.646× 10^6

7-2 Economical analysis of Jericho configuration Jer-1

Another configuration of scenario A (Fig 5.1), a radial one, is considered for economical analysis, to cover all possibilities. The same procedure is followed here.

Capital cost

1- Transformers

The following table shows transformers selection for Jer-1 :

Table (7.11): Jer-1 transformers

District	Load MVA	Trans Rating MVA	Standard Trans rating MVA	Rated voltage kV	Type	Required No of trans
Jenin	61.07	43.62	40	132/33	2 wind	2 × 40
Tubas	17.53	12.52	16	132/33	2 wind	2 × 16
Tulkarem	70.23	50.16	63	230/33	2 wind	2 × 63
Qalqelia	32.38	23.13	25	230/33	2 wind	2 × 25
Nablus	204.99	146.42	150	230/132/33	3 wind	2 × 150
Salfit	12.71	9.079	16	230/33	2 wind	2 ×16
Ramallah	178.5	127.5	150	230/33	2 wind	2 × 150
Jericho	1061	757.6	4 × 200	132/33/230	3 wind	8 × 200
Jerusalem	218.6	156.1	2 ×80	230/33	2 wind	4 × 80
Beithlehm	122.9	87.79	100	230/33	2 wind	2 × 100
Hebron	186.6	133.3	150	230/33	2 wind	2 × 150

The capital cost of the selected transformers in the above configuration Jer-1, is listed in table 7.12 on the following page. [5]

Table (7.12): Jer-1 transformers cost

	132/33 kV				230/33 kV			
District	**Trans Rating MVA**	**Type**	**No of trans**	**Cost KUS$**	**Trans Rating**	**Type**	**No of trans**	**Cost KUS$**
Jenin	40	2 wind	2	2×618	-	-	-	-
Tubas	16	2 wind	2	2×374				
Talkarem	-	-	-	-	63	2 wind	2	2×1127
Qalqelia	-	-	-	-	25	2 wind	2	2×630
Nablus	-	-	-	-	150	3 wind	2	2×1938×1.1
Salfit	-	-	-	-	16	2 wind	2	2×504
Ramallah	-	-	-	-	150	2 wind	2	2×1938
Jericho	-	-	-	-	200	3 wind	8	8×2303×1.1
Jerusalem	-	-	-	-	80	2 wind	4	4×1320
Beithlehem	-	-	-	-	100	2 wind	2	2×1520
Hebron	-	-	-	-	150	2 wind	2	2×1938
Total				1,984				45,124

2- Overhead lines

Table 7.13 shows O.H. lines selection for Jer-1. Aluminum conductors steel reinforced (ACSR) are used. [7]

Table (7.13): Jer-1 Overhead lines

Line	**Load MVA**	**Ckt norm. current A**	**Fault current A**	**Required cross section mm^2**	**Standard cross section mm^2**	**Type**	**Max current /phase**
Jer-Ram	1026.8	1288.7	2577	1841	4×565	4×Finch	4×906
Ram-Jsm	528.09	662.8	1325.6	946.8	2×529	2×Moose	2×874
Jsm-BL	309.5	388.5	776.9	554.9	565	Finch	906
BL-Heb	186.6	234.2	468.4	334.6	381	Bison	718
Ram-Sal	320.3	402	804	574.3	565	Finch	906
Sa-Nab	307.6	386.1	772.2	551.6	565	Finch	906
Nab-Tub	78.58	171.9	343.7	245.5	381	Bison	718
Nab-Tm	102.58	128.7	257.5	183.9	381	Bison	718
Tub-Jen	61.07	133.6	267.1	190.8	381	Bison	718
Qal-Tkm	32.37	40.67	81.256	58.04	381	Bison	718

The capital costs for Jer-1 O.H. lines, are figured in table 7.14 [5]

Table (7.14): Jer-1 Overhead lines cost

Line	Type	Length km	Cost KUS$
Jer-Ram	4 Finch	35	35×228×2
Ram-Jsm	2 Moose	32	18×221
Jsm-BL	1 Finch	10.3	10.3×163
BL-Heb	1 Bison	16.5	16.5×142
Ram-Sal	1 Finch	24	24×163
Sa-Nab	1 Finch	28	28×163
Nab-Tub	1 Bison	20	20×142
Nab-Tkm	1 Bison	25	25×142
Tub-Jen	1 Bison	29	29×142
Qal-Tkm	1 Bison	25	25×142
Total			$46,494,000

3- Switchgear

Table 7.15 shows the switchgear selected for Jer-1 and for clarity reasons, the cost is included also in this table. [5]

Table (7.15): Jer-1 Switchgear cost

132 kV switch gear

Type	Cost KUS$	District
A/132/40×2	3160	Jenin
A/132/16×2	4160	Tubas
Total	7320	

230 kV switch gear

Type	Cost KUS$	District
C/230/150×2	8,375	Ramallah
B/230/80×4	8,615	Jerusalem
B/230/100×2	6,555	Beithlehem
A/230/150×2	4,735	Hebron
C/230/150×2	11,255	Nablus
B/11-33-230/200×8	14910	Jericho
B/230/63×2	6,555	Talkarem
A/230/25×2	4,735	Qalqelia
B/230/16×2	6,555	Salfit
Total	72,290	

A summary of total capital costs for Jer-1is shown in table 7.16.

Table (7.16): Jer-1 capital cost

Element	Cost	Cost
Transmission Lines	$46,494,000	
132 kv switch gear	$7,320,000	
230 kv switch gear	-	$72,290,000
132 kv transformer	$1,984,000	
230 kv transformer	-	$45,124,000
Sub total		
Total	$173,210,000	

Running cost for Jer-1

The same procedure used with Jer-6 is followed here to calculate the running cost.

The running cost of transmission lines, transformers, and switchgear is merely percentages of the capital cost of each.

1- Running cost of transformers $ 3,694,300……....(8)

2- Running cost of switchgear $ 6,282,800………(8)

3- Running cost of transmission lines $ 1,301,800……….(7)

4- Running cost of power losses

4-1 Running cost of power losses for Jer-1 – constant part

Table 7.17 on the following page shows the P_{oc} of transformers in Jer-1 configuration.

Table (7.17): Jer-1 transformer Poc

District	Transformer (MVA)	Poc (KW)	Notes
Jenin	2 × 40	2× 41.19	132 kv 2 wind
Tubas	2 × 16	2 × 21	132 kv 2 wind
Talkarem	2 × 63	2 × 82	230 kv 2 wind
Qalqelia	2× 25	2 × 31.25	230 kv 2 wind
Nablus	2 × 150	2 ×85	230 kv 3 wind
Salfit	2× 16	2 × 20	230 kv 2 wind
Ramallah	2 × 150	2 × 157.8	230 kv 2 wind
Jericho	8 × 200	8 × 125	230 kv 3 wind
Jerusalem	4 × 80	4 × 105	230 kv 2 wind
Beithlehem	2 × 100	2 × 115	230 kv 2 wind
Hebron	2 × 150	2 × 157.8	230 kv 2 wind
Total		2092.1	

The constant power loss P_{oc} losses will be plugged into equation 9, and afterwards in equation 14 . The results are reflected in table 7.20 .

4-2 Running cost of Power losses for Jer-1 – variable part

4-2-1 Conductors variable power losses

Table 7.18 shows the variable power losses of conductors in Jer-1.

Table (7.18): Jer-1 conductor variable power losses

conductor	Losses
1- Jer- Ram	4665 kw
2- Ram-Jsm	1370 kw
3- Jsm-BL	498.82 kw
4- Bl-Heb	424.24 kw
5- Ram-Sal	1244.9 kw
6- Sal-Nab	1339.4 kw
7- Nab-Tub	276.87 kw
8- Nab-Tkm	194.26 kw
9- Tub-Jen	242.47 kw
10- Qal-Tkm	19.34 kw
Total	10,275 kw

4-2-2 Transformer variable power losses for Jer-1

Table 7.19 shows the variable power losses of transformers :

Table (7.19): Jer-1 transformer variable power losses

	Location	Transformer	Losses
1	Jenin	2 wind 2 × 40 MVA	321.07 kw
2	Tubas	2 wind 2× 16 MVA	73.198 kw
3	Tulkarem	2 wind 2× 63 MVA	181.8 kw
4	Qalqelia	2 wind 2×25 MVA	66.39 kw
5	Nablus	3 wind 2×150 MVA	328.05 kw
6	Salfit	2 wind 2×16 MVA	11.26 kw
7	Ramalah	2 wind 2×150 MVA	325.11 kw
8	Jericho	3 wind 8×200 MVA	2340 kw
9	Jerusalem	2 wind 4×80 MVA	655 kw
10	Beithlehem	2 wind 2×100 MVA	271.15 kw
11	Hebron	2 wind 2×150 MVA	355.44 kw
	Total		4927.8 kw

The variable power losses of Jer-1 are then plugged in equation 13 and 14 to calculate the energy losses running cost. The results are reflected in table 7.20

Summary:

Using equation (5) and taking CRF as 0.12 [6], the following items are calculated and listed in table 7.20 below

Table (7.20): Jer-1 yearly cost

1	Capital recovery factor × Capital cost	$0.12×173,210,000
2	Yearly running cost of transformers	$3,694,300
3	Yearly running cost of switchgear	$6,282,800
4	Yearly running cost of Transmission lines.	$1,301,800
5	Yearly running cost of variable and constant power losses	$7,684,500
	Total yearly cost	$39.749 × 10^6

7-3 Economical analysis of Configuration Jer/Nab-6 (Fig 6.12)

Table 7.21 shows the yearly cost of Jer/Nab-6. Details are in appendix A.

Table (7.21): Jer/Nab-6 yearly cost

1	Capital recovery factor × Capital cost	\$0.12×148,650,000
2	Yearly running cost of transformers	\$3,396,000
3	Yearly running cost of switchgear	\$5,874,200
4	Yearly running cost of Transmission lines.	\$834,370
5	Yearly running cost of variable and constant power losses	\$6,909,400
	Total yearly cost	$\$34.852\times 10^6$

7-4 Economical analysis of configuration Jer/Nab-1 (Fig 5.2)

Table 7.22 below shows yearly cost of Jer/Nab-1. Details are in appendix A.

Table (7.22): Jer/Nab-1 yearly cost

1	Capital recovery factor × Capital cost	\$0.12×159,670,000
2	Yearly running cost of transformers	\$3,396,000
3	Yearly running cost of switchgear	\$6,158,100
4	Yearly running cost of Transmission lines.	\$1,041,000
5	Yearly running cost of variable and constant power losses	\$7,127,100
	Total yearly cost	$\$36.883 \times 10^6$

7-5 Economical analysis of configuration Ram-6 (Fig 6.18)

Table 7.23 on the following page shows the yearly cost of Ram-6. Details are in appendix A.

Table (7.23): Ram-6 yearly cost

1	Capital recovery factor × Capital cost	$ 0.12×154,720,000
2	Yearly running cost of transformers	$ 3,380,700
3	Yearly running cost of switchgear	$ 5,838,200
4	Yearly running cost of Transmission lines.	$ 1,056,200
5	Yearly running cost of variable and constant power losses	$ 6,765,500
	Total yearly cost	$ 35.607× 10^6

7-6 Economical analysis of configuration Ram-1

Table 7.24 shows the yearly cost of Ram-1. Details are in appendix A.

Table (7.24): Ram-1 yearly cost

1	Capital recovery factor × Capital cost	$ 0.12×154,320,000
2	Yearly running cost of transformers	$ 3,380,700
3	Yearly running cost of switchgear	$ 5,979,800
4	Yearly running cost of Transmission lines.	$ 994,110
5	Yearly running cost of variable and constant power losses	$ 6,430,300
	Total yearly cost	35.303× 10^6

Table 7.25 summarizes the yearly cost of the six selected configurations:

Table (7.25): Summary of the yearly cost for the six configurations

Configuration	Yearly cost
Jer-6	$ 39,646,000
Jer-1	$ 39,749,000
Jer/Nab-6	**$ 34,852,000**
Jer/Nab-1	$ 36,883,000
Ram-6	$ 35,607,000
Ram-1	$ 35,303,000

As shown in table 7.25, the lowest yearly cost design is Jer/Nab-6 and, So it will be the optimum design and this design will be selected and will be analyzed for load flow calculations using a load flow program called ETAP power station.

The target is to reduce the voltage drop, minimize power losses, flatten voltage profile, check network capacity to withstand unexpected load increase, and to check network load flow in every branch.

7-7 Cost of transmission of Electrical energy.

The cost of electricity is composed mainly of the cost of Generation, cost of transmission, cost of overhead (administrators and technical staff), and the cost of tariff. The cost of Generation is controlled by the Arab countries which will generate electricity and the final tariff is decided by ministry of energy.

At present the average price paid for IEC at its medium voltage is estimated 7.7 U. S. cents/ kwh including VAT [3]. The average price for end users is about 15 U.S. cents / kwh because this price includes all above mentioned costs.

Yet, for our network, the cost of transmission can be calculated as follows :

Cost of transmission= Yearly running cost/ Yearly sold energy...(14)

$$= \text{Yearly running cost} \quad / \quad T_{max} \times \sum P_{max}$$

$$= \$\ 17{,}014{,}000 \quad / \quad 4000\ \text{hr} \times 1012\ \text{MW}$$

$$= 4.2031\ \$\ / \text{MWh}$$

When other factors are built into this cost, which include the cost of generation and the cost of distribution of energy at lower voltages, the final cost for the end user will be more than above value, but still less than the present cost sold by the IEC.

Chapter 8
Load Flow Analysis

Power station-ETAP- is used to calculate the load flow which includes the bus voltages, branch power factor, currents, and power flow in the most economic configuration, which is **Jer-Nab/6.**

ETAP differentiate between the connection to grid and the connection to a generator and allows multiple power sources. ETAP recognizes three types of busses; swing bus, voltage controlled bus, and load bus.

ETAP handles both radial and loop systems, and is considered as a state of the art in this regard.

Load flow analysis gives an idea about line, transformer, and grid real and reactive power flow, in addition to the voltage at every bus. This information is important for any modification or expansion in the future.

Mathematically, numerical analysis is required to solve 2n nonlinear algebraic equations (for n busses) which are listed in table 8.1 below ;

Table (8.1): Types of busses

Bus type	Unknown values	Known values
Slack Bus	P, Q	V, δ
Load Bus	V, δ	P,Q
Generator Bus	Q, δ	P,V

Where δ is voltage angle

The starting point in ETAP, requires lines series impedances and shunt admittances, transformer impedances, static and dynamic loads, and generators capacity and power factor.

ETAP can do the load flow analysis using many methods. This thesis selected Newton-Raphson method.

The analysis is carried out for Four cases :

1. Max load case
2. Min load case
3. Post fault case
4. Future forecasted load

The aim of improvement is to reduce the real power losses and to improve the voltage level to be in an acceptable range.

For maximum load case, all the voltages are desired to become within the range of 1.05 – 1.1 of nominal voltage. For minimum load case, all the voltages are desired to become within the range of 1.0 – 1.05 of nominal voltage. For post fault case, all the voltages are desired to be above 1.0 of nominal voltage.

This will result in reducing the total cost of energy transmission and increasing the quality of electrical energy sold.

Fig 8.1 below shows the one line diagram for the selected network which is used for for the load flow study using ETAP power station program.

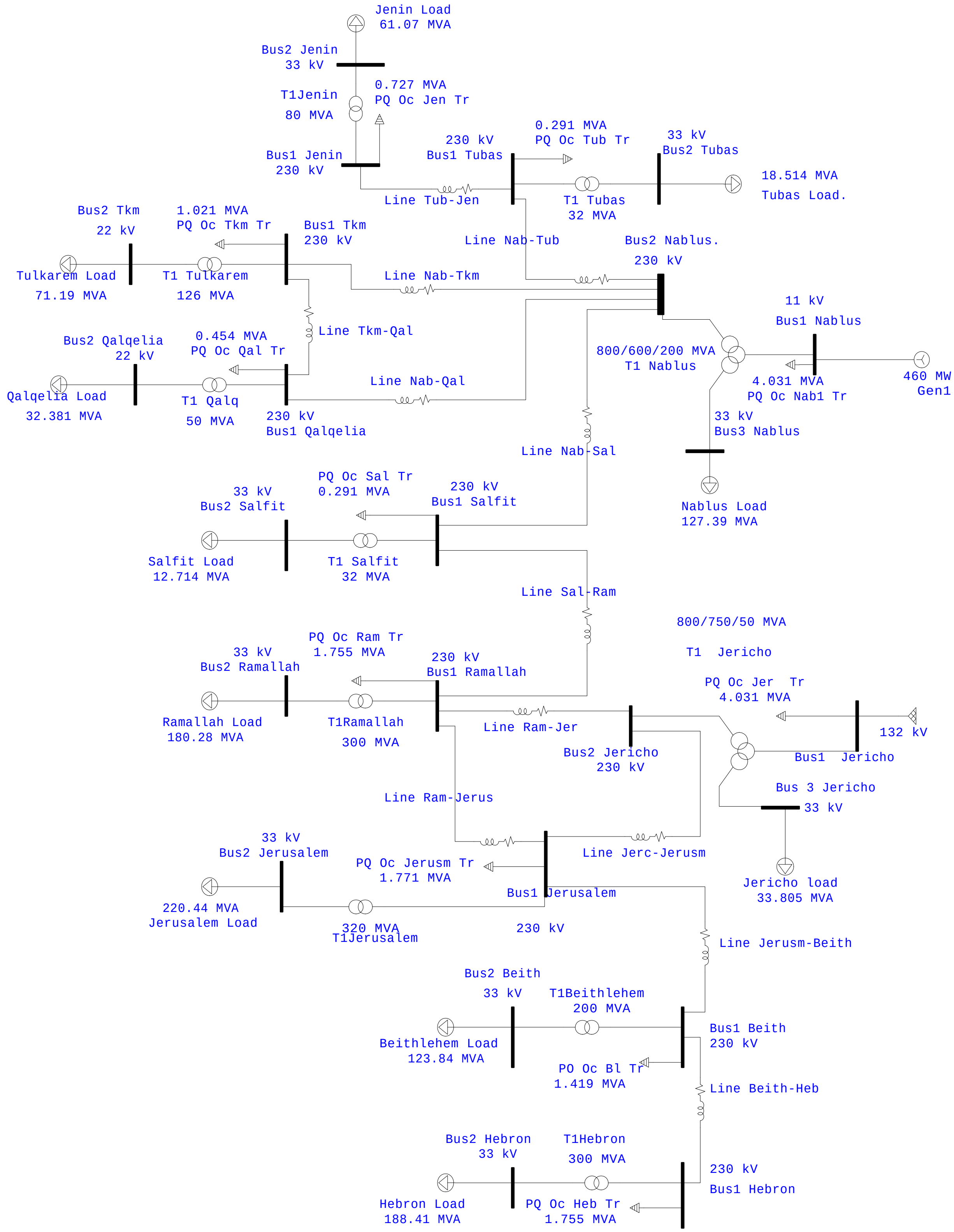

Fig. (8.1): One line diagram for Jer/Nab-6 configuration for Palestinian Electrical Network

1- Maximum load case

The original case, (Case 1.1 in Table 8.2), in which peak loads are assumed to flow in the network, ETAP load flow analysis indicates that the voltages on load busses drop to a minimum of 94.5 % and a maximum of 99.5% of nominal voltages. Power losses reached **9,201.2 kW.**

The voltage on load buses must equal 1.05-1.10 of nominal bus voltages in order to reduce voltage drop effect on the loads and simultaneously reduce power losses.

In case 1.2 in table 8.2, the source voltage is raised by 5% and Tap changing under load transformers are increased by 5%. This measure inflected some power loss reduction (Approximately **981.6 kW**).The minimum voltage on the load busses becomes 103.7 % and the maximum voltage becomes 104.8 % of nominal voltage.

In case 1.3, table 8.2, 2.9 MVAR capacitor is added to every load bus in case 1.2 This didn't produce notable difference upon the voltages. Cases 1.2 and 1.3 were excluded from further improvement.

In case 1.4, table 8.2, the voltage controlled bus and swing bus voltages are increased by 10% (set at 110% of nominal voltage) and TCUL transformers are increased by 10% (set at 110% of nominal voltage).

This yielded much better results. The minimum load bus voltage is 108 % and the maximum is 110 %. Power losses dropped by **1,809.2 kW** from initial max load case 1.1 .

To explore further the possibility to reduce losses and maintain load bus voltages closer to the required value of 110% of the nominal value, eleven 2.9 MVAR regulated capacitors were added gradually to case 1.4 resulting in cases 1.5 to 1.15.

In general, capacitors are added at the bus with minimum voltage, then load flow is calculated to select the next bus with lowest voltage for the next capacitor installation and so on.

Case 1.15 achieved power losses reduction of **1,913.6 kW** from initial max load case 1.1., and only 105 kW power losses reduction from case 1.4.

To find if it is cost effective to install 2.9 MVAR capacitors in case 1.15, compared with case 1.4, the following feasibility study is done :

Yearly saving from reducing power losses

$= [\ \Delta P\ (\text{case}1.4) - \Delta P(\text{ case } 1.15)] \times \tau \times 140\$/\ \text{MWh}$……………(15)

$= [7.392\ \text{MW} - 7.2876\ \text{MW}\ ] \times 2405\text{hr} \times 140\$\ /\ \text{MWh}$

$= 35{,}151\ \$\ /\ \text{Year}$

Taking into account that capacitors are regulated ;

Cost of capacitors(Ccap) = 11cap×2.9 MVAR×\$7,000 / MVAR [5]

= US \$ 223,300

Annual cost of capacitors(Acap) = CRF × capital cost…………(16)

= $ 0.12 × 223,300

= 26,796 $ / year

Annual saving = Yearly saving from Power losses – Annual cost of capacitors

= $ 35,151 – $ 26,796 …………………………(17)

= $ 8,355

The simple pay back period(SPBP) = cost of capacitors/Annual saving...(18)

= $ 223,300 / $ 8,355

= 26.7 year.

So, case 1.15 is not cost effective and case 1.4 is selected as the optimized maximum load case.

As seen, the installation of capacitors wasn't cost effective in max load case, due to the fact that the voltages have been increased to the acceptable level by using other measures like increasing the source voltage and adjusting TCUL transformers. As a result, the further reduction of real power losses due to the installation of capacitors was small and so it didn't give economical saving.

2- Minimum load case

The low demand time in the West Bank happens after midnight , as most businesses take place from 8 a.m. to 5 p.m. A load of 40% is simulated in case 2.1, table 8.2. The losses were **6616.9 kW** and the minimum and maximum load bus voltages were 98.3 % and 100.5 % respectively of nominal voltage.

In case 2.2 table 8.2, the voltage of sources are increased by 5% The power losses became **5,995.4 kW** indicating 10% losses reduction**.** Minimum and maximum voltages on load busses are 103.5 % and 105.6 % respectively, which is acceptable.

In case 2.3 table 8.2, TCUL transformers of case 2.2 were adjusted by 5%. Power losses remained the same, although minimum bus voltage became 104.1 %. This case is selected as the optimum case of minimum load.

3- Post fault case

Some times faults or maintenance (corrective or preventive) calls for shutting down one of the two lines in parallel in the network . This causes the power to flow in the branch in one line, resulting in higher voltage drop and higher power losses.

Therefore, in case 3.1, a fault is introduced on the heaviest loaded branch in the optimized case 1.4. The load bus voltages remained within reasonable limits, i.e., minimum voltage approached 107.2 % and maximum voltage 110 % of the nominal value. This range of voltages is acceptable. Power losses increased to **9,303 kW.**

In case 3.2, 2.9 MVAR capacitor is added to every load bus of case 3.1. Losses were reduced to **9,160 kW**. Minimum bus voltage became 107.5 %. and maximum 110 % of nominal value.

To decide whether adding capacitors is cost effective, the following feasibility study is done.

Yearly saving from reducing power losses ;

= [ΔP (case 3.1) – ΔP (case 3.2)]×2405 hr×140$ = $ 48,148

Acap   = $ 26,796 / year ……………………..…(16)

Annual saving   = $ 21,352…………………………...(17)

SPBP   = 10.45 year…………………………..(18)

So, addition of capacitors is hardly cost effective and case 3.1 is selected for post fault case.

4- Future forecasted load.

In the case of political peace process success, it is not a far fetch, to have tremendous development and increase in industrial and domestic energy need beyond expected. The two factors for deciding future demand are:

- Value of electric demand in initial year.
- The relationship between demand for electricity and variables that influence demand in this society.

Case 4.1 table 8.2 examined the effect of such load increase, therefore, the loads in case 1.4 (which is the improved case of max load) are increased gradually, and load flow analysis carried out repeatedly. The result of 25% increase to case 1.4 loads , is reflected here to indicate the good performance of the network. Power losses became **12,099.2 kW**, and minimum and maximum bus voltages are 108 % and 109.9% respectively.

In case 4.2(refer to table 8.2) , capacitors are added to every load bus of case 4.1(29 MVAR capacitors are added to Ramallah,Jerusalem, Beithlehem, and Hebron load busses as these are far and large loads , while 2.9 MVAR capacitors are added to the rest) Losses came to be **10,890.8 kW** which is less than 1% of power generation. Minimum and maximum voltages are 109.2 % and 112 % respectively.

To find if case 4.2 is cost effective, the following feasibility study is done.

Yearly saving from reducing power losses =

$$[\Delta P \text{ (case 4.1)} - \Delta P\text{(case 4.2)}]\times 2405 \text{ hr}\times 140\$/\text{MWh}$$

= $ 406,870

Ccap = $ 954,100

Acap = $ 114,490 / year

Annual saving = $ 292,380

SPBP = 3.26 year

Case 4.2 is selected for future forecasted load case.

Here, current capacities of over head lines were checked for normal and faulty operation. Only on Jerusalem – Beithlehem radial branch, fault to one of the parallel cables result in 1123A going in the Finch cable installed there which can take 953A max .

Previous studies in west bank assumed a 64% to 67% growth in energy demand every 10 years interval [10]. case 4.3 simulated a 67% load increase to the max load case 1.4. The results show a real power loss of **24,321.7 kW** and a minimum and maximum voltages of 105 % and 110 % respectively. The average percentage of power losses is about 1.415 %. These are acceptable results.

In case 4.4, capacitors were added to every load bus of case 4.3. It is evident from load flow analysis that voltages range from 108.2 % to 109.8 % , which are within acceptable range. Also, power losses are acceptable (about 1.3825 %). Branch currents are within capacity in normal case, but some branches are overloaded in post fault case which can be solved later by various measures.

Table 8.2 is a summary of ETAP load flow runs. The ones in bold letter represent the best run for each case (case 1.4, case 2.3, case 3.1, and case 4.2)

Table (8.2): Summary of all load flow runs in ETAP

#	Case	Power Generated MW	Power losses kW	Percentage of power losses	Min voltage on buses	Max voltage on buses
1.1	p.e.n. (Base case)	1,024.659	9,201.2	0.897 %	94.5 %	99.5%
1.2	p.e.n. with 5% Hv and 5% Ltc	1,023.96	8,219.6	0.802 %	103.7 %	104.8 %
1.3	p.e.n. with 5% Hv and 5% Ltc plus capacitors	1,023.849	8,099.1	0.791 %	103.8 %	104.9%
1.4	p.e.n. with 10% Hv and 10% Ltc	1,023.42	7,392	0.722 %	108 %	110 %
1.5	p.e.n. 10% Hv 10% Ltc fixed 1 Cap (Hebron)					
1.6	p.e.n. 10% Hv 10% Ltc fixed 2 Cap (Beithlehem)					
1.7	p.e.n. 10% Hv 10% Ltc fixed 3 Cap (Jerusalem)					
1.8	p.e.n. 10% Hv 10% Ltc fixed 4 Cap (Jericho)					
1.9	p.e.n. 10% Hv 10% Ltc fixed 5 Cap(Ramallah)					
1.10	p.e.n. 10% Hv 10% Ltc fixed 6 Cap (Salfit)					
1.11	p.e.n. 10% Hv 10% Ltc fixed 7 Cap (Nablus)					
1.12	p.e.n. 10% Hv 10% Ltc fixed 8 Cap (Qalqelia)					
1.13	p.e.n. 10% Hv 10% Ltc fixed 9 Cap (Tulkarem)					
1.14	p.e.n. 10% Hv 10% Ltc fixed 10 Cap (Tubas)					
1.15	p.e.n. 10% Hv 10% Ltc fixed 11 Cap (Jenin)	1,023.334	7,287.6	0.712 %	108 %	110.2 %
2.1	p.e.n. Min	425.6	6,616.9	1.5547 %	98.3 %	100.5 %

#	Case	Power Generated MW	Power losses kW	Percentage of power losses	Min voltage on buses	Max voltage on buses
2.2	p.e.n. Min with 5% Hv	425.128	5,995.4	1.4103 %	103.5%	105.6%
2.3	p.e.n. Min with 5% Hv and 5% Ltc	425.128	5,995.4	1.4103 %	104.1%	105.6%
3.1	p.e.n. with 10% Hv and 10% Ltc plus fault on Jer-Jsm branch.	1,025.674	9,303	0.907 %	107.2 %	110 %
3.2	p.e.n. with 10% Hv and 10% Ltc plus fault on Jer-Jsm and capacitors	1,025.542	9,160	0.893 %	107.5 %	110 %
4.1	p.e.n.10%Ltc10% future1.25	1,280.759	12,099.2	0.945 %	108 %	109.9%
4.2	p.e.n.10%HvLtc 10% With Cap 1.25 Future	1,279.611	10,890.8	0.851 %	109.2%	112 %
4.3	p.e.n.10%Ltc10% future1.67%	1718.312	24,321.7	1.4154 %	105 %	110 %
4.4	p.e.n.10%Ltc10% W Cap 1.67 Future	1,717.647	23,746.1	1.3825 %	108.2 %	109.8 %

Where

Pen : Palestinian Electric network.

Ltc : Tap changing under load.

Hv : Voltage of sources.

Cap : Capacitors to be installed.

Table 8.3 shows the cases before and after improvement.

Bus voltages are kept within required range, and power losses are minimized. For post fault the network voltages will not be affected but an increase in power losses will occur. For load increase of 67% the network will perform well as voltages will remain within range, despite the increase in power losses and the fact that some post fault currents are beyond line current capacities.

Table (8.3): Comparison between original case and optimized / improved case

#	Case	Power Generated MW	Power losses kW	Percentage of power losses	Min voltage on buses	Max voltage on buses
1.1	p.e.n. (Base case)	1,024.659	9,201.2	0.897 %	94.5 %	99.5%
1.4	p.e.n. with 10% Hv and 10% Ltc	1,023.42	7,392	0.722 %	108 %	110 %
2.1	p.e.n. Min	425.6	6,616.9	1.5547 %	98.3 %	100.5 %
2.3	p.e.n. Min with 5% Hv and 5% Ltc	425.128	5,995.4	1.4103 %	104.1%	105.6%
3.1	p.e.n. with 10% Hv and 10% Ltc plus fault on Jer-Jsm branch.	1,025.674	9,303	0.907 %	107.2 %	110 %
4.1	p.e.n.10%Ltc10% future1.25	1,280.759	12,099.2	0.945 %	108 %	109.9%
4.2	p.e.n.10%HvLtc10% W Cap 1.25 Future	1,279.611	10,890.8	0.851 %	109.2%	112 %

The following summarizes the information given to computer.

Line impedances (± 5 %) :

1- Finch R = 0.0856Ω/mile = 0.0535 Ω/km

XL= 0.380 Ω/mile

XC= 0.0866 M Ω*mile

2- Moose R = 0.0924 Ω/mile = 0.05775 Ω/km

XL= 0.3895 Ω/mile

XC= 0.0884 M Ω*mile

3- Bison R = 0.125 Ω/mile = 0.078 Ω/km

XL= 0.40252 Ω/mile

XC= 0.092122 M Ω*mile

The data of the one line diagram of the selected network, including the series impedance, and open circuit losses of transformers, and the series impedance and shunt admittances of transmission lines are shown in tables 8.4 and 8.5 respectively.

Table (8.4): Transformers data for Jer/Nab-6 used for ETAP load flow analysis.

District	Transformer Load	Number /Rating	Voltage	Wind-ing	Poc kW	Qoc kVAR	R	X
Jenin	57.9+J19.42	2×40	230/33	2	2×50	2×360	5.6/2	158.7/2
Tubas	16.9+J7.56	2×16	230/33	2	2×20	2×144	2.24/2	63.4/2
Talkarem	67.2+J23.5	2×63	230/33	2	2×82	2×504	3.9/2	100.7/2
Qalqelia	30.5+J10.875	2×25	230/33	2	2×31.2	2×225	3.5/2	99.19/2
Nablus*	460+J222.6	4×200	11/230/33	3	4×125	4×1000	*	*
Salfit	12+J4.2	2×16	230/33	2	2×20	2×144	2.24/2	63.4/2
Ramallah	170.8+J57.7	2×150	230/33	2	2×157.8	2×862.8	1.17/2	43.07/2
Jericho	552.9+J122	4×200	11/230/33	2	4×200	4×900	0.77	32.2
Jerusalem	209.2+J69.5	4×80	230/33	2	4×105	4×480	2.9/4	80.5/4
Beithlehem	117.3+J39.7	2×100	230/33	2	2×115	2×700	1.9/2	63.5/2
Hebron	178.7+J59.7	2×150	230/33	2	2×157.8	2×862.8	1.17/2	43.07/2

*** Nablus transformer has 3 winding**

Impedance	Rh	Rm	Rl	Xh	Xm	Xl
Nablus	0.3/4	0.3/4	0.6/4	30.4/4	0	54.2/4

Table (8.5): Lines data for Jer/Nab-6 for ETAP load flow analysis

Line	Distance km	Voltage kv	Type	Line R Ώ	Line Xl Ώ	Line Xc Ώ	Y µ S
Jer-Ram	35	230	2×Moose	1.0106	4.26	2,020	495
Jer-Jsm	32	230	2×Moose	0.924	3.895	2,210	452
Ram-Jsm	18	230	Finch	0.963	4.275	7,697	130
Nab-Tkm	25	230	Bison	1.9531	6.289	5,896	169
Nab-Qal	31	230	Bison	2.422	7.7988	4,754.8	210
Qal-Tkm	25	230	Bison	1.9531	6.289	5,896	169
Nab-Tub	20	230	Bison	0.781	2.5158	3,685	271
Tub-Jen	29	230	Bison	1.1328	3.6478	2,541	393
Nab-Sal	28	230	Bison	1.0938	3.5221	2,632	380
Sal-Ram	24	230	Bison	0.9375	3.0189	3,070	325
Jsm-BL	10.3	230	Finch	0.2755	1.2231	6,726	148
BL-Heb	16.5	230	Bison	0.6445	2.075	4,466	224

Chapter 9
Conclusions and Recommendations

The design of an electrical network for another free country is somewhat easier than designing electrical network for the Palestinian occupied territories .

Here in the West Bank , There are uncertainties involved like load forecast . Because of economical and demographic changes , it is difficult to determine the electrical demand growth rate accurately, because the economic and social factors which decide the rate are affected by the political and geographic factors . Accordingly, it is normal to find different suggestions for electrical demand rate. PEA considered a 4.3% growth rate [5]. Another study [10] considered 6.7% growth rate.

Most important, this thesis assumed geographic unity of Palestinian land in the West Bank, an essential need for an integrated network.

This thesis tried to deal with these uncertainties with caution. Unexpected load increase is dealt with. Therefore, this design can supply the West Bank with about 150% of design load under extreme load demand condition, but with less efficiency. Overhead lines routes have 10% extra length as safe margin. Reliability and security of supply has been considered as a priority.

Many scenarios and configurations are discussed, and configuration Jer/Nab-6 is selected as it is the one with the lowest yearly cost, and the highest in reliability. Many load flow analysis were carried out to optimize the design. The power losses were reduced to 0.722% , and all load busses have approximately reached 108% to 110% of nominal voltage.

Full load case, minimum load case, post fault case, and future forecasted load case (unexpected load increase) were all considered and analyzed to ensure good technical performance of the network.

This design , Jer/Nab-6 case 1.4 , will provide high quality, reliable, and affordable electrical energy for a country eager to start developing residential, commercial and industrial needs.

For future steps , it is recommended to study and analyze the design of power plant .

Also , as it is difficult to determine the exact final location of electrical substations and the final overhead line routes because current facts on land which is controlled by Israel may be a huge obstacle , we recommend addressing this issue in next studies .

Energy management , and connection with Gaza may also be another issue to study .

Another good step to take from this study is to design selected network with GIS ; in which case the distribution network can be included.

Last , but not least , it is recommended to study the potential to connect solar electric generator panels to our main grid .

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Appendix

Economical analysis of Configuration Jer/Nab-6 (Fig 6.12)

Capital cost

1- Transformers

Table 1 shows transformers selection for Jer/Nab-6

Table 1
Jer/Nab-6 transformers

District	Load MVA	Trans Rating MVA	Standard trans rating MVA	Rated voltage kV	Type	Required No of Trans
Jenin	61.07	43.62	40	230/33	2 wind	2×40
Tubas	18.5	13.22	16	230/22	2 wind	2×16
Tulkarem	71.19	50.85	63	230/33	2 wind	2×63
Qalqelia	32.38	23.13	25	230/33	2 wind	2×25
Nablus	511	365	2×200	11/230/33	3 wind	4×200
Salfit	12.71	9.079	16	230/33	2 wind	2×6
Ramallah	180.3	128.8	150	230/33	2 wind	2×150
Jericho	566.2	404.3	2×200	132/230/33	3 wind	4×200
Jerusalem	220.4	157.4	2×80	230/33	2 wind	4×80
Beithlehm	123.8	88.43	100	230/33	2 wind	2×100
Hebron	188.4	134.6	150	230/33	2 wind	2×150

The capital cost of the selected transformers in the above Jer/Nab-6 is listed in table 2 . [5]

Table 2
Jer/Nab-6 transformer cost

	132/33 kV				230/33 kV			
District	Trans Rating	Type	No of Trans	Cost KUS$	Trans Rating	Type	No of Trans	Cost K US $
Jenin	-	-	-	-	40	2 wind	2	2×835
Tubas	-	-	-	-	16	2 wind	2	2×504
Talkarem	-	-	-	-	63	2 wind	2	2×1127
Qalqelia	-	-	-	-	25	2 wind	2	2×630
Nablus	-	-	-	-	200	3 wind	4	4×2303×1.1
Salfit	-	-	-	-	16	2 wind	2	2×504
Ramallah	-	-	-	-	150	2 wind	2	2×1938
Jericho	-	-	-	-	200	3 wind	4	4×2303×1.1
Jerusalem	-	-	-	-	80	2 wind	4	4×1320
Beithlehem	-	-	-	-	100	2 wind	2	2×1520
Hebron	-	-	-	-	150	2 wind	2	2×1938
Total				-				43,538

2- Overhead lines

Table 3 shows O.H. lines selection for Jer/Nab-6.
Aluminum conductors steel reinforced (ACSR) are used. [7]

Table 3
Jer/Nab-6 Overhead lines

Line	Load MVA	Ckt norm. current A	Fault current A	Required cross section mm^2	Standard cross section mm^2	Type	Max current /phase
Jer-Ram	201.6	506.1	1339	956.4	2×529	2×Moose	2×874
Jer-Jsm	331.7	832.7	1339	956.4	2×529	2×Moose	2×874
Ram-Jsm	203.4	510.6	832.7	594.8	565	Finch	906
Nab-Tkm	61.58	154.6	259.9	185.6	381	Bison	718
Nab-Qal	41.59	105.3	259.6	185.6	381	Bison	718
Qal-Tkm	9.57	-	154.6	110.4	381	Bison	718
Nab-Tub	79.5	99.78	199.6	142.6	381	Bison	718
Tub-Jen	61	76.56	153.1	109.4	381	Bison	718
Nab-Sal	205.5	257.9	515.9	368.5	381	Bison	718
Sal-Ram	193.4	242.7	485.5	346.8	381	Bison	718
Jsm-BL	312.2	391.9	783.7	559.8	565	Finch	906
BL-Heb	188.4	236.5	472.9	337.8	381	Bison	718

The capital cost of above O.H. lines for Jer/Nab-6 is reflected in table 4 . [5]

Table 4
Jer/Nab-6 Overhead lines cost

Line	Type	Length km	Cost K US $
	2 Moose	35	35×138
Jer-Jsm	2 Moose	32	32×138
Ram-Jsm	Finch	18	18×102
Nab-Tkm	Bison	25	25×89
Nab-Qal	Bison	31	31×89
Qal-Tkm	Bison	25	25×89
Nab-Tub	Bison	20	20×89
Tub-Jen	Bison	29	29×89
Sal-Nab	Bison	28	28×89
Ram-Sal	Bison	24	24×89
Jsm-BL	Finch	10.3	10.3×102
BL-Heb	Bison	16.5	16.5×89
Total			29,799

3- Switchgear

Table 5 shows the switchgear selected for Jer/Nab-6 and for clarity reasons, the cost is included also in this table. [5]

Table 5
Jer/Nab-6 switchgear cost
230 kV switch gear

Type	Cost K US $	District
A/230/2×40	4,735	Jenin
B/230/2×16	6,555	Tubas
A/230/2×63	4,735	Tulkarem
A/230/2×25	4,735	Qalqelia
B/230/2×16	6,555	Salfit
B/230/2×150	6,555	Ramallah
B/230/4×80	8,615	Jerusalem
B/230/2×100	6,555	Beithlehem
A/230/2×150	4,735	Hebron
D/11-33-230/4×200	12,590	Nablus
B/11-33-230/4×200	8,945	Jericho
Total	75,310	

Table 6
Jer/Nab-6 capital cost

Element	Cost	Cost
Transmission Lines	$29,799,000	
132 kv switch gear		
230 kv switch gear	-	$75,310,000
132 kv transformer		
230 kv transformer	-	$43,538,000
Sub total		
Total	$148,650,000	

Running cost for Jer/Nab-6

The running cost of transmission lines, transformers, and switchgear is merely percentages of the capital cost of each.

1- Running cost of transformers $3,396,000………..…(8)
2- Running cost of switchgear $5,874,200………..…(8)
3- Running cost of transmission lines $834,370……….….(7)
4- Running cost of Power losses
4-1 Running cost of power losses for Jer/Nab-6 – constant part

Table 7 shows the Poc of transformers in Jer/Nab-6.

Table 7
Jer/Nab-6 transformer Poc

District	Transformer(MVA)	Poc (kW)	Notes
Jenin	2×40	2×50	230kv 2 wind
Tubas	2×16	2×20	230 kv 2 wind
Talkarem	2×63	2×82	230 kv 2 wind
Qalqelia	2×25	2×31.25	230 kv 2 wind
Nablus	4×200	4×125	230 kv 3 wind
Salfit	2×16	2×20	230 kv 2 wind
Ramallah	2×150	2×157.8	230 kv 2 wind
Jericho	4×200	4×125	230 kv 3 wind
Jerusalem	4×80	4×105	230 kv 2 wind
Beithlehem	2×100	2×115	230 kv 2 wind
Hebron	2×150	2×157.8	230 kv 2 wind
Total		2687.7	

The constant power losses P_{oc} loss will be plugged into equation 9 and 14 . The results are reflected in table 10

4-2 Running cost of Power losses for Jer/Nab-6- variable part.

4-2-1 Conductors variable power losses

Table 8 shows the variable power losses of conductors in Jer/Nab-6.

Table 8
Jer/Nab-6 conductor variable power losses

conductor	Losses
1- Jer- Ram	776.45 kW
2- Jer-Jsm	1921.8 kW
3- Ram-Jsm	753.13 kW
4- Nab-Tkm	140.01 kW
5- Nab-Qal	80.529 kW
6- Qal-Tkm	3.3814 kW
7- Nab-Tub	93.34 kW
8- Tub-Jen	79.682 kW
9- Nab-Sal	873.14 kW
10- Sal-Ram	662.87 kW
11- Jsm-BL	507.66 kW
12- BL-Heb	432.46 kW
Total	6324.5 kW

Table 9
Jer/Nab-6 transformer variable power losses

	Location	transformer	losses
1	Jenin	2 wind 2 × 40 MVA	197.41 kW
2	Tubas	2 wind 2× 16 MVA	23.867 kW
3	Tulkarem	2 wind 2× 63 MVA	186.82 kW
4	Qalqelia	2 wind 2×25 MVA	66.396 kW
5	Nablus	3 wind 4×200MVA	973.22 kW
6	Salfit	2 wind 2×16 MVA	11.253 kW
7	Ramalah	2 wind 2×150 MVA	331.84 kW
8	Jericho	3 wind 4×200 MVA	1312 kW
9	Jerusalem	2 wind 4×80 MVA	665.74 kW
10	Beithlehem	2 wind 2×100 MVA	275.24 kW
11	Hebron	2 wind 2×150 MVA	362.33 kW
	Total		4407 kW

The variable power losses of Jer/Nab-6 are plugged into equation 13 and 14 to calculate the energy losses running cost. The results are reflected in table10

Summary:
Using equation 5 and taking CRF as 0.12, the following items are calculated and listed in table 10 below.

Table 10
Jer/Nab-6 yearly cost

1	Capital recovery factor × Capital cost	\$0.12×148,650,000
2	Yearly running cost of transformers	\$3,396,000
3	Yearly running cost of switchgear	\$5,874,200
4	Yearly running cost of Transmission lines.	\$834,370
5	Yearly running cost of variable and constant power losses	\$6,909,400
	Total yearly cost	\$34.852× 10^6

Economical analysis of Jericho/Nablus configuration Jer/Nab-1 (Fig 5.2)

Same procedure is followed here in finding yearly cost. Only tables for important data are shown.

Capital cost

1- Transformers

Table 11
Jer/Nab-1 transformers

District	Load MVA	Trans Rating MVA	Standard trans rating MVA	Rated voltage kV	Type	Required No of trans
Jenin	61.07	43.62	40	230/33	2 wind	2×40
Tubas	18.5	13.22	16	230/22	2 wind	2×16
Tulkarem	71.19	50.85	63	230/33	2 wind	2×63
Qalqelia	32.38	23.13	25	230/33	2 wind	2×25
Nablus	511	365	2×200	11/230/33	3 wind	4×200
Salfit	12.71	9.079	16	230/33	2 wind	2×16
Ramallah	180.3	128.8	150	230/33	2 wind	2×150
Jericho	566.2	404.3	2×200	132/230/33	3 wind	4×200
Jerusalem	220.4	157.4	2×80	230/33	2 wind	4×80
Beithlehm	123.8	88.43	100	230/33	2 wind	2×100
Hebron	188.4	134.6	150	230/33	2 wind	2×150

Table 12
Jer/Nab-1 transformer cost

	132/33 kV				230/33 kV			
District	**Trans Rating MVA**	**Type**	**No of trans**	**Cost KUS$**	**Trans Rating MVA**	**Type**	**No of trans**	**Cost KUS$**
Jenin	-	-	-	-	40	2 wind	2	2×835
Tubas	-	-	-	-	16	2 wind	2	2×504
Talkarem	-	-	-	-	63	2 wind	2	2×1127
Qalqelia	-	-	-	-	25	2 wind	2	2×630
Nablus	-	-	-	-	200	3 wind	4	4×2303×1.1
Salfit	-	-	-	-	16	2 wind	2	2×504
Ramallah	-	-	-	-	150	2 wind	2	2×1938
Jericho	-	-	-	-	200	3 wind	4	4×2303×1.1
Jerusalem	-	-	-	-	80	2 wind	4	4×1320
Beithlehem	-	-	-	-	100	2 wind	2	2×1520
Hebron	-	-	-	-	150	2 wind	2	2×1938
Total				-				43,538

2- Overhead lines

Table 13
Jer/Nab-1 Overhead lines

Line	Load MVA	Ckt norm. current A	Fault current A	Required cross section mm^2	Standard cross section mm^2	Type	Max current /phase
Tub-Jen	61	76.56	153.1	109.4	381	Bison	718
Nab-Tub	79.5	99.78	199.6	142.6	381	Bison	718
Nab-Tkm	103.6	130	260	185.72	381	Bison	718
Qal-Tkm	32.38	40.6	81.281	58.05	381	Bison	718
Nab-Sal	205.5	257.9	515.9	368.5	381	Bison	718
Sal-Ram	193.4	242.7	485.5	346.8	381	Bison	718
Jer-Ram	532.62	668.5	1337	954.9	2×529	2×Moose	2×874
Ram-Jsm	532.69	668.6	1337.2	955.14	2×529	2×Moose	2×874
Jsm-BL	312.2	391.9	783.7	559.8	565	Finch	906
BL-Heb	188.4	236.5	472.9	337.8	381	Bison	718

Table 14
Jer/Nab-1 Overhead lines cost

Line	Type	Length km	Cost KUS$
Tub-Jen	Bison	29	29×142
Nab-Tub	Bison	20	20×142
Nab-Tkm	Bison	25	25×142
Qal-Tkm	Bison	25	25×142
Nab-Sal	Bison	28	28×142
Sal-Ram	Bison	24	24×142
Jer-Ram	2×Moose	35	35×221
Ram-Jsm	2×Moose	18	18×221
Jsm-BL	Finch	10.3	10.3×163
BL-Heb	Bison	16.5	16.5×142
			$37,177,000

3-Switchgear

Table 15
Jer/Nab-1 switchgear cost
230 kv switch gear

Type	**Cost KUS $**	**District**
A/230/2×40	4,735	Jenin
B/230/2×16	6,555	Tubas
B/230/2×63	6,555	Tulkarem
A/230/2×25	4,735	Qalqelia
B/230/2×16	6,555	Salfit
C/230/2×150	8,375	Ramallah
B/230/4×80	8,615	Jerusalem
B/230/2×100	6,555	Beithlehem
A/230/2×150	4,735	Hebron
D/11-33-230/4×200	12,590	Nablus
B/11-33-230/4×200	8,945	Jericho
Total	$78,950,000	

Table 16
Jer/Nab-1 capital cost

Element	**Cost**	**Cost**
Transmission Lines	$37,177,000	
132 kv switch gear	-	
230 kv switch gear	-	$78,950,000
132 kv transformer	-	
230 kv transformer	-	$43,538,000
Sub total		
Total	$159,670,000	

Running cost for Jer/Nab-1

1- Running cost of transformers $3,396,000………(8)
2- Running cost of switchgear $6,158,100………(8)
3- Running cost of transmission lines $1,041,000………(7)
4- Running cost of power losses.
4-1 Running cost of power losses for Jer/Nab-1 – constant part

Table 17
Jer/Nab-1 transformer Poc

District	Transformer(MVA)	Poc (kW)	Notes
Jenin	2×40	2×50	230kv 2 wind
Tubas	2×16	2×20	230 kv 2 wind
Talkarem	2×63	2×82	230 kv 2 wind
Qalqelia	2×25	2×31.25	230 kv 2 wind
Nablus	4×200	4×125	230 kv 3 wind
Salfit	2×16	2×20	230 kv 2 wind
Ramallah	2×150	2×157.8	230 kv 2 wind
Jericho	4×200	4×125	230 kv 3 wind
Jerusalem	4×80	4×105	230 kv 2 wind
Beithlehem	2×100	2×115	230 kv 2 wind
Hebron	2×150	2×157.8	230 kv 2 wind
Total		2687.7	

The constant power losses P_{oc} loss will be plugged into equation 9 and 14 The results are reflected in table 20 on the following page .

4-2 Running cost of power losses for Jer/Nab-1 – variable part.

4-2-1 Conductors variable power losses in Jer/Nab-1.

Table 18
Jer/Nab-1 conductor variable power losses

conductor	Losses
1- Tub-Jen	79.865 kW
2- Nab-Tub	93.38 kW
3- Nab-Tkm	198.06 kW
4- Qal-Tkm	19.355 kW
5- Nab-Sal	873.14 kW
6- Sal-Ram	662.58 kW
7- Jer-Ram	2709.9 kW
8- Ram-Jsm	1394 kW
9- Jsm-BL	507.8 kW
10- BL-Heb	432.46 kW
Total	6970.6 kW

4-2-2 Transformer variable power losses for Jer/Nab-1.

Table 19
Jer/Nab-1 transformer variable power losses

	location	Transformer	losses
1	Jenin	2 wind 2 × 40 MVA	197.41 kW
2	Tubas	2 wind 2× 16 MVA	23.867 kW
3	Tulkarem	2 wind 2× 63 MVA	186.82 kW
4	Qalqelia	2 wind 2×25 MVA	66.396 kW
5	Nablus	3 wind 4×200MVA	973.22 kW
6	Salfit	2 wind 2×16 MVA	11.253 kW
7	Ramalah	2 wind 2×150 MVA	331.84 kW
8	Jericho	3 wind 4×200 MVA	1312 kW
9	Jerusalem	2 wind 4×80 MVA	665.74 kW
10	Beithlehem	2 wind 2×100 MVA	275.24 kW
11	Hebron	2 wind 2×150 MVA	362.33 kW
	Total		4407.2 kW

The variable power losses of Jer/Nab-1 are plugged in equation 13 and 14 to calculate the energy losses running cost. The results are reflected in table 20

Summary:
Using equation 5, and taking CRF as 0.12 [6] , the following items are calculated and listed in table 20.

Table 20
Jer/Nab-1 yearly cost

1	Capital recovery factor × Capital cost	$0.12×159,670,000
2	Yearly running cost of transformers	$3,396,000
3	Yearly running cost of switchgear	$6,158,100
4	Yearly running cost of Transmission lines.	$1,041,000
5	Yearly running cost of variable and constant power losses	$7,127,100
	Total yearly cost	$36.883 × 10^{6}

Economical analysis of Ramallah configuration Ram-6 (Fig 6.18)

Capital cost

1- Transformers

Table 21
Ram-6 transformers

District	Load MVA	Trans Rating MVA	Standard trans Rating MVA	Rated voltage kV	Type	Required No of Trans
Jenin	61.07	43.62	40	132/33	2 wind	2 × 40
Tubas	17.53	12.52	16	132/22	2 wind	2 × 16
Tulkarem	70.23	50.16	63	230/33	2 wind	2 × 63
Qalqelia	32.38	23.13	25	230/33	2 wind	2 × 25
Nablus	205	146.4	150	230/132/33	3 wind	2 × 150
Salfit	12.71	9.079	16	230/33	2 wind	2 ×16
Ramallah	1065	760	4 × 200	11/230/33	3wind	8× 200
Jericho	33.81	24.15	25	230/33	2wind	2× 25
Jerusalem	219.5	156.8	150	230/33	2 wind	2× 150
Beithlehm	123.8	88.43	100	230/33	2 wind	2 × 100
Hebron	188.4	134.6	150	230/33	2 wind	2 × 150

Table 22
Ram-6 transformers cost

	132/33 kV				230/33 kV			
District	**Trans Rating**	**Type**	**No of trans**	**Cost KUS $**	**Trans Rating**	**Type**	**No of trans**	**Cost K US $**
Jenin	40	2 wind	2	2×618	-	-	-	-
Tubas	16	2 wind	2	2×374				
Talkarem	-	-	-	-	63	2 wind	2	2×1127
Qalqelia	-	-	-	-	25	2 wind	2	2×630
Nablus	-	-	-	-	150	3 wind	2	2×1938 1.1
Salfit	-	-	-	-	16	2 wind	2	2×504
Ramallah	-	-	-	-	200	2 wind	2	2×2303 1.1
Jericho	-	-	-	-	25	2wind	2	2×630
Jerusalem	-	-	-	-	150	2 wind	2	2×1938
Beithlehem	-	-	-	-	100	2 wind	2	2×1520
Hebron	-	-	-	-	150	2 wind	2	2×1938
Total				1984				41,104

2- Overhead lines

Table 23
Ram-6 Overhead lines

Line	Load MVA	Ckt norm. current A	Fault current A	Required cross section mm^2	Standard cross section mm^2	Type	Max current /phase
Nab-Tkm	60.88	152.8	257.2	183.7	381	Bison	718
Nab-Qal	41.59	104.4	257.2	183.7	381	Bison	718
Qal-Tkm	9.31	-	152.8	109.1	381	Bison	718
Ram-Jer	132.5	332.6	1411	1000	2×529	2×Moose	2×874
Ram-Jsm	433.1	1078	1411	1000	2×529	2×Moose	2×874
Jer-Jsm	98.68	247.7	1078	770	2×381	2×Bison	2×718
Jsm-BL	312.2	391.9	783.7	559.8	565	Finch	906
BL-Heb	188.4	236.5	472.9	337.8	381	Bison	718
Ram-Sal	320.3	402	804	574.3	565	Finch	906
Sal-Nab	307.6	386.1	772.2	551.6	565	Finch	906
Nab-Tub	78.58	171.9	343.7	245.5	381	Bison	718
Tub-Jen	61.07	133.6	267.1	190.8	381	Bison	718

Table 24
Ram-6 Overhead lines cost

Line	Type	Length km	Cost K US $
Nab-Tkm	Bison	25	25×89
Nab-Qal	Bison	31	31×89
Qal-Tkm	Bison	25	25×89
Ram-Jer	2×Moose	35	35×138
Ram-Jsm	2×Moose	18	18×138
Jer-Jsm	2×Bison	32	32×117
Jsm-BL	Finch	10.3	10.3×163
BL-Heb	Bison	16.5	16.5×142
Ram-Sal	Finch	24	24×163
Sal-Nab	Finch	28	28×163
Nab-Tub	Bison	20	2×142
Tub-Jen	Bison	29	29×142
Total			37,723

3- Switchgear

Table 25
Ram-6 switchgear cost

132 kV

Type	**Cost KUS$**	**District**
A/132/40×2	3160	Jenin
B/132/16×2	4160	Tubas
Total	7,320	

230 kV

Type	**Cost KUS$**	**District**
A/230/63×2	4,735	Tulkarem
A/230/25×2	4,735	Qalqelia
B/230/16×2	6,555	Salfit
A/230/25×2	4,735	Jericho
B/230/150×2	6,555	Jerusalem
B/230/100×2	6,555	Beitlehem
A/230/150×2	4,735	Hebron
C/230-132-33/150×2	11,255	Nablus
C/11-33-230/200×8	16,730	Ramallah
Total	66,590	

Table 26
Ram-6 capital cost

Element	**Cost**	**Cost**
Transmission Lines	$37,723,000	
132 kv switch gear	$7,320,000	
230 kv switch gear		$66,590,000
132 kv transformer	$1,984,000	
230 kv transformer		$41,104,000
Sub total		
Total	$154,720,000	

Running cost for Ram-6 configuration.

1- Running cost of transformers $3,380,700……….(8)
2- Running cost of switchgear $5,838,200……….(8)
3- Running cost of transmission lines $1,056,200……….(7)
4- Running cost of power losses
4-1 Running cost of power losses for Ram-6 – constant part.

Table 27
Ram-6 transformers Poc

District	Transformer(MVA)	Poc (kW)	Notes
Jenin	2 × 40	2× 41.19	132 kV 2 wind
Tubas	2 × 16	2 × 21	132 kV 2 wind
Talkarem	2 × 63	2 × 82	230 kV 2 wind
Qalqelia	2× 25	2 × 31.25	230 kV 2 wind
Nablus	2 × 150	2 ×85	230 kV 3 wind
Salfit	2× 16	2 × 20	230 kV 2 wind
Ramallah	8 × 200	8×125	230 kV 2 wind
Jericho	2× 25	2×31.25	230 kV 3 wind
Jerusalem	2×150	2×157.8	230 kV2 wind
Beithlehem	2×100	2×115	230 kV 2 wind
Hebron	2×150	2×157.8	230 kV 2 wind
Total		2,484.6	

The constant power losses P_{oc} loss will be plugged into equation 9 and 14 The results are reflected in table 30 on the following page .

4-2 Running cost of power losses for Ram-6 – variable part.

4-2-1 Conductors variable power losses

Table 28
Ram-6 conductor variable power losses

Conductor	losses
1- Nab-Tkm	136.84 Kw
2- Nab-Qal	79.19 kW
3- Qal-Tkm	3.198 kW
4- Jer- Ram	335.4 kW
5- Ram-Jsm	1843 kW
6- Jer-Jsm	230.1 kW
7- Jsm-BL	507.66 kW
8- Bl-Heb	432.46 kW
9- Ram-Sal	1245.1 kW
10- Sal-Nab	1339.7 kW
11- Nab-Tub	6672 kW
12- Tub-Jen	242.47 kW
Total	6672 kW

4-2-2 Transformer variable power losses for Ram-6

Table 29
Ram-6 transformer variable power losses

1	Jenin	2 wind 2 × 40 MVA	321.07 kW
2	Tubas	2 wind 2× 16 MVA	73.198 kW
3	Tulkarem	2 wind 2× 63 MVA	181.8 kW
4	Qalqelia	2 wind 2×25 MVA	66.39 kW
5	Nablus	3 wind 2×150 MVA	328.05 kW
6	Salfit	2 wind 2×16 MVA	11.25 kW
7	Ramalah	3 wind 8×200 MVA	2,188.2 kW
8	Jericho	3 wind 8×200 MVA	72.39 kW
9	Jerusalem	2 wind 4×80 MVA	491.82 kW
10	Beithlehem	2 wind 2×100 MVA	275.24 kW
11	Hebron	2 wind 2×150 MVA	362.33 kW
	Total		4371.8 kW

The variable power losses of Ram-6 are then plugged in equation 13 and 14 to calculate the energy losses running cost. The results are reflected in table 30

Summary

Using equation 5, and taking CRF as 0.12, the following items are calculated and listed in table 30 below

Table 30
Ram-6 yearly cost

1	Capital recovery factor × Capital cost	$0.12×154,720,000
2	Yearly running cost of transformers	$3,380,700
3	Yearly running cost of switchgear	$5,838,200
4	Yearly running cost of Transmission lines.	$1,056,200
5	Yearly running cost of variable and constant power losses	$6,765,500
	Total yearly cost	$35.607× 10^6^

Economical analysis of Ramallah configuration Ram-1

Capital cost

1- Transformers

Table 31
Ram-1 transformers

District	Load MVA	Trans Rating MVA	Standard trans Rating MVA	Rated voltage kV	Type	Required No of trans
Jenin	61.07	43.62	40	132/33	2 wind	2 × 40
Tubas	17.53	12.52	16	132/22	2 wind	2 × 16
Tulkarem	70.23	50.16	63	230/33	2 wind	2 × 63
Qalqelia	32.38	23.13	25	230/33	2 wind	2 × 25
Nablus	205	146.4	150	230/132/33	3 wind	2 × 150
Salfit	12.71	9.079	16	230/33	2 wind	2 ×16
Ramallah	1065	760.7	4 × 200	11/230/33	3wind	8× 200
Jericho	33.81	24.15	25	230/33	2wind	2× 25
Jerusalem	219.5	156.8	150	230/33	2 wind	2× 150
Beithlehm	123.8	88.43	100	230/33	2 wind	2 × 100
Hebron	188.4	134.6	150	230/33	2 wind	2 × 150

Table 32
Ram-1 transformers cost

	132/33 kV				230/33 kV			
District	Trans Rating MVA	Type	No of Trans	Cost KUS$	Trans Rating MVA	Type	No of Trans	Cost KUS$
Jenin	40	2 wind	2	2×618	-	-	-	-
Tubas	16	2 wind	2	2×374				
Talkarem	-	-	-	-	63	2 wind	2	2×1127
Qalqelia	-	-	-	-	25	2 wind	2	2×630
Nablus	-	-	-	-	150	3 wind	2	2×1938 1.1
Salfit	-	-	-	-	16	2 wind	2	2×504
Ramallah	-	-	-	-	200×4	3 wind	8	8×2303 1.1
Jericho	-	-	-	-	25	2wind	2	2×630
Jerusalem	-	-	-	-	150	2 wind	2	2×1938
Beithlehem	-	-	-	-	100	2 wind	2	2×1520
Hebron	-	-	-	-	150	2 wind	2	2×1938
Total				1,984				41,104

2- Overhead lines

Table 33
Ram-1 Overhead lines

Line	Load MVA	Ckt norm. current A	Fault current A	Required cross section mm^2	Standa-rd cross section mm^2	Type	Max current /phase
Ram-Jer	33.8	42.42	84.84	60.6	381	Bison	
Ram-Jsm	531.77	667.4	1334.9	953.5	2×529	2×Moose	
Jsm-BL	312.24	391.9	783.79	559.8	565	Finch	
BL-Heb	188.4	236.5	472.9	337.8	381	Bison	
Ram-Sal	320.3	402	804	574.3	565	Finch	
Sal-Nab	307.6	386.1	772.2	551.6	565	Finch	
Nab-Tkm	102.58	128.7	257.2	183.7	381	Bison	
Qal-Tkm	32.381	40.64	81.28	58.05	381	Bison	
Nab-Tub	78.58	171.9	343.7	245.5	381	Bison	
Tub-Jen	61.07	133.6	267.1	190.8	381	Bison	

Table 34
Ram-1 Overhead lines cost

Line	Type	Length km	Cost KUS$
Ram-Jer	Bison	35	35×142
Ram-Jsm	2×Moose	18	18×221
Jsm-BL	Finch	10.3	10.3×163
BL-Heb	Bison	16.5	16.5×142
Ram-Sal	Finch	24	24×163
Sal-Nab	Finch	28	28×163
Nab-Tkm	Bison	25	25×142
Qal-Tkm	Bison	25	25×142
Nab-Tub	Bison	20	2×142
Tub-Jen	Bison	29	29×142
Total			35,504

2- Switchgear

Table 35
Ram-1 switchgear cost
132 kV switch gear

Type	Cost KUS $	District
A/132/40×2	3160	Jenin
B/132/16×2	4160	Tubas
Total	7,320	

23o kV switchgear

Type	Cost KUS $	District
B/230/63×2	6,555	Tulkarem
A/230/25×2	4,735	Qalqelia
C/230/150×2	11,255	Nablus
A/230/16×2	4,735	Salfit
D/230/200×8	18,545	Ramallah
A/230/25×2	4,735	Jericho
B/230/150×2	6,555	Jerusalem
B/230/100×2	6,555	Beitlehem
A/230/150×2	4,735	Hebron
Total	68,405	

Table 36
Ram-1 capital cost

Element	Cost	Cost
Transmission Lines	$35,504,000	
132 kv switch gear	$7,320,000	
230 kv switch gear		$68,405,000
132 kv transformer	$1,984,000	
230 kv transformer		$41,104,000
Sub total		
Total	$154,320,000	

Running cost for Ram-1 configuration.

1- Running cost of transformers $3,380,700………(8)
2- Running cost of switchgear $5,979,800………(8)
3- Running cost of transmission lines $994,110………..(7)
4- Running cost of power losses
4-1 Running cost of power losses for Ram-1- constant part.

Table 37
Ram-1 transformer Poc

District	Transformer MVA)	Poc (kW)	Notes
Jenin	2 × 40	2× 41.19	132 kv 2 wind
Tubas	2 × 16	2 × 21	132 kv 2 wind
Talkarem	2 × 63	2 × 82	230 kv 2 wind
Nablus	2 × 150	2 ×85	230 kv 3 wind
Qalqelia	2× 25	2 × 31.25	230 kv 2 wind
Salfit	2× 16	2 × 20	230 kv 2 wind
Ramallah	8 × 200	8×125	230 kv 3 wind
Jericho	2× 25	2×31.25	230 kv 2 wind
Jerusalem	2×150	2×157.8	230 kv 2 wind
Beithlehem	2×100	2×115	230 kv 2 wind
Hebron	2×150	2×157.8	230 kv 2 wind
Total		2,484.6	

The constant power losses P_{oc} loss will be plugged into equation 9 and 14. The results are reflected in table 40

4-2 Running cost of Power losses for Ram-1 – variable part.

4-2-1 Conductor variable power losses

Table 38
Ram-1 conductor variable power losses

conductor	losses
1- Jer- Ram	29.52 kW
2- Ram-Jsm	1,389.2 kW
3- Jsm-BL	507.79 kW
4- Bl-Heb	432.51 kW
5- Ram-Sal	1244.9 kW
6- Sal-Nab	1339.4 kW
7- Nab-Tkm	194.25 kW
8- Qal-Tkm	19.356 kW
9- Nab-Tub	276.86 kW
10- Tub-Jen	242.47 kW
Total	5,676.3 kW

4-2-2 Transformer variable power losses for Ram-1

Table 39
Ram-1 transformer variable power losses

	Location	Transformer	losses
1	Jenin	2 wind 2×40 MVA	321.19 kW
2	Tubas	2 wind 2× 16 MVA	73.192 kW
3	Tulkarem	2 wind 2× 63 MVA	181.8 kW
4	Qalqelia	2 wind 2×25 MVA	66.39 kW
5	Nablus	3 wind 2×150 MVA	328.05 kW
6	Salfit	2 wind 2×16 MVA	11.25 kW
7	Ramalah	3 wind 8×200 MVA	2,188.2 kW
8	Jericho	3 wind 8×200 MVA	72.39 kW
9	Jerusalem	2 wind 2×150 MVA	491.82 kW
10	Beithlehem	2 wind 2×100 MVA	275.24 kW
11	Hebron	2 wind 2×150 MVA	362.33 kW
	Total		4371.8 kW

The variable power losses of Ram-1 are then plugged in Equation 13 and 14 to calculate the energy losses running cost. The results are reflected in table 40 .

Summary

Using equation 5 and taking CRF as 0.12, the following items are calculated and listed in table 40 below

Table 40
Ram-1 yearly cost

1	Capital recovery factor × Capital cost	\$0.12×154,320,000
2	Yearly running cost of transformers	\$3,380,700
3	Yearly running cost of switchgear	\$5,979,800
4	Yearly running cost of Transmission lines.	\$994,110
5	Yearly running cost of variable and constant power losses	\$6,430,300
	Total yearly cost	$\$35.303 \times 10^6$

جامعة النجاح الوطنية
كلية الدراسات العليا

تصميم وتحليل الأداء الأمثل لشبكة كهرباء فلسطينية مقترحة الضفة الغربية

إعداد
عبد الله نزار حسني البسطامي

إشراف
د. ماهر خماش

قدمت هذه الاطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الاستهلاك من كلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.

2008م

تصميم وتحليل الأداء الأمثل لشبكة كهرباء فلسطينية مقترحة

الضفة الغربية

إعداد

عبد الله نزار حسني البسطامي

إشراف

د. ماهر خماش

الملخص

تكمن أهمية شبكات الكهرباء ذات الضغط العالي في أنها تقوم بنقل الطاقة الكهربائية إلى جميع قطاعات المجتمع السكنية والتجارية والصناعية، ولذالك فهي مهمة لتطور المجتمع بحيث يتم توفير طاقه بشكل امن و بتكلفه اقتصاديه محفزه. في هذه الرسالة تم وضع عدة مقترحات لتوفير الطاقه الكهربائيه للضفه الغربيه و يشمل ذلك مكان الربط و موضع محطة الكهرباء الرئيسية المنوي اقامتها في الضفه الغربيه وعدة طرق لتوصيل الكهرباء للمحطات الفرعية في كل مقترح، من أجل تحديد الموضع والطريقة الأمثل من حيث التكلفة والأداء.

لقد اظهرت نتائج هذه الدراسه ان هذه الشبكة الكهربائية المقترحه يمكن ان تعمل بنجاح تحت جميع الظروف المختلفة مثل الحمل الأدنى وعطل بعض الكوابل الكهربائية الرئيسية والأحمال الإضافية المستقبلية.

في هذه الرسالة تم الوصول الى تصميم شبكة كهرباء رئيسية متكاملة ومتصلة بأكثر من مصدر وكانت الخسائر الكهربائية فيها قليلة، والجهود الكهربائية بقيت ضمن الحدود المسموح بها عالميا على جميع أطراف الشبكة الكهربائية.

هذه الشبكة المقترحه تعمل على فولتيات قياسية وهي ضرورية للربط مع الشبكة السباعية العربيه للمنطقه ، كما أنها ستوفر الكهرباء بتكلفة أقل من التكلفة الحالية وبشكل مستقر وامن اكثر.