An-Najah National University

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Energy Management and Analysis of Ramallah Electrical Network

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Dedication

إلى من أكرمني الله بأن جعلني ابنا لهم، إلى والديَّ اللذين أغدقا وما زالا علي وعلى أسرتي الصغيرة الحب والعطف والرعاية، إلى من حباني الله بها زوجتي ديانا، التي تحملت انشغالي عنها برضاً وحب، إلى من رزقنا الله به، وأنار به حياتنا إلى صغيري محمود، إلى أختي التي احترفت الغربة وساندتني من بعيد، وإلى أخوتي المهندسين الصغار.

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الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Energy Management and Analysis of Ramallah Electrical Network

أقر بأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وأن 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.

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Abbreviations

ACCC	Aluminum Conductor Composite Core
ACSR	Aluminum Conductor Steel Reinforced
GPP	Gaza Power Plant
HEPCO	Hebron Electric Power Company
IEC	Israeli Electricity Company
IRR	Internal Rate of Return
JDECO	Jerusalem District Electrical Company
LV	Low Voltage
MV	Medium Voltage
NEDCO	Northern Electricity Distribution Company
NIS	New Israeli Shekel
NPV	Net Present Value
PF	Power Factor
PW	Present Worth
PA	Palestinian Authority
PCBS	Palestinian Central Bureau of Statistics
R.O.R.	Rate of Return
SCADA	Supervisory Control and Data Acquisition
SELCO	Southern Electric Company
TOU	Time Of Use
VAR	Voltage Automatic Regulator
VI%	Voltage Impedance

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Abstract

The medium voltage network in Ramallah, Al-Berih and Beitunya is to be studied and analyzed to find out its weaknesses, and provide scenarios for resolving these weaknesses. PowerWorld Simulator were used to simulate real data collected from the SCADA system of the company, the output of the simulation highlighted two main problems, overloading and relatively high technical losses. Conservation measures were suggested in order to resolve the problems highlighted during the simulation, these measures can be summarized in upgrading the transmission lines to ACCC, reconfigure part of the medium voltage network, reducing neutral current in low voltage network, and replace the power transformers with high efficiency power transformers. The suggested measures then were examined using the simulator to simulate the improvements expected after applying the improving measure. Also, financial analysis of energy management measures in Ramallah electrical network was performed over all the suggested measures, which led to approving the first three measures and rejecting the fourth one. The financial analysis showed savings potential of about 15 million dollars during the life time of the project which is 15 years.

Chapter One

Electrical Energy Status in Palestine

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1.1.Overview of the Palestinian Energy Sector

The main characteristics of the energy sector in Palestine (the West Bank and Gaza) are:

- The total energy consumed in West Bank and Gaza is small compared to regional standards, and even smaller compared to international standards, which limits the scope for achieving economies of scale.
- Household sectors account for most of the energy demand (75%), because of the relatively little activity in manufacturing.
- Nearly all the electrical energy is purchased from Israel.
- West Bank and Gaza have different energy supply options.
- The electricity system in the West Bank consists of numerous isolated distribution systems that are not integrated into a distribution network, and it has no generation capacity or transmission network. [1]

1.2.Electrical Energy Consumption in Palestine

Electrical energy in 2006 accounted for 21.59% of the total consumed energy in West Bank and Gaza. This percentage was derived from PCBS - Energy Balance in the Palestinian territory 2006, October, 2008.

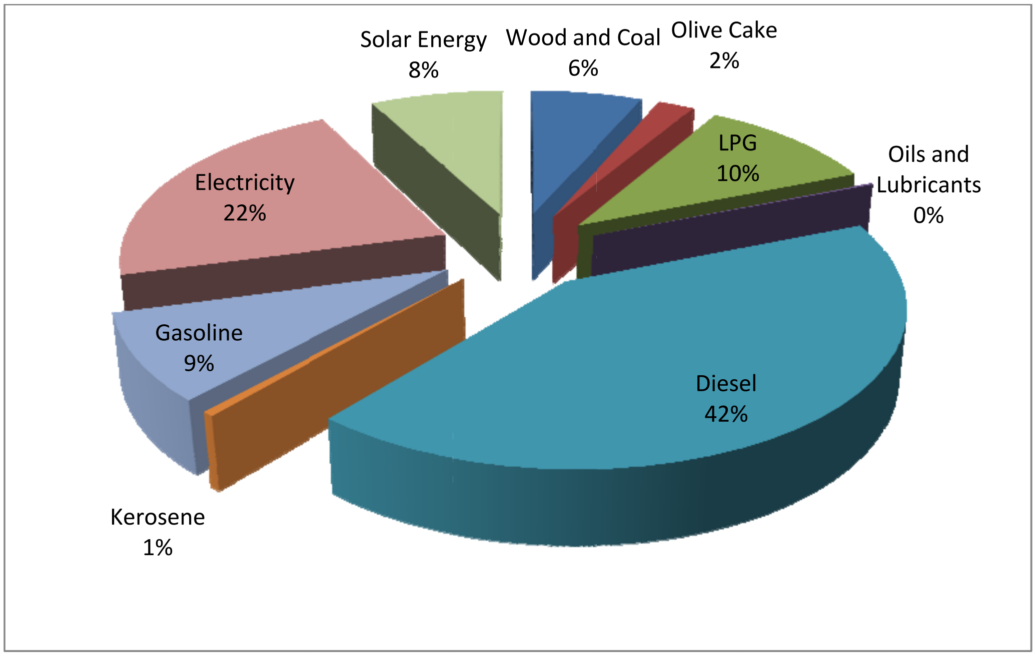

Figure 1.1: Consumption of Energy in 2006 by Source of Energy

A growth of 6.4% annually from 1999 to 2005 in the consumption of electricity in the West Bank – as indicated by imports from Israel – was reported. In Gaza the growth on average was about 10% annually from 1999 to 2005; this increase in consumption in Gaza was largely met by the output from GPP from late 2002 onwards.

In 2006, the imports from electricity in Palestine reached 3,096 thousand MWh while the production reached 345 thousand MWh most of it from Gaza Power Plant. [3]

And the total electrical energy purchases in 2006 were 3,441,700 MWh; divided to 2,331,110 MWh in the West Bank and 1,110,590 MWh in Gaza Strip. [3]

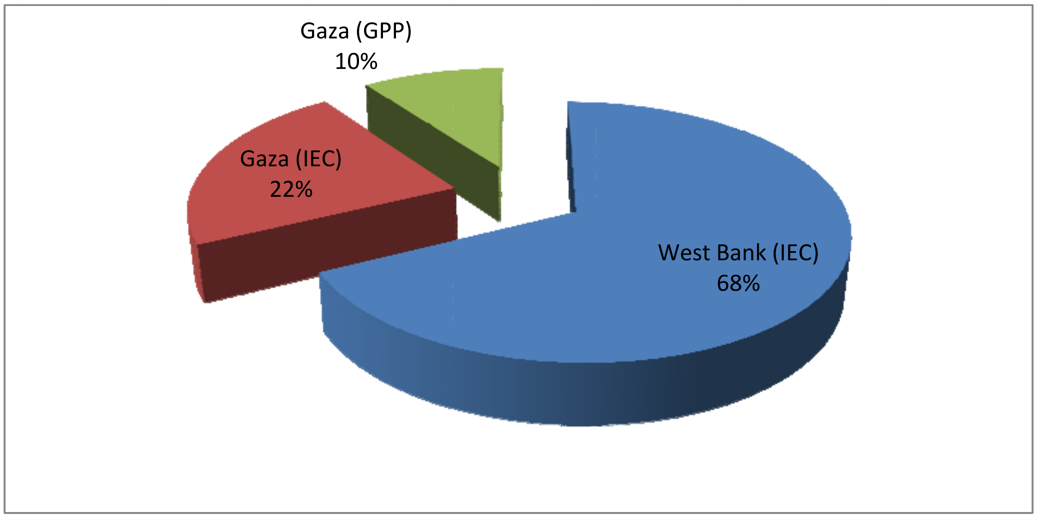

Figure 1.2: Electrical Energy Consumption in Palestine in 2006

The average monthly household consumption of electricity in Palestine reached 259.6 kWh (233.6 kWh in the West Bank and 267.1 kWh in Gaza Strip). [2]

As the average household size in West Bank is about 6 persons, the estimated per capita consumption is about 675 kWh/year. Average billed consumption is highest in cities, lower in villages and lowest in refugee camps. Commercial activities are most electricity intensive in the Hebron area, where the average annual consumption averaged about 43,800 kWh in 2006.

1.3. Electrical Distribution Companies in the West Bank

Power supply and distribution in the West Bank is the responsibility of four power utilities which are:

1. Jerusalem District Electricity Company (JDECO) serving the central area around Jerusalem.

2. Hebron Electric Power Company (HEPCO) serving the southern area around Hebron.
3. Southern Electric Company (SELCO), the newly formed utility serving the rest of the southern area.
4. Northern Electricity Distribution Company (NEDCO), the newly formed utility serving the northern area.

The new utilities were formed by taking over the electricity assets and businesses of the municipalities and village councils in the service areas of these utilities, in return for which ownership of the shares of these utilities is vested in these municipalities and councils. [1]

Table 1.1: Electricity Sales in West Bank by Supplier 2005 [1]

	JDECO	HEPCO	SELCO	W. Bank Munic.	Nablus	Grand Total
Total billed consumption (GWh)						
Households	503	110	35	213	73	934
Commercial	363	77	14	227	78	759
Number of consumers						
Households	143,000	26,000	15,000	104,000	36,000	324,000
Commercial	31,000	2,000	1,000	29,000	10,000	73,000
Average consumption (MWh)						
Households	3.5	4.2	2.4	2.1	2.1	2.9
Commercial	11.8	43.8	18.7	7.9	7.9	10.4

In 2005 the established power utilities were under considerable financial stress due to three factors:

1. Low unit mark-up (trading margin).

2. Substantially lower amount billed to customers than the amount of electricity purchased from IEC. This loss is the result of technical transmission losses, inefficient billing, and theft. [1]
3. The low cash collection rates. In 2008, cash collection rates were around 90% by JDECO.

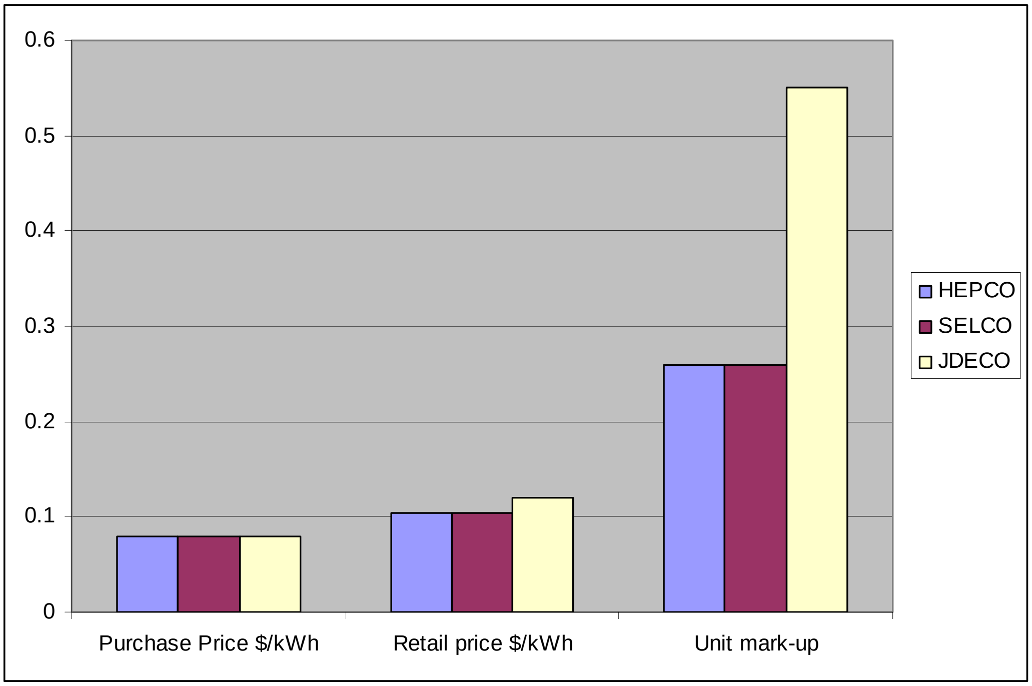

Figure 1.3: Comparison between purchase price, retail price and unit mark-up for JDECO, HEPCO and SELCO

1.4. Electrical Networks in the West Bank

The electricity in the West Bank is supplied mainly by three 161/ 33 KV substations located in:

- The south in area C close to Hebron.
- The north in Ariel settlement (area C) close to Nablus.
- The middle in Atarot industrial area (area C) near Jerusalem.

Figure 1.4: Electricity Supply System in West Bank and Gaza [1]

In 2007, the contracted capacity from IEC was about 600MVA divided into 380MVA for the central area under JDECO, 125MVA for the north and 95MVA for the south, and as a result to the agreement between the PA and Jordan to connect the Palestinian power grid to that of Jordan at Jericho through a 33kV line via King Abdallah Bridge (the line was built to carry electricity at 132kV) JDECO disconnected Jericho from IEC grid and now supplies it with electricity from Jordan. The tariff in Jericho right now is deferent than the tariff adopted in Jerusalem, Ramallah and Bethlehem.

The present load in the West Bank is in the order of 600 to 700MW and is supplied from several points within the IEC network. The electrical networks in the West Bank are all considered distribution networks at 33 and 22kV.

The number of the connection points (to the IEC network) is about 190, of which 120 in the Northern area, about 45 in the Southern area and 25 points in the JDECO area. The connection points are not physically connected by an integrated network that will allow the transfer of any unused capacity from one point to another or the use of one point as a backup to another point in case of an emergency situation. But this is not the case for JDECO; due to the existence of an integrated network.

The average losses are about 20%-30%, and this is mainly due to theft and technical losses due to the lack of financing because of the deteriorating situation in the collection of the electricity bills in utilities, municipalities, and villages which affected the maintenance of the networks, and it is in turn increased losses, outages and overloading of feeders.

The Palestinians are requesting increase in the capacity of the existing connection points or new connection points, but the IEC for the time being rejects most of these requests, claiming lack of capacity in the existing 161kV substations or overloading of its distribution feeders, and so, asupply bottleneck has been created, which in turn may trigger load shedding in some areas. The area most affected will be the Nablus area, which is the main load center in the northern region.

1.5.Electrical Energy Resources in Palestine

The GPP is the only significant generation capacity in West Bank and Gaza. This plant has the capacity to supply only 20% of the combined needs of West Bank and Gaza, but it can supply about two-thirds of the current maximum load on the Gazan electricity system (it is constrained to using 50% of capacity right now because of the limitations of the transmission network taking the power out from the plant). The plant generates electricity at high cost because it uses diesel.

1.6.JEDCO

As mentioned before, JDECO distributes electrical energy in eastern Jerusalem, Ramallah, Bethlehem and Jericho. The electrical network of JDECO is supplied by IEC through 25 injection points; these points and its main features are introduced in table 1.2:

Table 1.2: Injection points and summery about their information for JDECo

Injection Point	Area 50%	Area 50%	No. of Injection Points	Total Capacity (MVA)	Capacity (MVA)	Peak Load in 2007 (kW)	Avg. Consumption (kWh/month)	Operating Voltage (kV)
Al-Barid	Jerusalem	Ramallah	3	-	20.00	13,950	6,056,640	33.0
Rama 1	Jerusalem	Ramallah			20.00	20,120	6,632,260	33.0
Sur Baher	Jerusalem	Bethlehem			15.00	7,240	2,342,880	33.0
Erez	Jerusalem		8	152.50	20.00	17,330	5,080,770	33.0
Hetsav					20.00	19,100	5,923,180	33.0
Rakefet					20.00	17,330	7,410,800	33.0
Beit Safafa					2.50	2,335	894,982	13.8
Al-Tur					15.00	13,950	4,804,120	33.0
Abu Dis					15.00	16,840	5,512,200	33.0
Nabi Samuel					7.50	11,320	2,260,670	33.0
Zaayem					15.00	11,690	4,870,200	33.0
Rammalh	Ramallah		8	122.50	20.00	19,100	7,579,460	33.0
Ofer					20.00	15,290	7,692,409	33.0
Ein Samya					10.00	3,220	1,172,500	33.0
Nabi Saleh					7.50	6,440	2,599,790	33.0
Pereg					20.00	17,970	5,520,740	33.0
Al-Ram					20.00	17,490	5,734,200	33.0
Beit Horon					5.00	4,670	1,450,250	33.0
Sinjel					10.00	3,490	2,806,766	33.0
Beit Eil (spare)							68,345	33.0
Bethlehem	Bethlehem		4	73.50	20.00	17,430	7,452,420	33.0
Shufat					20.00	17,060	8,340,440	33.0
Hana					20.00	17,110	5,015,800	33.0
Tquoa					6.00	3,220	342,750	33.0
Afrat (spare)							647,360	33.0
Aqbat Jaber	Jericho		2	25.00	10.00	8,050	3,457,040	33.0
Jericho					15.00	6,810	2,273,620	33.0
Total			25	373.50	373.50	253,520		

In 2007, the total number of customers served by JDECO reached 187,164 customers as shown in figure 1.5.

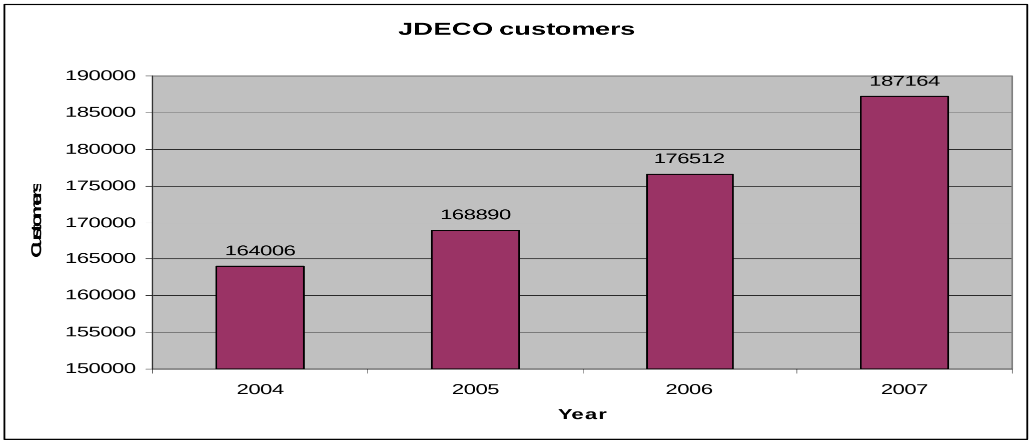

Figure 1.5: JDECO customers from 2004 to 2007

In 2007, about 42,134 (22.51% of the total customers) are without bill (illegal customers); figure 1.6 shows the number of the customers without bill from 2004 to 2007

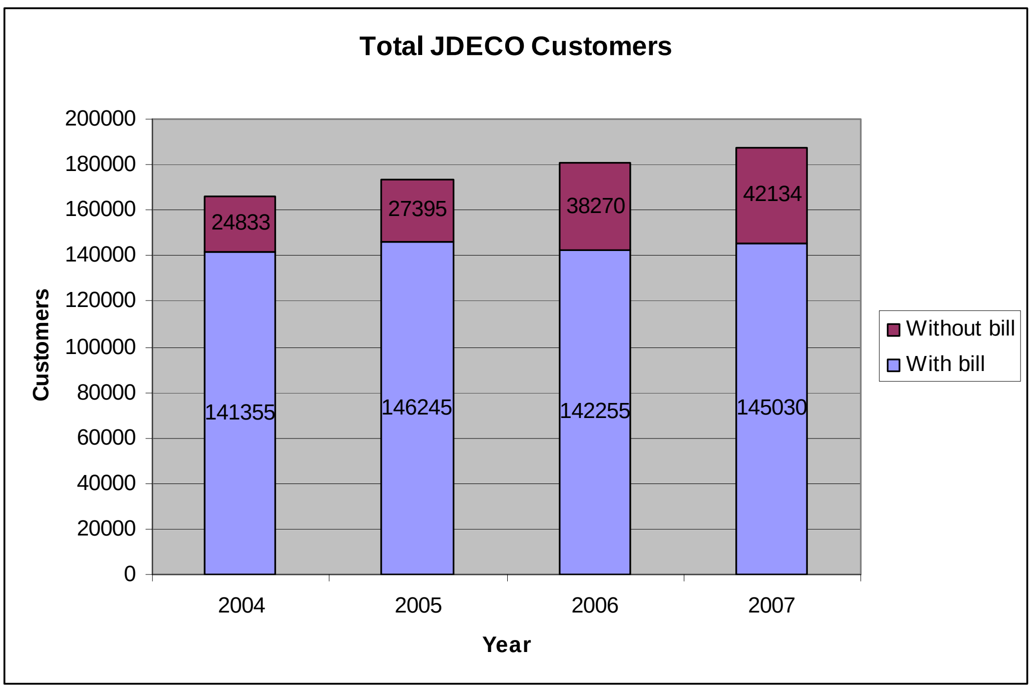

Figure 1.6: Total JDECO customers from 2004 to 2007

The increase in the customers was accompanied with increase in the consumed (imported) MWh and in the peak MW, as shown in table 1.3, the annual increase in 2007 was 8.76%.

Table 1.3: Annual imported MWh from 2004 to 2007

Year	Imported MWh	Annual increase
2004	1,076,636	10.25%
2005	1,237,407	14.93%
2006	1,261,708	1.96%
2007	1,372,187	8.76%

Table 1.4: Annual peak load for JDECo

Year	Peak Load MW
2004	225.30
2005	244.52
2006	253.52
2007	275.00

The effect of the illegal customers on the billed consumption is clear in, where only 999,763 MWh from the imported 1,372,187 MWh is billed, that is the total losses in the system is 27.14%.

Despite the uncertain and difficult situation, JDECO has had a reasonably satisfactory performance with sales growing at an annual rate of 17% during 2005. System losses have gone down from a high of 20% in 2004 to 18% in 2005 and back up to 23-25% in 2007 and 2008. The company has had a significant drop in trading margin (total sales minus import cost) in recent years. Against the annual increase of 17% in sales in recent years, the import cost of electricity has been growing by an annual rate of 25% during the same period causing the trading margin to drop. Increased efforts for efficiency improvements together with adjustments in the sales tariff should result in a better margin for JDECO to cover its operating and financing costs.

Overall cash collection performance improved significantly from 71% for 2002 to over 112% by the end of 2005. The PA agencies have big accumulated electricity bills, government employees cannot pay for their accumulated electricity consumption because of non-payment of salaries for about year and a half, and an increasing numbers of unemployed consumers are not paying for their electricity consumption. Consequently, the overall collection rate started to decline again, and it had dropped to 82.6% by the middle of November 2006. This level is not sustainable, and the disconnection of delinquent customers has led to a rapid increase in illegal connections, which in turn has resulted in rising non-technical losses.

1.7.Electrical Network Problems

Israel Electric Corporation Ltd (IEC) recovers part of its unpaid bills supplied to West Bank and Gaza from the tax revenue that the Israeli Ministry of Finance collects on behalf of the PA which, by agreement, is supposed to be transferred to the PA on a monthly basis in advance of the regular transfer of tax revenues.

In summary, despite the several rehabilitation programs executed in the different regions of the West Bank, several factors have adversely affected the electricity networks, namely: lack of capital and a decrease in the collection of electricity bills resulting in poor maintenance in the network; no control of the connection points by Palestinian utilities and municipalities with the result that feeders are extended at LV instead of at MV; and insufficient supply at the connection points controlled by IEC. These factors have led to an increase of technical and non technical losses, increase in network outages, deterioration of the quality of supply for the end consumer, and overloading of feeders.

Investments are needed to reduce the high level of technical losses in the power networks, and to expand the capacity to distribute more imported power to consumers as their demand grows by consolidating the numerous low voltage feeders into larger medium voltage feeders served by new substations under Palestinian control.

Chapter Two

Energy Management in Electrical Network

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1.8. Energy Conservation Measures in Electrical Network

In any medium voltage electrical distribution network there are many factors that contribute to the loss of energy, these factors mainly are technical, and they include:

a) Power and distribution transformers' losses.
b) Cross sectional area of the conductors vs. the carried load and the length of the carriers and distributers.
c) The use of low operating voltages.
d) The load centers and incorrect positioning of the power transformers.
e) Low power factor of the loads.

In this chapter we will represent the most economical measures to reduce the losses caused by each one of the factors mentioned above.

It is important to keep in mind that losses are divided such that about 60% are from lines and 40% are from transformers (most of which are for distribution) [5].

1.9. Energy Conservation in Power Transformers

The main reasons for considering energy management for transformers are given below.

1. The large number of distribution transformers in use and the fact that all electric power generated continuously passes through them implies that even small improvements in transformer efficiency can result in substantial energy and greenhouse gas savings. Despite high

2. average efficiencies (from 95 to 99.75%), transformers have a significant environmental impact because they continuously consume power. This might be considered as a 2^{nd} standby loss, after the standby power loss in electrical equipments [7]. The energy losses in electricity transformers fall into two components:

2.1. No-load losses or iron losses which are resulting from energizing the iron core; this phenomenon occurs 24 hours per day, 7 days per week, over the lifetime of the transformer, 30 years in average. This loss represents the greater part of the losses, and it is possible to reduce such no load loss dramatically through the adoption of amorphous transformers which use amorphous alloy as the core material of the transformers. It was found that if the amorphous transformers replace the general purpose transformers in Japan then the energy-saving scale is about 1% of power requirements, while in China the energy-saving scale is about 5% of power requirements [6]. Distribution transformers built with amorphous cores can reduce no-load losses by more than 70% compared to the best conventional designs [7].

2.2. Load losses arising when providing power to a user, from the resistance of the coils when the transformer is in use and for eddy currents due to stray flux. Also, transformers may lose 1 to 2% of energy transformed as heat when they are lightly loaded.

3. In most electricity grid, up to 2% of total electricity generated is estimated to be lost in distribution transformers, representing nearly one-third of overall system losses keeping in mind that the technical loss is about 7% of total electricity generated in EU for example. For comparison, in the European Union, to compensate the energy losses in distribution transformers, it takes about six large nuclear stations [7].

4. The environmental benefits of energy-efficient transformers are very high. A 400 kVA transformer, typical for urban distribution, has lifetime losses equivalent to 125 – 184 tones of CO^2 emissions. Electricity losses cost two to three times more than the original purchase price of the transformer. An energy-efficient transformer could reduce CO^2 emissions to 56 tones (figures for The Netherlands) [7].

5. Utility's investment in energy-efficient distribution transformers has an economic payback time between 1.4 and 8 years, and an internal rate of return between 7% and 11%. There are a variety of additional cost savings and benefits associated with energy-efficient transformers. They include:

5.1. Reduced transformer heating, hence lower need for additional cooling or insulation (hence reduced variable costs such as coolants, ageing insulation materials);

5.2. Longer operating lifetime.

5.3. Low-loss transformers also better withstand electronic (harmonic) loads.

1.10. Energy Conservation in Transmission and Distribution Lines

Transmission losses depend on the voltage level and the distance between feed-in location and consumer.

There are several methods to reduce losses in transmission and distribution lines, we will introduce three of them:

1. Resizing of the conductors to match the carried load, or using new low-loss conductors like ACCC. Composite-core, low-sag transmission conductors (ACCC) can transport two to three times as much power as conventional conductors over the same rights-of-way and with no tower modifications. In addition, the conductor's core has 25% lower electrical resistances than steel, enabling higher transmission efficiencies [5].
2. Reconfiguration of the distribution system in order to minimize the losses. Feeder reconfiguration for loss minimization in distribution systems is realized by changing the status of sectionalizing and tie switches. Most electric distribution networks are operated radially. Configuration alterations are performed by changing the state of network switches, in such a way that radiality is always preserved. The optimal operating condition of distribution networks is obtained when line losses are minimized without any violations of branch loading and voltage limits. Therefore, feeder reconfiguration is implemented to minimize real power losses and at the same time alleviate transformer overload, feeder thermal overload and abnormal voltages of the system. There are two types of switches in the system: one is normally closed switches connecting the line sections called sectionalizing switches and the other is normally open switches on the tie-lines connecting either two primary

3. feeders or two substations called tie-switches [8]. The change in network configuration is achieved by opening or closing of these two types of switches in such a way that the radiality of the network is maintained. Distribution lines or line sections show different characteristics as each has a different mixture of residential, commercial and industrial type loads and their corresponding peak times are not coincident. This is due to the fact that some parts of the distribution system becomes more heavily loaded at certain times of the day and less heavily loaded at other times. Therefore, by shifting the loads in the system, the radial structure of the distribution feeders can be modified from time to time in order to reschedule the load currents more efficiently for loss minimization. During normal operating conditions, networks are reconfigured for two purposes:

3.1. To minimize the system real power losses in the net work.

3.2. To relieve the overloads in the feeders.

The former is referred to as feeder reconfiguration for loss reduction and the latter as load balancing.

4. Using capacitor banks along the transmission or distribution line, in carefully selected spots so that to reduce the current in the conductors by reducing the total transmitted kVAR from the source.

5. Reducing the losses in the neutral conductors of the low voltage feeders by reducing the neutral current through minimizing the .

6. unbalance caused by not distributing the consumers on the low voltage feeders in a uniform manner.

1.11. Reduction of the Electrical Losses Using Higher Transmission and Distribution voltages

For a given amount of power to be transmitted, the current flowing in the conductors can be reduced using higher voltages and thus the resistive losses in the conductors are reduced. In this study we will investigate the advantages, disadvantages and the investment needed to unify the electrical system in Ramallah to 33kV, keeping in mind that the current electrical system in Ramallah is mixed 11/33kV.

1.12. Reduction of the Electrical Losses by Improving the Network's Power Factor

For low power factors losses will increase. Utilities worldwide add capacitor banks (as described before in 2.3), phase-shifting transformers and static VAR compensators in order to control reactive power flow and hence to reduce the losses and stabilize the system voltage.

1.13. Previous Projects and Experiences

1.13.1. Ho Chi Minh City Power Company in Vietnam

Ho Chi Minh City Power Company in Vietnam suffered from huge losses in the past, the total loss in 1995 was 17.48%, and with technical measures the losses were reduced to 5.9% in 2009, and it is planned to get down to 5.2% in 2010.

The city's population is over 6 million, and it covers 2000 m^2, and its electrical load is divided into:

1. 45% industrial loads.
2. 12% service.
3. 35% household.

While its peak load reached 2,050 MW in 2007.

The company's customer growth rate is 9.6% per year, its customers were 1.5 million customers in 2007, and its energy sales growth rate is 12.6% per year, the company's energy sales reached 11.56 GWh in 2007.

The company's electrical system consists of:

1. Sources:

1.1. One 500 kV and six 220 kV substations.

1.2. 42 110 kV substations with capacity of 3,450 MVA.

2. MV network: 15kV and 22kV with 3,600 km of overhead lines and 1,118 km underground cables.

3. LV network: 220/380V with 8,600 km of overhead lines and underground cables.

Technical Measures Taken to Reduce the Losses

1. Shorter or More Direct Lines (Reconfiguration of the Distribution System)

1.1. Energizing new substations with new feeders.

1.2. Changing the locations of open and closed points on a circuit.

2. Optimizing Voltage Levels

2.1. Transmission system was unified from 66/110 kV to 110kV in 2003. Loss rate decreased by about 0.5%.

2.2. Medium voltage network was unified from 6.6/15kV to 15kV in 2003. Loss rate decreased by about 0.5%. Plan of upgrading to 22kV is being re-considered.

2.3. Low voltage network was upgraded from 120/208V to 220/380V in early 1990s. Loss rate decreased by about 2%.

3. Standardization of power network

3.1. Quality of transformer core material. Old transformers with high loss are replaced.

3.2. Balancing 3-phase loads and exchanging overload and underload transformers periodically.

3.3. Increasing the cross sectional area of lines and cables, reinforcing connectors, changing open points reasonably.

1.13.2. Bani Zeid Feeder in JDECO

The Palestinian Energy and Natural Resources Authority conducted a study about Bani Zaid feeder in year 2000 to improve its technical situation, but the second intifada prevented the implementation of the suggested measures.

Bani Zeid feeder is an 11kV feeder out of Ramallah North substation, it supplies 19 villages (with a total number of 4159 consumer), Birzeit University, two oil pressers, three stone cutters and a water pump in the north west of Ramallah. The total length of the line is about 60 km and is mainly 50mm^2 ACSR, with 38-distribution transformers with total capacity of 8 MVA. The maximum load at the 0.4kV side of the distribution transformers during January 2000 is 2.8 MW and the estimated consumption for year 2000 is 15.7 GWh.

The losses in this feeder was found to be as stated in table 2.1.

Table 2.1: Bani Zeid feeder calculated losses in year 2000

System Component		Max. Power Losses		Energy Losses	
		MW	%	MWh	%
11 kV lines		0.636	23.09	2106	13.1
Distribution Transformer Losses	No Load	0.012	0.44	105	0.65
	Load	0.029	1.05	38	0.23
Power Transformer	No Load	0.011	0.40	96	0.60
	Load	0.013	0.47	128	0.80
Total		**0.701**	**25.45**	**2473**	**15.38**

Also, the power factor of the feeder is about 0.86, and the maximum voltage drop on the line is 24 % at Shoqba.

At that time two scenarios to reduce the losses were proposed, the first scenario was the installation of capacitor banks, while the other scenario was the introduction of a new 33/11 kV substation.

Analyzing the first scenario indicated that installing capacitor banks will improve voltage profile and power factor, selected MV and LV substations sites have been analyzed, it was found that the best location is near Nabi Saleh substation with a size of 0.8 MVAR, which will raise the P.F to 0.92 while reducing the maximum voltage drops is 18.5% at Shoqba.

The effect of the capacitors on each component of the system losses is shown table 2.2.

Table 2.2: Bani Zeid feeder calculated losses in year 2000 after installing capacitor banks

System Component		Max. Power Losses		Energy Losses	
		MW	%	MWh	%
11 kV lines		0.468	17.00	1566	9.75
Distribution Transformer Losses	No Load	0.013	0.47	114	0.71
	Load	0.026	0.94	112	0.70
Power Transformers	No Load	0.011	0.40	96	0.60
	Load	0.010	0.36	38	0.24
Total		0.528	19.17	1926	12.00

Analyzing the second scenario showed that introducing a new 33/11 kV near Dir Nizam vilage. This new substation will feed part of the load that Ramallah North substation is currently feeding.

The existing Bani Zeid feeder will be divided into 2 parts; the first will be fed from Ramallah North substation and the other from the proposed substation.

Also capacitor banks are introduced at Shoqba and at Shaheen to improve the power factor and to reduce losses, the optimal sizes of these capacitor banks are 300 kVAR and 200 kVAR.

Operational actions for the transformer tap changers are to be taken to set the taps of all the transformers to the normal location (i.e 11/0.4 kV location).
The effect of this scenario on each component of the system losses on year 2000 is shown in table 2.3.

Table 2.3: Bani Zeid feeder calculated losses in year 2000 after introducing a new substation and installing capacitor banks

System Component		Max. Power Losses (MW)			%	Energy Losses (MWh)			%
		Ramallah North substation	Proposed substation	Total		Ramallah North substation	Proposed substation	Total	
11 kV lines		0.026	0.029	0.055	2.00	101	120	221	1.38
Distribution Transformer losses	No Load	0.006	0.008	0.014	0.51	53	70	123	0.77
	Load	0.012	0.011	0.023	0.84	50	49	99	0.62
Power Transformers	No Load	0.011	0.011	0.022	0.80	96	96	192	1.20
	Load	0.001	0.003	0.004	0.15	6	11	17	0.11
Total		0.056	0.062	**0.118**	**4.30**	306	346	**652**	**4.08**

The investment required to implement the first scenario was found to be NIS58,000, while the expected savings are presented in table 2.4.

Table 2.4: Financial evaluation summary of scenario A

Year	Investment NIS	Capacity Savings MW	Energy Savings MWh	NPV Savings NIS	IRR
2000	58,000	0.172	547	149,000	
2001		0.200	632	166,000	
2002		0.239	727	185,000	
2003		0.299	841	208,000	
2004		0.422	982	243,000	268%

It can be seen that the total net present value was found to be NIS892,000.

The investment required to implement the second scenario was found to be NIS1,730,000, while the expected savings are presented in table 2.5.

Table 2.5: Financial evaluation summary of scenario B

Year	Investment NIS	Capacity Savings MW	Energy Savings MWh	NPV Savings NIS	IRR
2000	1,730,000	0.582	1821	497,000	
2001		0.688	2091	552,000	
2002		0.825	2409	616,000	
2003		1.017	2792	695,000	
2004		1.325	3266	798,000	22%

It can be seen that the total net present value was found to be NIS1,428,000.

The conclusions that the study makers reached are stated here as taken from the source:

♦ Based on the above results and analysis, it is obvious that the Bani Zeid feeder suffers from very high losses and voltage drop.

♦ Scenario A has the highest IRR and CBR but will not solve the technical problems, the losses and voltage drop will remain high.

♦ Scenario B is the best solution as

- It will solve the voltage and losses problems.
- It has a high IRR and CBR
- It has a high and positive NPV which shows the feasibility of the scenario.
- The payback period of the investment is 3 years.

♦ The reduction in West Bank and Gaza total losses due to implementing scenario B is about 0.1%.

1.14. Summery

It is clear that there are many ways to improve the efficiency and the reliability of any electrical network as can be seen from the previous experiments. This leads to studying improvements to JDECo's electrical network in Ramallah. But first it is important to study the existing system, which will be done in chapter 3.

Chapter Three

Introduction about the Electrical System in Ramallah and Al-Berih District

Chapter Three

Introduction about the Electrical System in Ramallah and Al-Berih District

Ramallah and Al-Berih district consists of three adjacent cities (Ramallah, Al-Berih and Beitunya) and 80 villages and camps; the electricity of these communities is supplied by JDECo (Jerusalem District Electricity Company), which by its turn is a customer of IEC (Israeli Electricity Company).

This thesis will not include the surrounding villages of the district, and it will focus on Ramallah, Al-Berih and Beitunya (including the refugee camps situated in them).

3.1. The Main Parameters of the Electrical System of Ramallah and Al-Berih District

The peak demand for Ramallah and Al-Berih District is in the range of 61.8MW (Oct. 2007) to 96.7MW (Feb. 2008), about 70% of this demand is located in the cities of Ramallah, Al Berih and Beitunya, that is the peak demand of the three cities (including the refugee camps situated in them) is in the range of 43.3MW to 67.9MW.

3.1.1. The Main Incomers

1. Al-Ram incomer.
2. Ramallah incomer.
3. Pereg incomer.
4. Offer incomer.
5. Rama-1 incomer.
6. Beit Eil (or IP-200) incomer (available after IEC approval – only when other incomer is out).

All of the above incomers are 33kV and 20MVA except the IP-200 incomer which only can give up to 100A on 33kV

3.1.2. The Main Substations

1. Silvana substation:

1.1. Ramallah incomer (has a branch that supplies Dar Al-Mo’alimen substation before going to Silvana substation).

1.2. Pereg incomer (just bypass to Al-Teerih substation and Ramallah North substation).

1.3. Offer incomer.

2. Dar Al-Mo’alimen substation:

2.1. Al-Ram incomer (has a branch that supplies Al-Tahounih substation before going to Dar Al-Mo’alimen substation).

2.2. Ramallah incomer

3. Betin-West substation:

3.1. Rama-1 incomer.

4. Al-Tahounih substation:

4.1. Al-Ram incomer.

5. Ramallah North substation:

Gets its supply from Pereg incomer in Silvana substation through Al-Teerih substation.

6. Al-Teerih substation:

Gets its supply from Pereg incomer in Silvana substation.

Most of the load carried by these incomers is delivered to the three cities, and a slight fragment is delivered to the surrounding villages.

3.1.3. The Power Transformers of the Main Substations and Network Configuration

The scheme of the main substations, the 33kV incomers and the 11kV feeders are presented in this section.

The power transformers in the substations supplying Ramallah are as below:

1. Silavana substation:

a. T1: 33kV/11kV, 15MVA, Dy11, impedance=10.52%

b. T2: 33kV/11kV, 15MVA, Dy11, impedance=10.46%

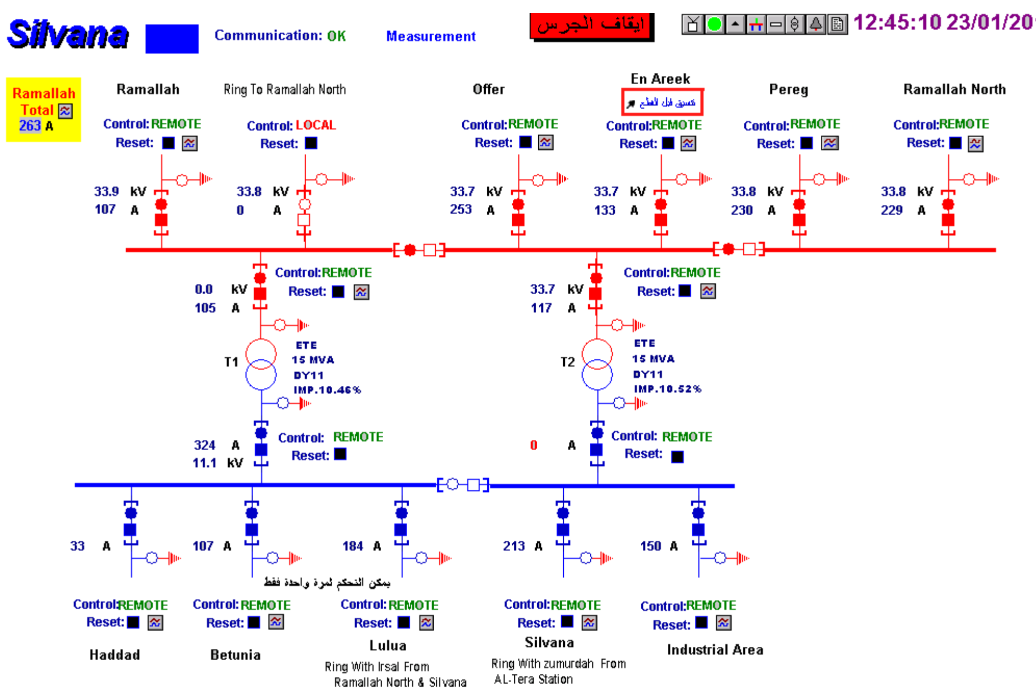

Figure 3.1 Silvana substation layout

As seen in figure 3.1 Offer 33kV incomer supplies one of the power transformers in addition to the Ain Areek village and its surrounding villages.

2. Al-Teerih substation:

a. T1: 33kV/11kV, 5MVA, Dy11, impedance=7.523%

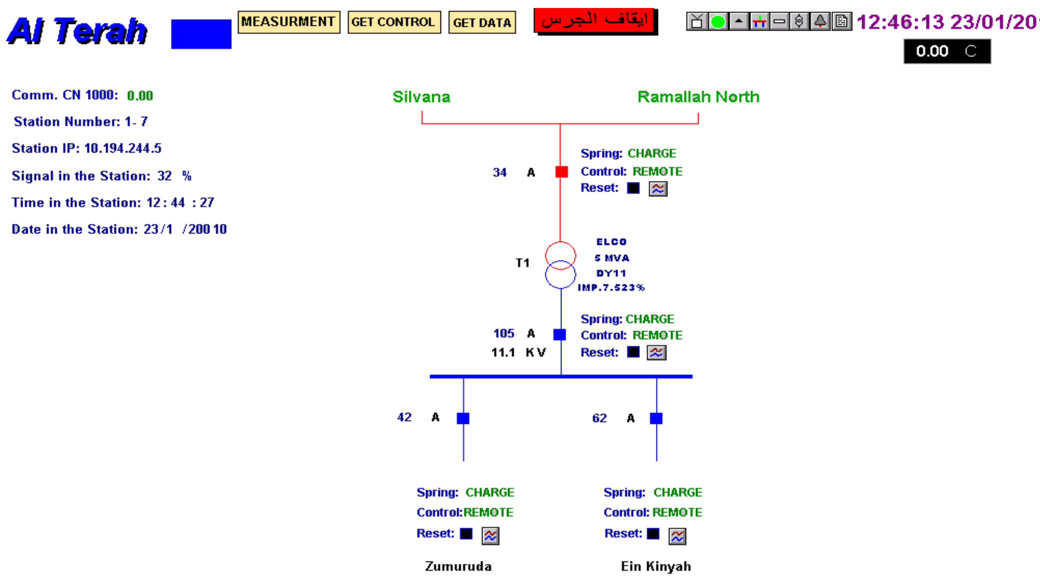

Figure 3.2 Al-Teerih substation layout

3. Dar Al-Mo'alimen substation:

a. T1: 33kV/11kV, 15MVA, Dy11, impedance=8.83%

b. T2: 33kV/11kV, 10MVA, Yy0 (turned off right now).

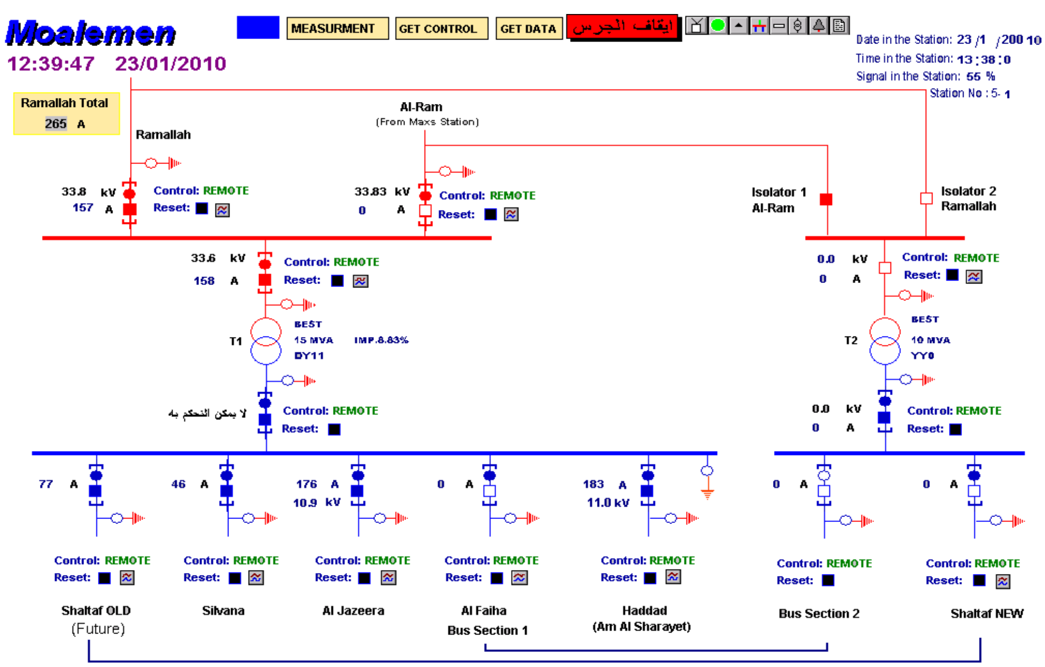

Figure 3.3 Dar Al-Mo'alimen substation layout

4. Ramallah North substation:

   a. T1: 33kV/11kV, 15MVA, Dy11, impedance=10.34%
   b. T2: Installed but not operating.

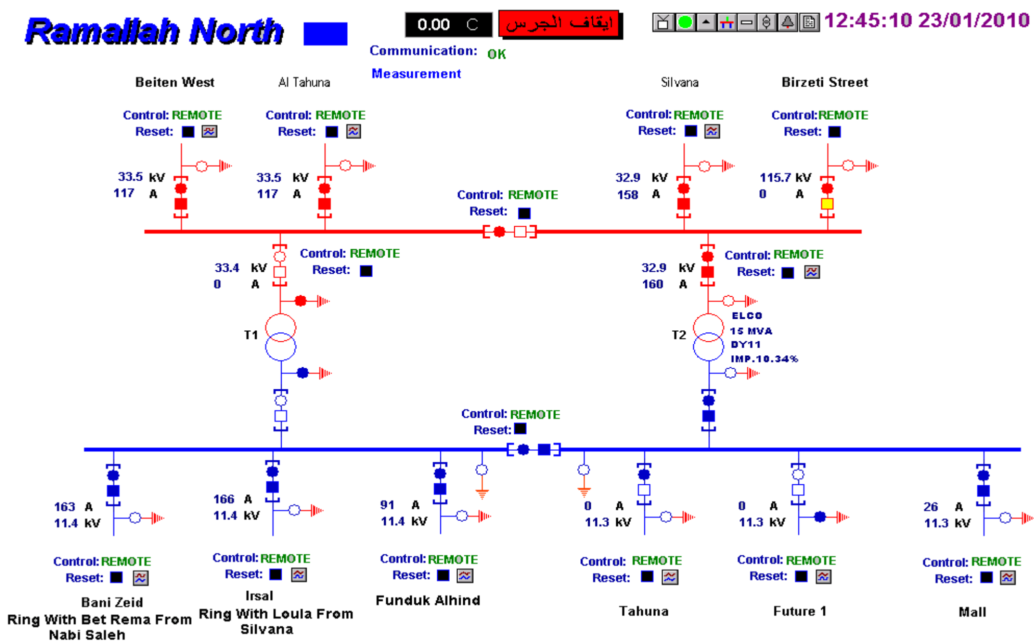

Figure 3.4 Ramallah North substation layout

As seen in figure 3.4 Ramallah North substation supplies the village of Surda and the surrounding villages through Bani Zeid 11kV.

5. Al-Tahounih substation:

   a. T1: 33kV/11kV, 10MVA, Yy0d11, impedance= 7%

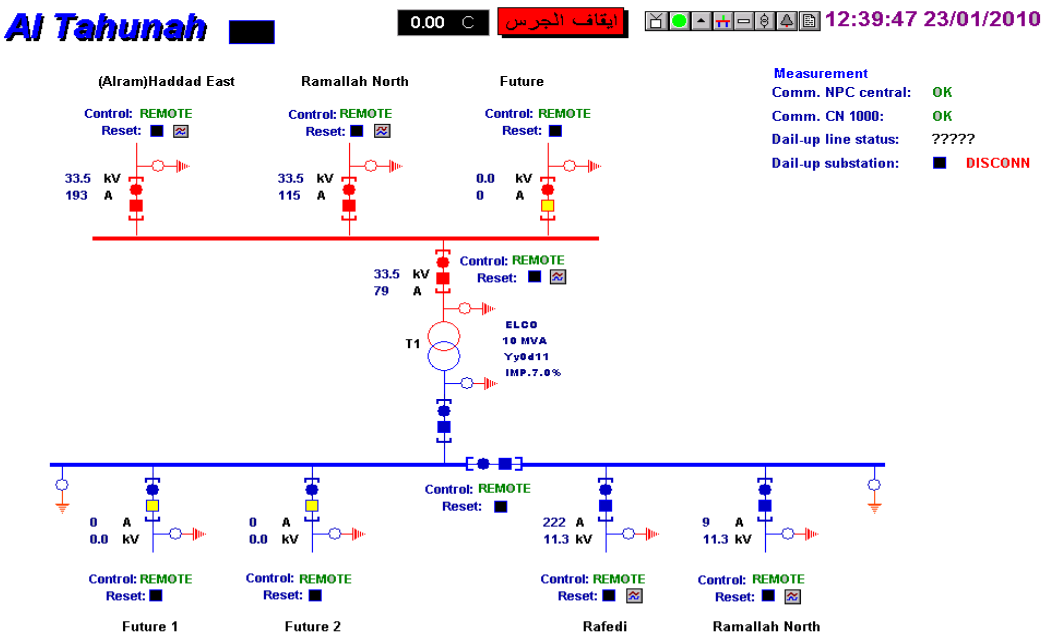

Figure 3.5 Al-Tahounih substation layout

6. Betin-West substation:

   a. T1: 33kV/11kV, 10MVA, impedance= 8.2%.

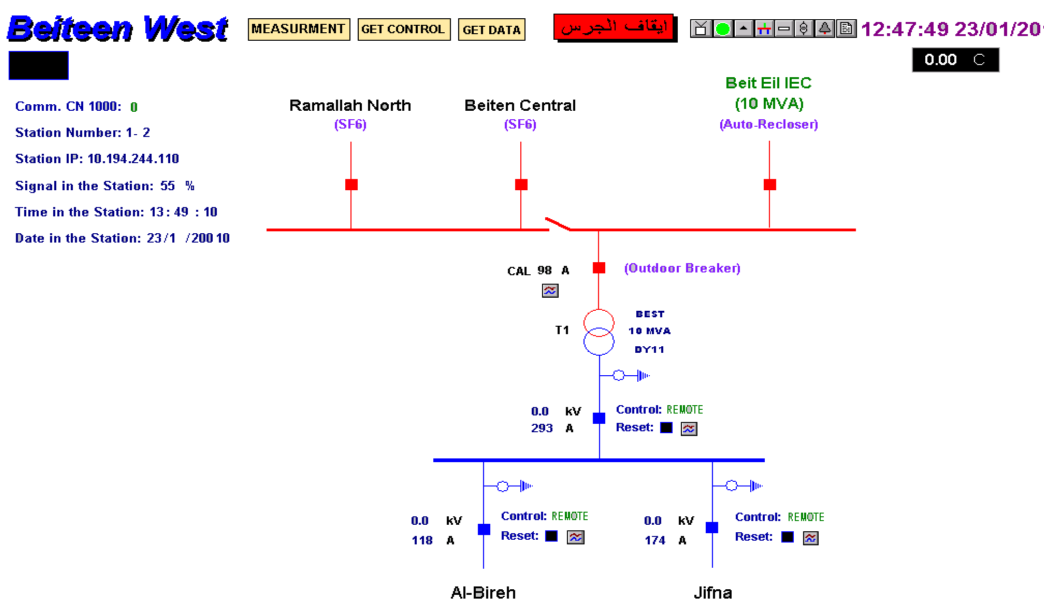

Figure 3.6 Betin West substation layout

As seen in figure 3.6 Betin West substation supplies the village of Jifna and the surrounding villages.

7. Betin Central substation:

a. T1: 33kV/11kV, 3MVA, Yy0d11, impedance= 6.8%

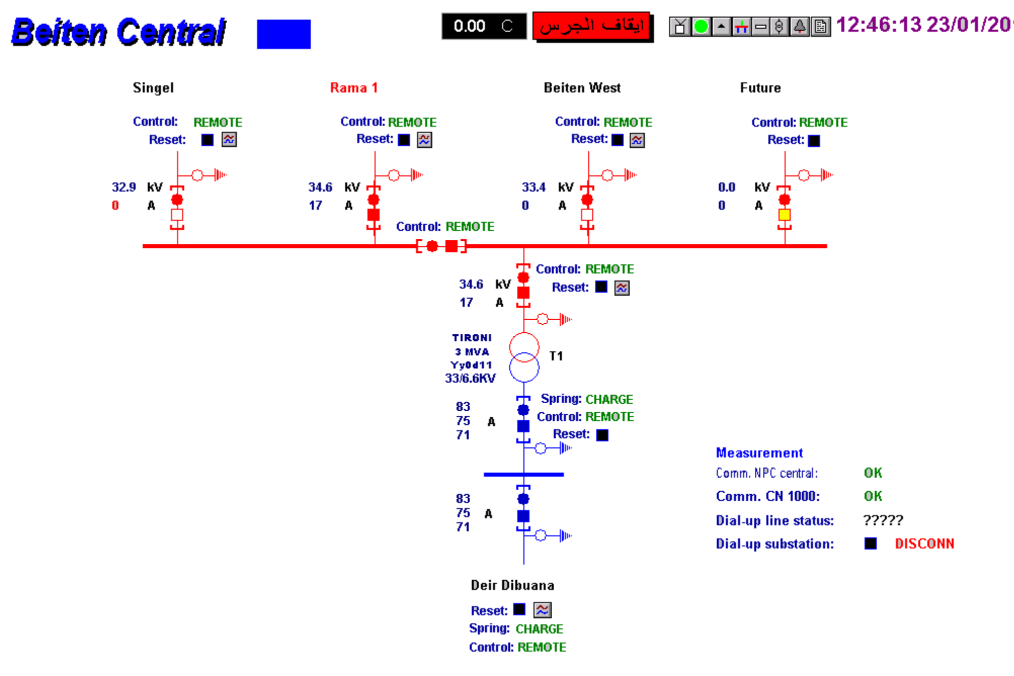

Figure 3.7 Betin Central substation layout

As seen in figure 3.7 Betin Central substation supplies the village of Der Dibwan.

That is 9 power transformers operate in the three cities to step-down the voltage from 33kV to 11kV for distribution (Including the non-operating transformers in Ramallah North substation and Dar Al-Mo'alimen substation).

3.1.4. Distribution Transformers

There are about 450 distribution transformers in the three cities ranging from 100kVA to 1MVA, some of these transformers may experience unbalanced loading due to the fact that there are still some low voltage single phase distribution feeders, or due to unsymmetrical distribution of consumers on some of the feeders, which creates neutral current that leads to higher losses according to equation 3.1.

$$P_{loss} = I^2 \times \mathrm{r} \tag{3.1}$$

3.1.5. Energy Losses

The electrical loss in the three cities alone is not available right now because of the nature of the supply network, but for the District as whole the electrical losses is about 25% (including the black losses).

3.1.6. Tariff Structure

IEC uses sliding scale tariff with JDECo, JDECo in its turn started to use this structure with customers with consumption above 50’000 kWh/year only, while using flat rate tariff elsewhere.

The customers of JDECo are categorized as following:

1. Commercial
2. Domestic
3. Temporary
4. Street lighting
5. Stare case
6. Water pumping

3.2.Main Problems

The main problems that face the electrical system in the three cities are:

1. High electrical losses.
2. The high demand that sometimes exceed the capacity of the incomers also in the winter.
3. The outages that occur during the winter.
4. The tempering cases, which is beyond the scope of this thesis.

3.3.Summery

Since the main characteristics and problems of Ramallah's electrical network have been stated, it is necessary to analyze Ramallah's electrical network and to find solutions for above problems. Analyzing the network will be done using PowerWorld Simulator software in chapter 4.

Chapter Four

Analysis of Ramallah Existing Electrical Network Using PowerWorld Simulator

Chapter Four
Analysis of Ramallah Existing Electrical Network Using PowerWorld Simulator

4.1. Description of PowerWorld Simulator

PowerWorld Simulator is a registered trade mark of PowerWorld Corporation; it is an interactive power systems simulation package designed to simulate high voltage power systems operation on a time frame ranging from several minutes to several days. The software contains a highly effective power flow analysis package capable of efficiently solving systems with up to 100,000 buses. [10]

In this thesis the simulation is done by PowerWorld Simulator 8.0.

4.2. Data Collection and Input

The data about Ramallah M.V. electrical network were obtained from JDECo, and this data were then inputted to the PowerWorld Simulator after processing it.

4.2.1. Inputting Bus Information

Beside the display options of the bus, the main information needed to be fed to the simulator after specifying the bus name and number is the area name and number (for multiple-area networks), zone name and number (if multi-zone network is simulated), the nominal voltage, voltage p.u., angle, and if the bus is a slack bus or not.

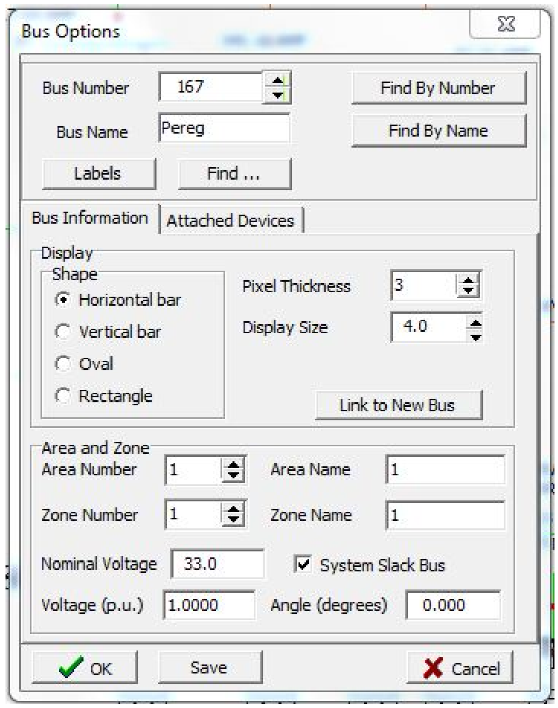

Figure 4.1 Bus information dialogue box

4.2.2. Inputting Power Transformer or Line Information

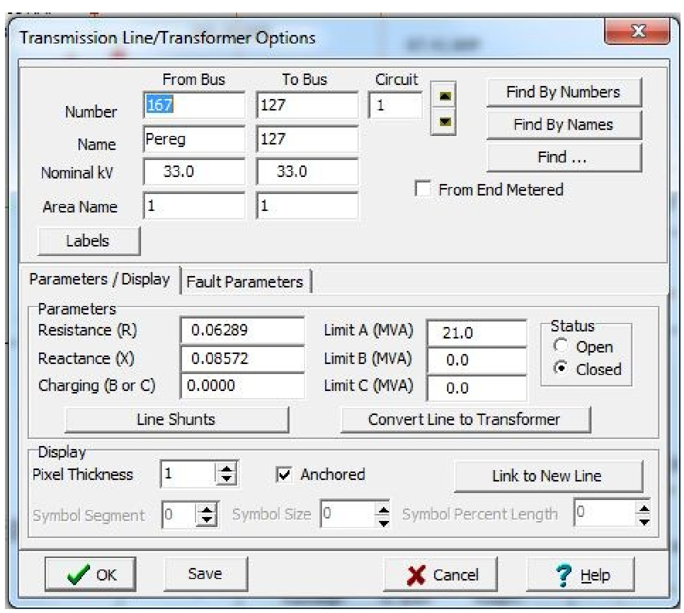

Figure 4.2 Line or transformer information dialogue box – Parameters/Display tab

After specifying the names, numbers, nominal voltage, and the area number of the two buses that the line or the transformer is connecting, the parameters of the line or transformer must be entered in both the parameters/display tab (the normal condition parameters) and the fault parameters tab.

The needed parameters for each tab are shown in figure 4.2 and figure 4.3.

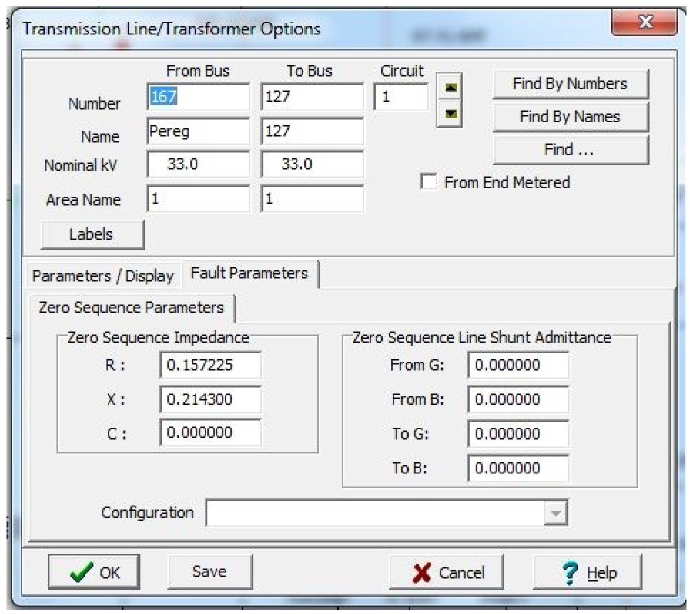

Figure 4.3 Line or transformer information dialogue box – Fault Parameters tab

For the transformers, to find R and X, the voltage impedance% (VI%) of the power transformer is used, where

$$R \approx 0.1 \times \text{VI\%} \quad (4.1)$$

$$X \approx 0.9 \times \text{VI\%} \quad (4.2)$$

For example, R and X for a power transformer with VI% of 10.52% are:

$$R \approx 0.01052\,\Omega$$

$$X \approx 0.09468\,\Omega$$

4.2.3. Inputting Load Information

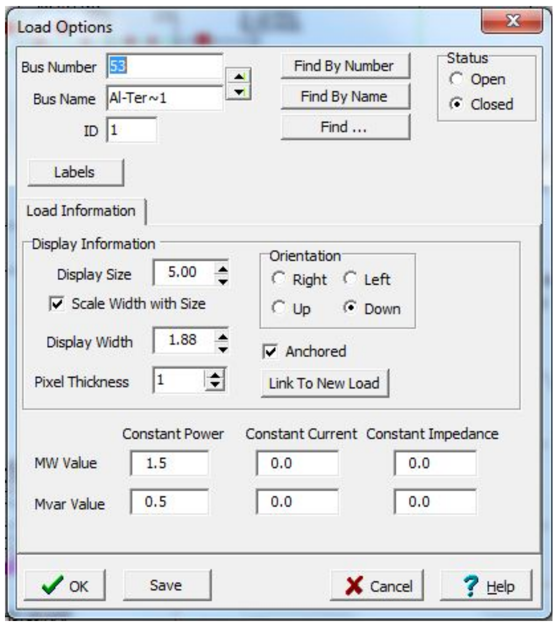

Figure 4.4 Load options dialogue box

The bus number and name where the load is attached must be specified, then the load ID must be entered (to define multiple loads at the same bus if needed), then the display options are available for modification if desired. At last the load MVA and MVAR must be inputted.

4.3.Information about the One-Line Diagram

The one-line diagram presented in figure 4.5 shows the M.V. network of Ramallah, Al-Berih and Beitunya, it also includes the loads that are being fed through the incomers that feed the network of the three main cities.

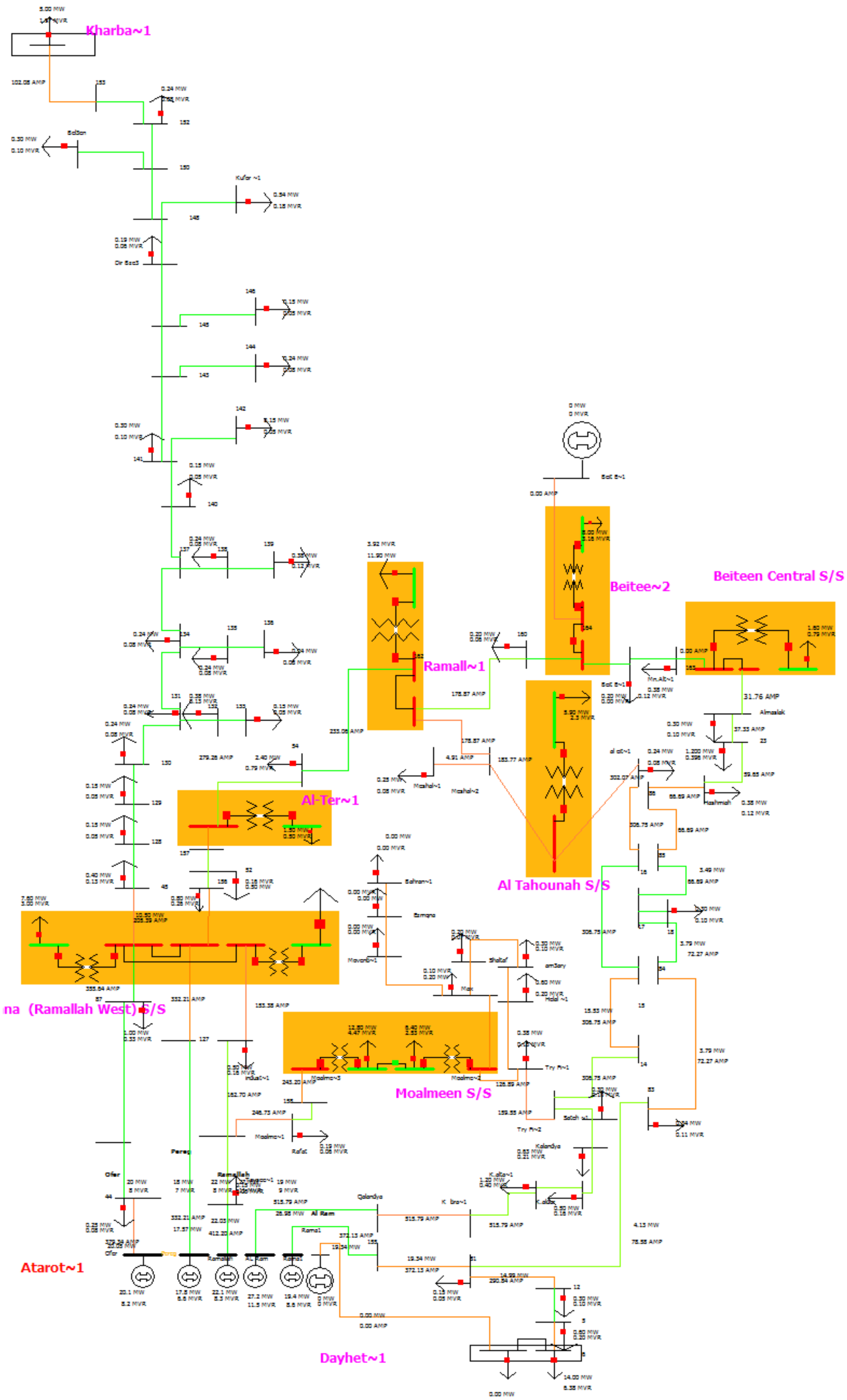

Figure 4.5 The one line diagram of Ramallah, Al-Berih and Beitunya

These loads are: Jifna and the surrounding villages fed from Betin West substation, Dahiyit Al-Bareed substation fed from Rama 1 incomer, and the villages from Ein Areek to Kharbatha and its surrounding villages fed from Offer incomer.

All the loads are attached directly to the 33kV network, no 33/0.4 kV were inserted in the diagram, the loads have the symbol of an arrow attached directly to a bus.

As seen in figure 4.5 any load or line can be turned on and off during simulation, which is done through the red rectangles, the red color suggests that the switch is closed, while the green color suggests that the switch is open.

The buses are used to:

- Connect two different types of line, or
- To represent load, or
- In the substations to insert the power transformers, or
- Represent the main incomers.

The buses that represent the incomers are all set to serve as slack bus, so that all the needed power is covered. But it must be remembered always that each one of these incomers has a maximum capacity of 20 MVA only.

4.4.Simulation Results:

The first simulation was processed under the following conditions:

- Only 33kV lines were included.
- No distribution or power transformers were included.

- The Beit Eil incomer was turned off (which is the normal case).
- The loads were set to the maximum load on 31-12-2008 that occurred at 14:09 which was 111.2 MVA (including the areas that are fed from the main incomers but not situated in the main three cities).

These conditions ensure that the resulting losses represent the 33kV lines' losses only.

As can be seen in table 4.1, the loss in the 33kV lines is 3.39MW that is 3.19%.

Table 4.1: Simulation results of the one-line diagram including 33kV lines only

	Area Num	Area Nam ▲	Gen MW	Gen Mvar	Load MW	Load Mvar	Loss MW	Loss Mvar
1	1	1	106.43	42.60	103.04	38.64	3.39	3.96
2	4	4	0.00	0.00	0.00	0.00	0.00	0.00

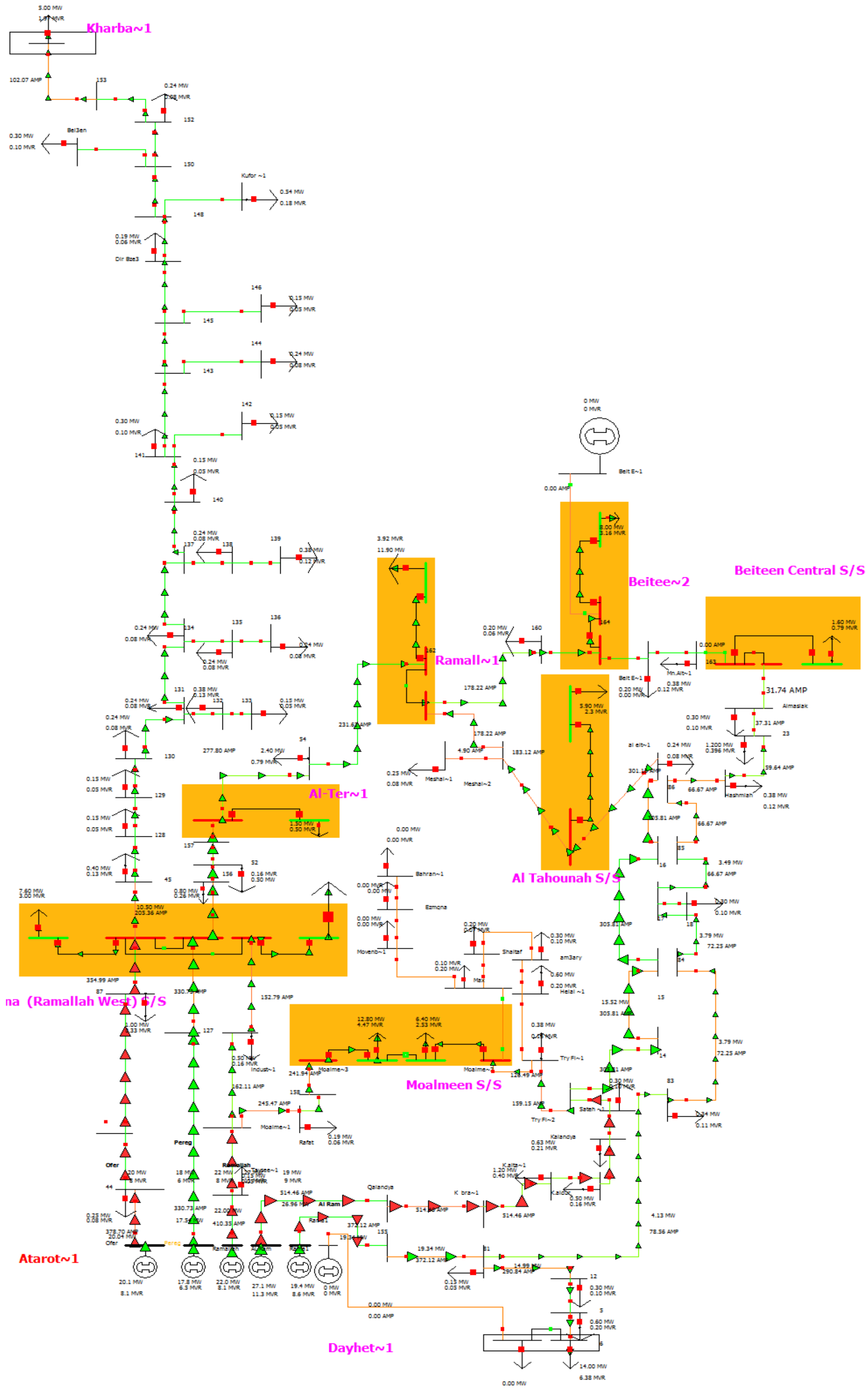

Figure 4.6 One line diagram as seen during the first simulation

To make the status of the network more imaginable, contouring in the PowerWorld Simulator was used during this first simulation, it is clear as would be seen that all the incomers are overloaded which marks a great problem to the network during the very cold days.

It can be seen (as mentioned above) that Beit Eil incomer is not utilized, which overloads Al-Ram incomer to almost twice its capacity.

Figures 4.7 and 4.8 below illustrate the problems mentioned above

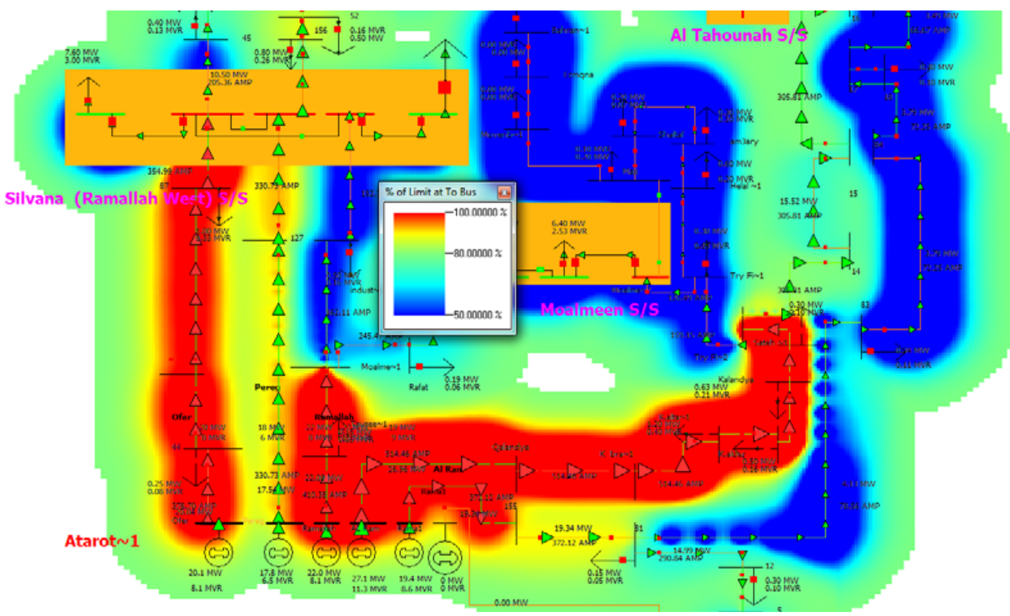

Figure 4.7 The main incomers seen during the first simulation with contouring

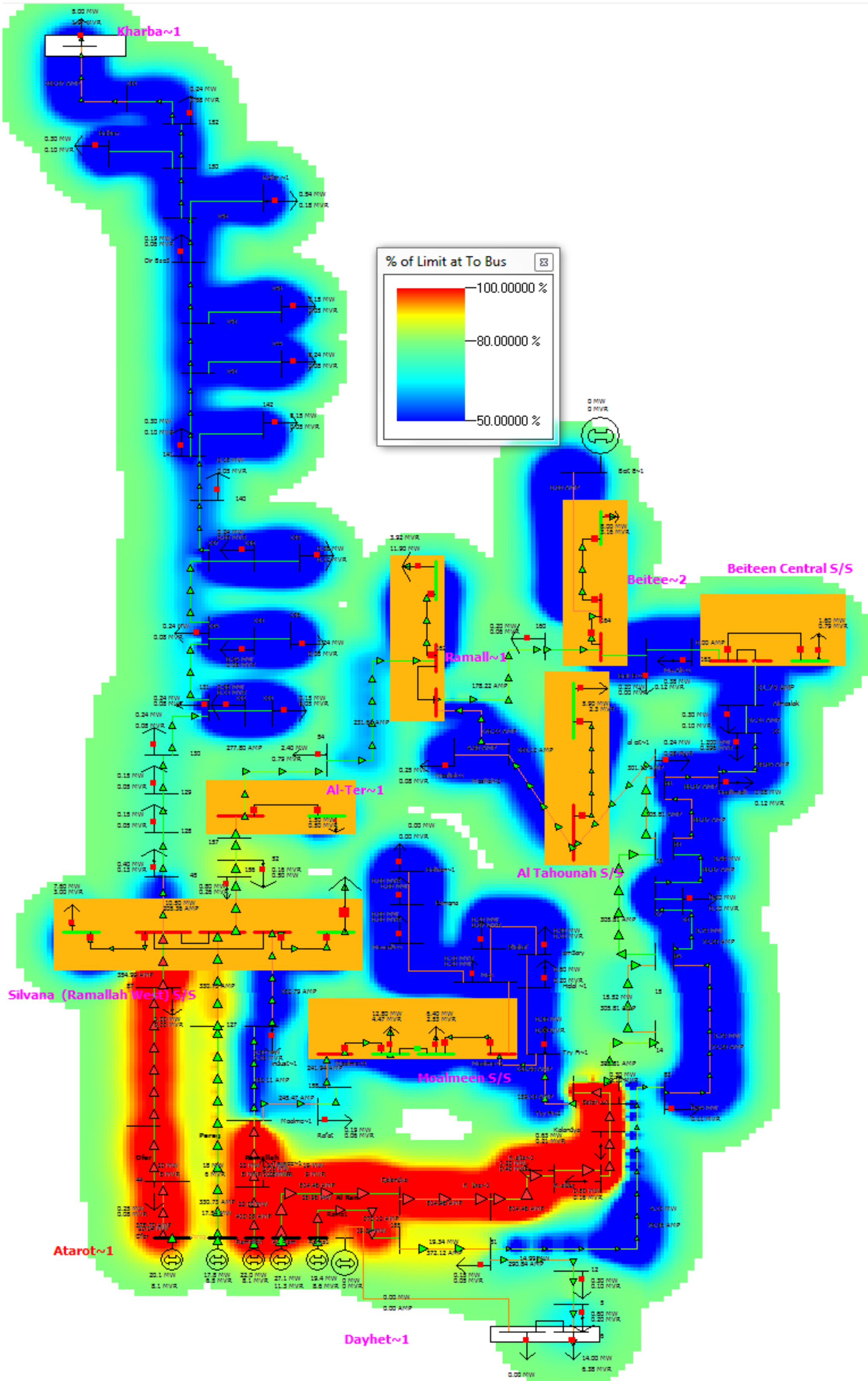

Figure 4.8 The one line diagram as seen during the first simulation with contouring

The second simulation was conducted under the following conditions:

- Only 33kV lines and 33/11kV power transformers were included.
- No distribution transformers were included.
- The Beit Eil incomer was turned off (which is the normal case).
- The loads were set to the maximum load on 31-12-2008 that occurred at 14:09 which was 111.2 MVA (including the areas that are fed from the main incomers but not situated in the main three cities).

The result is shown in the figure below.

As can be seen in table 4.2, the loss in the 33kV lines is 3.47 that is 3.26%.

Table 4.2: Simulation results of the one-line diagram with the main power transformers

	Area Num	Area Nam	Gen MW	Gen Mvar	Load MW	Load Mvar	Loss MW	Loss Mvar
1	1	1	106.51	43.24	103.04	38.64	3.47	4.59
2	4	4	0.00	0.00	0.00	0.00	0.00	0.00

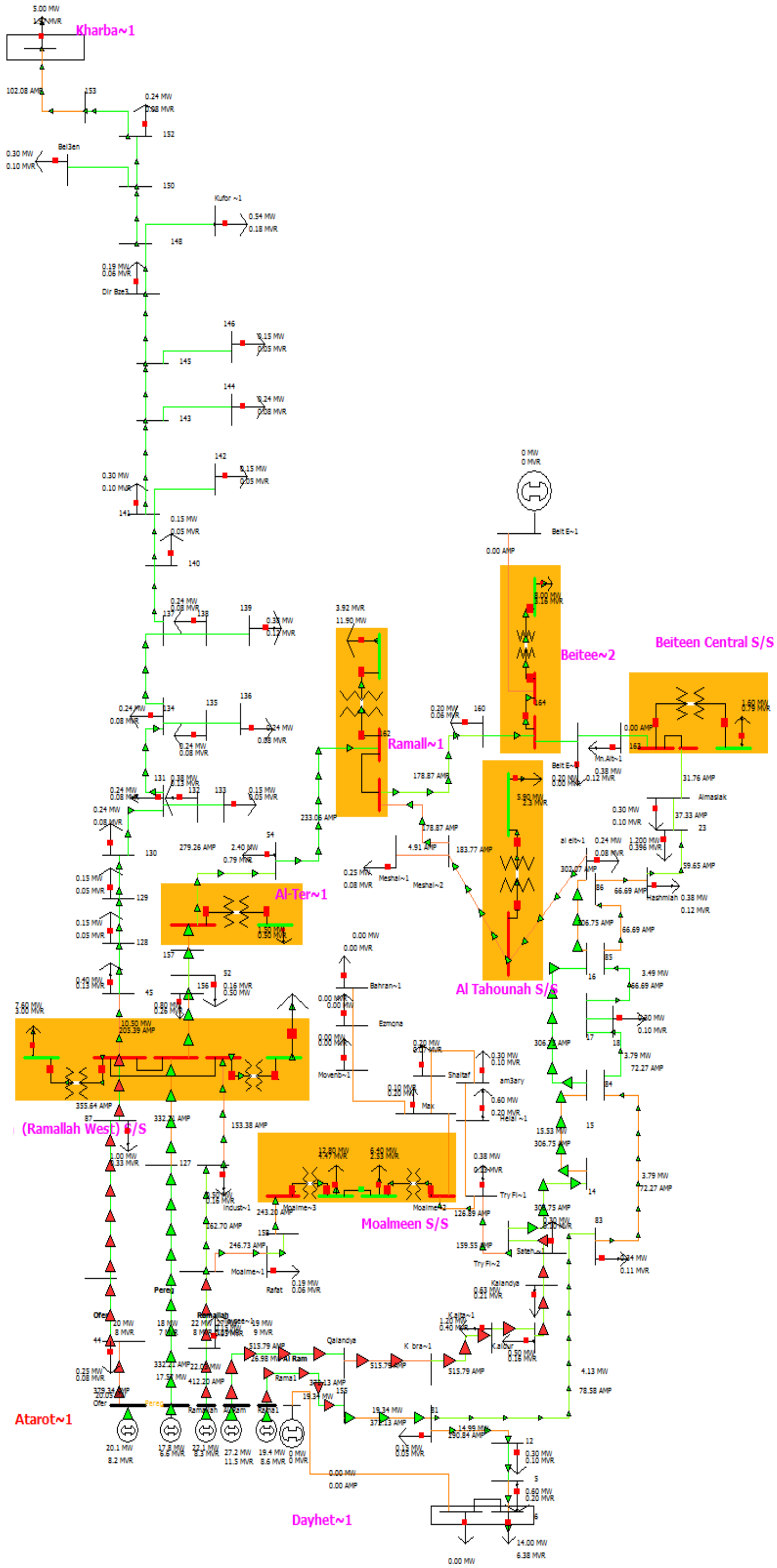

Figure 4.9 One line diagram as seen during the second simulation

As in the first simulation, to make the status of the network more imaginable, contouring in the PowerWorld Simulator was used during the second simulation, it is clear as would be seen that all the incomers are overloaded which marks a great problem to the network during the very cold days.

It can be seen (as mentioned above) that Beit Eil incomer is not utilized, which overloads Al-Ram incomer to almost twice its capacity.

Figures 4.10 and 4.11 below illustrate the problems mentioned above.

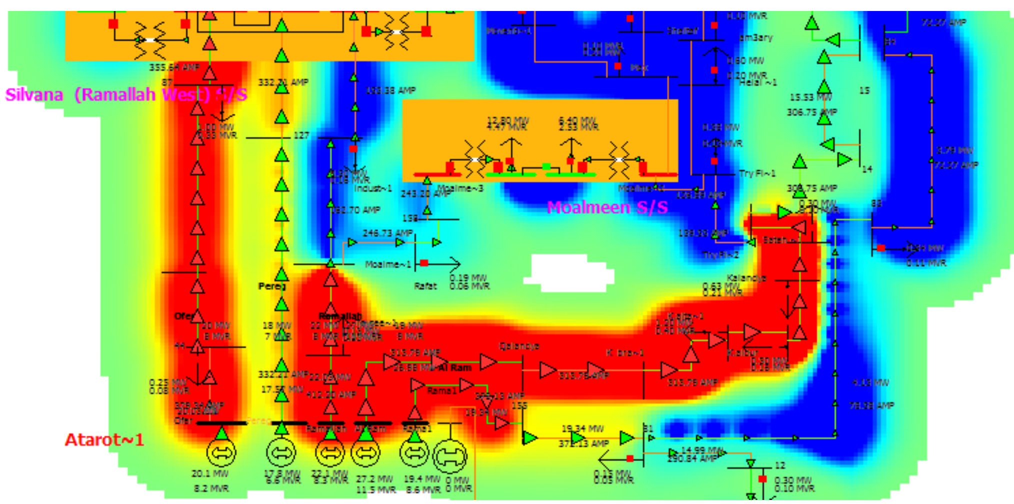

Figure 4.10 The main incomers seen during the second simulation with contouring

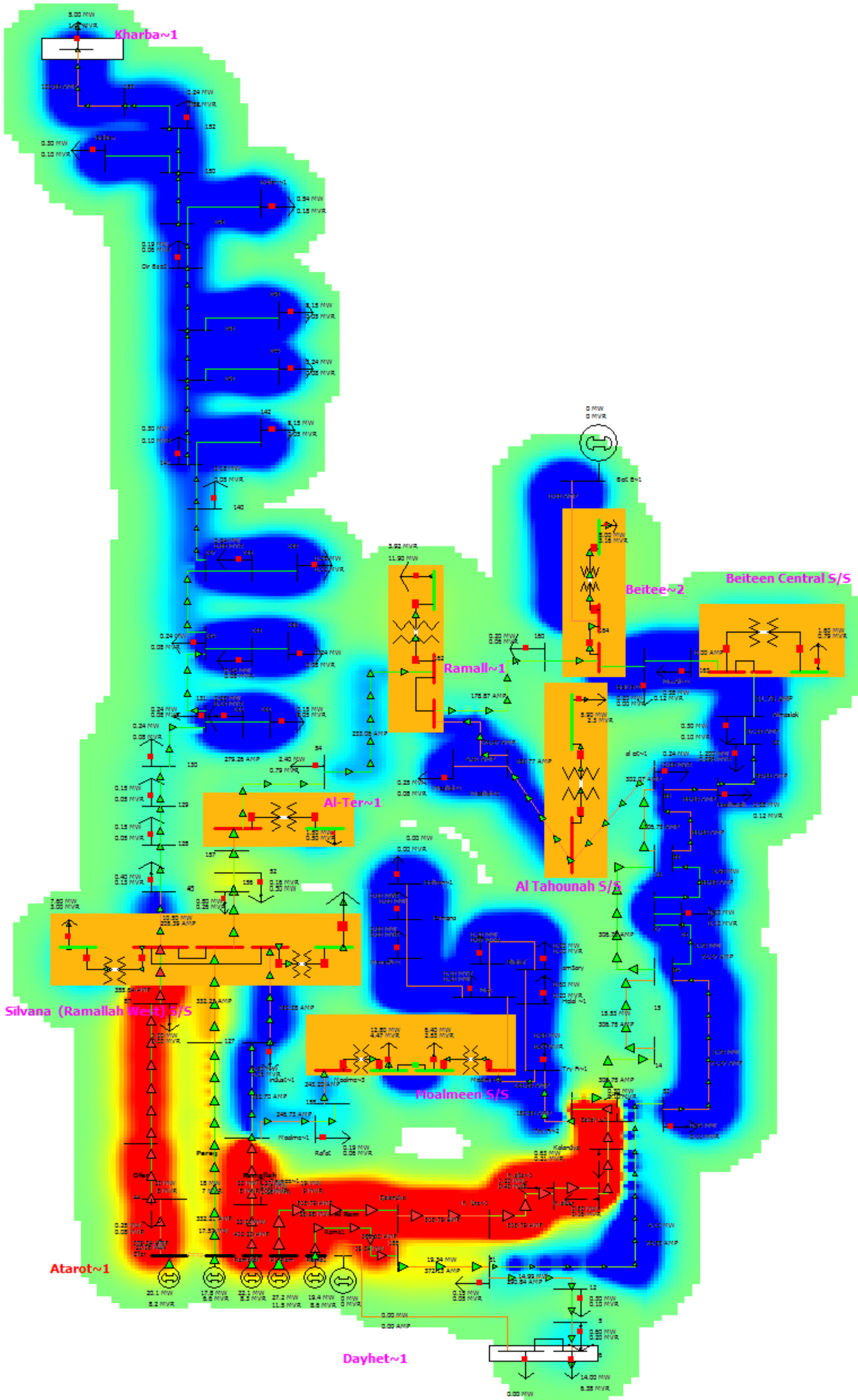

Figure 4.11 The one line diagram as seen during the second simulation with contouring

4.5. The Main Results

4.5.1. Losses in the Electrical Network

As can be seen above, the losses in Ramallah electrical network is about 3.26%, which is somewhat high, these losses are made of power transformer losses and transmission line losses, so in order to reduce these losses, then the electrical network must be upgraded by using more efficient transmission lines and power transformers.

4.5.2. Overloading of the Electrical Network

It was obvious during the simulations that the main incomers are overloaded due to the fact that the load used in the simulation was the maximum load that occur in 2008, and the fact that in real, the network is reconfigured to coup with this demand by using the IP200 incomer, and disconnect the power transformer in Al-Dahyih substation (in Jerusalem) from Rama1 incomer, and supply it by other incomers from Jerusalem, and in some extreme cases, disconnect Kharbatha substation from Offer incomer, and supply it from other less efficient incomer.

But to solve the problem of overloading, reconfiguration of the network is needed.

4.5.3. Power Factor of the Electrical Network

The power factor calculated using the results obtained from the simulator (generated MW = 106.51 and generated MVAR = 43.24) was around 92.7% which is very good, and no need for further improvements in this field is required.

4.6. Summery

The analysis of the electrical network of Ramallah showed that there are conservation opportunities that can lead to operating the network with higher efficiency. These conservation measures must be analyzed in depth to find out their effectiveness.

Chapter Five

Energy Conservation Opportunities in Ramallah Electrical Network

Chapter Five

Energy Conservation Opportunities in Ramallah Electrical Network

5.1. Energy Management in Power Transformers

Energy management in power transformers can be achieved by sizing the power transformer in accordance with the load, so that its loading would be 65% to 75% of its rated S, and also by choosing power transformer with lower voltage impedance.

In Ramallah network the power transformers are almost well sized in accordance with the load, so this leaves us only with using power transformers with lower voltage impedance in order to reduce the losses in these transformers.

According to the IEC 76-5 code, the power transformer used in Ramallah must have maximum voltage impedance of:

Table 5.1: Voltage impedance as stated by IEC

Transformer rating kVA	Maximum VI%
1,251-3,150	6.25
3,151-6,300	7.15
6,301-12,500	8.35
12,501-25,000	10.0

It can be seen that some of the voltage impedances' for the power transformers in Ramallah as presented in chapter 3 are above the maximum voltage impedance stated by IEC. So, the use of power transformers with lower voltage impedance shall be investigated, in terms of the effect on the losses.

The suggested power transformers have voltage impedances that are within the range recommended by IEC 76-5, thus, the voltage impedances in table 5.2 are used in the suggested one-line diagram:

Table 5.2: VI% of the new power transformers

Rating MVA	Voltage impedance %
3	5.80
5	6.50
7	7.00
10	7.80
15	8.83

The one-line diagram in figure 5.1 has one change from the main one presented in chapter 4, which is the use of new power transformers with lower voltage impedances.

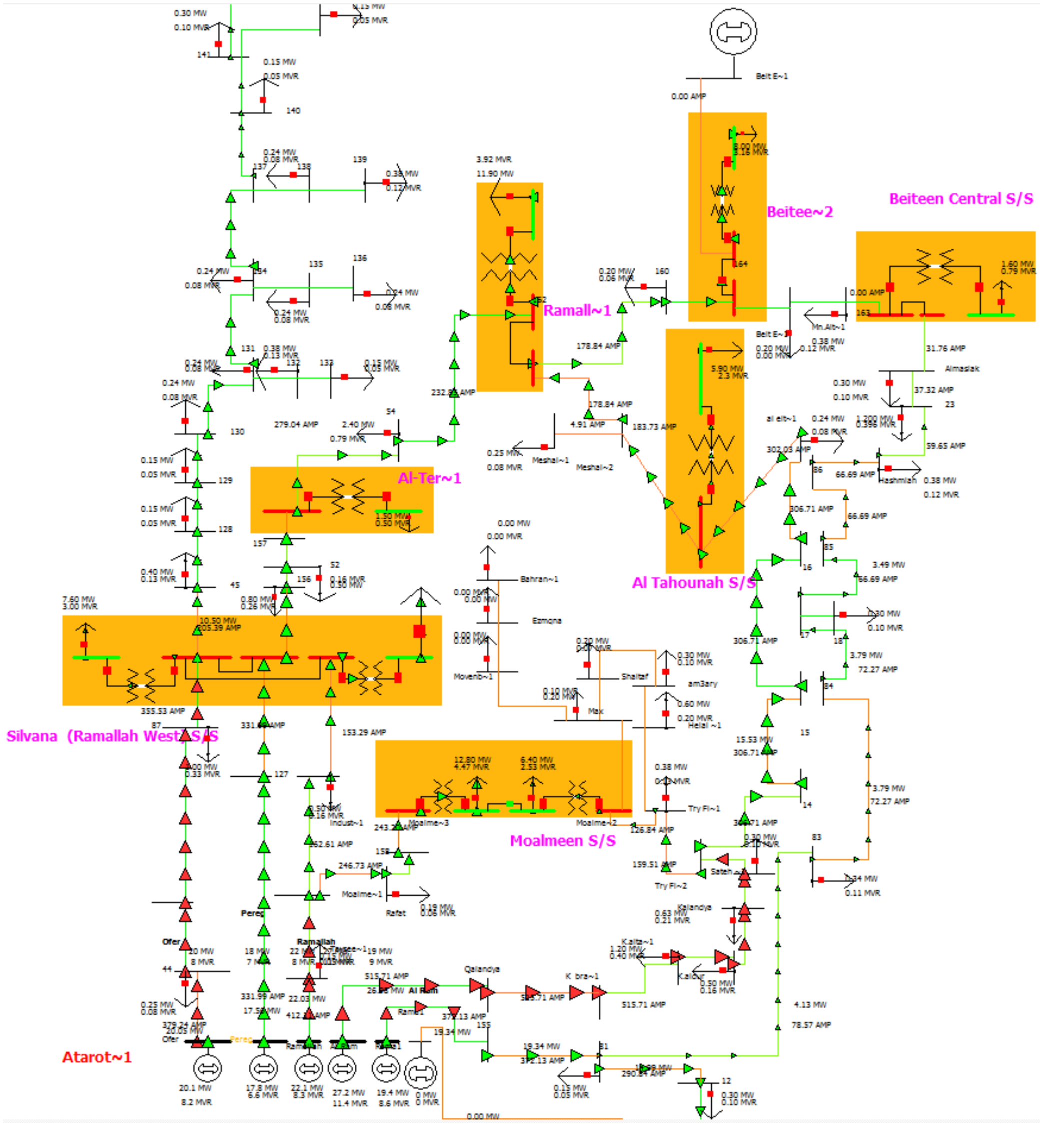

Figure 5.1 Simulation of the one-line diagram using new power transformers

Table 5.3: Simulation results of the one-line diagram presenting the new power transformers

	Area Num	Area Nam	Gen MW	Gen Mvar	Load MW	Load Mvar	Loss MW	Loss Mvar
1	1	1	106.51	43.17	103.04	38.64	3.46	4.53
2	4	4	0.00	0.00	0.00	0.00	0.00	0.00

As can be seen, the loss in the network is 3.46 MW, which lower than the original case by 0.01 MW.

It is important to note that there is no need to change the power transformers in Al-Moa'limeen substation and Al-Tahoonih substation because they meet the suggested VI%.

5.2. Energy Conservation in Electrical Lines

Energy losses in electrical lines are caused by the resistivity of the materials that the transmission line is made of, in the case of Ramallah electrical network is the ACSR. The use of ACCC to upgrade the existing lines will have an effect on the losses caused by the transmission lines itself.

To find the extent of the loss reduction, all the over-head transmission lines in the suggested one-line diagram will be represented using the characteristics of ACCC conductors which are presented in table 5.4:

Table 5.4: Technical specifications of the suggested ACCC conductor

CODE WORD (7)	SIZE kcmil	NO. OF ALUM. WIRES	NO. OF ALUM. LAYERS	ALUM. STRANDING	EQUIV. ALUM. DIA	FILL FACTOR	RESISTANCE (8) Ohms/1000 ft				AMPS 75°C (9)	AMPS 200°C (10)	GMR (11) (ft)	INDUCTIVE REACTANCE ohm/kft (12)	CAPACITIVE REACTANCE megohm.kft (13)
							DC@20°C	AC@25°C	AC@75°C	AC@200°C					
LINNET ACSR	336.4	26	2	10, 16	0.1137	75	0.0506	0.0517	0.0619	-	530	-	0.0242	0.0855	0.5492
LINNET ACSS	336.4	26	2	10, 16	0.1137	75	0.0491	0.0503	0.0605	0.0860	535	945	0.0242	0.0855	0.5492
LINNET ACSS/TW	336.4	18	2	7, 11	0.1367	91	0.0490	0.0501	0.0603	0.0858	525	920	0.0223	0.0874	0.5620
LINNET ACSS/TWD	398.7	18	2	7, 11	0.1489	91.6	0.0414	0.0423	0.0509	0.0724	580	1030	0.0243	0.0855	0.5492
LINNET ACCC/TW	**431**	**16**	**2**	**6, 10**	**0.1641**	**93**	**0.0390**	**0.0400**	**0.0481**	**0.0683**	**600**	**1060***	**0.0239**	**0.0858**	**0.5491**

The following one-line diagram in figure 5.2 has one change from the main one presented in chapter 4, which is the use of LINNET ACCC/TW for transmission lines to replace ACSR – Wolf conductors. The chosen ACCC conductor is larger than the ACSR – Wolf, but it is the smallest available size, and it is capable of carrying up to 600 Ampere, while the ACSR – wolf can carry up to 400 Ampere. The lines that are changed to ACCC are colored in dark blue, and these lines are the main incomers.

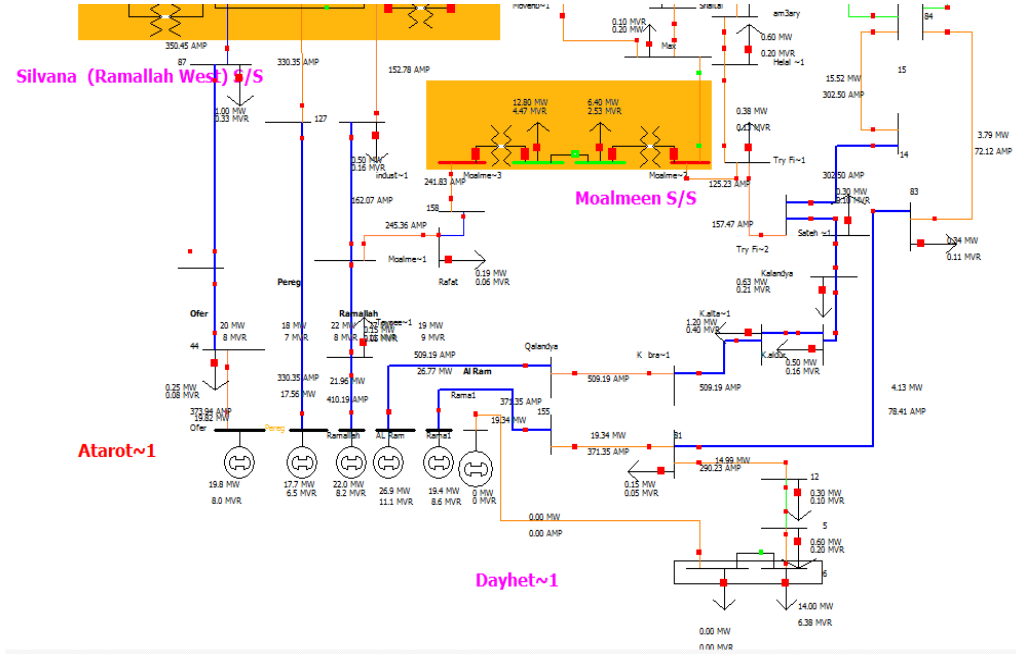

Figure 5.2 The one-line diagram using ACCC.

After simulating the new situation the results is presented in table 5.5

Table 5.5: Simulation results of the one-line diagram presenting ACCC

	Area Num	Area Nam	Gen MW	Gen Mvar	Load MW	Load Mvar	Loss MW	Loss Mvar
1	1	1	105.84	42.37	103.04	38.64	2.79	3.72
2	4	4	0.00	0.00	0.00	0.00	0.00	0.00

It is clear that the loss in the network has dropped from 3.47 MW to 2.79 MW, that is, 0.68 MW reduction in loss.

5.3. Power Factor Improvement and its Effect on the Network

The result found in chapter 4 about the power factor suggests that there are no needed actions to improve that power factor further.

5.4. Reconfiguration of the Electrical Network

It is obvious that during the cold winter days some of the main incomers are critically over loaded (above their breaking point), in this situation, the engineers in JDECo – Ramallah, reconfigure the network in order to reduce the load on the heavily loaded incomers, but this causes significant voltage drop to the service delivered to the consumers. Also a big center of load is developing in Qalandya refugee camp and its surrounding (due to many reasons which are beyond the scope of this study), so a new substation is needed, and the construction works are under process for this station.

The reconfiguration of the electrical network includes new substation at Qalandya refugee camp with a power transformer of 15 MVA, which will supply about 3.8 MVA temporarily until a new incomer is achieved.

The second change on the network is disconnecting Al-Dahyah substation (Jerusalem area).

The last modification is that the load of Biteen West substation to be carried by Rama1 incomer instead of Al-Ram incomer.

As the previous measures, these reconfiguration steps and its effect on the overall losses must be investigated.

The one-line diagram in figure 5.3 has been reconfigured to include a new substation in Qalandya camp which will supply about 3.8 MVA to Qalandya camp and its surrounding instead of supplying it from Al-Moa'limeen substation, disconnect Al-Dahyah substation (Jerusalem area), and the load of Biteen West substation to be carried by Rama1 incomer instead of Al-Ram incomer.

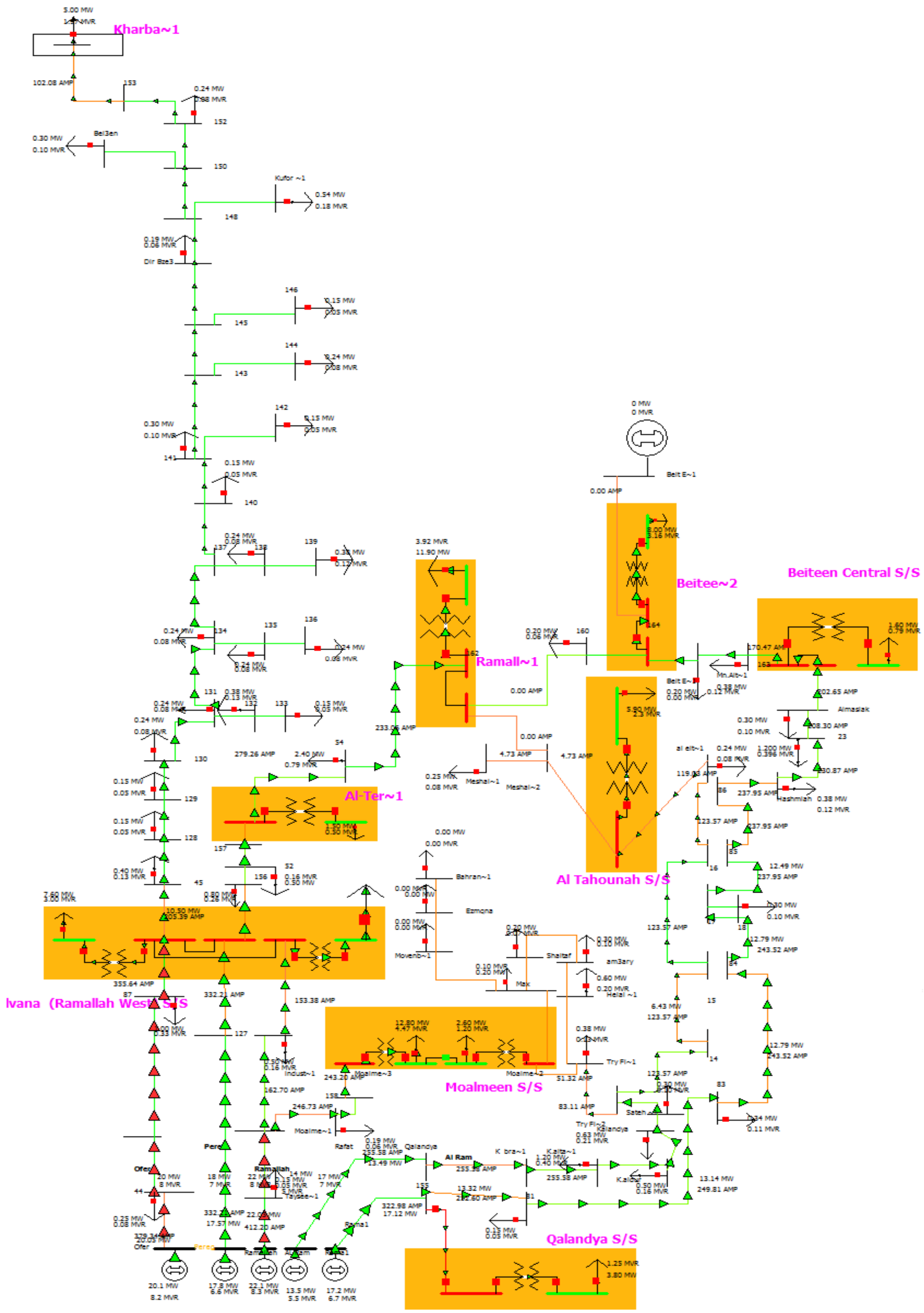

Figure 5.3 Simulation of the reconfigured one-line diagram.

It can be seen that the MW loss decreased dramatically to 2.50MW, one of the main reasons is that the load of Al-Dahyah substation was transferred to another incomer from Jerusalem area. But another factor

that contributed to this loss is loading Biteen Central on Rama1 incomer instead of Al-Ram incomer, where the loss will increase to 2.95MW if Biteen Central stays fed by Al-Ram incomer.

The result of the simulation is shown in table 5.6

Table 5.6: Simulation results of the one-line diagram presenting ACCC

	Area Num	Area Nam ▲	Gen MW	Gen Mvar	Load MW	Load Mvar	Loss MW	Loss Mvar
1	1	1	90.65	35.34	88.14	31.89	2.50	3.45
2	4	4	0.00	0.00	0.00	0.00	0.00	0.00

The mentioned measures decreased the losses from 3.47MW to 2.50 MW, which is 0.97MW reduction.

5.5. Analysis of the Effect of Unsymmetrical Loads on Electrical Losses in Low Voltage Distribution Network

Ramallah District electricity network operates more than 450 distribution transformers. In this section, the unbalanced loading of distribution transformers and its effect on the losses due to the fact that there is a high neutral current will be analyzed; currents carried by feeders of a sample of eight distribution transformers were measured and listed in table 5.7.

The neutral current for each feeder is divided by the maximum phase current for that feeder, and a percentage is found; if this percentage is lower than 20% then nothing needs to be done, but if the percentage is above 20% then the neutral current needs to be lowered to at least 20%.

Table 5.7: Sample of distribution transformers and their readings

Transformer No	Rated kVA	feeder No	A_R Amps	A_Y Amps	A_B Amps	A_N Amps	A_N %
1	160	1	75	55	130	17	0.131
		2	104	70	110	83	0.755
2	1000	1	300	250	140	100	0.333
		2	235	165	160	60	0.255
		3	300	410	320	90	0.220
		4	860	880	920	90	0.098
		5	250	400	430	100	0.233
		6	230	140	130	80	0.348
		7	390	360	390	30	0.077
3	400	1	40	50	63	7	0.111
		2	190	120	150	43	0.226
		3	40	6	84	67	0.798
		4	95	75	53	32	0.337
		5	33	12	30	11	0.333
4	630	1	330	315	440	67	0.152
		2	480	435	380	120	0.250
		3	245	185	100	83	0.339
		4	411	250	375	90	0.219
5	630	1	290	300	310	30	0.097
		2	300	250	210	75	0.250
		3	210	150	172	45	0.214
		4	210	150	145	40	0.190
6	250	1	110	58	77	46	0.418
		2	42	56	143	86	0.601
		3	47	55	108	48	0.444
7	630	1	180	40	104	42	0.233
		2	265	270	247	60	0.222
		3	25	20	24	4	0.160
		4	24	20	24	4	0.167
8	1000	1	14	30	130	20	0.154
		2	195	100	173	95	0.487
		3	247	202	232	22	0.089
		4	110	135	170	25	0.147
		5	180	2	150	116	0.644
		6	250	177	278	80	0.288

It is important to find the effect of balancing the three phase loads on the low voltage distribution feeders.

The first factor to be found is P_{loss} caused by each neutral current is found using equation 5.1

$$P_{Loss} = I_N^2 \times R_N \tag{5.1}$$

Where

P_{loss} is the lost power due to I_N.

I_N is the neutral current.

R_N is the resistance of the neutral conductor.

Assuming that all the feeders of these transformers are 500 meter long, and ABC 50mm^2 is used to build these feeders, and then R_N would be 0.389 .

Then, it is important to find the total energy lost per year for each feeder of the case described by table 5.7 before and after modification, using utilization factor of 0.6 leads us to table 5.8.

The total annual energy losses presented in table 5.8 were found using the following equations

$$E_{Loss} = P_{Loss} \times time \times UF \tag{5.2}$$

Where

E_{loss} is the total energy loss.

P_{loss} is the lost power from equation 5.1.

Time is the time period to be used; 8760h per year were used.

UF is the utilization factor.

Table 5.8: Losses caused by neutral currents before and after modifications

Transformer No	Rated kVA	feeder No	Old A_N Amps	Old AN %	A_N New Amps	Old Losses kWh/year	New Losses kWh/year
1	160	1	17	0.131	17	590.88	590.88
		2	83	0.755	22	14,085.14	989.58
2	1000	1	100	0.333	60	20,445.84	7,360.50
		2	60	0.255	47	7,360.50	4,516.49
		3	90	0.220	82	16,561.13	13,747.78
		4	90	0.098	90	16,561.13	16,561.13
		5	100	0.233	86	20,445.84	15,121.74
		6	80	0.348	46	13,085.34	4,326.34
		7	30	0.077	30	1,840.13	1,840.13
3	400	1	7	0.111	7	100.18	100.18
		2	43	0.226	38	3,780.44	2,952.38
		3	67	0.798	17	9,178.14	577.06
		4	32	0.337	19	2,093.65	738.09
		5	11	0.333	7	247.39	89.06
4	630	1	67	0.152	67	9,178.14	9,178.14
		2	120	0.250	96	29,442.01	18,842.89
		3	83	0.339	49	14,085.14	4,909.05
		4	90	0.219	82	16,561.13	13,814.93
5	630	1	30	0.097	30	1,840.13	1,840.13
		2	75	0.250	60	11,500.79	7,360.50
		3	45	0.214	42	4,140.28	3,606.65
		4	40	0.190	40	3,271.33	3,271.33
6	250	1	46	0.418	22	4,326.34	989.58
		2	86	0.601	29	15,121.74	1,672.39
		3	48	0.444	22	4,710.72	953.92
7	630	1	42	0.233	36	3,606.65	2,649.78
		2	60	0.222	54	7,360.50	5,962.01
		3	4	0.160	4	32.71	32.71
		4	4	0.167	4	32.71	32.71
8	1000	1	20	0.154	20	817.83	817.83
		2	95	0.487	39	18,452.37	3,109.81
		3	22	0.089	22	989.58	989.58
		4	25	0.147	25	1,277.87	1,277.87
		5	116	0.644	36	27,511.92	2,649.78
		6	80	0.288	56	13,085.34	6,320.55
Total kWh losses per year						313,720.97	159,793.48

Balancing the loading of each feeder to reduce the neutral current is achieved by redistributing all the loads of the unbalanced feeder almost equally for each phase, and this can be done by the technical teams of JDECo.

It is obvious that the total energy loss will be reduced from 313,720.97 kWh to 159,793.48 kWh if the neutral current in each feeder reduced to maximum 20% of the maximum phase current for that feeder.

5.6. The One-Line Diagram Including all the Modifications

The one-line diagram in figure 5.4 includes all the changes mentioned before.

All the changes are indicated by the thick dark blue lines.

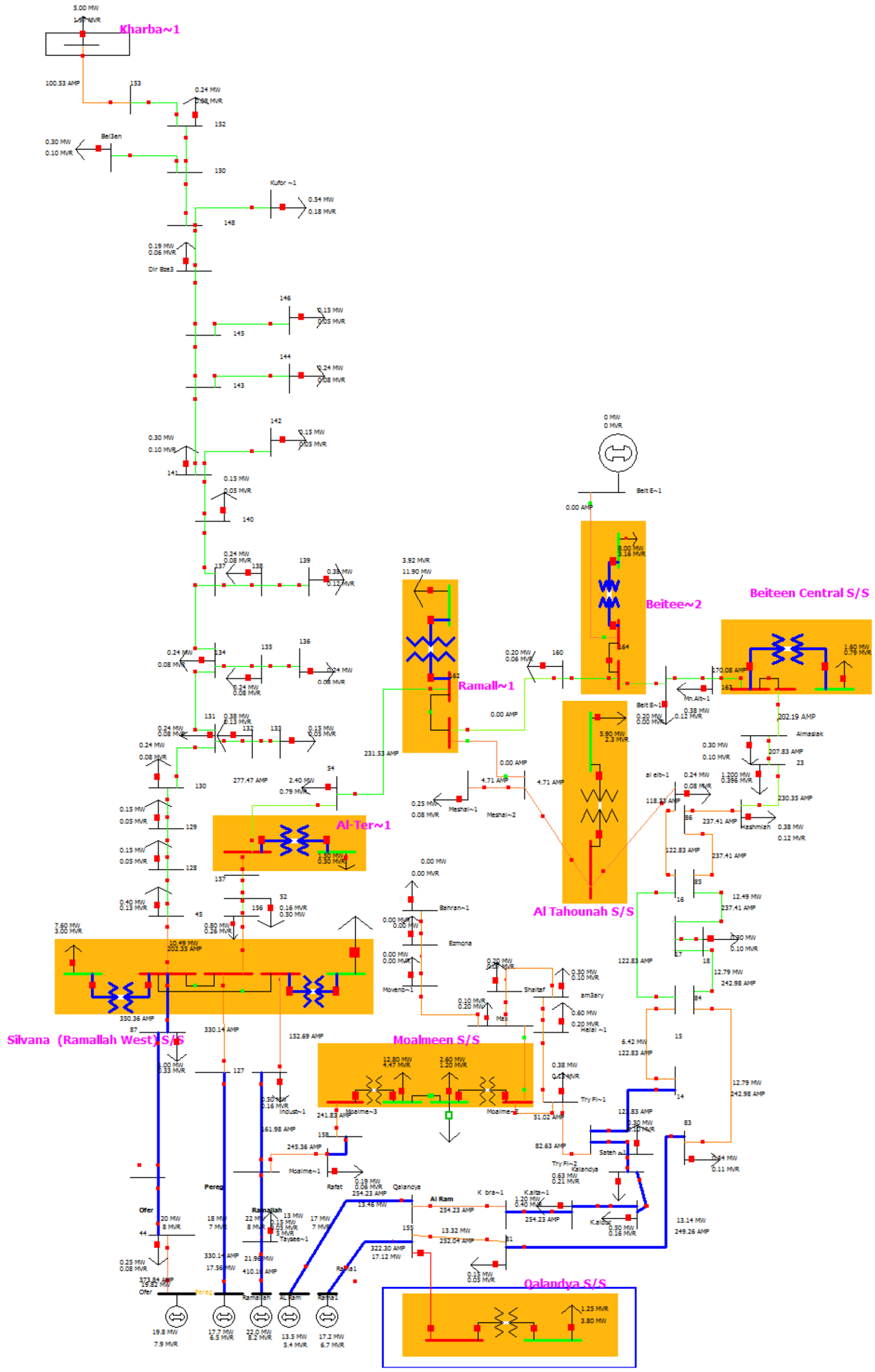

Figure 5.4 The one-line diagram with all the modifications

The simulated one-line diagram is shown in figure 5.5

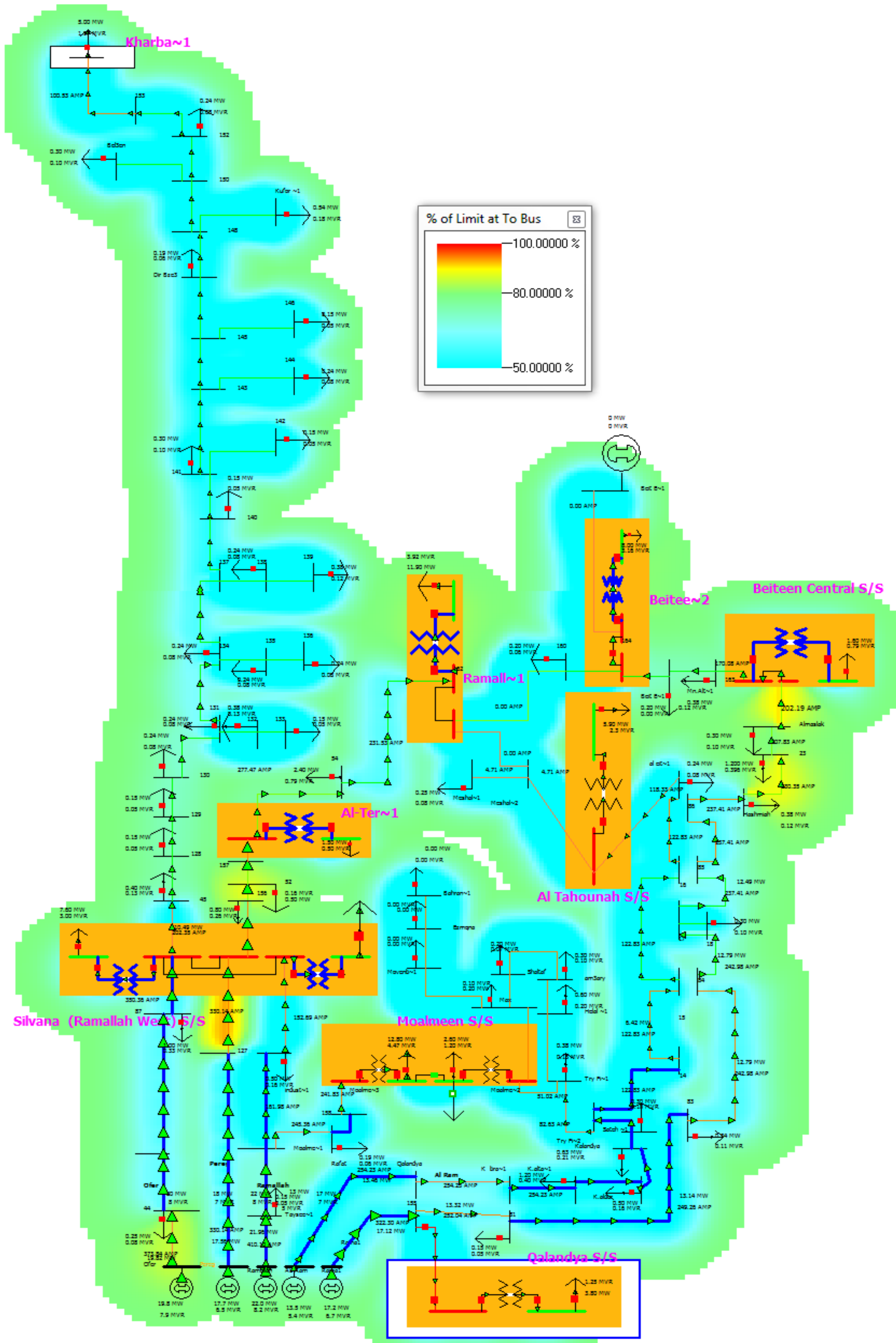

Figure 5.5 The simulated one-line diagram with all the modifications

It is clear that there is no overloading, and the main reason for this is that the suggested ACCC lines can carry up to 34MVA at 33kV.

The result of the simulation is shown in table 5.9:

Table 5.9: Simulation results of the one-line diagram presenting all the suggested measures

	Area Num	Area Nam ▲	Gen MW	Gen Mvar	Load MW	Load Mvar	Loss MW	Loss Mvar
1	1	1	90.18	34.70	88.14	31.89	2.03	2.81
2	4	4	0.00	0.00	0.00	0.00	0.00	0.00

The total losses in the network dropped to 2.03MW (2.25%) from 3.47 MW (3.26%), that is, a decrease of 1.44MW (1.01%) in losses is achieved.

5.7. Comparing the Network Parameters Before and After Improvements

The result of the last simulation shows three main changes from the existing situation:

- The problem of the overloading has been solved.
- The losses decreased from 3.47MW (3.26%) to 2.03MW (2.25%).
- The calculated power factor dropped from 92.7% to 92.3% which is still acceptable with no needed corrective measures.

5.8.Summery

It is clear that there are many conservation measures available to increase the efficiency of the electrical network of Ramallah, the analysis of the suggested improvements yielded energy saving opportunities, so, these improvements need to be economically analyzed to determine its feasibility.

Chapter Six

Management of the Tariff System in JDECo

Chapter Six
Management of the Tariff System in JDECo

6.1. Categories of JDECo Customers

JDECo adopts the flat rate tariff throughout its concession in the West Bank; six categories are used to define the customers:

1. **Commercial**

   This tariff is dedicated to the commercial sector regardless of its type, that is, the tariff is the same for all commercial and industrial customers. The average consumption of the commercial services was 58.82% of the total consumption in 2008, divided into commercial services without kVAR metering which consumed 18.06% of the total consumption in 2008, and commercial services with kVAR metering (industrial) which consumed 40.76% of the total consumption in 2008.

2. **Domestic**

   This tariff is intended for domestic households, whether it is single phase or three phase. The average consumption of the domestic services was 36.81% of the total consumption in 2008.

3. **Temporary**

   This tariff is the most expensive tariff, and it is intended to supply electrical energy to the construction works. It will not be discussed or studied during this thesis because the main use of these services is during the day not the night. The average consumption of the temporary services was 2.24% of the total consumption in 2008.

4. Street Lighting

This tariff is specified for the services that supply the street lighting in the different counsels and municipalities. The average consumption of the street lighting services was 0.57% of the total consumption in 2008.

5. Stare Case

This tariff is for services that supply stare cases (lighting and elevators) in multi-story buildings. The average consumption of the stare case services was 0.87% of the total consumption in 2008.

6. Water Pumping

This tariff is specified for water pumping services. The average consumption of the water pumping services was 0.53% of the total consumption in 2008.

All the above numbers resulted from processing data extracted from the data base of JDECo for 2008. And as mentioned before, all the above tariffs are flat rate. But IEC uses Time of Use tariff (sliding scale) in billing JDECo. The IEC tariff and the alternatives of the flat rate tariff will be presented in the next sections.

6.2. Time of Use Tariff (Sliding Scale)

The Time of Use tariff was specified to cover all the days of the year based on the seasons:

- **Winter Season Tariff**

  Starts on 1/12 of each year and ends on 31/3.

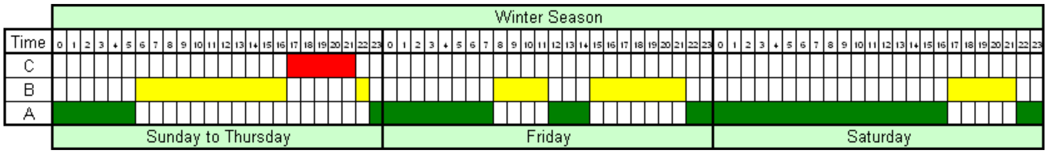

Figure 6.1 Winter season tariff

- **Spring Season Tariff**

  Starts on 1/4 of each year and ends on 30/6.

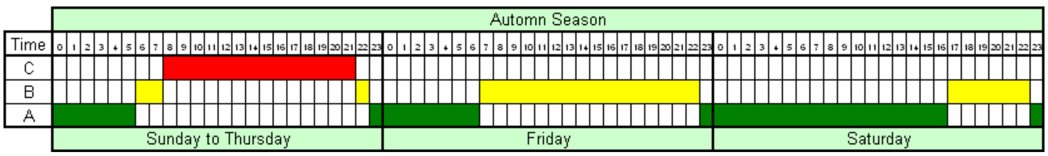

Figure 6.2 Autumn season tariff

- **Summer Season Tariff**

  Starts on 1/7 of each year and ends on 30/9.

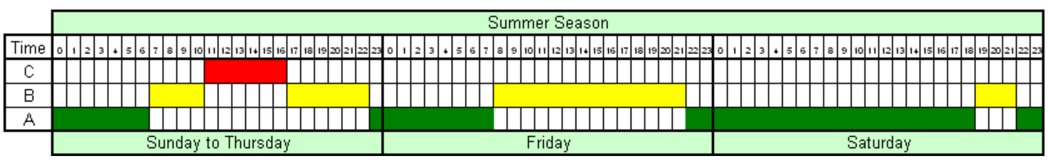

Figure 6.3 Summer season tariff

- **Autumn Season Tariff**

  Starts on 1/10 of each year and ends on 30/11.

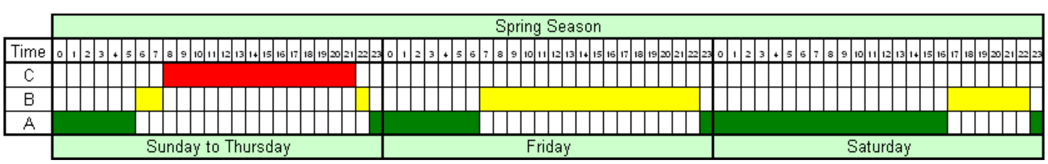

Figure 6.4 Spring season tariff

Throughout a day there are three rates, A (low), B (medium), and C (high), these rates have two values, one for the M.V. tariff and the other is for L.V. tariff.

The tariff throughout the week is not the same, as can be seen from the figures above. From Sunday to Thursday the same tariff throughout the season applies. On Friday (the day before week end) the tariff is cheaper. On Saturday (the week end day) the tariff is cheapest.

6.3. Tariff for Domestic Services in Jerusalem

Flat rate tariff is used for domestic services; it consists of two parts, the fixed part which is 13.39 NIS/month and the consumption which is found by multiplying the consumed energy by 0.4511 NIS/kWh.
And the total bill can be found using the equation below:

$$Total\ Bill = A + (E \times B) \tag{6.1}$$

Where
A is the fixed monthly amount
B is the cost of one kWh in NIS

So, if a domestic service consumed 250 kWh in a given month, the total electrical bill using equation 6.1 would be

$$13.39 + 250 * 0.4511 = 126.17 \text{ NIS}$$

6.4. Tariff for Domestic Services in Ramallah, Bethlehem, and Jericho

Flat rate tariff is used for domestic services; it consists of two parts, the fixed part which is 14.1102 NIS/month and the consumption which is found by multiplying the consumed energy by 0.5191 NIS/kWh.

That is, if a domestic service consumed 250 kWh in a given month, the total electrical bill using equation 6.1 would be

$$14.1102 + 250 * 0.5191 = 143.89 \text{ NIS}$$

6.5. Tariff for Commercial Services in Jerusalem (Low Voltage)

6.5.1. Time of Use Tariff

The time of use tariff – L.V. is intended only for the customer who consumes 50 MWh/year or more. The costs of this tariff are shown in table 6.1.

Table 6.1: Sliding scale tariff for commercial services in Jerusalem – L.V.

	Winter	Summer	Autumn and Spring
Fixed charge (NIS/month)	178.02	178.02	178.02
Time interval A (NIS/kWh)	0.1623	0.1747	0.1664
Time interval B (NIS/kWh)	0.4557	0.5208	0.3904
Time interval C (NIS/kWh)	0.7825	0.8152	0.6255

6.5.2. Flat Rate Tariff (for Three Phase Services)

It consists of two parts, the fixed part which is 56.66 NIS/month and the consumption which is found by multiplying the consumed energy by 0.4759 NIS/kWh.

That is, if a commercial service that is billed using flat rate tariff consumed 250 kWh in a given month, the total electrical bill using equation 6.1 would be

$$56.55 + 250 * 0.4759 = 175.53 \text{ NIS}$$

6.6. Tariff for Commercial Services in Ramallah, Bethlehem, and Jericho (Low Voltage)

6.6.1. Time of Use Tariff

The time of use tariff – L.V. is intended only for the customer who consumes 50 MWh/year or more. The costs of this tariff are shown in table 6.2:

Table 6.2: Sliding scale tariff for commercial services in Ramallah, Bethlehem, and Jericho – L.V.

	Winter	Summer	Autumn and Spring
Fixed charge (NIS/month)	187.817	187.817	187.817
Time interval A (NIS/kWh)	0.1976	0.2127	0.2026
Time interval B (NIS/kWh)	0.5550	0.6342	0.4754
Time interval C (NIS/kWh)	0.9529	0.9927	0.7617

6.6.2. Flat Rate Tariff (for Three Phase Services)

It consists of two parts, the fixed part which is 59.5918 NIS/month and the consumption which is found by multiplying the consumed energy by 0.5806 NIS/kWh.

That is, if a commercial service that is billed using flat rate tariff consumed 250 kWh in a given month, the total electrical bill using equation 6.1 would be

$$59.5918 + 250 * 0.5806 = 204.74 \text{ NIS}$$

6.7. Tariff for Commercial Services in Jerusalem (Medium Voltage)

The M.V. supply is intended for services with "customer contribution contract" of 915 Ampere or above. The costs of this tariff are shown in table 6.3.

Table 6.3: Sliding scale tariff for commercial services in Jerusalem – M.V.

	Winter	Summer	Autumn and Spring
Fixed charge (NIS)	290.63	290.63	290.63
Time interval A (NIS/kWh)	0.1132	0.1246	0.1176
Time interval B (NIS/kWh)	0.3950	0.4508	0.3355
Time interval C (NIS/kWh)	0.6935	0.7154	0.5621

6.8. Tariff for Commercial Services in Ramallah, Bethlehem, and Jericho (Medium Voltage)

The M.V. supply is intended for services with "customer contribution contract" of 915 Ampere or above. The costs of this tariff are shown in table 6.4.

Table 6.4: Sliding scale tariff for commercial services in Ramallah, Bethlehem, and Jericho – M.V.

	Winter	Summer	Autumn and Spring
Fixed charge (NIS)	306.6213	306.6213	306.6213
Time interval A (NIS/kWh)	0.1368	0.1506	0.1421
Time interval B (NIS/kWh)	0.4774	0.5448	0.4054
Time interval C (NIS/kWh)	0.8381	0.8645	0.6793

6.9. Tariff for Lighting Services in Jerusalem (Three Phase Services)

Flat rate tariff is used for lighting services; it consists of two parts, the fixed part which is 56.55 NIS/month and the consumption which is found by multiplying the consumed energy by 0.3875 NIS/kWh.

That is, if a lighting service consumed 250 kWh in a given month, the total electrical bill using equation 6.1 would be

$$56.55 + 250 * 0.3875 = 153.43 \text{ NIS}$$

6.10. Tariff for Lighting Services in Ramallah, Bethlehem, and Jericho (Three Phase Services)

Flat rate tariff is used for lighting services; it consists of two parts, the fixed part which is 59.5918 NIS/month and the consumption which is found by multiplying the consumed energy by 0.4219 NIS/kWh.
That is, if a lighting service consumed 250 kWh in a given month, the total electrical bill using equation 6.1 would be

$$59.5918 + 250 * 0.4219 = 165.07 \text{ NIS}$$

6.11. Analysis of Four Days Consumption Distributed on the Four Seasons

In order to analyze the consumption of the loads during different times throughout the year, and to find saving opportunities by restructuring the tariff, four days were selected, each day belongs to a different season.

All the data in this section were obtained from the SCADA system at JDECo in Excel Spreadsheet format, and were processed using Excel.

- **31-12-2008 (Winter Tariff)**

In order to find out the total energy consumption in kWh on 31-12-2008, the average power is needed:

$$E = P_{avg} \times t \qquad (6.2)$$

Where
E is the total energy cosumption in kWh

P_{avg} is the average power in kW

t is the time in hours

Using Excel software P_{avg} is found to be 54,144.38 kW, substituting in equation 6.2

$$E = 1,299,465 \text{ kWh}$$

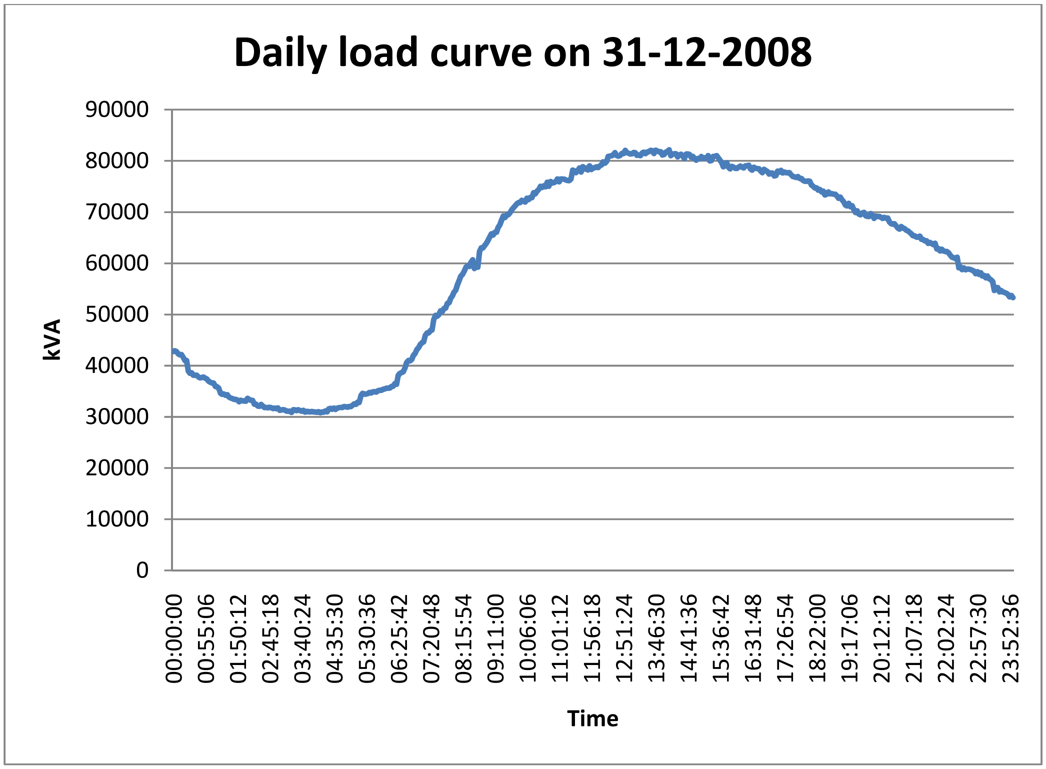

Figure 6.5 Daily load curve on 31-12-2008

Now, it is needed to find out the energy consumed in each tarrif rate through the day.

- **Energy Consumed in Time Interval A**

Figures 6.6 and 6.7 show the load curve during rate A zone, using Excel software, the average power during this zone is 33,330.17 kW, substituting in equation 6.2

$$E_A = 233,311 \text{ kWh}$$

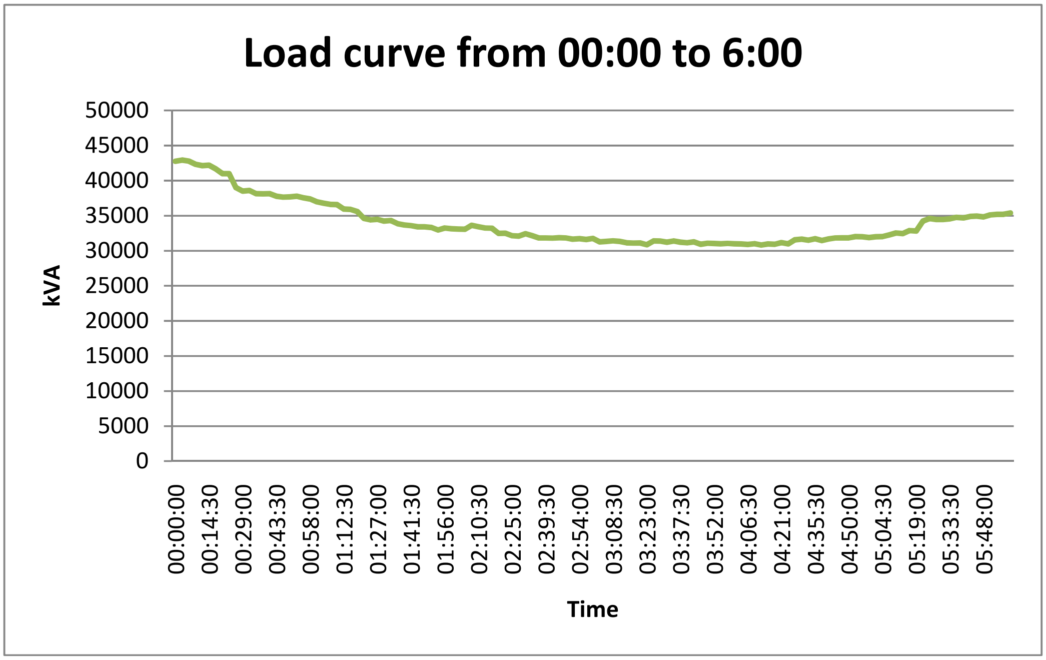

Figure 6.6 Load curve from 00:00 to 6:00

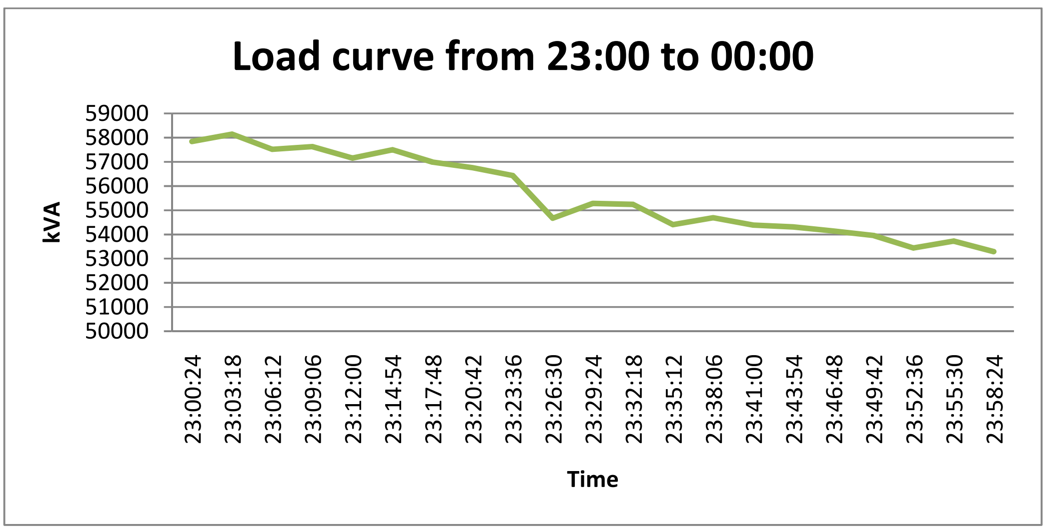

Figure 6.7 Load curve from 23:00 to 00:00

It can be seen that the energy consumed in rate A zone accounts for 17.95% of the total energy consumed on 31-12-2008.

•Energy Consumed in Time Interval B

Figures 6.8 and 6.9 show the load curve during rate B zone, using Excel software, the average power during this zone is 62,269.47 kW, substituting in equation 6.2

$$E_B = 747{,}233 \text{ kWh}$$

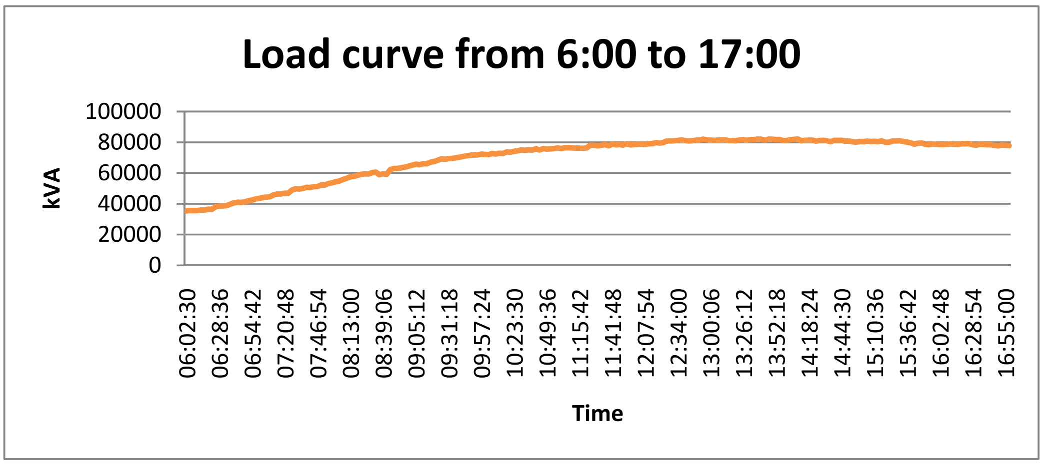

Figure 6.8 Load curve from 6:00 to 17:00

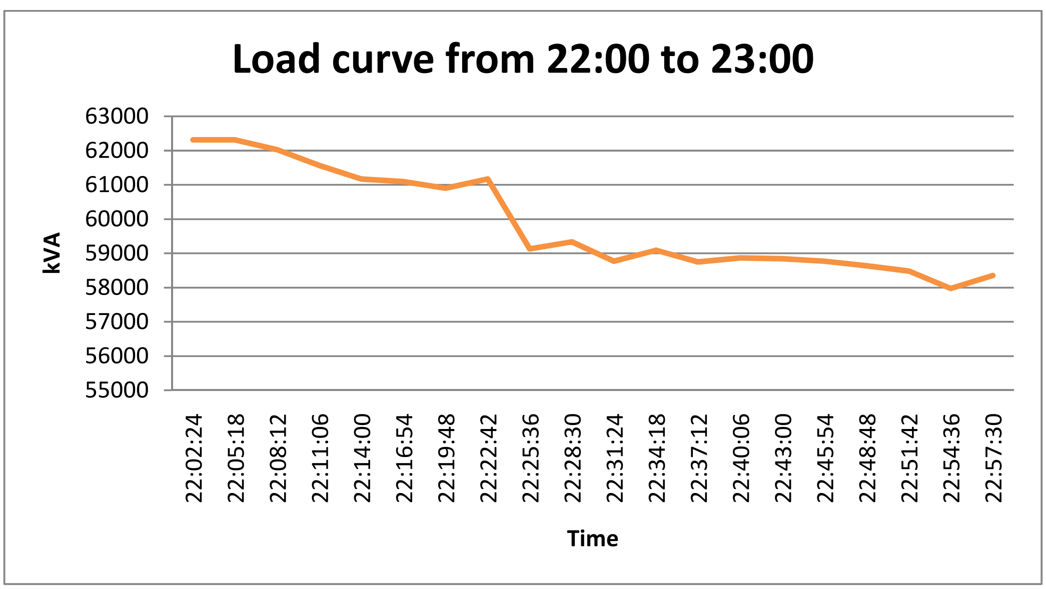

Figure 6.9 Load curve from 22:00 to 23:00

It can be seen that the energy consumed in rate B zone accounts for 57.5% of the total energy consumed on 31-12-2008.

•Energy Consumed in Time Interval C

Figure 6.10 shows the load curve during rate C zone, using Excel software, the average power during this zone is 63,784.29 kW, substituting in equation 6.2

$$E_C = 318{,}921 \text{ kWh}$$

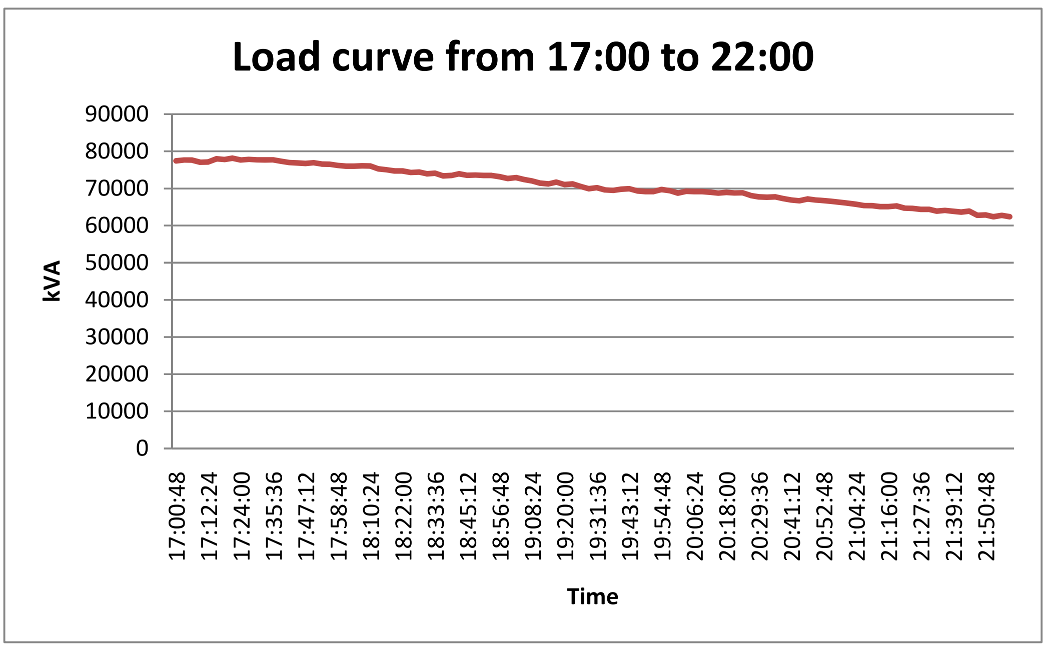

Figure 6.10 Load curve from 17:00 to 22:00

It can be seen that the energy consumed in rate C zone accounts for 24.54% of the total energy consumed on 31-12-2008.

- **4-5-2008 (Spring Tariff)**

In order to find out the total energy consumption in kWh on 4-5-2008, the average power is needed, using Excel software P_{avg} is found to be 35,875.79 kW, substituting in equation 6.2

$$E = 861{,}019 \text{ kWh}$$

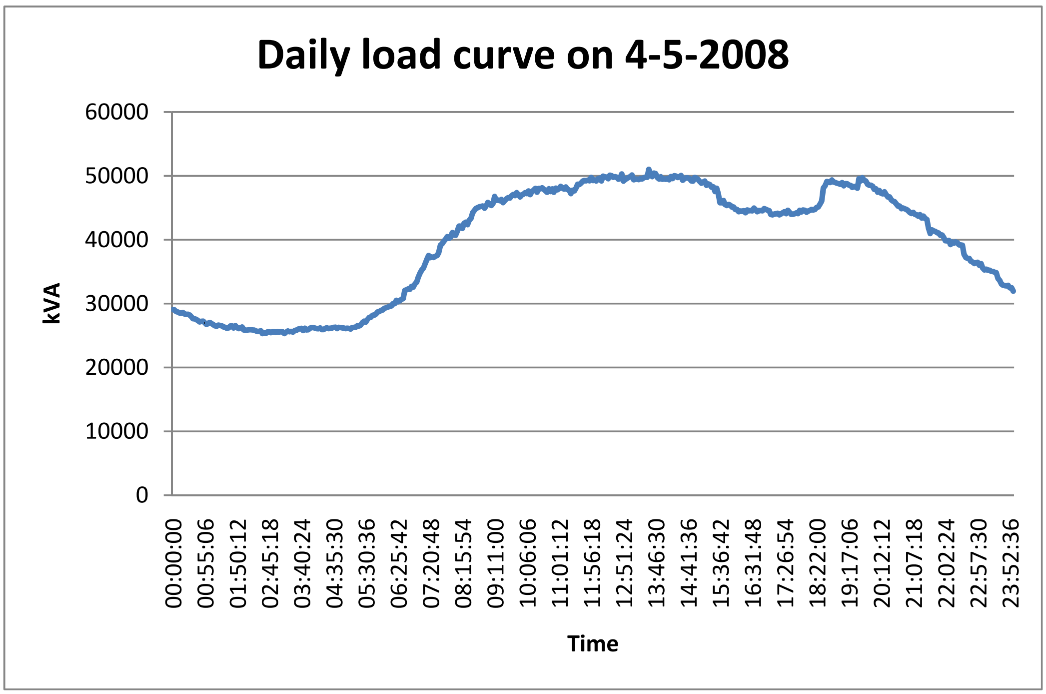

Figure 6.11 Daily load curve on 4-5-2008

Now, it is needed to find out the energy consumed in each tarrif rate through the day.

•Energy Consumed in Time Interval A

Figures 6.12 and 6.13 show the load curve during rate A zone, using Excel software, the average power during this zone is 24,916.91 kW, substituting in equation 6.2

$$E_A = 174{,}418 \text{ kWh}$$

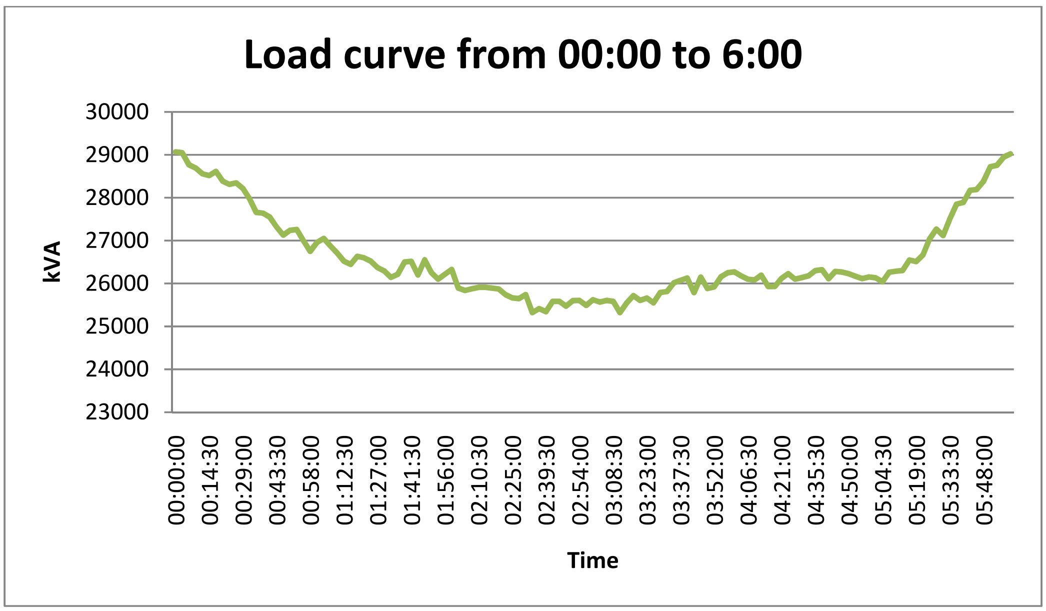

Figure 6.12 Load curve from 00:00 to 6:00

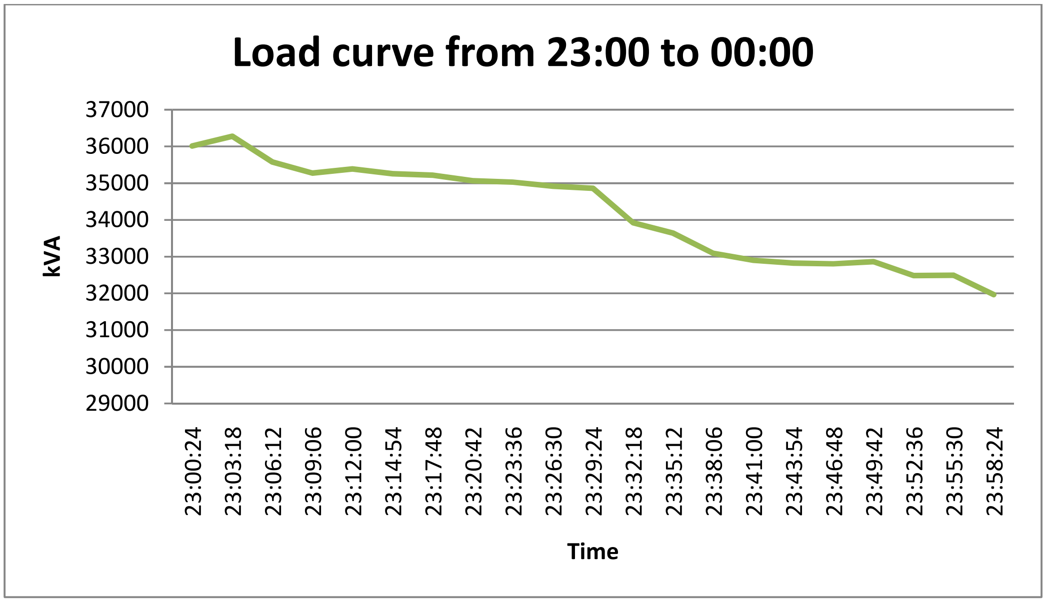

Figure 6.13 Load curve from 23:00 to 00:00

It can be seen that the energy consumed in rate A zone accounts for 20.26% of the total energy consumed on 4-5-2008.

• **Energy consumed in Time Interval B**

Figures 6.14 and 6.15 show the load curve during rate B zone, using Excel software, the average power during this zone is 32,201.55 kW, substituting in equation 6.2

$$E_B = 96{,}604 \text{ kWh}$$

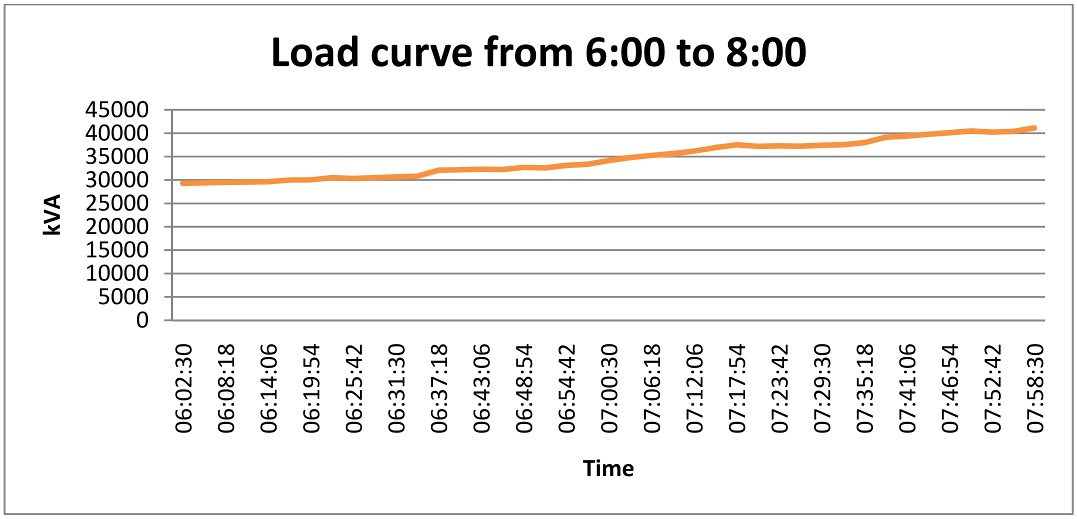

Figure 6.14 Load curve from 6:00 to 8:00

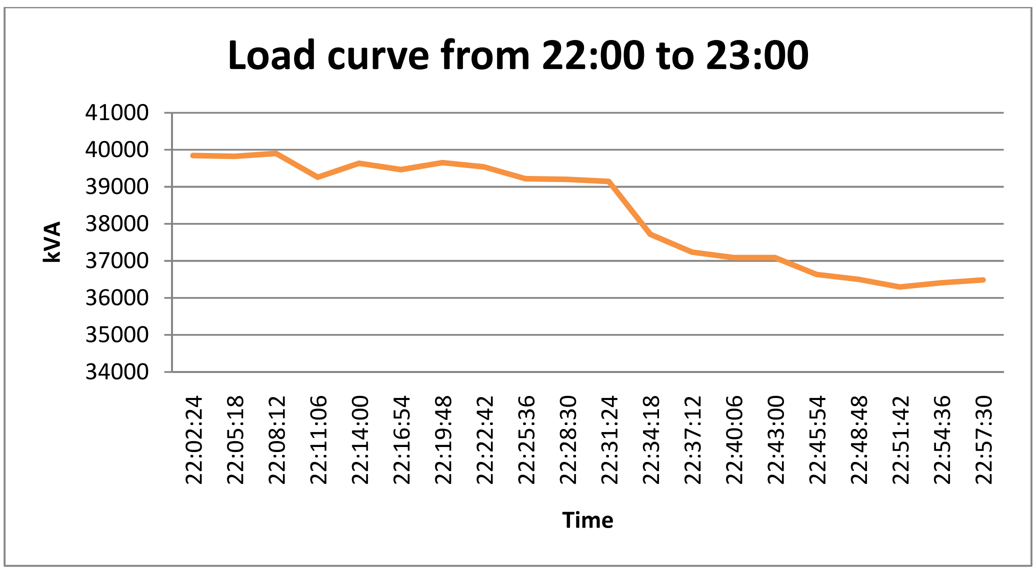

Figure 6.15 Load curve from 22:00 to 23:00

It can be seen that the energy consumed in rate B zone accounts for 11.22% of the total energy consumed on 4-5-2008.

•**Energy consumed in Time Interval C**

Figure 6.16 shows the load curve during rate C zone, using Excel software, the average power during this zone is 42,142.71 kW, substituting in equation 6.2

$$E_C = 589{,}997 \text{ kWh}$$

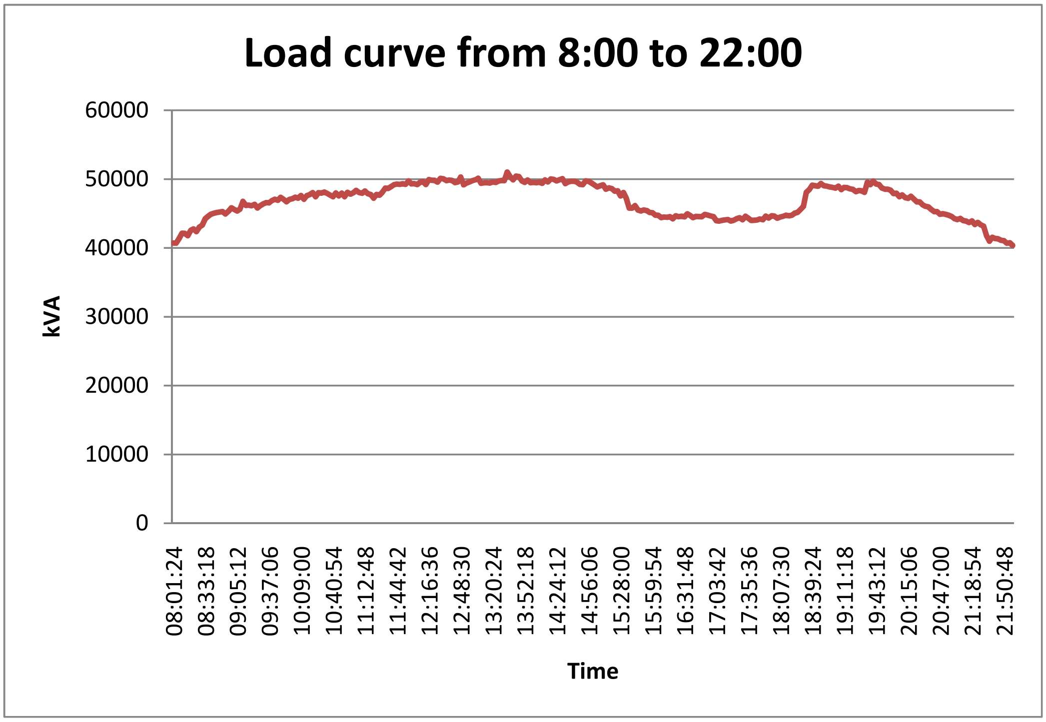

Figure 6.16 Load curve from 8:00 to 22:00

It can be seen that the energy consumed in rate C zone accounts for 68.52% of the total energy consumed on 4-5-2008.

- **28-8-2008 (Summer Tariff)**

In order to find out the total energy consumption in kWh on 28-8-2008, the average power is needed, using Excel software P_{avg} is found to be 41,896.96 kW, substituting in equation 6.2

$$E = 1{,}005{,}527 \text{ kWh}$$

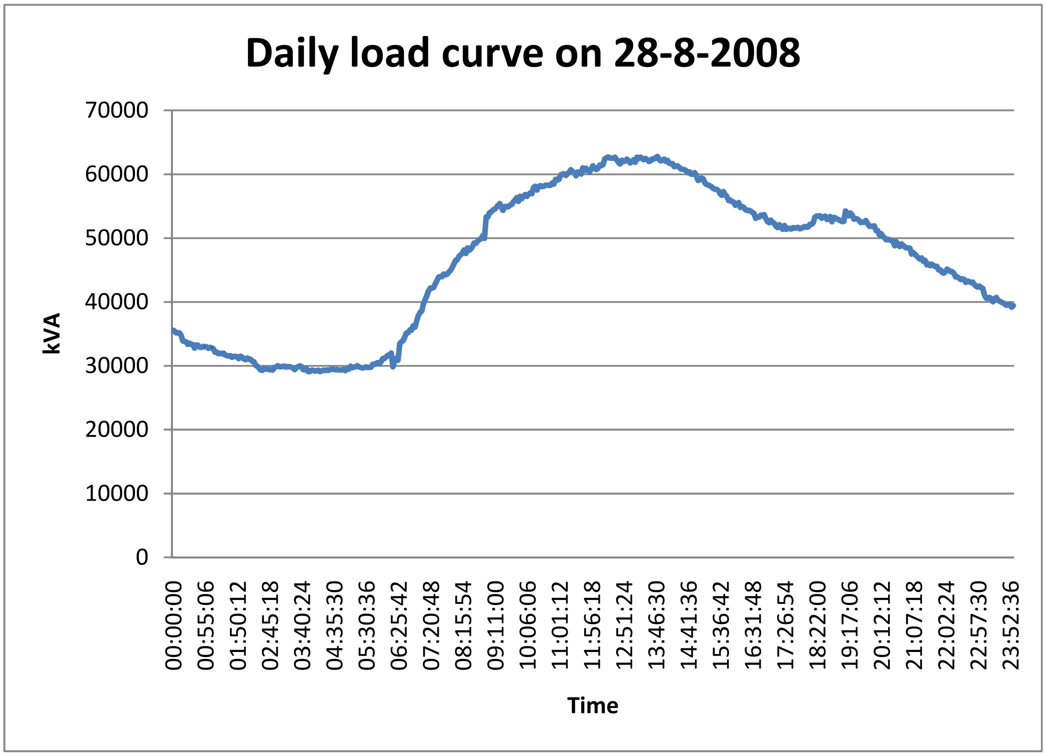

Figure 6.17 Daily load curve on 28-8-2008

Now, it is needed to find out the energy consumed in each tarrif rate through the day.

- **Energy Consumed in Time Interval A**

Figures 6.18 and 6.19 show the load curve during rate A zone, using Excel software, the average power during this zone is 29,098.74 kW, substituting in equation 6.2

$$E_A = 232{,}789 \text{ kWh}$$

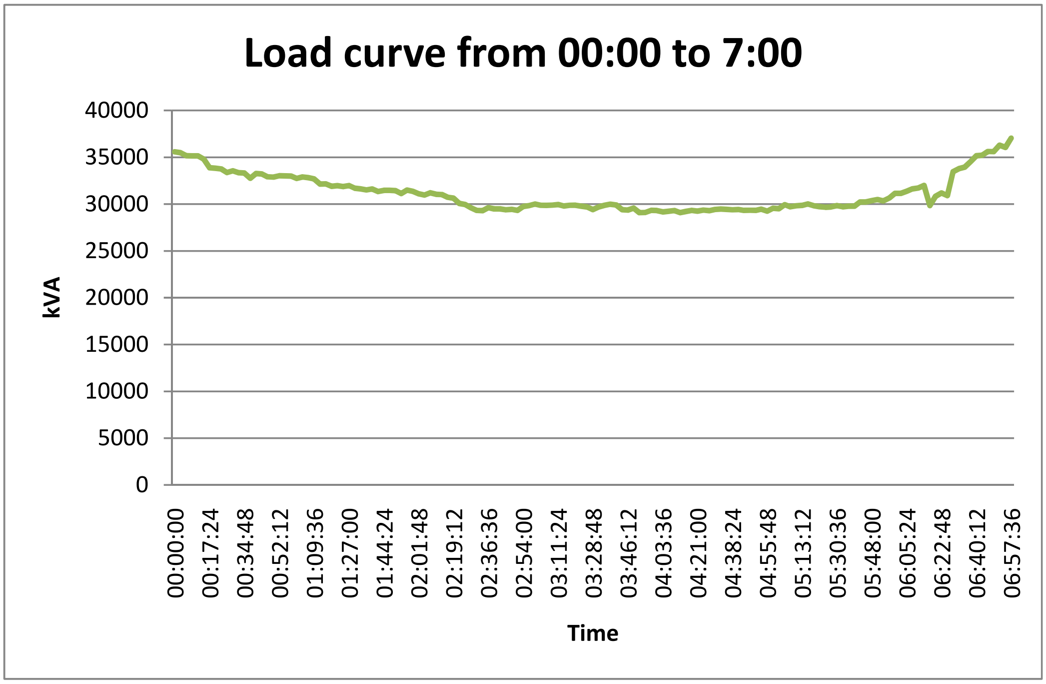

Figure 6.18 Load curve from 00:00 to 7:00

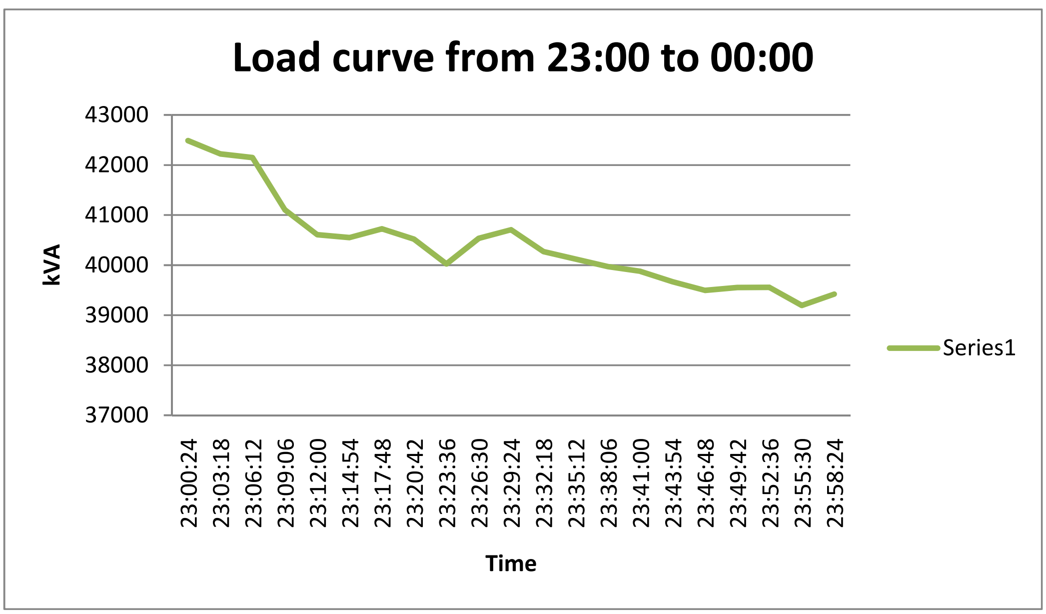

Figure 6.19 Load curve from 23:00 to 00:00

It can be seen that the energy consumed in raate A zone accounts for 23.15% of the total energy consumed on 28-8-2008.

- **Energy Consumed in Time Interval B**

Figures 6.20 and 6.21 show the load curve during rate B zone, using Excel program, the average power during this zone is 45,122.03 kW, substituting in equation 6.2

$$E_B = 451{,}220 \text{ kWh}$$

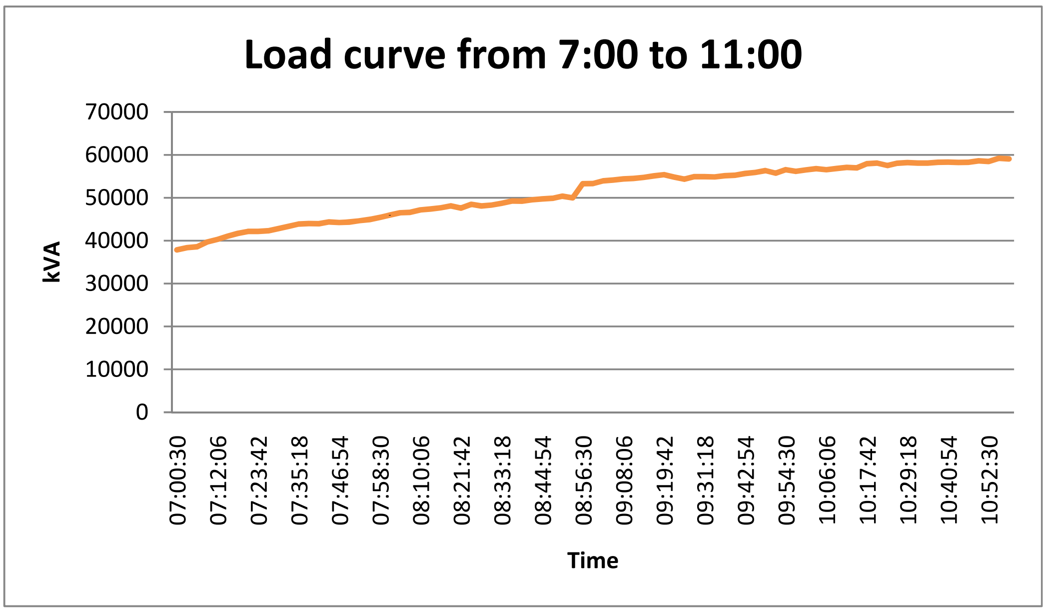

Figure 6.20 Load curve from 7:00 to 11:00

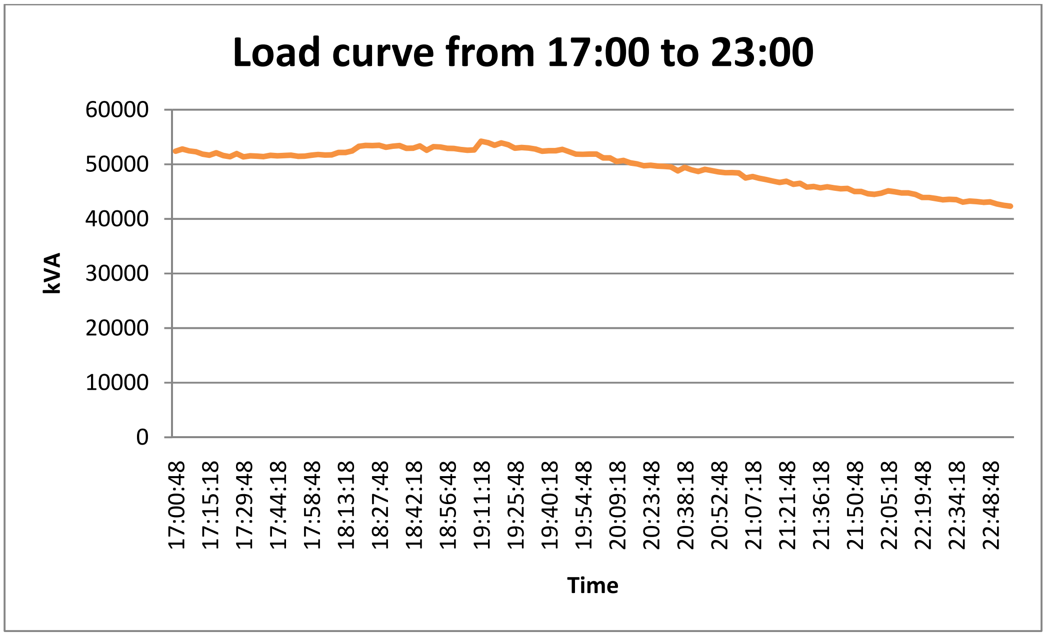

Figure 6.21 Load curve from 17:00 to 23:00

It can be seen that the energy consumed in raate B zone accounts for 44.87% of the total energy consumed on 28-8-2008.

- **Energy Consumed in Time Interval C**

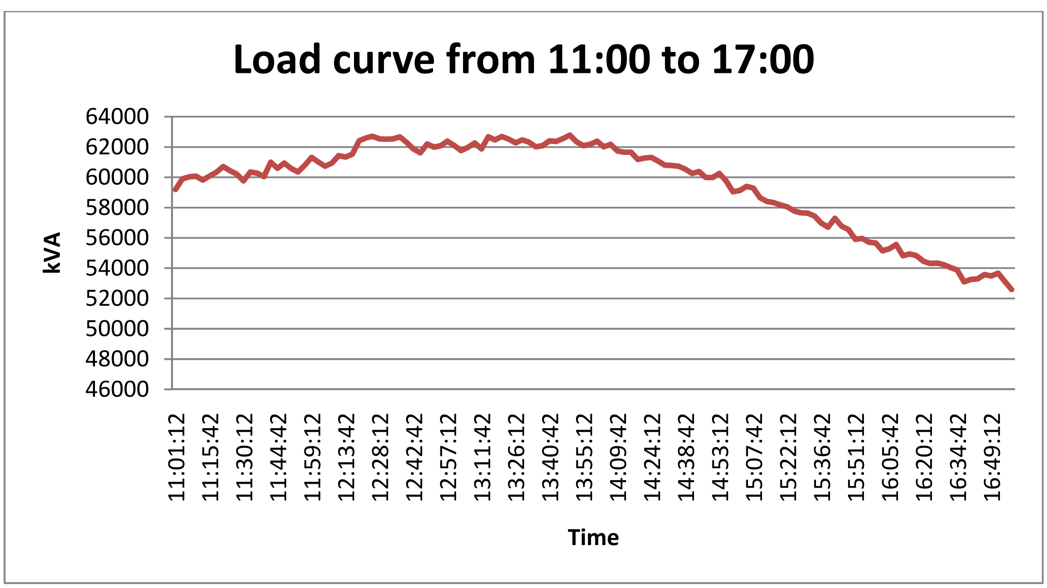

Figure 6.22 Load curve from 11:00 to 17:00

Figure 6.22 shows the load curve during rate C zone, using Excel program, the average power during this zone is 53,586.16 kW, substituting in equation 6.2

$$E_C = 321{,}516 \text{ kWh}$$

It can be seen that the energy consumed in rate C zone accounts for 31.98% of the total energy consumed on 28-8-2008.

- **29-10-2008 (autumn tariff)**

In order to find out the total energy consumption in kWh on 29-10-2008, the average power is needed, using Excel software P_{avg} is found to be 39,893.38 kW, substituting in equation 6.2

$$E = 957{,}441 \text{ kWh}$$

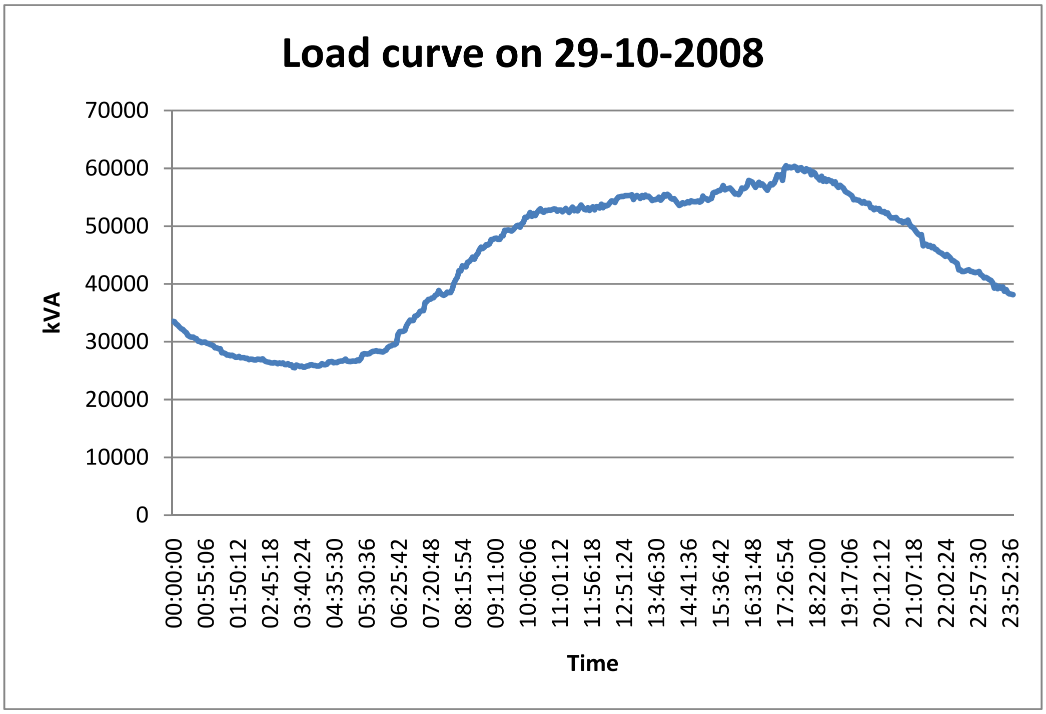

Figure 6.23 Daily load curve on 29-10-2008

Now, it is needed to find out the energy consumed in each tarrif rate through the day.

- **Energy Consumed in Time Interval A**

Figures 6.24 and 6.25 show the load curve during rate A zone, using Excel program, the average power during this zone is 26,516.16 kW, substituting in equation 6.2

$$E_A = 185{,}613 \text{ kWh}$$

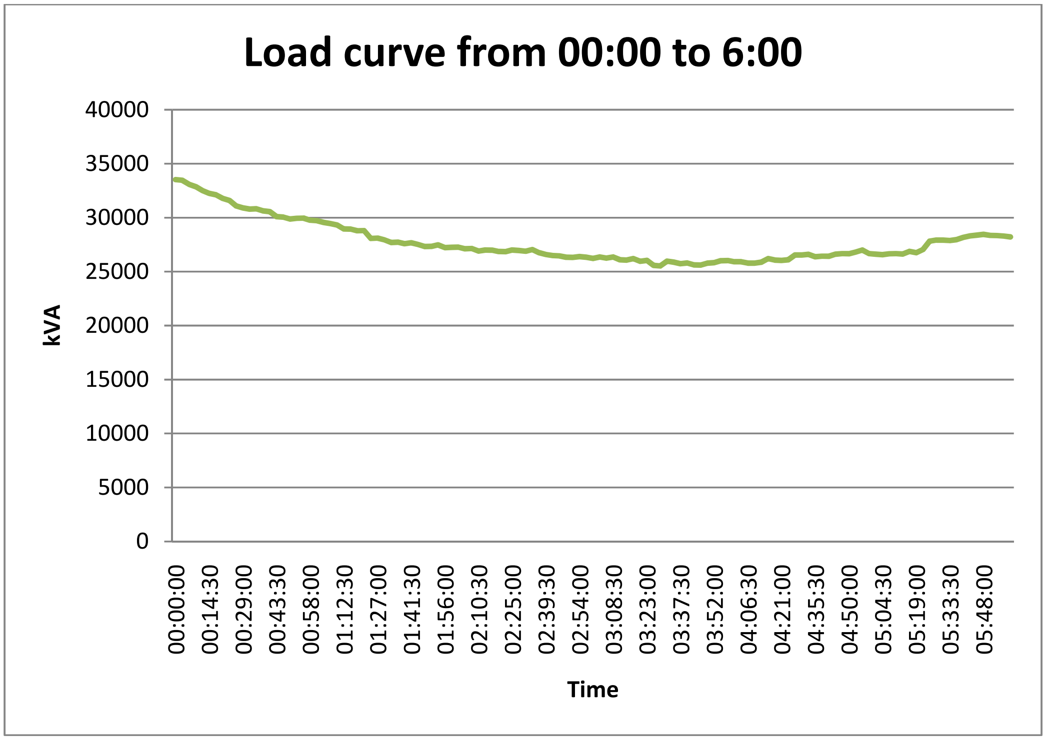

Figure 6.24 Load curve from 00:00 to 6:00

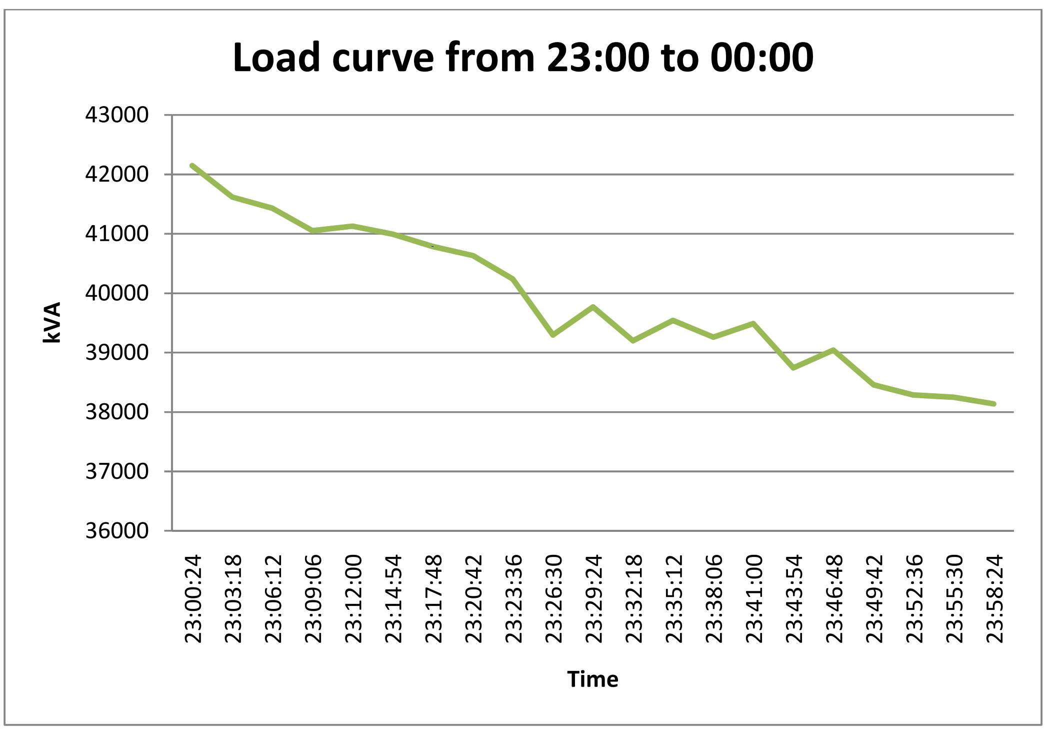

Figure 6.25 Load curve from 23:00 to 00:00

It can be seen that the energy consumed in rate A zone accounts for 19.38% of the total energy consumed on 29-10-2008.

- **Energy Consumed in Time Interval B**

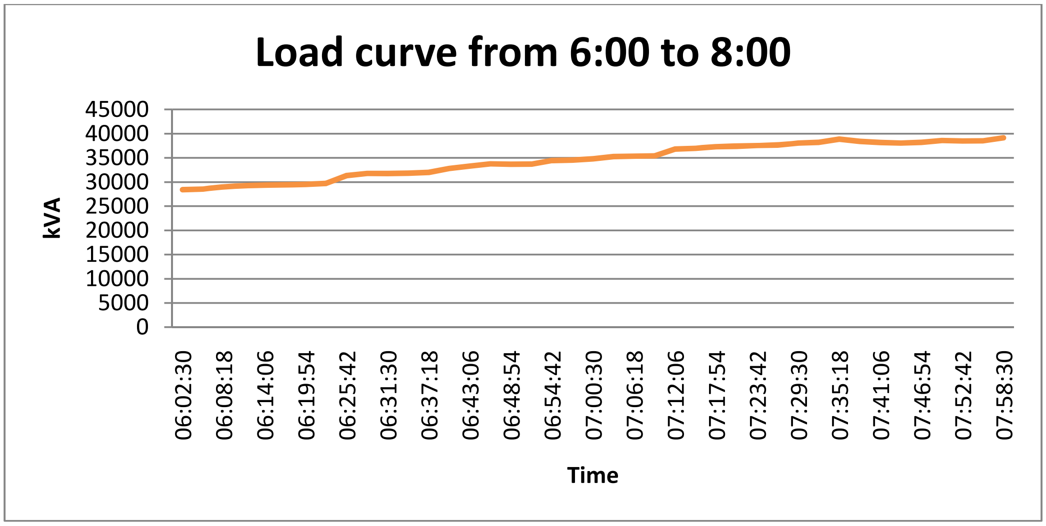

Figure 6.26 Load curve from 6:00 to 8:00

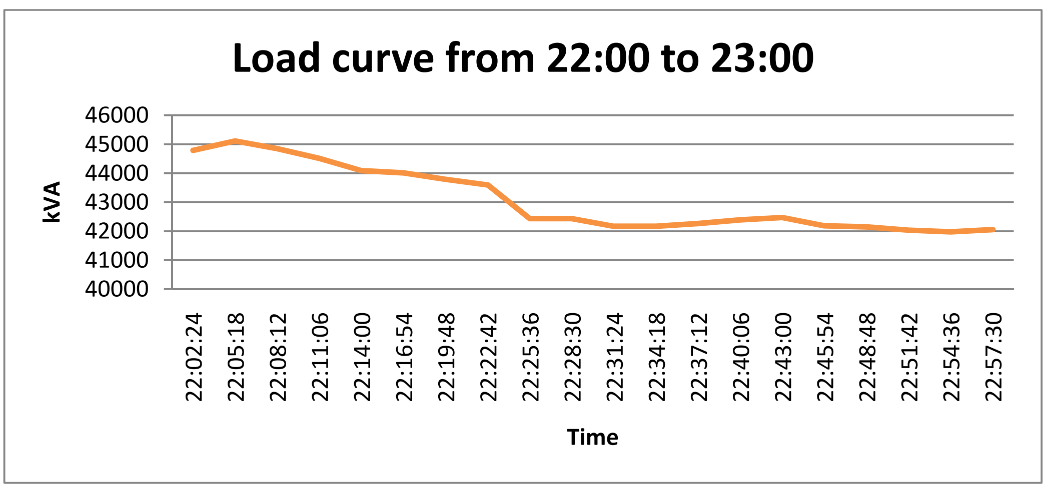

Figure 6.27 Load curve from 22:00 to 23:00

Figures 6.26 and 6.27 show the load curve during rate C zone, using Excel program, the average power during this zone is 33,594.42 kW, substituting in equation 6.2

$$E_B = 100{,}783 \text{ kWh}$$

It can be seen that the energy consumed in raate B zone accounts for 10.53% of the total energy consumed on 29-10-2008.

- **Energy Consumed in Time Interval C**

Figure 6.28 shows the load curve during rate C zone, using Excel program, the average power during this zone is 47,931.8 kW, substituting in equation 6.2

$$E_C = 671{,}045 \text{ kWh}$$

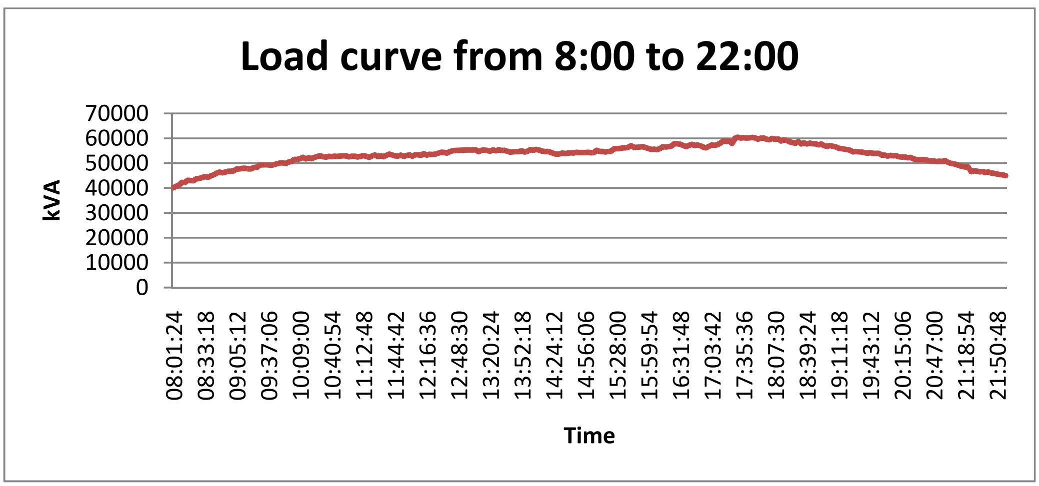

Figure 6.28 Load curve from 8:00 to 22:00

It can be seen that the energy consumed in rate C zone accounts for 70.09% of the total energy consumed on 29-10-2008.

The above analysis can be summarized in table 6.4

Table 6.5: Energy percentage consumed during each time interval in the four seasons

	Consumption during time interval A %	Consumption during time interval B %	Consumption during time interval C %
Winter season	17.95	57.50	24.54
Spring season	20.26	11.22	68.52
Summer season	23.15	44.87	31.98
Autumn season	19.38	10.53	70.09

It is clear that the energy consumed during time interval A, with the cheapest cost didn't exceed 23% of the total consumption, while in Spring and Autumn seasons the energy consumption during time interval C with the highest cost reached 70% of the total consumption. By shifting some of the loads to the more economical time intervals (A or B) JDECo and its consumers can save money.

The consumption of a commercial service in Ramallah will be analyzed in the next section, and find out if there is an opportunity to gain economical savings by reallocating the consumption.

6.12. Example of a Commercial Service in Ramallah

In this section the electrical consumption of Al Addasi Constructions in Ramallah industrial area will be studied and a comparison between the company's electricity bill using flat rate tariff and time-of-use tariff.

The monthly load curve of the factory is shown in the figure below, the readings started on 16-1-2010 and ended on 15-2-2010. Using the data registered by the VIP we got the following monthly load curve shown in figure 6.29

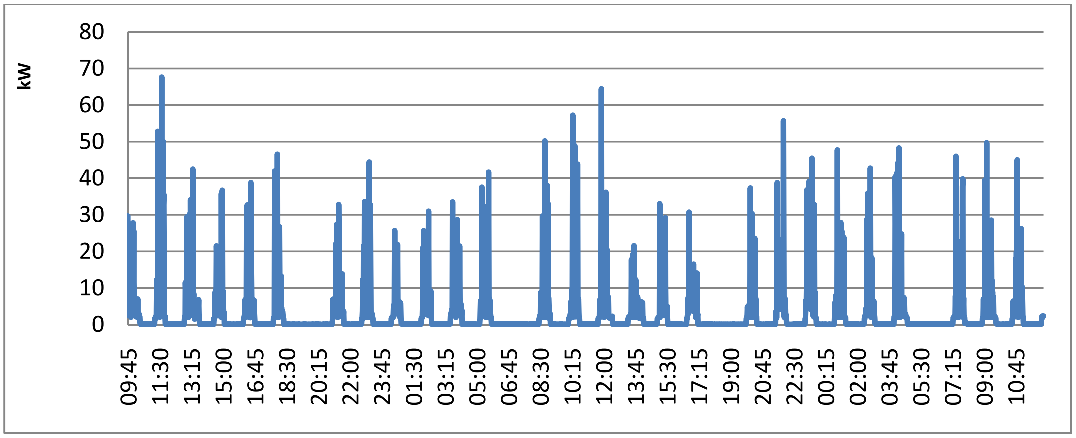

Figure 6.29 Monthly load curve of Al Addasi Constructions

Using VIP, it was found that the total kWh consumption during the monitoring period is 2,066.19 kWh.

The daily load curve for 17-1-2010 is shown in figure 6.30

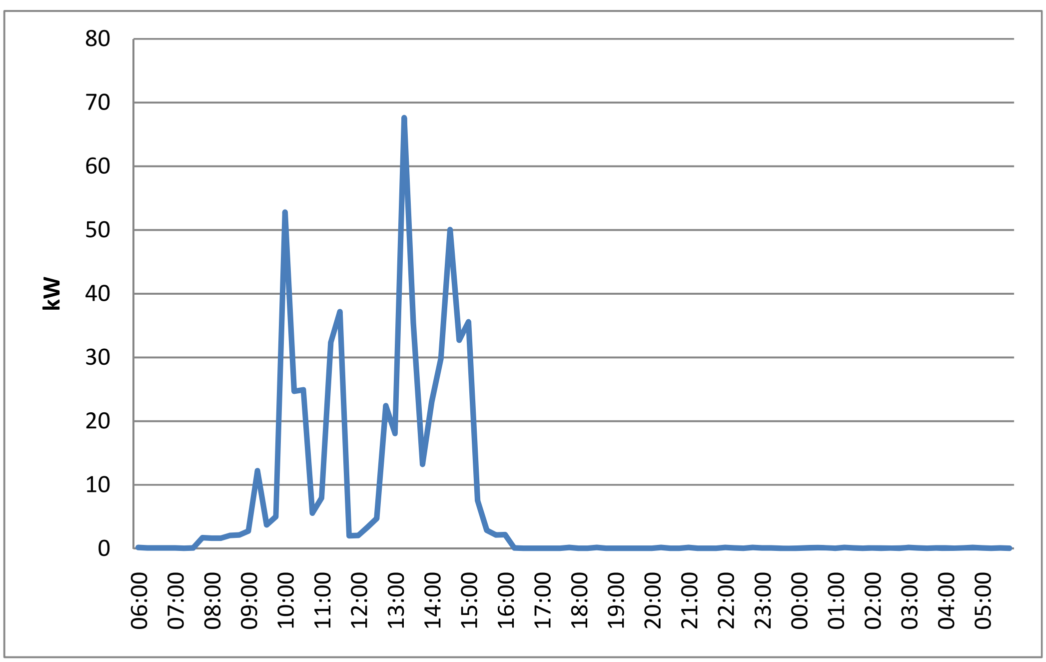

Figure 6.30 Daily load curve of Al Addasi Constructions

Using the flat rate tariff described before, the electrical bill of this company during the monitoring period can be found using equation 6.1 to be

$$59.5918 + 2066.19 * 0.5806 = 1441.8 \text{ NIS}$$

To study the TOU tariff for this company, the consumption in rate A zone, rate B zone, and rate C zone must be found.

Since the readings were taken during January and February 2010, the winter tariff is to be used. Microsoft Excel were used to find the total consumption during time intervals A, B, and C

$$E_A = 29.69 \text{ kWh}$$
$$E_B = 1{,}907.22 \text{ kWh}$$
$$E_C = 129.28 \text{ kWh}$$

The electrical bill using TOU tariff can be found using the following equation

$$Total\ Bill = \mathrm{K} + (\mathrm{E_A} \times \mathrm{Cost_A}) + (\mathrm{E_B} \times \mathrm{Cost_B}) + (\mathrm{E_C} \times \mathrm{Cost_C}) \qquad (6.3)$$

Where

K is the fixed monthly amount.

E_A is the total energy consumed in time interval A in kWh.

$Cost_A$ is the cost of one kWh consumed in time interval A in NIS.

E_B is the total energy consumed in time interval B in kWh.

$Cost_B$ is the cost of one kWh consumed in time interval B in NIS.

E_B is the total energy consumed in time interval B in kWh.

$Cost_C$ is the cost of one kWh consumed in time interval C in NIS.

The electrical bill using TOU winter tariff can be found using equation 6.3 to be

187.817 + (29.69 * 0.1976) + (1,907.22 * 0.5550) + (129.28 * 0.9529) = 1,375.38 NIS

The calculated bill using winter TOU tariff is lower than the bill calculated using flat rate tariff by 66.42 NIS.

If the measured consumption occurred during the summer season, then the total consumption during rate A, B, and C zones would have been

E_A = 33.81 kWh

E_B = 718.73 kWh

E_C = 1,313.65 kWh

And the electrical bill using summer TOU tariff using equation 6.3 would have been

187.817 + (33.81 * 0.2127) + (718.73 * 0.6342) + (1,313.65 * 0.9927) = 2,238.35 NIS

The calculated bill using winter TOU tariff is greater than the bill calculated using flat rate tariff by 796.55 NIS.

And finally, if the measured consumption occurred during the spring or autumn seasons, then the total consumption during rates A, B, and C zones would have been

E_A = 29.69 kWh

E_B = 27.62 kWh

E_C = 2,008.88 kWh

And the electrical bill using summer TOU tariff using equation 6.3 would have been

187.817 + (29.69 * 0.2026) + (27.62 * 0.4754) + (2,008.88 * 0.7617) = 1989.01 NIS

The calculated bill using winter TOU tariff is greater than the bill calculated using flat rate tariff only by 547.21 NIS.

To compare the annual electricity bill using flat rate tariff and TOU tariff for this company assuming that the electrical consumption is identical throughout the year, then the cost of the consumed energy using flat rate tariff would be:

1441.8 NIS/month * 12 months = 17,301.6 NIS / year

And the cost of the consumed energy using TOU rate tariff would be:

1,375.38 NIS/month * 3 months + 2,238.35 NIS/month * 3 months + 1989.01 NIS/month * 6 months = 22,775.25 NIS / year

Since IEC uses TOU tariff to bill JDECo, it is clear that with this individual consumer JDECo looses 5,473.65 NIS / year. And this loss can be avoided by using TOU tariff to bill JDECo large consumers, and this would yield two advantages:

- Financial advantage of avoiding low profit since IEC uses TOU tariff to bill JDECo.
- Technical advantage, because the TOU gives the consumer the ability to control his bill by moving his consumption to periods of the day

- where the cost of kWh is low, and thus reducing the overall peak load of the network during the day, which minimizes the need for extra installed capacity.

Chapter Seven

Financial Analysis of Energy Management Measures in Ramallah Electrical Network

Chapter Seven
Financial Analysis of Energy Management Measures in Ramallah Electrical Network

7.1. Investment Cost for the Suggested Measures

The investment cost of each one of the suggested measures in chapter 5 will be considered in this section.

7.1.1. Investment Cost of New Power Transformers

As mentioned in chapter 5, there is no need to change the power transformers in Al-Mo'alimen substation and Al-Tahounih substation because they meet the suggested VI%.

This leaves us with three 15MVA power transformers, one 10MVA power transformer, one 5MVA power transformer, and one 3MVA power transformer to be replaced by power transformers with higher efficiency.

The investment cost of this measure is shown in table 7.1

Table 7.1: Cost of the power transformers

Power transformer rating MVA	Cost of one unit $	Total cost of each type $
15	320,000	960,000
10	260,000	260,000
5	120,000	120,000
3	70,000	70,000
Total cost		1,410,000

So, the total cost of the six power transformers and the cost of installing them will reach $1,450,000.

Assuming that each of the power transformers in service right now will be sold for two thirds of the suggested cost, then the “salvage” value of the six power transformers will be $940,000.
So, the total investment cost of replacing the power transformers would be

$$\$1,450,000 - \$940,000 = \$510,000$$

7.1.2.Investment Cost of Using ACCC for the Main Incomers

The total distance of all the incomers to be replaced by ACCC is 19km, that is, we need 60km of ACCC (taking into account the sag of the lines).
Knowing that the cost of the suggested ACCC is NIS150,000/ km (all costs except the outages caused by replacing the lines are included in the cost).
Knowing that the salvage value of the mixed ACSR in use right now is NIS6000/ton (the current value as obtained from the market), and knowing that the mass of the used ACSR – Wolf lines is 727kg/km, and as mentioned before, the total length of the lines is 60km, so the total weight of 60km of ACSR – Wolf lines is 43.62 ton, and so, the total salvage value of the old lines would be:

$$NIS6000/ton \times 43.62ton = NIS261,720$$

So, the total investment in using ACCC for the main incomers would be:

$$NIS150{,}000/km \times 60km - NIS261{,}720 = NIS8{,}738{,}280$$

And so, the total investment would be $2,342,702.

7.1.3.Investment Cost of Reconfiguring the Network

The reconfiguration of the network can be divided in to two parts

1. Part one: no cost measure

This measure is achieved by changing the status of some of the switches in the network, in this case, the changes was done by disconnecting Dahyit Al-Bareed substation and loading it on another incomer from Jerusalem area, disconnecting Biteen central substation from Al-Ram incomer and loading it on Rama1 incomer.

2. Part two: high cost measure

This measure is adding a new substation at Qalandya camp area, total installation cost of $1,490,000 divided as following:

- The land: $100,000.
- Civil works: $270,000.
- Power transformer: $320,000.
- Switch gear: $500,000.
- Installation and new cables: $300,000.

7.1.4. Investment Cost of Reducing Neutral Current in Unbalanced Feeders in Low Voltage Distribution Network

This measure is a no-cost measure, and so, there is no investment needed for this measure.

7.2. Energy and Economical Savings Achieved from Applying the Suggested Measures

7.2.1.Savings Achieved from Using New Power Transformers

The results obtained in chapter 5 showed that the losses dropped from 3.47MW to 3.46MW as a result of replacing the power transformer, that is, 0.01MW saving.

The energy saved can be found using the following equation

$$E = P \times t \tag{7.1}$$

Where

E is the total saved energy.

P is the total power saved.

t is the time interval of interest (8760 hours here).

Using equation 7.1 the total energy saved would be

$$E = 87.6MWh/year$$

Assuming that the cost of the kWh from the IEC is NIS0.42, the total saving would be NIS36,792 per year, which is around $9,900 per year.

7.2.2.Savings Achieved from Using ACCC for the Main Incomers

The results obtained in chapter 5 showed that the losses dropped from 3.47MW to 2.79MW as a result of replacing the ACSR used in the main incomers by ACCC, that is, 0.68MW saving.
Using equation 7.1 the energy saved would be

$$E = 5{,}956.8MWh/year$$

Assuming that the cost of the kWh from the IEC is NIS0.42, the total saving would be NIS 2,501,856 per year, which is around $670,739 per year.

7.2.3.Savings Achieved from Reconfiguring the Network

The results obtained in chapter 5 showed that the losses dropped from 3.47MW to 2.50MW as a result of reconfiguring the network, that is, 0.97MW saving.
Using equation 7.1 the energy saved would be

$$E = 8{,}497.2MWh/year$$

Assuming that the cost of the kWh from the IEC is NIS0.42, the total saving would be NIS 3,568,824 per year, which is around $957,789 per year.

7.2.4.Savings Achieved from Reducing Neutral Current in Unbalanced Feeders in Low Voltage Distribution Network

The results obtained in chapter 5 showed that the losses dropped from 313,720.97 kWh to 159,793.48 kWh, thus savings would be

$$Savings = (Old\ energy\ loss - New\ energy\ loss) \times C \quad (7.2)$$

Where
C is the cost of kWh

Assuming that the cost of each kWh is NIS0.42/kWh, then the annual savings for these eight transformers using equation 7.2 would be NIS64,650 per year.

Knowing that there are 450 distribution transformers in Ramallah district, and assuming that 25% of these transformers have unbalanced loads, that is 110 transformers, and assuming that the above eight transformers represent the total 110 transformers, then reducing the neutral current for these transformers would yield annual saving of about NIS905,100 per year, that is $242,654 per year.

7.3. S.P.B.P. for the Suggested Measures

In this section the simple payback period of each measure will be investigated.
The S.P.B.P. can be found using equation 7.3

$$S.P.B.P. = I/A \tag{7.3}$$

Where
I is the investment in $.
A is annual savings in $.

7.3.1.S.P.B.P. of Replacing the Power Transformers

The cost of replacing the power transformers was found to be $510,000 and the savings was found to be $9,900 per year, so, the S.P.B.P. using equation 7.3 would be

$$S.P.B.P. = 51.5\ years$$

The measure of replacing the power transformers with more efficient ones turned out to be economically unfeasible, so, this measure to be ruled out and will not be considered any further.

7.3.2. S.P.B.P. of Using ACCC for the Main Incomers

The cost of using ACCC for the main incomers was found to be $5,533,512 and the savings was found to be $670,739 per year, so, the S.P.B.P. using equation 7.3 would be

$$S.P.B.P. = 3.45\ years$$

The measure of using ACCC for the main incomers can be considered economical if we know that the life time of the lines would be in the range of 25 to 30 years, this will yield an annual savings of $670,739/year from the fourth year till the end of the life time of the lines.

So, this measure will be recommended to JDECo.

7.3.3. S.P.B.P. of Reconfiguring the Network

The cost of reconfiguring the network was found to be $1,490,000 and the savings was found to be $957,789 per year, so, the S.P.B.P. using equation 7.3 would be

$$S.P.B.P. = 1.47\ years$$

The measure of reconfiguring the network is economically feasible and will be recommended to JDECo.

7.3.4. S.P.B.P. of Reducing Neutral Current in Unbalanced Feeders in Low Voltage Distribution Network

As mentioned before in chapter 5, this measure is a no-cost measure, that is, it yields savings without investment.

So, there will be no S.P.B.P. for this measure, and the savings will be achieved instantly.

7.4. P.W. and R.O.R. for all the Suggested Measures

To find the present worth for the mentioned measures above all together except changing the power transformers, the present worth and the rate of return methods will be used.

7.4.1. P.W. for all the Suggested Measures

To find the present worth, all the needed investments and the achieved savings will be presented in figure 7.1 that represents the cash flow, where the life time of the network assumed to be 15 years.

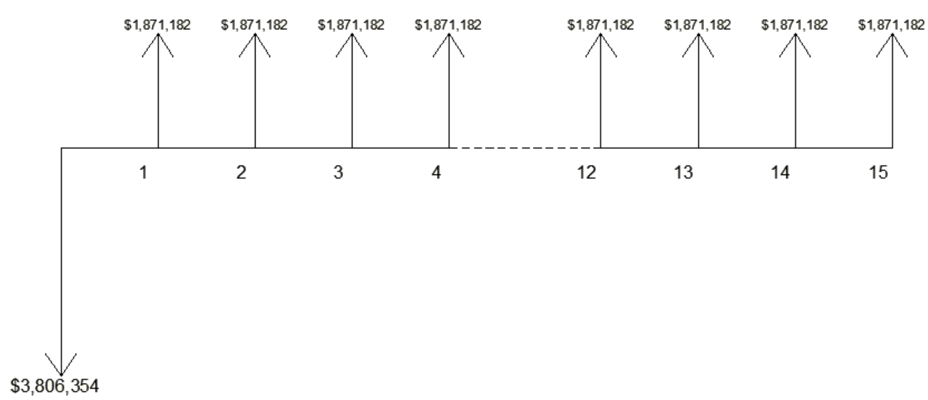

Figure 7.1 Cash flow for the investment and savings for all the suggested measures

The present value of such a cash flow can be found using the following equation

$$P.W = A \times (P/A\,,i,15) - I \qquad (7.4)$$

Where
A is the annual savings in \$
(P/A,i,15) the factor used to convert all the annual savings to present value.
I is the total investments.

Assuming interest rate of 5%, then the factor (P/A,i,15) from the tables would be 10.38, and so P.W. using equation 7.4 would be

$$P.W. = \$1{,}871{,}182 \times 10.38 - \$3{,}832{,}702 = \$15{,}590{,}167$$

7.4.2 R.O.R. for all the Suggested Measures

The rate of return for all the mentioned measures except for changing the power transformers will be found in this section using the idea represented by the following equation

$$P.W = A \times (P/A\,,i^{*},15) - I = 0 \qquad (7.5)$$

Where
A is the annual savings in \$.
i^* is the internal rate of return to be found.
I is the total investments.

For simplicity of the calculations, Microsoft Excel was used to find i^* using IRR function built in the software. IRR function uses the values of the investments (uses negative sign) and the annual savings (uses positive sign).

After giving all the needed information for Microsoft Excel software, the resulting i^* is

$$i^* = 48.69\%$$

It is clear that the IRR is significantly high, and this is due to the fact that the total invest cost is somewhat low compared to the annual savings achieved from applying the mentioned conservation measures.

Conclusion

The electrical network of Ramallah suffers of technical problems summarized in high losses, high demand that sometimes exceed the capacity of the incomers also in the winter, the outages that occur during the winter, and the tempering cases.

All of these problems except the tempering cases were addressed in this thesis; four conservation measures were analyzed to increase the efficiency of the electrical network of Ramallah.

One of the conservation measures failed to be economically feasible, while the other three measures showed high loss reduction which leaded to energy savings and proved to be economically feasible.

As a result it is important to analyze the electrical networks of other municipalities and distribution companies, in order to achieve higher efficiencies, to reduce the IEC bill, and to allow these networks to cope with the increased demand without the need increase the installed capacity.

Also, it is highly recommended to implement the measures suggested in this thesis in Ramallah electrical network to achieve the benefits mentioned above.

Recommendations

1. To expand such studies to include the distribution networks (0.4kV), this will help increase the efficiency; reduce the losses, which will yield economical benefits.

2. To analyze in more details energy conservation opportunities in commercial and industrial sector in electrical network.

3. To upgrade the tariff structure to more sophisticated structures such as the sliding scale tariff (time of use), which will allow the distribution of the demand more uniformly during the day, and will allow more profit to be gained by the distribution companies due to the fact that the IEC uses TOU tariff to bill the distribution companies.

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[7] Benoit Lebot, "*Energy-Efficient Distribution Transformers*: **a Hidden Opportunity for Large Scale Energy Savings**", September, 2007

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Appendices

Appendix 1:
ACSR vs. ACCC/TW, Comparison of Physical and Electrical Properties of Equivalent Sizes.

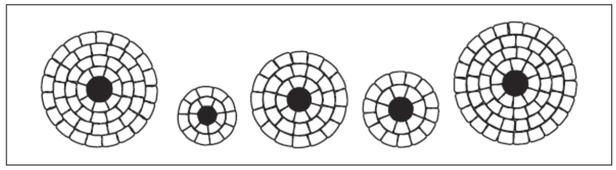
Appendix 1:
ACSR vs. ACCC/TW, Comparison of Physical and Electrical Properties of Equivalent Sizes.

TransPowr™ ACCC/TW Bare Overhead Conductor

Trapezoidal Aluminum Conductor Composite Core Concentric-Lay-Stranded

Product Construction:

Complete Conductor:
The TransPowr™ ACCC/TW is a marriage of General Cable's TransPowr ACSS/TW technology and CTC Cable Corporation's pultruded composite technology. Together these two technologies create the transmission and distribution conductor of the future.



TransPowr ACCC/TW is a Trapezoidal Aluminum Conductor Composite Core Concentric-Lay-Stranded conductor. The aluminum strands are trapezoidal in shape allowing for a more compact placement of the aluminum strand wires. TransPowr ACCC/TW conductors are designed to maintain the same overall diameter as a conventional round wire ACSR or ACSS conductor. The compact trapezoidal conductors, coupled with a smaller composite core, result in a TW conductor that has approximately 28% more aluminum cross-sectional area than ACSR or ACSS conductors. The greater aluminum content, combined with the capability to work at high operating temperatures, can double the current carrying capacity of an existing transmission line.

The central strength member component of the TransPowr ACCC/TW conductor is a proprietary high-strength carbon and glass fiber composite core patented by CTC Cable Corporation, around which are stranded two, three or four layers of annealed 1350 aluminum alloy wires. The annealed aluminum strand wires of the TransPowr ACCC/TW conductors are manufactured in accordance with the requirements of the latest issue of ASTM B857 and ASTM B609 specifications.

The TransPowr ACCC/TW conductor is designed to match the overall diameter of an existing concentric round ACSR or ACSS conductor. Because the TransPowr ACCC/TW conductor is so new, there are as yet no unique code word names assigned to these conductors. Consequently, the TransPowr ACCC/TW conductor has adopted the code word name of the original ACSR or ACSS conductor with the same matching overall diameter.

Performance
The TransPowr ACCC/TW conductor is superior to existing bare overhead conductors such as concentric round ACSR and ACSS in a number of key performance areas — capacity, sag, line losses and support structures. These performance advantages, that quickly and cost-effectively increase the ampacity of existing transmission and distribution lines, proactively address the problems plaguing the utility market, offering significant benefits to electric utility companies and ultimately to their industrial, commercial and residential customers.

Features and Benefits
In comparison to conventional concentric round ACSR conductors, and in some aspects to ACSS conductors, TransPowr ACCC/TW conductors additionally have some very important key features and benefits. For example: a) Compared to ACSR, the TransPowr ACCC/TW conductor can be operated continuously at high temperatures—180˚C without damage, and at 200˚C for short-term durations; b) Compared to ACSR, ACSS and any other steel-cored conductors, the TransPowr ACCC/TW composite core material has a very low thermal expansion coefficient. At elevated temperatures, the composite core material determines the sag characteristics of the conductor; c) The TransPowr ACCC/TW conductor is not affected by long-term creep of the aluminum; d) The overall mass (weight) of the TransPowr ACCC/TW conductor, even with the increased aluminum content, can be lighter than the original ASCR or ACSS conductor it is replacing; e) The annealed aluminum strand wires in the TransPowr ACCC/TW conductor have self-damping properties which may eliminate the need for dampers and other anti-vibration devices; and f) TransPowr ACCC/TW's composite core material will not rust or corrode like existing zinc or zinc-5% aluminum mischmetal coated steel materials.

Applications:
TransPowr ACCC/TW conductors have been specifically designed for overhead power distribution and transmission lines.

Physical and Electrical Parameters:
The following two tables provide the physical and electrical properties for ten (10) different TransPowr ACCC/TW conductor sizes. The information is provided to allow a side-by-side comparison of conventional conductor designs, the results of which will assist in the introduction and adoption of the TransPowr ACCC/TW product. The diagrams on the last page provide comparison details of the TransPowr ACCC/TW product which supports its superior sag and tension claim.

Contact General Cable's BICC® Brand Energy product team at (800) 237-2726 or email us at info@generalcable.com for other conductor sizes, designs and/or specific installation requirements not shown in the following tables. Visit us on the website at www.generalcable.com.

Appendix 1:
ACSR vs. ACCC/TW, Comparison of Physical and Electrical Properties of Equivalent Sizes.

TransPowr™ ACCC/TW Bare Overhead Conductor

Trapezoidal Aluminum Conductor Composite Core Concentric-Lay-Stranded

ACSR vs ACSS vs ACSS/TW vs ACCC/TW CONDUCTORS - COMPARISON OF PHYSICAL PROPERTIES OF EQUIVALENT SIZES

CODE WORD (1)	SIZE kcmil	TYPE (2)	NO. OF ALUM. WIRES	CORE	CORE O.D. INCHES	CROSS-SECTIONAL AREA (in²) TOTAL	CROSS-SECTIONAL AREA (in²) ALUM.	NOMINAL O.D. INCHES	NOMINAL WEIGHT lb/1000 ft TOTAL	NOMINAL WEIGHT lb/1000 ft ALUM.	NOMINAL WEIGHT lb/1000 ft CORE	RATED STRENGTH lb (3) CTC CORE	RATED STRENGTH lb (3) GA/MA STEEL	RATED STRENGTH lb (3) HS/MS STEEL	AMPS 75°C (4)	AMPS 200°C (5)	PERCENT BY WEIGHT ALUM.	PERCENT BY WEIGHT CORE	STANDARDPACKAGE (6) REEL SIZE	STANDARDPACKAGE (6) WGHT. Pounds	STANDARDPACKAGE (6) LNGTH. Feet
LINNET ACSR	336.4	16	26	7x0.0884	0.2652	0.3071	0.2641	0.720	462	317	145	-	14100	14900	530	-	68.5	31.5	RMT 84.36	75580	16390
LINNET ACSS	336.4	16	26	7x0.0884	0.2652	0.3071	0.2641	0.720	462	317	145	-	11200	12300	535	945	68.5	31.5	RMT 84.36	7580	16390
LINNET ACSS/TW	336.4	16	18	7x0.0884	0.2652	0.3071	0.2641	0.663	462	316	145	-	11200	12300	525	920	68.5	31.5	RMT 84.36	7880	17080
LINNET ACSS/TWD	398.7	16	18	7x0.0962	0.2886	0.3641	0.3132	0.720	547	375	172	-	13000	14300	580	1030	68.5	31.5	RMT 84.36	7880	14410
LINNET ACCC/TW	**431**	**A**	**16**	**1x0.2350**	**0.2350**	**0.3819**	**0.3385**	**0.720**	**441**	**405**	**36**	**16300**	**-**	**-**	**600**	**1060***	**92.1**	**7.9**	**RM 78.48**	**5010**	**11400**
HAWK ACSR	477	16	26	7x0.1053	0.3159	0.4353	0.3744	0.858	656	449	206	-	19500	20700	660	-	68.5	31.5	RMT 84.36	7580	11560
HAWK ACSS	477	16	26	7x0.1053	0.3159	0.4353	0.3744	0.858	656	449	206	-	15600	17100	665	940	68.5	31.5	RMT 84.36	7580	11560
HAWK ACSS/TW	477	16	18	7x0.1053	0.3159	0.4353	0.3745	0.789	655	448	206	-	15600	17100	650	1160	68.5	31.5	RMT 84.36	7890	12050
CALUMENT ACSS/TW	565.3	16	20	7x0.1146	0.3438	0.5161	0.4438	0.858	776	531	244	-	18400	20200	725	1295	68.5	31.5	RMT 84.36	8760	11300
HAWK ACCC/TW	**611**	**A**	**16**	**1x0.2800**	**0.2800**	**0.5415**	**0.4799**	**0.858**	**624**	**574**	**51**	**23200**	**-**	**-**	**745**	**1330***	**92.1**	**7.9**	**RM 78.48**	**3420**	**5500**
DOVE ACSR	556.5	16	26	7x0.1138	0.3414	0.5083	0.4371	0.927	765	524	241	-	22600	24000	725	-	68.5	31.5	RMT 84.36	7580	9910
DOVE ACSS	556.5	16	26	7x0.1138	0.3414	0.5083	0.4371	0.927	765	524	241	-	18200	20000	735	1315	68.5	31.5	RMT 84.36	7580	9910
DOVE ACSS/TW	556.5	16	20	7x0.1138	0.3414	0.5083	0.4371	0.850	764	523	241	-	18200	19900	720	1280	68.4	31.6	RMT 84.36	8760	11470
OSWEGO ACSS/TW	664.8	16	20	7x0.1244	0.3732	0.6073	0.5222	0.927	913	625	288	-	21700	23400	800	1440	68.4	31.6	RMT 84.36	8770	9610
DOVE ACCC/TW	**713**	**A**	**18**	**1x0.3050**	**0.3050**	**0.6328**	**0.5597**	**0.927**	**728**	**669**	**59**	**27500**	**-**	**-**	**820**	**1470***	**92.0**	**8.0**	**RM 78.48**	**3850**	**5350**
GROSBEAK ACSR	636	16	26	7x0.1216	0.3648	0.5807	0.4994	0.990	874	599	275	-	25200	26800	790	-	68.5	31.5	RMT 84.36	7580	8670
GROSBEAK ACSS	636	16	26	7x0.1216	0.3648	0.5807	0.4994	0.990	874	599	275	-	20800	22400	800	1435	68.5	31.5	RMT 84.36	7580	8670
GROSBEAK ACSS/TW	636	16	20	7x0.1216	0.3648	0.5809	0.4996	0.908	873	598	275	-	20800	22400	780	1400	68.5	31.5	RMT 84.36	8760	10040
WABASH ACSS/TW	762.8	16	20	7x0.1331	0.3993	0.6963	0.5989	0.990	1046	717	330	-	24900	26800	875	1570	68.5	31.5	RMT 84.36	8760	8370
GROSBEAK ACCC/TW	**816**	**A**	**19**	**1x0.3200**	**0.3200**	**0.7215**	**0.6411**	**0.990**	**832**	**766**	**66**	**30400**	**-**	**-**	**890**	**1610***	**92.3**	**7.7**	**RM 78.48**	**4730**	**5700**
DRAKE ACSR	795	16	26	7x0.1360	0.4080	0.7263	0.6246	1.107	1093	749	344	-	31500	33500	905	-	68.5	31.5	RMT 84.36	7590	6940
DRAKE ACSS	795	16	26	7x0.1360	0.4080	0.7263	0.6246	1.107	1093	749	344	-	26000	28000	915	1660	68.5	31.5	RMT 84.36	7590	6940
DRAKE ACSS/TW	795	16	20	7x0.1360	0.4080	0.7259	0.6242	1.010	1091	747	344	-	25900	28000	895	1615	68.5	31.5	RMT 84.36	8760	8030
SUWANNEE ACSS/TW	959.6	16	22	7x0.1493	0.4479	0.8764	0.7539	1.108	1317	902	415	-	30700	33100	1006	1825	68.5	31.5	RMT 84.36	9640	7320
DRAKE ACCC/TW	**1020**	**A**	**22**	**1x0.3750**	**0.3750**	**0.9112**	**0.8014**	**1.108**	**1046**	**957**	**89**	**41100**	**-**	**-**	**1025**	**1865***	**91.6**	**8.4**	**RM 78.48**	**5960**	**5700**
CARDINAL ACSR	954	13	54	7x0.1329	0.3987	0.8462	0.7491	1.196	1227	899	329	-	33800	35700	995	-	73.2	26.8	RMT 90.45	11780	9600
CARDINAL ACSS	954	13	54	7x0.1329	0.3987	0.8462	0.7491	1.196	1227	899	329	-	26000	28000	1006	1824	73.2	26.8	RMT 90.45	11780	9600
CARDINAL ACSS/TW	954	13	21	7x0.1329	0.3987	0.8463	0.7492	1.084	1224	895	329	-	26000	28000	995	1805	73.1	26.9	RMT 84.36	8620	7040
HUDSON ACSS/ TW	1158.4	13	26	7x0.1467	0.4401	1.0279	0.9096	1.196	1488	1087	401	-	31100	33500	1120	2050	73.1	26.9	RMT 84.36	10670	7170
CARDINAL ACCC/TW	**1222**	**B**	**36**	**1x0.3450**	**0.3450**	**1.0536**	**0.9601**	**1.196**	**1228**	**1152**	**76**	**37100**	**-**	**-**	**1140**	**2080***	**94.0**	**6.0**	**RM 78.48**	**6990**	**5700**
BITTERN ACSR	1272	7	45	7x0.1121	0.3363	1.0679	0.9988	1.345	1432	1198	234	-	34100	35400	1185	-	83.7	16.3	RMT 90.45	10740	7500
BITTERN ACSS	1272	7	45	7x0.1121	0.3363	1.0679	0.9988	1.345	1432	1198	234	-	22300	24000	1195	2200	83.7	16.3	RMT 90.45	10740	7500
BITTERN ACSS/TW	1272	7	33	7x0.1121	0.3363	1.0685	0.9994	1.215	1432	1198	234	-	22300	24100	1165	2130	83.7	16.3	RMT 84.36	11830	8260
POTOMAC ACSS/TW	1557.4	7	36	7x0.1241	0.3723	1.3084	1.2237	1.345	1754	1467	287	-	27400	29000	1320	2430	83.7	16.3	RMT 84.45	12910	7360
BITTERN ACCC/TW	**1572**	**B**	**39**	**1x0.3450**	**0.3450**	**1.3283**	**1.2348**	**1.345**	**1554**	**1478**	**76**	**39300**	**-**	**-**	**1320**	**2440***	**95.3**	**4.7**	**RMT 90.45**	**8850**	**5700**
LAPWING ACSR	1590	7	45	7x0.1253	0.3759	1.3353	1.2490	1.504	1790	1498	292	-	42200	43800	1355	-	83.7	16.3	RMT 90.45	10740	6000
LAPWING ACSS	1590	7	36	7x0.1253	0.3759	1.3351	1.2488	1.361	1790	1498	292	-	27400	29100	1370	2545	83.7	16.3	RMT 90.45	10740	6000
LAPWING ACSS/TW	1590	7	36	7x0.1253	0.3759	1.3351	1.2488	1.361	1790	1498	292	-	27900	29600	1330	2460	83.7	16.3	RMT 84.45	12900	7210
ATHABASKA ACSS/TW	1949.6	7	56	7x0.1382	0.4146	1.6367	1.5317	1.502	2195	1840	355	-	34000	36100	1506	2815	83.8	16.2	RMT 96.60	20040	9130
LAPWING ACCC/TW	**1966**	**B**	**56**	**1x0.3850**	**0.3850**	**1.6608**	**1.5444**	**1.504**	**1960**	**1864**	**96**	**49000**	**-**	**-**	**1500**	**2805***	**95.3**	**4.7**	**RMT 90.45**	**11150**	**5700**
CHUKAR ACSR	1780	8	84	19x0.0874	0.4370	1.5113	1.3974	1.601	2071	1685	387	-	51000	53100	1450	-	81.3	18.7	RMT 96.60	19060	9200
CHUKAR ACSS	1780	8	84	19x0.0874	0.4370	1.5113	1.3974	1.601	2071	1685	387	-	35300	38200	1465	2750	81.3	18.7	RMT 96.60	19060	9200
CHUKAR ACSS/TW	1780	8	38	19x0.0874	0.4370	1.5122	1.3982	1.447	2061	1674	387	-	35400	38200	1420	2630	81.2	18.8	RMT 84.45	14030	6810
POWDER ACSS/TW	2153.8	8	64	19x0.0961	0.4805	1.8293	1.3915	1.602	2510	2042	467	-	42100	45500	1600	3010	81.4	18.6	RMT 96.60	23590	9400
CHUKAR ACCC/TW	**2242**	**B**	**56**	**1x0.3950**	**0.3950**	**1.883**	**1.761**	**1.602**	**2225**	**2126**	**99**	**52700**	**-**	**-**	**1610**	**3045***	**95.7**	**4.3**	**RMT 90.45**	**12670**	**5700**
BLUEBIRD ACSR	2156	8	84	19x0.0961	0.4805	1.8308	1.6930	1.762	2508	2041	467	-	60300	62800	1620	-	81.4	18.6	RMT 96.60	18810	7500
BLUEBIRD ACSS	2156	8	84	19x0.0961	0.4805	1.8308	1.6930	1.762	2508	2041	467	-	42100	45500	1640	3110	81.4	18.6	RMT 96.60	18810	7500
BLUEBIRD ACSS/TW	2156	8	64	19x0.0961	0.4805	1.8312	1.6934	1.612	2512	2045	467	-	42100	45500	1600	3010	81.4	18.6	RMT 96.60	23590	9390
SANTEE ACSS/TW	2627.3	8	64	19x0.1062	0.5310	2.2327	2.0645	1.762	3062	2492	571	-	51400	55600	1785	3405	81.4	18.6	RMT 96.60	23610	7710
BLUEBIRD ACCC/TW	**2727**	**B**	**64**	**1x0.4150**	**0.4150**	**2.277**	**2.1424**	**1.762**	**2696**	**2586**	**110**	**59800**	**-**	**-**	**1790**	**3430***	**96.1**	**3.9**	**RMT 96.60**	**15350**	**5700**

* The continuous temperature rating for the TransPowr ACCC/TW conductor is 180°C. The 200°C temperature is a short-duration emergency operation temperature.

Footnotes

(1) Code words are grouped into sets of five showing similar constructions for concentric round ACSR and ACSS conductor, followed by a same kcmil size, but reduced diameter ACSS conductor, then followed by a same diameter, but expanded kcmil size ACSS, and finally the equivalent diameter ACCC/TW conductor.

(2) Type - a numerical value represents the ratio of the cross-sectional area of the aluminum strands to the cross-sectional area of the steel core material, expressed as a percent. For the ACCC conductor, the letter "A" signifies that even with a greater aluminum metal content than the equivalent diameter ACSR or ACSS conductor, the overall mass of the conductor design is lower. For the ACCC conductor, the letter "B" signifies an ACCC conductor design where the overall mass is greater than the equivalent diameter ACSR or ACSS conductor.

(3) Rated strengths shown are applicable to the conductor built with the CTC Composite Carbon Fiber Fiber Glass core; with GA (ASTM B498) or MA (ASTM B802) regular strength steel core, or with HS (ASTM B606) or MS (ASTM B803) high strength steel core.

(4), (5) Based on conductivity of 61.2% (average lot) IACS @ 20°C for the aluminum in ACSR; 63.0% (average lot) IACS @20°C for aluminum in all other conductors; and 8% IACS @20°C for steel core, for the 75°C ampacity rating a conductor temperature rise of 50°C over 25°C ambient, 2 ft/sec crosswind, .5 coefficient of emissivity, with sun (96 W/ft²). For the 200°C ampacity rating, a conductor rise of 175°C over 25°C ambient.

(6) Indicated reel designation and size may change. Weights shown are for conductor only. All weights and lengths are nominal. Normal length and shipping tolerances apply.

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ACSR vs. ACCC/TW, Comparison of Physical and Electrical Properties of Equivalent Sizes.

TransPowr™ ACCC/TW Bare Overhead Conductor

Trapezoidal Aluminum Conductor Composite Core Concentric-Lay-Stranded

ACSR vs ACSS vs ACSS/TW vs ACCC/TW CONDUCTORS - COMPARISON OF ELECTRICAL PROPERTIES OF EQUIVALENT SIZES

CODE WORD (7)	SIZE kcmil	NO. OF ALUM. WIRES	NO. OF ALUM. LAYERS	ALUM. STRANDING	EQUIV. ALUM. DIA	FILL FACTOR	RESISTANCE (8) Ohms/1000 ft				AMPS 75°C (9)	AMPS 200°C (10)	GMR (11) (ft)	INDUCTIVE REACTANCE ohm/kft (12)	CAPACITIVE REACTANCE megohm.kft (13)
							DC@20°C	AC@25°C	AC@75°C	AC@200°C					
LINNET ACSR	336.4	26	2	10, 16	0.1137	75	0.0506	0.0517	0.0519	-	530	-	0.0242	0.0855	0.5492
LINNET ACSS	336.4	26	2	10, 16	0.1137	75	0.0491	0.0503	0.0505	0.0860	535	945	0.0242	0.0855	0.5492
LINNET ACSS/TW	336.4	18	2	7, 11	0.1367	91	0.0490	0.0501	0.0503	0.0858	525	920	0.0223	0.0874	0.5620
LINNET ACSS/TWD	398.7	18	2	7, 11	0.1489	91.6	0.0414	0.0423	0.0509	0.0724	580	1030	0.0243	0.0855	0.5492
LINNET ACCC/TW	**431**	**16**	**2**	**6, 10**	**0.1641**	**93**	**0.0390**	**0.0400**	**0.0481**	**0.0683**	**600**	**1060***	**0.0239**	**0.0858**	**0.5491**
HAWK ACSR	477	26	2	10, 16	0.1354	75	0.0357	0.0365	0.0437	-	660	-	0.0288	0.0815	0.5218
HAWK ACSS	477	26	2	10, 16	0.1354	75	0.0347	0.0355	0.0427	0.0607	665	940	0.0288	0.0815	0.5218
HAWK ACSS/TW	477	18	2	7, 11	0.1628	91.3	0.0346	0.0354	0.0426	0.0605	650	1160	0.0266	0.0834	0.5349
CALUMENT ACSS/TW	565.3	20	2	8, 12	0.1681	91.5	0.0292	0.0300	0.0360	0.0511	725	1295	0.0290	0.0814	0.5217
HAWK ACCC/TW	**611**	**16**	**2**	**6, 10**	**0.1954**	**93**	**0.0275**	**0.0283**	**0.0340**	**0.0483**	**745**	**1330***	**0.0284**	**0.0818**	**0.5218**
DOVE ACSR	556.5	26	2	10, 16	0.1463	75	0.0306	0.0314	0.0375	-	725	-	0.0311	0.0797	0.5097
DOVE ACSS	556.5	26	2	10, 16	0.1463	75	0.0297	0.0305	0.0367	0.0521	735	1315	0.0311	0.0797	0.5097
DOVE ACSS/TW	556.5	20	2	8, 12	0.1668	91.8	0.0296	0.0304	0.0366	0.0519	720	1280	0.0287	0.0816	0.5232
OSWEGO ACSS/TW	664.8	20	2	8, 12	0.1823	92.3	0.0248	0.0255	0.0307	0.0435	800	1440	0.0313	0.0796	0.5096
DOVE ACCC/TW	**713**	**18**	**2**	**7, 11**	**0.1990**	**93**	**0.0236**	**0.0243**	**0.0292**	**0.0414**	**820**	**1470***	**0.0309**	**0.0799**	**0.5096**
GROSBEAK ACSR	636	26	2	10, 16	0.1564	75	0.0267	0.0275	0.0329	-	790	-	0.0333	0.0782	0.4992
GROSBEAK ACSS	636	26	2	10, 16	0.1564	75	0.0260	0.0268	0.0321	0.0456	800	1435	0.0333	0.0782	0.4992
GROSBEAK ACSS/TW	636	20	2	8, 12	0.1783	92.0	0.0259	0.0267	0.0320	0.0455	780	1400	0.0307	0.0801	0.5129
WABASH ACSS/TW	762.8	20	2	8, 12	0.1953	92.9	0.0216	0.0223	0.0268	0.0379	875	1570	0.0335	0.0781	0.4993
GROSBEAK ACCC/TW	**816**	**19**	**2**	**7, 12**	**0.2072**	**93**	**0.0206**	**0.0214**	**0.0256**	**0.0362**	**890**	**1610***	**0.0330**	**0.0784**	**0.4993**
DRAKE ACSR	795	26	2	10, 16	0.1749	75	0.0214	0.0221	0.0264	-	905	-	0.0372	0.0756	0.4818
DRAKE ACSS	795	26	2	10, 16	0.1749	75	0.0208	0.0215	0.0258	0.0365	915	1660	0.0372	0.0756	0.4818
DRAKE ACSS/TW	795	20	2	8, 12	0.1993	93.1	0.0207	0.0214	0.0257	0.0364	895	1615	0.0342	0.0776	0.4962
SUWANNEE ACSS/TW	959.6	22	2	9, 13	0.2089	93.4	0.0172	0.0178	0.0214	0.0302	1005	1825	0.0376	0.0754	0.4817
DRAKE ACCC/TW	**1020**	**22**	**2**	**8, 14**	**0.2154**	**93.8**	**0.0165**	**0.0172**	**0.0206**	**0.0291**	**1025**	**1865***	**0.0371**	**0.0757**	**0.4817**
CARDINAL ACSR	954	54	3	12, 18, 24	0.1329	75	0.0179	0.0186	0.0228	-	995	-	0.0401	0.0739	0.4697
CARDINAL ACSS	954	54	3	12, 18, 24	0.1329	75	0.0174	0.0181	0.0223	0.0318	1005	1824	0.0401	0.0739	0.4697
CARDINAL ACSS/TW	954	21	2	8, 13	0.2131	93.9	0.0173	0.0180	0.0216	0.0305	995	1805	0.0364	0.0762	0.4851
HUDSON ACSS/TW	1158.4	26	2	10, 16	0.2111	93.7	0.0143	0.0150	0.0179	0.0252	1120	2050	0.0402	0.0738	0.4697
CARDINAL ACCC/TW	**1222**	**36**	**3**	**8, 12, 16**	**0.1843**	**93**	**0.0138**	**0.0146**	**0.0174**	**0.0245**	**1140**	**2080***	**0.0398**	**0.0741**	**0.4697**
BITTERN ACSR	1272	45	3	9, 15, 21	0.1681	75	0.0135	0.0144	0.0171	-	1185	-	0.0443	0.0716	0.4513
BITTERN ACSS	1272	45	3	9, 15, 21	0.1681	75	0.0131	0.0140	0.0167	0.0236	1195	2200	0.0443	0.0716	0.4513
BITTERN ACSS/TW	1272	33	3	7, 11, 15	0.1964	93.3	0.0131	0.0140	0.0167	0.0235	1165	2130	0.0402	0.0739	0.4672
POTOMAC ACSS/TW	1557.4	36	3	8, 12, 16	0.2080	93.2	0.0107	0.0116	0.0138	0.0193	1320	2430	0.0445	0.0715	0.4513
BITTERN ACCC/TW	**1572**	**39**	**3**	**8, 13, 18**	**0.2008**	**93**	**0.0107**	**0.0116**	**0.0138**	**0.0192**	**1320**	**2440***	**0.0445**	**0.0715**	**0.4513**
LAPWING ACSR	1590	45	3	9, 15, 21	0.1880	75	0.0108	0.0117	0.0139	-	1355	-	0.0496	0.0690	0.4338
LAPWING ACSS	1590	45	3	9, 15, 21	0.1880	75	0.0105	0.0115	0.0136	0.0190	1370	2545	0.0496	0.0690	0.4338
LAPWING ACSS/TW	1590	36	3	8, 12, 16	0.2102	93	0.0105	0.0114	0.0136	0.0190	1330	2460	0.0450	0.0712	0.4495
ATHABASKA ACSS/TW	1949.6	56	4	8, 12, 16, 20	0.1866	93.6	0.00860	0.00958	0.0112	0.0155	1505	2815	0.0499	0.0689	0.4341
LAPWING ACCC/TW	**1966**	**56**	**4**	**8, 12, 16, 20**	**0.1880**	**93**	**0.00864**	**0.00966**	**0.0113**	**0.0156**	**1500**	**2805***	**0.0499**	**0.0689**	**0.4338**
CHUKAR ACSR	1780	84	4	12, 18, 24, 30	0.1455	75	0.00970	0.0106	0.0125	-	1450	-	0.0532	0.0674	0.4240
CHUKAR ACSS	1780	84	4	12, 18, 24, 30	0.1455	75	0.00943	0.0104	0.0122	0.0169	1465	2750	0.0532	0.0674	0.4240
CHUKAR ACSS/TW	1780	38	3	8, 13, 17	0.2164	93.5	0.00937	0.0103	0.0124	0.0174	1420	2630	0.0482	0.0697	0.4398
POWDER ACSS/TW	2153.8	64	4	10, 14, 18, 22	0.1834	92.2	0.00781	0.00880	0.0103	0.0142	1600	3010	0.0535	0.0673	0.4239
CHUKAR ACCC/TW	**2242**	**56**	**4**	**8, 12, 16, 20**	**0.2001**	**93**	**0.00758**	**0.00869**	**0.0101**	**0.0138**	**1610**	**3045***	**0.0531**	**0.0675**	**0.4239**
BLUEBIRD ACSR	2156	84	4	12, 18, 24, 30	0.1602	75	0.00801	0.00903	0.0105	-	1620	-	0.0586	0.0652	0.4090
BLUEBIRD ACSS	2156	84	4	12, 18, 24, 30	0.1602	75	0.00778	0.00883	0.0103	0.0142	1640	3110	0.0586	0.0652	0.4090
BLUEBIRD ACSS/TW	2156	64	4	10, 14, 18, 22	0.1835	91	0.00780	0.00879	0.0103	0.0141	1600	3010	0.0538	0.0671	0.4229
SANTEE ACSS/TW	2627.3	64	4	10, 14, 18, 22	0.2027	93.1	0.00640	0.00751	0.00870	0.0118	1785	3405	0.0589	0.0651	0.4090
BLUEBIRD ACCC/TW	**2727**	**64**	**4**	**9, 14, 18, 23**	**0.2065**	**93**	**0.00623**	**0.00750**	**0.00860**	**0.0116**	**1790**	**3430***	**0.0583**	**0.0653**	**0.4090**

* The continuous temperature rating for the TransPowr ACCC/TW conductor is 180°C. The 200°C temperature is a short duration emergency operation temperature.

Footnotes

(7) Code words are grouped into sets of five showing similar constructions for concentric round ACSR and ACSS conductor, followed by a same kcmil size, but reduced diameter ACSS conductor, then followed by a same diameter, but expanded kcmil size ACSS, and finally the equivalent diameter ACCC/TW conductor.

(8) Based on conductivity of 61.2% (average lot) IACS @20°C for the aluminum in ACSR; 63.0% (average lot) IACS @20°C for aluminum in all other conductors; and 8% IACS @20°C for steel core.

(9) (10) Based on conductivity of 61.2% (average lot) IACS @20°C for the aluminum in ACSR; 63.0% (average lot) IACS @20°C for aluminum in all other conductors; and 8% IACS @20°C for steel core, for the 75°C ampacity rating a conductor temperature rise of 50°C over 25°C ambient, 2 ft/sec crosswind, .5 coefficient of emissivity, with sun (96 W/ft²). For the 200°C ampacity rating, a conductor rise of 175°C over 25°C ambient.

(11) GMR is calculated using 61.2% (ACSR) or 63.0% (ACSS) conductivity for the aluminum and 8% IACS conductivity for the steel core.

(12), (13) Values for Inductive Reactance and Capacitive Reactance are expressed in terms of 1 ft radius.

Information provided is presented solely as a guide to the product selection. Information has been calculated using known formulae and the values are believed to be accurate and concise.

BICC BRAND General Cable

Appendix 1:
ACSR vs. ACCC/TW, Comparison of Physical and Electrical Properties of Equivalent Sizes.

TransPowr™ ACCC/TW Bare Overhead Conductor

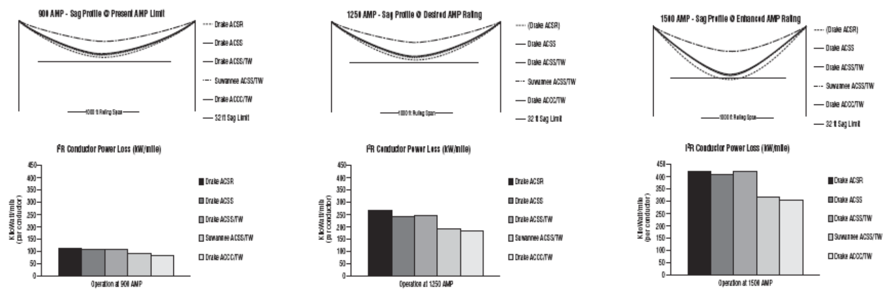
Trapezoidal Aluminum Conductor Composite Core Concentric-Lay-Stranded

The following examples look at two re-conductoring applications where the TransPowr ACCC/TW conductor provides the highest current carrying capabilities and minimizes the amount of conductor sag and I²R transmission line power loss.

Example #1:

The Utility wants to increase the line current carrying capability from 900A to 1250A, and if possible to 1500A. The Utility also wants to utilize the existing transmission line and has defined limits for the maximum allowable sag, a maximum line tension and a maximum vertical weight condition that must be observed. The existing conductor is a DRAKE ACSR. The line is located in an NESC Heavy area and there is an additional design load requirement at 32˚F with 1.0 inch of ice. The line is based on a 1000 ft ruling span.

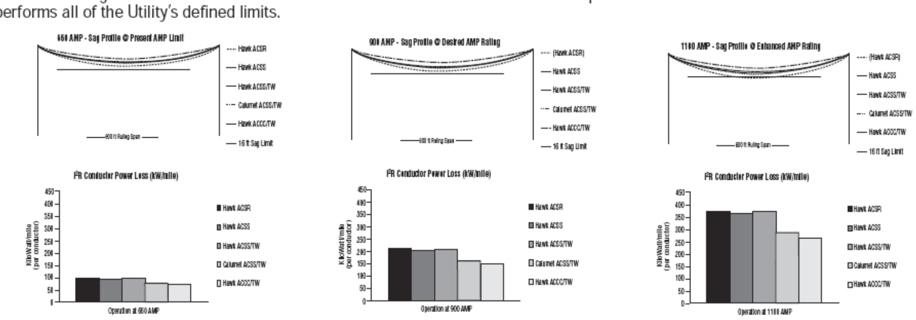
The tables on the previous two pages provided a comparison of ACSR, ACSS and ACCC conductors. The following illustrations show the outcome of the sag and tension calculations for these conductors and the resultant I²R power loss. The TransPowr ACCC/TW conductor outperforms all of the Utility's defined limits.



Example #2:

The Utility wants to increase the line current carrying capability from 660A to 900A, and if possible to 1100A. The Utility also wants to utilize the existing transmission line and has defined limits for the maximum allowable sag, a maximum line tension and a maximum vertical weight condition that must be observed. The existing conductor is a HAWK ACSR. The line is located in an NESC Heavy area and there is an additional design load requirement at 32˚F with 1.0 inch of ice. The line is based on a 600 ft ruling span.

The tables on the previous two pages provided a comparison of ACSR, ACSS and ACCC conductors. The following illustrations show the outcome of the sag and tension calculations for these conductors and the resultant I²R power loss. The TransPowr ACCC/TW conductor outperforms all of the Utility's defined limits.



Ampacity ratings and AC resistance of conductor calculations are based on the following assumptions: 25˚C ambient temperature, 2.0 ft/sec wind speed, 96.0 W/ft² solar heat radiation, 30˚ Northern latitude line location, July 1st 12 noon sun angle, East/West line direction, wind angle is perpendicular to the line direction, at sea level elevation, and clear atmospheric conditions. The conductivity value for the ACSR aluminum is 61.2% IACS @ 20˚C. The conductivity value for the ACSS and ACCC aluminum is 63.0% IACS @ 20˚C. For the ACSR and ACSS, the conductivity value for the steel is assumed to be 8.0% IACS @ 20˚C. The sag and tension calculations for the ACSS and ACSS/TW conductors utilized a high strength steel core.

جامعة النجاح الوطنية

كلية الدراسات العليا

تحليل وإدارة الطاقة لشبكة رام الله الكهربائية

إعداد

ثائر محمود توفيق جرادات

إشراف

د. عماد بريك

قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الاستهلاك بكلية الدراسات العليا في جامعة النجاح الوطنية في نـــابلس، فلسطين.

2010 م

تحليل وإدارة الطاقة لشبكة رام الله الكهربائية

إعداد

ثائر محمود توفيق جرادات

إشراف

د. عماد بريك

الملخص

تهدف هذه الأطروحة إلى دراسة واقع شبكة الضغط المتوسط الكهربائية في مدن رام الله البيرة وبيتونيا التابعة لشركة كهرباء محافظة القدس، بحيث يتم تبيان نقاط الضعف الموجودة في الشبكة الكهربائية. وقد تم استخدام برنامج الــ PowerWorld Simualtor لتحليل الشبكة عن طريق استخدام بيانات تم جمعها من نظام السكادا التابع للشركة، حيث ظهرت مشكلاتان في الشبكة الكهربائية وهما زيادة التحميل وارتفاع الفاقد.

وقد تم اقتراح مجموعة من الوسائل لتحسين الوضع الفني للشبكة، ويمكن تلخيص هذه المقترحات بتطوير خطوط النقل باستخدام موصلات الــ ACCC وإعادة ترتيب جزء من شبكة الضغط المتوسط وتقليل تيار المحايد في شبكات الضغط المنخفض، وأخيرا تبديل محولات القدرة بمحمولات قدرة ذات كفاءة عالية. أيضا تم دراسة المقترحات باستخدام برنامج المحاكاة مرة أخرى من أجل بيان التحسن المتوقع من تطبيق المقترحات.

وبدراسة الجدوى الاقتصادية للمقترحات تبين قابلة تطبيق المقترحات الثلاثة الأولى، أما المقترح الرابع فقد تبين عدم جدواه اقتصاديا. وقد أظهرت دراسة الجدوى الاقتصادية فرصة توفير مادية تقدر بـــ 15 مليون دولار خلال العمر الزمني للمشروع والمقدر بـــ 15 سنة.